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**Final
Remedial Investigation Report
Presidio Main Installation
Presidio of San Francisco**

**Volume I
Text**

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Prepared by

 **DAMES & MOORE**

Prepared for

**U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland 21010-5401**

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**U.S. Army
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Final Remedial Investigation Report Presidio Main Installation

Presidio of San Francisco

**Executive
Summary**

Contract No. DAAA15-90-D-0018
Task Order 0002, Data Item A009

Prepared by

 **DAMES & MOORE**

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**TABLE OF CONTENTS
EXECUTIVE SUMMARY**

	Page
1. INTRODUCTION	1
1.1 Purpose of the Remedial Investigation	1
1.2 Background on the Remedial Investigation.....	2
1.3 Prior and Concurrent Environmental Programs	4
1.3.1 Programs by the U.S. Army Corps of Engineers	4
1.3.2 Programs by Other Agencies.....	6
2. BACKGROUND	8
2.1 Historical Background.....	8
2.2 Demography and Land Use	8
2.3 Physical Setting	9
2.3.1 Environmental Factors	9
2.3.2 Hydrogeology and Beneficial Use of Groundwater Areas.....	11
2.3.2.1 Hydrogeology of Groundwater Basins.....	12
2.3.2.2 Beneficial Use of Groundwater	13
3. REMEDIAL INVESTIGATION METHODS.....	18
3.1 Site Conceptual Model	18
3.2 Field Investigations	20
3.3 Chemical Analysis	23
3.4 Contaminant Identification	23
3.4.1 Overview of Regional Soil Data.....	25
3.4.2 PSF Ambient Soil Evaluation.....	26
3.5 Risk Assessment	30
3.5.1 Interpreting Human Health Risk Assessment Results	30
3.5.2 Interpreting Ecological Risk Assessment Results	33

TABLE OF CONTENTS (continued)
EXECUTIVE SUMMARY

	Page
4. NIKE FACILITY	36
5. CRISSY FIELD STUDY AREA	37
5.1 Consolidated Motor Pool	37
5.2 POL Area.....	37
5.3 Fill Site 7	38
5.4 Buildings 609, 611, and 633	39
5.5 Sewer Lift Stations	39
5.6 Proposed Wetlands Restoration Area	39
5.7 Potential Impacts to the Bay	39
6. BUILDING 900S SERIES STUDY AREA.....	41
6.1 Vehicle Maintenance Area	41
6.2 Storage Building Area	42
6.3 Building 979.....	42
6.4 Groundwater	42
6.5 Potential Impacts to the Bay	43
7. DIRECTORATE OF ENGINEERING AND HOUSING STUDY AREA	45
8. MAIN POST STUDY AREA	46
8.1 Building 215.....	46
8.2 Building 231.....	47
8.3 Building 1057.....	47
8.4 Building 1065.....	48
8.5 Building 1167.....	49

**TABLE OF CONTENTS (continued)
EXECUTIVE SUMMARY**

	Page
8.6 Building 1151	49
9. FILL SITES AND LANDFILLS	50
9.1 Fill Site 1 and Landfill 2.....	50
9.2 Transfer Station	51
9.3 Landfill 4 and Fill Site 5.....	52
9.4 Fill Site 6	52
9.5 Graded Area 9	53
9.6 Landfill E	53
10. MISCELLANEOUS SITES	55
10.1 Building 662	55
10.2 Building 680	55
10.3 Building 1244	56
10.4 Building 1351	56
10.5 Fort Point U.S. Coast Guard Station.....	56
10.6 Lobos Creek.....	57
10.7 Mountain Lake.....	58
11. GOLDEN GATE BRIDGE HIGHWAY AND TRANSPORTATION DISTRICT STUDY AREA	59
11.1 Transformer Area.....	59
11.2 Underground Storage Tank Area.....	59
11.3 Paint Operations Area	59
11.4 Bone Yard Storage Area	60
12. BAKER BEACH STUDY AREA.....	61

TABLE OF CONTENTS (continued)
EXECUTIVE SUMMARY

	Page
13. BATTERY HOWE/WAGNER.....	62
14. MISCELLANEOUS FOLLOW-ON SITES.....	63
14.1 Building 302.....	63
14.2 Building 669.....	63
14.3 Building 1245.....	64
14.4 Building 1369.....	64
14.5 Building 1388.....	65
14.6 Building 1750.....	65
14.7 East of Mason.....	65
15. BASELINE RISK ASSESSMENT.....	66
15.1 Human Health Risk Assessment Summary.....	66
15.2 Ecological Risk Assessment Summary.....	70
15.2.1 Comparison of Risk Assessment Results to the Assessment and Measurement Endpoints.....	72
15.2.1.1 Ability of the Crissy Field Study Area to Serve as Suitable Wetland Habitat as a Future Use.....	73
15.2.1.2 Survivability and Reproduction of Populations of Avifauna (passerines, raptors).....	73
15.2.1.3 Survivability and Reproduction of Special Status Species and Plant Communities.....	76
15.2.1.4 Survivability and Reproduction of Populations of Small Mammals that could Serve as Prey for Raptors and Other Predators.....	77
15.2.2 Recommendations.....	79

1. INTRODUCTION

This Executive Summary presents, in condensed form, the basis and results of the Final Remedial Investigation (RI) conducted at the Presidio of San Francisco (PSF) Main Installation. This summarized form of the RI report is intended to make the RI results more accessible to all individuals who take an interest in the U.S. Army's efforts to identify and remediate contamination resulting from the U.S. Army's activities at the PSF. To that end, this Executive Summary provides the RI results in a concise form with a minimum of technical jargon.

Because the PSF is so valuable for its scenic beauty and recreational use, the U.S. Army, the National Park Service (NPS, which currently controls the PSF)), the State of California, and the general public want to ensure that the area does not pose a risk to either human health or the environment. As part of that effort, this Executive Summary serves as a convenient reference to the RI results and to interpretive information that helps readers put the results into a realistic perspective. The interpretation of results from RI studies is crucial. While scientific study yields valid information on environmental contamination and associated adverse effects, that data must be evaluated against inherent qualifying factors. Only then can the most appropriate resources be committed to remediating contamination in the environment.

The first three sections of this Executive Summary summarize the RI program; describe the background of the PSF, its history, use and physical setting; and presents the investigative methods used to collect data, along with information on how to interpret the risk assessment. sections 4 through 14 describe the RI sites individually and present the findings of contaminant investigations. The final section, section 15 summarizes the results of the human health and ecological risk assessments.

1.1 Purpose of the Remedial Investigation

The purpose of the Main Installation RI is to characterize the nature and extent of contamination resulting from U.S. Army activities at the PSF and to assess associated risks to human health and/or the environment. When the PSF was closed as a U.S. Army base and

was transferred in 1994 to the National Park Service (NPS), it was required by the Base Closure and Realignment Act to undergo environmental studies. As a result of early studies, a number of sites were identified for investigation under the Main Installation RI. The Main Installation RI is only one of several environmental studies initiated by the U.S. Army.

The specific objectives of the PSF RI are to

- Identify and characterize potential sources of contamination at Main Installation sites
- Define the concentrations and distribution of chemicals of potential concern in environmental media (soil, water, sediments)
- Evaluate the risks to human health and the environment which may be posed by these chemicals.

In addition, data from the RI will support the Main Installation Feasibility Study (FS). The FS will identify procedures to mitigate environmental contaminants that present an unacceptable risk to human health or the environment.

The RI was conducted in accordance with the U.S. Environmental Protection Agency (USEPA) guidance for activities performed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act, the National Environmental Policy Act of 1969 (NEPA), and the President's Council on Environmental Quality 40 Code of Federal Regulations 1500-1508. The investigative approach was based on recommendations in the USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (1988).

Furthermore, the procedures used in this RI are consistent with the Department of the Army policy of integrating the NEPA and CERCLA processes. Local and State environmental policies, laws, and regulations were also followed in conducting the RI.

1.2 Background on the Remedial Investigation

In December 1988, the U.S. Secretary of Defense's Commission on Base Realignments and Closures recommended closure of the PSF. The PSF was transferred to NPS on October 1, 1994, under Public Law 92-589, and became part of the Golden Gate National Recreation

Area (GGNRA). Before the property could be transferred, however, the Base Closure and Realignment Act required that environmental studies be performed.

To manage the Base Realignment and Closure Environmental Restoration Program, the USAEC, formerly U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), was assigned to plan, implement, and direct the U.S. Department of the Army Environmental Program. Thus, USAEC is responsible for conducting the environmental investigations necessary to transfer the PSF to the NPS. The Sacramento District Corps of Engineers is assigned to conduct any required remediation.

An Enhanced Preliminary Assessment (PA), was conducted by Argonne National Laboratory (ANL) in 1989. The purpose of the PA was to characterize environmentally significant operations, identify areas requiring immediate remedial actions, and evaluate areas that may need further investigation. The assessment was based on a review of available site records, aerial photographs, data from regulatory agencies, interviews with PSF personnel, and observations made during visits to the site. The conclusions of the Enhanced PA stated that the PSF does not present an "imminent or substantial threat to human health or the environment" and that emergency actions are not warranted. However, the Enhanced PA did identify areas potentially impacted by army activities and recommended additional studies in these areas. Information gathered during the Enhanced PA was used to develop work plans for this RI.

A conceptual site model was developed to establish potential contaminant sources, release mechanisms (ways in which contaminants escape into the environment), migration pathways, and routes of exposure (eating soil, touching dirt, etc.). Sampling media, locations, techniques, and analytical suites were selected after considering these potential sources and potential release mechanisms. The sampling program was designed to provide data that could be used to evaluate the sources, release mechanisms, and migration pathways and to quantitatively assess human and ecological risks posed by chemicals at the PSF. The model provides a framework for understanding sample results in the context of the environmental setting at the PSF.

This RI is structured on a study area basis. Each study area includes one or more investigated sites grouped by physical similarity, geographic proximity, and the field program in which the sites were added to the RI. The RI study areas are:

- Nike Facility
- Crissy Field Study Area
- Building 900s Series Study Area
- Directorate of Engineering and Housing Study Area
- Main Post Study Area
- Fill Sites and Landfills
- Miscellaneous Sites
- Golden Gate Bridge Highway and Transportation District Study Area
- Baker Beach Study Area
- Battery Howe/Wagner
- Miscellaneous Follow-on Sites.

The Main Installation RI is one of several environmental programs that have been completed or are ongoing at the PSF. Other environmental programs are summarized in the following sections.

1.3 Prior and Concurrent Environmental Programs

Several environmental programs which are separate from this RI have been performed or are currently being conducted at the PSF. These environmental programs address known and potential contamination issues which, with three exceptions, are not addressed in the Main Installation RI. The three exceptions are the Marine Ecological Sampling and Analysis and the U.S. Army's investigation of two study areas: the Golden Gate Bridge, Highway, and Transportation Study Area and the Fort Point U.S. Coast Guard Station.

1.3.1 Programs by the U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USCOE) has the lead role in a number of completed and ongoing environmental programs at the PSF.

Environmental Impact Statement. Based on the data presented in the Enhanced PA, USCOE prepared an Environmental Impact Statement (EIS). The EIS focused on the economic impacts of the closure of the base.

Firing Ranges. Under the direction of the USCOE, several sites at the PSF which have been used as small arms firing ranges have been investigated. Some of these firing range sites are located along the San Francisco Bay and some are located in inland areas. The final characterization report and remedial action plan for the firing range sites are expected to be issued in 1997.

Lead Contamination. The occurrence of lead-based paint in soils near all residential buildings constructed before 1978 has been investigated by USCOE. The U.S. Army is evaluating the need to remediate soil where elevated lead concentrations have been detected.

Petroleum Cleanup. USCOE is also conducting a petroleum cleanup program at PSF to correct petroleum contamination in soil and groundwater. Under this program, an extensive underground piping system used by the U.S. Army to distribute heating oil to many of the buildings at the PSF is being removed. At the time of this writing, about half of the fuel distribution system has been removed. The remainder of the fuel distribution system is expected to be removed or closed in place in 1997. The investigation and removal of underground storage tanks (USTs) and above ground storage tanks (ASTs) is ongoing. All indoor storage tanks have already been removed. Monthly updates on the progress and status of the petroleum cleanup program are available to the public at the monthly Restoration Advisory Board (RAB) meetings. Information on the schedule and location of the RAB meetings can be obtained by contacting the BRAC Public Affairs Office at (415) 289-7407.

Groundwater monitoring. Under the direction of the USCOE, Montgomery Watson is monitoring groundwater at nearly 200 PSF monitoring wells on a quarterly basis. This program includes monitoring wells installed under the Main Installation RI. The monitoring results are presented in quarterly reports and annual summary reports.

Historical Research. The USCOE is currently pursuing additional historical information. If information is obtained to identify additional target areas for environmental investigation,

these areas will not be added to the Main Installation RI but will be addressed in subsequent investigations.

1.3.2 Programs by Other Agencies

Additional environmental programs at the PSF, led by agencies other than the USCOE, include the following:

A Separate RI. Completely separate from the RI for the Main Installation is an RI conducted by the U.S. Army at the PSF for the former Public Health Services Hospital (PHSH). The successful PHSH RI led to a final Record of Decision (ROD) for PHSH, including Landfill 8 and Landfill 10. Groundwater monitoring and other actions stipulated by the PHSH ROD are currently being implemented by the USCOE. The PHSH is located in the southwest part of the PSF.

A Remedial Action Plan. For the Directorate of Engineering and Housing (DEH), the Presidio Base Closure Team (BCT) is developing a Remedial Action Plan (RAP). The BCT includes the U.S. Army, regulatory agencies and the NPS. The RAP will be submitted for public review and comment. After incorporation of public comments and the U.S. Army's responses, a final ROD will be issued.

An Engineering Evaluation/Cost Analysis. An Engineering Evaluation/Cost Analysis (EE/CA) for polychlorinated biphenyl (PCB) contaminated soils at Building 680 and an area between Buildings 1151 and 1152 has undergone public review. The U.S. Army is currently reviewing public comments and will issue a final PCB EE/CA in early 1997.

Plan for Removing Contaminated Soil. The California Department of Transportation has remediated an area beneath the Route 101 Presidio Viaduct and the Route 1 Presidio Viaduct Ramp. This work focused on soil which was contaminated with lead and chromium from past sandblasting and repainting activities associated with maintenance of the viaduct structures. All remediation activities associated with the maintenance of the Presidio viaduct are the responsibility of the California Department of Transportation.

A Survey for Explosives. Watkins-Johnson Environmental, Inc. (WJE) conducted a survey of magazines and coastal fortifications which included visual inspections and wipe sampling for compounds associated with explosives. A draft report of the results of the survey has been prepared by Dames & Moore and submitted to USAEC for review.

Groundwater Remediation. In 1994, WJE initiated an interim remedial action at Building 937 to remove a source of chlorinated solvents and petroleum contamination. This action also included the installation and operation of an innovative technology to remediate volatile hydrocarbon contamination in groundwater. A draft report of the effectiveness of the groundwater remediation system has been prepared by Dames & Moore and submitted to USAEC for review.

Marine Ecological Sampling and Analysis. Under the direction of the USAEC, Dames & Moore conducted the Marine Ecological Sampling and Analysis Program (ESAP) to assess potential adverse impacts to the San Francisco Bay. Dames & Moore assessed the chemical quality of stormwater that flows from the PSF to the San Francisco Bay and the chemical quality of the bay sediment near the stormwater outfalls. Toxicity bioassays were performed to determine whether marine biota are being adversely affected by potentially hazardous chemical contaminants transported from the PSF to the San Francisco Bay via groundwater or surface water runoff. Results of the ESAP are integrated into this RI as they relate to RI sites along the San Francisco Bay shoreline.

Other RI Study Areas. Under the Main Installation RI program, the U.S. Army has also investigated the Golden Gate Bridge, Highway, and Transportation District (GGBHTD) Study Area and the Fort Point U.S. Coast Guard Station; the results of these investigations are included in the Main Installation RI report. However, because GGBHTD and the Coast Guard have been responsible for these areas during the activities which motivated the investigations, the U.S. Army's position is that these two organizations are responsible for evaluating the remedial alternatives and conducting remediation at these sites.

2. BACKGROUND

The PSF is located in the City of San Francisco, at the northern tip of the San Francisco Peninsula. The PSF occupies approximately 1,416 acres and is bounded by San Francisco Bay on the north and the Pacific Ocean on the west. Densely populated residential areas of San Francisco border the PSF to the south and east. Background information summarized in the following sections includes historical, demographic, and physical setting information which provides a context in which to interpret the RI results.

2.1 Historical Background

The PSF was a U.S. Army installation from 1848 through 1994. The PSF has served as a mobilization and embarkation point during several overseas conflicts, a medical debarkation center, and a coastal defense for the San Francisco Bay area. Industrial operations formerly performed at PSF are associated with maintenance and repair of vehicles, aircraft, and base facilities.

In 1994 when the PSF was closed as a U.S. Army base and transferred to NPS, it was required by the Base Closure and Realignment Act to undergo environmental studies. As a result of early studies, a number of sites were identified for investigation under the Main Installation RI. The Main Installation RI is only one of several environmental studies initiated by the U.S. Army.

2.2 Demography and Land Use

The PSF lies within the 46.4 square mile area of the City and County of San Francisco. According to the 1990 census results, the population of San Francisco was 723,959 in 1990, which is a 6.6-percent increase from the 1980 population. The densely populated Richmond District, a residential neighborhood of one- and two-family houses, is located along the southern boundary of the PSF. The densely populated Marina District of the city is located along the eastern boundary of the PSF.

The NPS currently reports that 256 residences on the PSF are occupied by military personnel and 77 residences are occupied by persons who are employed by either the NPS or organizations with an NPS relationship. The commissary and main exchange are currently in operation. The Officers' Club is currently being used as a community hall.

The PSF, when under the U.S. Army's jurisdiction, was open to civilians, with numerous trails and roads used extensively by the public for hiking, bicycling, and other forms of recreation. The NPS continues to allow recreational use of the PSF. The City and County of San Francisco built and operates the 6-ac Julius Kahn Public Playground along the southern boundary of the PSF. The Presidio Golf Course is currently open to the public. Prior to the transfer of the PSF to the NPS, the 100-ac Baker Beach area, located along the northwest portion of the PSF, and 45 ac of the northern beach (Crissy Field Study Area) adjacent to the San Francisco Bay, were permitted to the GGNRA. Approximately 11.5 ac of the PSF at the southern end of the Golden Gate Bridge, consisting of toll plaza roadway and equipment and maintenance areas was permitted to the GGBHTD by the U.S. Army.

2.3 Physical Setting

Information about the physical setting of the PSF provides a basis for understanding additional data collected during the RI, the relationships among that data, and the significance of the data for risk assessment.

2.3.1 Environmental Factors

The Pacific Ocean and San Francisco Bay have a strong influence on the climate of the PSF. The temperature is moderate; winter months are characterized by rain and mild temperatures, and spring is usually sunny and mild. Fog often occurs in summer when warm, moist air is cooled by cold ocean water along the coast. Prevailing winds are from the north and northwest. The mean wind speed is 8.7 miles per hour. Gale force winds associated with Pacific storms of short duration may occur.

The average annual rainfall is 19.5 inches. Ninety percent of the rainfall on the San Francisco area occurs from November to April, which averages a total of 17.5 in

Ground surface elevations at the PSF range from sea level along the northern and western boundaries to approximately 400 feet above sea level. The topographic high point is located adjacent to the Presidio Golf Course in the south-central portion of the PSF. The northern area along San Francisco Bay is a flat low-lying area developed on fill material. Before filling operations of the early 1900s, much of this area consisted of interior marshlands with a sand spit. In contrast, the western boundary along the Pacific Ocean is very steep with slopes of about 50 percent. Baker Beach, at the base of these steep slopes, is a relatively narrow strip of land. The interior portions of the PSF, including the eastern and southern boundaries, are characterized by gently rolling to hilly topography.

Surface water from the PSF drains to the San Francisco Bay or to the Pacific Ocean. There are few perennial surface-water features at the PSF. The only stream with significant perennial flow is Lobos Creek, which flows along the PSF's southern boundary and drains into the Pacific Ocean. Mountain Lake is located on the southern boundary of the PSF, within the upper reaches of the Lobos Creek drainage. El Polin Spring is located in the southeastern portion of the PSF and flows to a nearby storm drain which drains to the San Francisco Bay. Stormwater runoff from developed portions of the installation is collected by a system of swales and storm drains and routed to the Pacific Ocean or the San Francisco Bay.

Flow in Lobos Creek is derived principally from groundwater. Approximately 85 percent of the surface drainage area that flows to Lobos Creek is located in the City and County of San Francisco south of the PSF. Except during periods of rainfall and runoff, discharge of Lobos Creek is relatively uniform. Historical flow measurements in the vicinity of Lincoln Boulevard have ranged from 1.2 to 2.1 million gallons per day. No sanitary sewers are known to discharge to Lobos Creek. A storm-drain line originating near Building 1794 may discharge into Lobos Creek approximately 800 feet upstream from where the creek discharges to the ocean. Nearly all water in Lobos Creek is diverted to the PSF water treatment plant when it is in operation. The PSF water plant is located in the group of buildings in the extreme southwestern portion of the PSF. Lobos Creek water that is not diverted at the water plant is released to the Pacific Ocean.

Mountain Lake is located on the southern boundary of the PSF adjacent to Park-Presidio Boulevard. The maximum depth of the lake is approximately 15 feet. Its sources of water are surface runoff and groundwater seepage. At normal stage, Mountain Lake does not discharge directly to Lobos Creek. Water leaves the lake primarily by groundwater seepage and evaporation. Approximately 85% of the surface drainage area associated with Mountain Lake and Lobos Creek is south of the PSF in a residential area of San Francisco.

Much of the PSF is covered by unconsolidated deposits of sand, silt, and clay. These unconsolidated deposits overlie bedrock which is formed by the geologically complex Franciscan Formation. The Franciscan Formation is an assemblage of volcanic rocks, metamorphic rocks, sandstone, shale, and siltstone. The unconsolidated deposits overlying the Franciscan Formation include the Colma Formation, modern beach sands, and sand dune deposits. The unconsolidated deposits were formed principally by weathering and erosion of the Franciscan Formation. Artificial fill deposits formed by various landfilling and construction activities are present at numerous locations, particularly along the San Francisco Bay. Mud deposits are interlayered with beach sand deposits along San Francisco Bay.

2.3.2 Hydrogeology and Beneficial Use of Groundwater Areas

The RI focuses on groundwater in the unconsolidated deposits overlying bedrock because significant amounts of groundwater storage and flow are found in the unconsolidated materials and generally do not occur in bedrock at the PSF. The PSF has been divided into three groundwater basins—the Marina, Lobos Creek, and Coastal Bluffs. This division is based on the primary drainage divides where bedrock topography, which generally follows surface topography, divides groundwater flow in the unconsolidated geologic units that overlie bedrock. Groundwater areas, as defined here, are areas within the groundwater basins where groundwater conditions may meet the criteria established by the State of California for evaluating whether groundwater is reasonably expected to constitute a resource for domestic or municipal water supply.

2.3.2.1 Hydrogeology of Groundwater Basins

The hydrogeology of the three groundwater basins and their constituent groundwater areas is discussed in the following sections. These descriptions are followed by a discussion of how groundwater at the PSF is recharged and how it discharges to other areas.

Marina Groundwater Basin. The Marina Groundwater Basin, which flows to the San Francisco Bay, comprises the West Valley Groundwater Area, the Northeastern Groundwater Area, and the Crissy Field Groundwater Areas. The West Valley and Northeastern Groundwater Areas are located in upland areas where groundwater flows into the Crissy Field Groundwater Area. The Crissy Field Groundwater area includes the low lying area along the San Francisco Bay, where the bedrock surface is generally below sea level, sea water intrusion is evident, and tidal fluctuations affect groundwater levels.

Lobos Creek Groundwater Basin. The Lobos Creek Groundwater Basin contains the Lobos Creek Groundwater Area. Groundwater in this area, which includes Mountain Lake, flows to the Pacific Ocean. Water from Lobos Creek and from wells near the mouth of Lobos has been used for drinking water supply. The PSF water supply plant, located at the mouth of Lobos Creek, has recently been upgraded, but is not currently in operation.

Coastal Bluffs Groundwater Basin. The Coastal Bluffs Groundwater Basin occupies the remainder of the PSF along the Pacific Ocean. This basin includes Baker Beach and the slopes that face the Pacific Ocean. The slopes are very steep, with thin accumulations of unconsolidated materials overlying bedrock. Under these conditions, the occurrence of water-saturated conditions in the unconsolidated material is expected to be limited to thin saturated zones in small areas. No specific groundwater areas were identified in the Coastal Bluffs Groundwater Basin during the RI investigation. A perennial seep occurs in the Baker Beach Study Area along the bluffs in Disturbed Area 1 (DA-1). This feature is termed a seep rather than a spring because it emanates from a broad area and consistently shows a very small flow. The flow from this seep has been visually estimated to be less than 1 gallon per minute at the point where it flows over bedrock outcrop at the edge of the beach.

Recharge and Discharge of Groundwater. Groundwater at the PSF is recharged (replenished) primarily by infiltration and percolation from precipitation and irrigation water.

Groundwater discharges (flows) primarily as seepage to surface water bodies, including Lobos Creek, Mountain Lake, the Pacific Ocean, and San Francisco Bay. Groundwater also discharges to several springs and seeps at PSF. El Polin Spring is a perennial spring located in the southeastern part of the PSF. A perennial seep is located near the Pacific Ocean in the Baker Beach area in Disturbed Area 1. A spring has been reported at the location of well LF8GW05. Well LF8GW05 is actually a dewatering sump which is used to prevent groundwater from seeping into the basement of Building 1801. An intermittent spring occurs in response to wet seasons at Landfill 2. Other intermittent springs may occur at other locations at the PSF; however, they are not well known because no documentation on them is available and they apparently were not flowing when RI sampling teams were in the field. Locally, underground utilities such as water lines and storm and sanitary sewers may affect groundwater recharge and discharge; however, the sewer and water distribution systems have recently been upgraded and no instances of underground utilities affecting groundwater recharge or discharge are known.

2.3.2.2 Beneficial Use of Groundwater

The State of California has designated beneficial uses for groundwater in each of the basins and groundwater areas defined at the PSF. The PSF groundwater basins and areas and their respective beneficial uses are listed as follows:

Groundwater Basin/Area	Beneficial Use
<u>Lobos Creek Groundwater Basin</u> Lobos Creek Groundwater Area	Municipal Surface Water Ecological
<u>Coastal Bluffs Groundwater Basin</u>	Municipal Recreational Surface Water Ecological
<u>Marina Groundwater Basin</u> West Valley Groundwater Area	Municipal Surface Water
Northeastern Groundwater Area	Municipal Recreational Surface Water Ecological

Crissy Field Groundwater Area

Municipal (low probability for future use)
Recreational
Surface Water
Ecological

Municipal use, as applied here, means the use of groundwater as a source of drinking water for human consumption. According to the State, groundwater may be excluded as a drinking water resource if any of the following criteria are met.

- Total dissolved solids (TDS) concentrations exceed 3,000 milligrams per liter (mg/L).
- Groundwater does not provide sufficient flow to a well to support an average, sustained yield of 200 gallons per day (gpd).
- Groundwater is contaminated either by natural processes or by human activity, that can not be reasonably treated for domestic use using either Best Management Practices or best economically achievable treatment practices.
- An aquifer is regulated as a geothermal energy-producing source or has been exempted administratively pursuant to Title 40 of the *Code of Federal Regulations (CFR)*, Section 146.4 for underground injection.

Some areas where groundwater was investigated in the RI might not be considered drinking water resources based on the criteria listed above. For example, future use of groundwater for municipal water supply in the Crissy Field Groundwater Area was designated "low probability" by the State because sea water intrusion could reach water supply wells, even in areas not currently affected by sea water intrusion. Surface water and groundwater have been used as municipal water supply in the Lobos Creek Groundwater Area. Although not currently in use, the recently upgraded water plant near the mouth of Lobos Creek could be used to purify surface and groundwater to supply potable water to the PSF.

The hydrogeology and beneficial uses of the four groundwater areas are summarized below. The hydrogeology summaries also characterize the interrelationships among specific sites at the PSF. Because the Coastal Bluffs Groundwater Basin does not include a specific groundwater area this basin is excluded from the discussion.

Lobos Creek Groundwater Area. The Lobos Creek Groundwater Area includes, or may be affected by, the Nike Facility, Landfill 8, Graded Area 9, Mountain Lake, and Building

1750. Landfill 8 was characterized in the PHSR RI report and is not evaluated in this RI report.

Groundwater at the most upgradient portions of Nike Facility occurs as a thin layer in dune sand overlying Colma Formation deposits. Further downgradient in the Nike Facility, groundwater occurs in the Colma Formation and flows into the Landfill 8 vicinity and potentially into the Mountain Lake vicinity, extending into the overlying dune sand in some places. Groundwater from Landfill 8 may also flow towards Building 1750. Groundwater below these sites may eventually flow into Lobos Creek and into the vicinity of the potable well field.

Beneficial uses to be protected in the Lobos Creek Groundwater Area include municipal water supply, surface water replenishment, and the ecological conditions of Mountain Lake and Lobos Creek.

West Valley Groundwater Area. The West Valley Groundwater Area includes the RI sites of Battery Howe/Wagner and Buildings 662, 669, 680, and 1245. Above this area, sites where no significant groundwater was found include the Transfer Station, Landfill 4, Fill Site 5, and Buildings 1244, 1351, and 1369.

Groundwater occurs in the slope debris and ravine fill and unconsolidated weathered bedrock deposits in the Battery Howe/Wagner vicinity and possibly flows to the vicinity of Building 662. Groundwater in the West Valley Groundwater Area apparently flows into the Crissy Field Groundwater Area towards FPCGS and in the vicinity of the Building 900s Series and Crissy Field Study Areas.

Beneficial uses to be protected in the West Valley Groundwater Area include municipal water supply and surface water replenishment. However, the development of municipal water supply in the West Valley Groundwater Area would be inadvisable regardless of any contamination associated with the RI sites because the area is urbanized, groundwater is shallow, sanitary sewers are present, and requirements for surface sanitary seals in water supply wells would likely extend through and block most or all of the saturated groundwater zone.

Northeastern Groundwater Area. The Northeastern Groundwater Area includes Fill Site 1, Landfill 2, and Landfill E in the uplands region to the south; Fill Site 6 on lower ground to the northeast; and Main Post sites including Building 215, a portion of Building 231, and Buildings 1057, 1065, 1151, and 1167. The Building 231 site actually overlaps onto both the Northeastern Groundwater Area and the Crissy Field Groundwater Area.

Groundwater occurs in the Colma Formation in the upland sites Fill Site 1, Landfill 2, and Landfill E. Groundwater appears to flow from these sites, through Colma Formation deposits, into lower ground in the Main Post Study Area. Some groundwater becomes confined as it flows into the interlayered beach sand and bay mud deposits near Building 231. Groundwater from these interlayered deposits and the Colma Formation flows into the Crissy Field Groundwater Area.

Beneficial uses to be protected in the Northeast Groundwater Area include municipal, recreational, surface water replenishment, and ecological. However, the development of municipal water supply in the Northeastern Groundwater Area would be inadvisable regardless of any contamination associated with the RI sites because the area is urbanized, groundwater is shallow, and sanitary sewers are present. Recreational use would apply to recreational users of the PSF who may come in contact with surface water at El Polin Spring or surface water that could flow in the planned restoration of the Tennessee Hollow riparian habitat. Groundwater in the Northeastern Groundwater Area replenishes surface water flow for a distance of about 100 feet at El Polin Spring. This flow then enters a storm drain which ultimately empties into the Bay. Depending on the configuration of the restored riparian habitat, groundwater could also replenish surface water and support the flora and fauna of that habitat.

Crissy Field Groundwater Area. The Crissy Field Groundwater Area includes the following study areas and investigation sites from west to east: the Building 900s Series Study Area, FPCGS, Crissy Field Study Area, EOM, DEH, and a portion of the Building 231 area.

Groundwater occurs in beach sand interlayered with bay mud deposits in the Crissy Field Study Area. To the northwest and east of Crissy Field Study Area, in the vicinities of

Building 900s Series and DEH Study Areas respectively, groundwater occurs in beach sand deposits devoid of interlayered Bay Mud. Groundwater below the Crissy Field Groundwater Area generally flows towards San Francisco Bay.

Beneficial uses to be protected at the Crissy Field Groundwater Area include municipal, recreational, surface water replenishment, and ecological. Municipal use has a low probability because sea water intrudes the groundwater in the area. The recreational, surface water replenishment, and ecological uses apply to this area because its groundwater flows to San Francisco Bay and would flow to the wetland planned by the NPS.

3. REMEDIAL INVESTIGATION METHODS

This section describes the methods used to perform the RI. An objective of the RI was to identify areas of the PSF that pose a threat to human health or the environment. To meet this objective, potential sources of contamination were evaluated and the possible release mechanisms, migration pathways, and receptors were identified. This information was incorporated into a generalized conceptual model of the site. Using the conceptual model, the field program requirements were established, including the sample media, numbers of samples, sampling locations, chemical analyses, sampling techniques, and data management and quality control procedures.

The Main Installation RI field program resulted in a substantial amount of data. Soil and/or sediment were sampled at 636 specific locations. One hundred and twenty-eight groundwater monitoring wells were installed. The total numbers of samples taken from these locations and analyzed in the laboratory are as follows:

- 1,053 soil samples
- 442 groundwater samples
- 151 sediment samples
- 31 surface water samples.

Analyzing these samples resulted in a database of 146,455 individual chemical concentration results.

After the field program was completed, analytical and other field data were interpreted to verify or modify the conceptual model. Interpretation of the field program results included assessing data quality and comparing the chemical data to ambient and regulatory levels to gain perspective on the meaning of the results. Then a Baseline Risk Assessment was conducted to estimate risks to human health and the environment in specific exposure scenarios identified at the PSF.

3.1 Site Conceptual Model

The PSF site conceptual model incorporates the potential contaminant sources, which were evaluated during the Enhanced Preliminary Assessment and the Supplemental RI Preliminary

Assessment, and by regulatory agencies and the public in response to previous Main Installation RI reports. The model also incorporates hydrogeologic data, population information, and land use patterns which are used to identify possible migration pathways and routes of exposure for human and ecological receptors (people, plants, and animals that could be exposed to contaminants). The model provides a framework for understanding sample results in the context of the environmental setting at the PSF.

The potential contaminant sources evaluated in the RI can be categorized as follows:

- Fill materials
- Underground storage tanks (USTs)
- Aground storage tanks (ASTs)
- Buildings, storage areas, and maintenance areas.

Fill materials. Areas containing fill materials include the landfills, fill sites, and graded areas, portions of the Crissy Field Study Area and the other areas along the San Francisco Bay shoreline, Battery Howe/Wagner, Baker Beach, and some of the building sites. Potential release mechanisms associated with these possible sources include surface-water runoff, infiltration of chemicals from the fill material to underlying soils and groundwater, transport of particulates from the surface, or biotic uptake into lower trophic levels.

Underground and Above Ground Storage Tanks. Petroleum storage tanks were investigated under the RI in the Main Post Study Area, in the POL area of the Crissy Field Study Area, at FPCGS, and at Buildings 937 and 1245. Releases from tanks result from leaks from the tank or piping, or spills during filling operations. These mechanisms could release contaminants to the surface or subsurface soils, sediment, surface water, or groundwater. Sites with contaminants other than petroleum were retained in this RI. Sites that have only petroleum contamination are addressed by a petroleum cleanup program led by USCOE; they are not addressed in this RI.

Buildings, Storage Areas, and Maintenance Areas. Buildings and storage and maintenance areas include motor pools in the DEH, Crissy Field, and Building 900s Series Study Areas, and several of the Miscellaneous Sites; above ground storage tanks in the FPCGS and Building 1388; storage areas such as the Bone Yard at the GGBHTD; and Buildings 293

and 302, which were used for pesticide storage. Spills or leaks from these potential sources would affect surface soils or generate residues which workers, residents, visitors, or biota could contact.

These potential sources and potential release mechanisms were considered in selecting the sampling media, locations, techniques, and analytical for the sampling program. The sampling program was designed to provide data that could be used to evaluate these sources and migration mechanisms.

3.2 Field Investigations

The field investigation methods were also selected to provide adequate data for evaluating the potential sources and chemical release and transport mechanisms developed in the site conceptual model. Samples were collected according to the detailed procedures specified in work plans for the Initial RI field program conducted in fall 1990, the Supplemental RI field program conducted in summer 1992 and the Follow-on RI field program conducted in the fall and winter of 1994-1995.

In the Follow-on RI field investigation, spatial criteria were developed to characterize the extent of potential contaminants in soil and groundwater. For soil, the vertical and lateral extent of chemicals was considered defined when each detection of concern was underlain by one sample in the vertical direction and surrounded by samples in lateral directions in which the concentration of the target analytes were below the established criteria. For groundwater investigations, the spatial criteria were two samples in the vertical direction and one in surrounding lateral directions, both below the specified concentration criterion.

Modifications to this approach were sometimes required due to field conditions, such as buildings, obstructions to drilling, sensitive plant habitats, or site hydrogeologic conditions, such as geologic units that are impermeable to groundwater.

The data from all sampling events are integrated to provide a single cohesive description of the nature and extent of potential chemicals of concern within each study area. Investigation methods are described in the following paragraphs.

Surface Geophysical Surveys. Geophysical surveys were conducted to help define the extent of fill materials. Surface geophysical surveys using resistivity and electromagnetic methods were conducted at Crissy Field and Battery Howe/Wagner Study Areas and Fill Sites 1 and 5, Landfill 4 and Graded Area 9. Resistivity methods were also used at Fill Site 6 and Landfill 2. These areas were identified as disturbed in aerial photographs; they were also identified in the Enhanced PA as areas containing unknown fill materials.

Wipe Sampling. Wipe samples were generally collected from stained areas or other locations on which spilled materials or residues may have accumulated. Wipe samples were collected from buildings in the Nike Facility, the Crissy Field Study Area, the Building 900s Series Study Area, the DEH Study Area, and at miscellaneous building areas to investigate the potential for hazardous chemical residues on structural surfaces. The potential surfaces evaluated were interior floors and walls, and outdoor paved areas that were used for chemical or equipment storage.

Because of the nature of wipe sampling, the results were used only to qualitatively evaluate whether chemical residues were present on surfaces and to decide whether further investigation was warranted. Wipe sampling results cannot be used in quantitative risk assessment.

Sediment Sampling. Sediments were sampled to evaluate whether potential contaminants had been transported from potential source areas by surface-water runoff and to assess the distribution of potential contaminants in the drainage pathways. Sediment samples were collected from inside storm drains or catch basins in the Nike Facility, Crissy Field, Building 900s Series, Main Post, GGBHTD, and DEH Study Areas. Sediments were also sampled from Lobos Creek, Mountain Lake, and a seep at Baker Beach. Sediment sample results were used in quantitative risk assessment for sediment locations that might allow exposure to human or ecological receptors.

Drilling. Six methods were used for drilling boreholes. Hand augers or hand-operated power augers were used for drilling shallow boreholes, and for drilling in areas with limited access. Truck mounted hollow-stem auger and mud-rotary drilling rigs were used to drill deeper boreholes for monitoring wells and to collect soil and discrete groundwater samples.

Geoprobe sampling and cone penetrometer testing were also used to obtain soil samples and discrete groundwater samples. Geoprobe sampling and cone penetrometer testing are direct-drive methods in which the sampling equipment is punched directly into the ground without rotation.

Soil Sampling. Soil samples from test pits, borings, and surfaces of unpaved areas were used to assess the physical and chemical characteristics of potential contaminant sources. The data are also used to evaluate the importance of the release mechanisms identified in the conceptual model. Physical characterization of soils included describing the lithology of natural soils, determining the depth of unsaturated soils, and identifying the nature and extent of fill materials. Fill materials were classified as artificial fill, debris fill, or landfill material. Artificial fill is comprised of locally derived native materials, whereas debris fill and landfill contain anthropogenic (manmade) materials. Debris fill consists of construction materials such as wood, metal, glass, and concrete rubble. Landfill consists of materials containing household and/or commercial refuse such as rags, newspapers, shoes, or cans

Groundwater Sampling. To provide groundwater samples and to monitor the elevation of the groundwater surface, groundwater monitoring wells and temporary piezometers were installed in boreholes. Samples of groundwater and surface water were collected to quantify the distribution of chemicals in these media. The data were also used to evaluate the effect of various transport mechanisms on the overall distribution of chemicals in each study area. In addition to sampling groundwater and surface-water bodies, samples of water in the Nike missile silos were collected.

Soil-Gas Sampling. Soil-gas samples were collected at building 1750 to investigate the potential for underground contamination in the form of volatile organic compounds. In this method, a small pipe is driven into the ground and a vacuum is applied to draw vapors samples from the soil. Soil-gas samples were analyzed by direct gas injection into a laboratory-grade, field-operable gas chromatograph.

Sample Location Surveying. The location, ground-surface elevation, and measuring-point elevation of permanent groundwater monitoring wells were surveyed by a California-licensed surveyor. The locations of all Supplemental and Follow-on RI soil borings and surface-soil

samples were also surveyed. Instead of being surveyed, some Initial RI soil-sample locations were mapped using tape measurements from surface landmarks and elevations were interpreted from topographic maps with 5-foot contour intervals.

Equipment Decontamination. Equipment used during drilling and excavation of test pits was decontaminated by steam cleaning with water from an approved clean water source. If steam cleaning alone could not remove the dirt or staining, brushes were used. If necessary, a dilute mixture of biodegradable detergent was also used. The equipment used for collecting soil and sediment samples was cleaned in a detergent solution and rinsed with distilled water before use.

3.3 Chemical Analysis

The chemicals to be analyzed were selected after evaluating the current or former activities at the sampled sites, the types of chemicals and waste handling procedures used in each building, and the regulatory agency concerns. To identify areas that have been impacted by spills or released wastes, historical records were reviewed. Analyses were then conducted on each sample to verify the presence and concentrations of the chemicals suspected to be present in the soil, sediments, water, or buildings.

Analyses were performed for the following:

- Inorganic chemicals
- Miscellaneous chemical parameters
- Volatile organic compounds
- Semivolatile organic compounds
- Pesticides, phlychlorinated byphenols (PCBs)
- Chlorinated herbicides
- Total petroleum hydrocarbons.

3.4 Contaminant Identification

For this RI, identifying contaminants is the process of evaluating the chemical analytical results to distinguish two types of chemicals: (1) those that represent contamination resulting from U.S. Army activities and (2) those that are representative of naturally-occurring

chemicals or are ubiquitous in urban or semi-urban environments. In short, it is the process of deciding what is contamination and what isn't. This process is especially challenging when dealing with inorganic chemicals, such as metals, that are known to occur naturally at wide-ranging concentrations.

Chemical contaminants are identified independently for surface soil, subsurface soil, groundwater, surface water, and sediments. To determine whether these media have been contaminated by army activities, it is necessary to identify the concentrations of chemicals occurring naturally and/or representing ubiquitous anthropogenic sources. These concentrations can be described as ambient or background:

Ambient: Chemical concentrations that are representative of ubiquitous anthropogenic and natural sources such as common urban activities and natural metals occurrence in geologic formations. These concentrations have not been influenced by Army activities.

Background: Concentrations representative of naturally occurring levels, with no contribution from any anthropogenic sources.

This RI does not characterize background concentrations because the RI sites have been influenced for many years by non-army activity such as motor traffic.

Ambient concentrations of chemicals in groundwater, surface water, and sediment were not characterized. In many cases, groundwater was not found in sufficient quantity to sample upgradient of the RI sites. Surface water bodies are entirely within the PSF and could not be sampled in areas that are clearly separate from army activities. Therefore, groundwater and surface water were evaluated in terms of human health and ecological risk, regardless of the source of chemicals of concern. Sediment that was collected from open ditches (versus storm drains) and from the Baker Beach seep, Lobos Creek, and Mountain Lake was evaluated based on the ambient soil concentrations because these sediments are derived from the surrounding soils.

The ranges of ambient concentrations of inorganic chemicals in soil were characterized as described in section 3.4.2.

In contrast to inorganics, organic constituents such as petroleum compounds and pesticides do not occur naturally at the PSF and are considered to be the result of human activity. Ambient organic concentrations for soil were not characterized. Although ambient levels of organic chemicals could result from ubiquitous sources such as fossil fuel emissions and routine pesticide use, it is assumed that the ambient levels of these chemical at the PSF are insignificant. This inference is based on pesticide results from background surface soil samples that were collected during the Initial RI. The results show very few detections and these detections were at very low concentrations. Also, because petroleum compounds at concentration levels of concern are generally absent at most of the RI sites, there appears to be little basis for characterizing ambient concentrations of these chemicals. Therefore, in this RI report, all detected organic constituents are considered possible site-related contaminants; they are characterized in terms of nature and extent and are included in the risk assessment.

3.4.1 Overview of Regional Soil Data

Characterizing the ambient conditions of soil is difficult because of the complexity of the physical setting of the PSF. Compounding this difficulty are the variability within each of the lithologic units (rock and soil formations), a long history of human activity at many study areas, and the extensive use of fill material in many areas. To aid in this evaluation, regional soil concentrations were reviewed.

Other investigators have interpreted the ranges of background concentrations of inorganic chemical constituents in soil at five sites located in the San Francisco Bay region. These studies were reviewed to provide a frame of reference for the concentrations observed in samples at the PSF. Data from the studies are used as a frame of reference and not as background or ambient values applied to the PSF, because they generally do not directly correlate with the lithologic units found at the PSF. However, they do provide perspective on concentrations that are considered to represent noncontaminated conditions at other nearby sites. These sites may be geologically similar to PSF lithologic units or fill materials that may have been brought onto the PSF. Information from the following locations was reviewed:

- Northern Santa Clara County

- Union City Pacific States Steel Corporation Site
- San Leandro - Roberts Landing Development Site (Area 2)
- Lawrence Berkeley Laboratory

These studies included a study conducted by the California Department of Soil and Environmental Sciences.

3.4.2 PSF Ambient Soil Evaluation

For the PSF, identifying potential contaminants and estimating ambient concentrations in soil were iterative processes, requiring statistical evaluation and professional judgment while recognizing the inherent variability of these naturally occurring constituents. A conservative approach was adopted because most RI sites lacked the operational history necessary to clearly indicate specific types of inorganic contamination. In some cases, the screening of RI site data against ambient values resulted in including metals in the risk assessment even though the metals are not attributable to any known contaminant sources. Given the levels present, and by including these chemicals as possible residuals of past army practices, an unacceptable risk to the potentially exposed receptors might result. However, the risk may not be substantially above the risk posed by ambient or background conditions at the PSF or at other sites in the region.

To deal with the complexity and uncertainties, a stepwise process is employed. The goal is to identify inorganic contaminants at the PSF which likely result from army activities and justify including these chemical constituents in the nature and extent assessment and the Baseline Risk Assessment (BRA) for the site. The process generally follows an approach recommended by the Region IX USEPA that has been used to evaluate ambient conditions at two other federal sites in the Bay Area. These sites are Mare Island Naval Shipyard in Vallejo, California (Dept. of Navy, 1995a) and Naval Station Treasure Island (Dept. of Navy, 1995b). Final ambient concentration values from these studies were not available at the time of this writing. The steps employed in assessing ambient inorganic concentrations in soil at the PSF include:

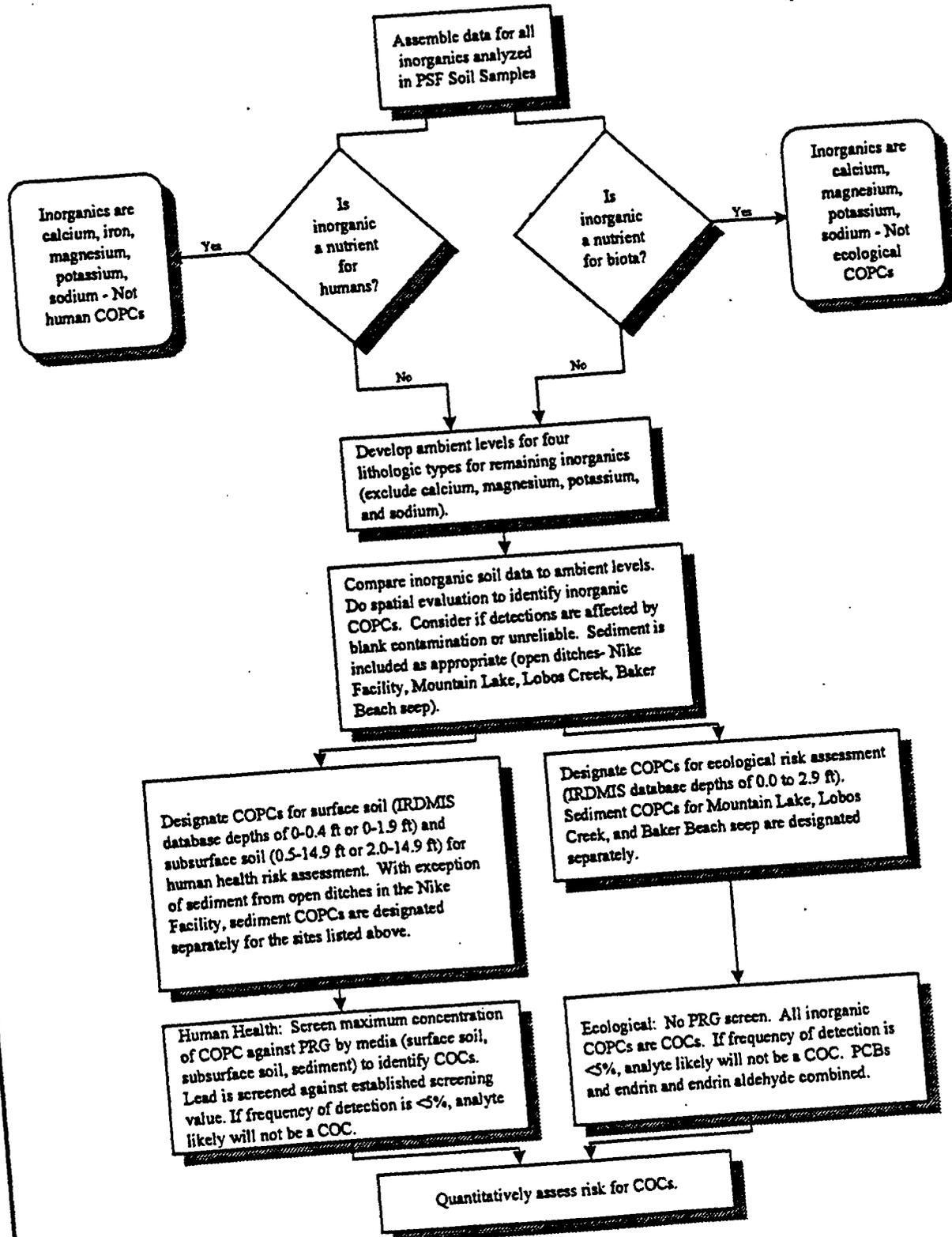
1. **Soils description and data compilation.** The purpose of this step is to combine the lithologic soil units that exhibit similar soil chemistry thus increasing the number of samples representing each unique chemistry.
2. **Risk-based screening of potential contaminants.** This step was performed to help focus the contaminant identification process on the appropriate chemicals. The elements calcium, magnesium, potassium, and sodium were eliminated as potential contaminants because they are common rock-forming elements and occur naturally at high levels.
3. **Ambient soil concentration estimation.** Statistical methods were used in this step to estimate ambient concentration limits for potential inorganic contaminants in soil that were identified in steps 1 and 2 of the contaminant identification process. This step involves three phases: data set preparation, identification of threshold concentrations, and ambient concentration calculations.
4. **Determination of ambient exceedences by study area.** In this step, samples with chemical concentrations above ambient values were assumed to be potentially impacted by site activities. At this point, study areas with results exceeding the established ambient concentration values are identified.
5. **Comparisons of investigative samples to ambient concentrations.** In this step, inorganic soil data (or sediment data in some cases) are compared on a sample-by-sample basis to the sample's respective lithologic-type ambient concentration. At this point, the comparisons are refined by considering whether the analytical results indicate that the sample is more similar to another lithologic category due to mixing of lithologies.
6. **Spatial analysis.** If an inorganic is present above the ambient concentration in one or more samples, it is included in the spatial analysis. The spatial analysis includes evaluation of the following conditions:
 - Location of sample with respect to known or suspected source areas
 - Patterns in vertical or lateral distribution
 - Depth of sample exceeding ambient concentrations
 - Association with organic analytes at site
 - Lithologic description of sample and other samples at the site
 - Physical setting of the site
 - Magnitude of ambient exceedence in relation to the range of concentrations at the site
 - Range of concentrations in background samples collected from the PSF

- Range of regional ambient concentrations and typical concentrations associated with specific rock composition
- Confidence in reported concentration (i.e., consider data footnotes, accuracy of method, analytical analyte interferences, dilution of sample, or sample collection from water saturated zone).

All of these items are considered in assessing whether an inorganic is to be a chemical of potential concern, meaning that the concentrations of the chemical could in fact be elevated as a result of army activities. If the inorganic is considered a chemical of potential concern for a particular site, it is included in the BRA. Although only one sample may exceed ambient, all of the site data for that inorganic are included in the risk assessment. In the human health risk assessment, only results that exceed risk-based screening criteria are identified as chemicals of concern and are evaluated. The ecological risk assessment evaluates all chemicals of potential concern.

The process of identifying inorganic chemicals of concern in soil is summarized in Figure 1. In Figure 1, the left side of the figure pertains to human health risk assessment; the right side to ecological risk assessment. The process begins with assembling the inorganic soil data and processing it separately for the human health and ecological risk assessments. All inorganics that are nutrients are excluded. Next, ambient concentration values are developed for each lithologic type. The data are then compared to the appropriate ambient concentration values and the entire data set for each chemical is retained if any of the data exceed the ambient value. Data that are retained are included in the spacial analysis as described in step 6 above. Data retained after the spacial analysis are designated chemicals of potential concern (COPCs).

For the human health risk assessment, the COPCs are designated separately for surface soil, subsurface soil, and sediment. The COPCs are then screened against risk-based Preliminary Remediation Goals (PRGs) set by USEPA to exclude COPCs that do not pose a risk. The remaining chemicals are designated as chemicals of concern (COCs) and are included in the quantitative risk assessment. Lead is screened separately from all other chemicals by determining whether it exceeds 840 mg/kg, the maximum level acceptable for human health under a recreational or industrial setting for the PSF RI.



PRG = Preliminary Remedial Goal. Humans: residential scenario (EPA Region IX, August 1996)
 COPC = Chemical of Potential Concern
 COC = Chemical of Concern

For the ecological risk assessment, only COPCs that occur at soil depths less than three feet are retained. Sediment data are screened separately from soil. All COPCs retained are considered COCs and are included in the quantitative risk assessment.

Note that any COC detected in less than 5 percent of the samples at a site is not included in the quantitative risk assessment.

3.5 Risk Assessment

The ultimate objective of the RI is to evaluate the risks to human health and the environment which may be posed by chemicals of concern. The risk assessment results presented in the RI are used in the Feasibility Study to identify the most appropriate remediation alternatives and to support risk management decisions. The following sections are intended to help the reader understand and interpret the results of the human health and ecological risk assessments.

3.5.1 Interpreting Human Health Risk Assessment Results

To calculate numerical estimates of health risk, the human health risk assessment combines toxicity factors with quantitative exposure estimates. This process includes the following components:

- Selection of chemicals of potential concern (COPCs) and chemicals of concern (COCs)
- Exposure assessment.
- Toxicity assessment.
- Risk characterization.

COPCs were identified using a conservative approach to ascertain which chemical data are appropriate and adequate for use in the risk assessment. Chemicals retained through this process are interpreted to be contamination resulting from army activities. From the list of COPCs, COCs were then selected which represent the most prevalent, toxic, persistent, or mobile contaminants at each PSF study area.

Exposure estimates are based on how people are expected to use sites at the PSF and on how people might be exposed to contaminants (the exposure pathways). Sites within each study area were evaluated separately according to the land use designated in Alternative A in the

1994 *Final General Management Plan Amendment: Environmental Impact Statement* for the Presidio of San Francisco, issued by the NPS. Land use scenarios used in the human health risk assessment include:

- Recreational (Open Space). This scenario was used predominantly for sites along the San Francisco Bay and Pacific shore regions where recreational land use is planned.
- Industrial (Institutional). This scenario was used at sites designated by the NPS for institutional use.
- Industrial (Commercial/Office). This scenario was used at sites designated by the NPS for Commercial/Office use.
- Industrial (Construction). This scenario was used to assess risk to construction workers who would work on the proposed wetland restoration at Crissy Field and construction projects in the Building 900s Series Study Area.
- Industrial. This scenario was used at sites designated by the NPS for Industrial use.

Where appropriate, the following exposure pathways were considered:

- Ingestion of and dermal contact with soil
- Ingestion of and dermal contact with drinking water
- Ingestion of and dermal contact with groundwater
- Ingestion of and dermal contact with surface water (older child only)
- Ingestion of and dermal contact with sediment (older child only)

The purpose of a toxicity assessment is to evaluate the potential for COCs to cause adverse health effects in exposed persons and to define, as thoroughly as possible, the relationship between the extent of exposure to a hazardous chemical and the likelihood and severity of any adverse health effects. Standard procedures for toxicity assessment include identifying toxicity values for carcinogenic and noncarcinogenic effects and summarizing other relevant toxicity information.

For the chemicals of concern, the risk characterization methods described in USEPA guidelines were used to calculate (1) excess cancer risks for potential carcinogens and (2) hazard indices for chemicals with noncarcinogenic effects. Upper-bound estimates of lifetime cancer risk were calculated for each of the land use scenarios. A target risk range of 1E-04

to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (Federal Register 56(20):3535, Wednesday, January 30, 1991). A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. (1E-06 equals 1×10^{-6} or .000001; the larger the number after the minus sign, the smaller the risk. Thus 1E-08 indicates a lesser risk than 1E-06, and 1E-2 indicates a greater risk.) The risk range of 1E-04 to 1E-06 was used as a basis for comparison of risk estimates calculated for carcinogens identified at the PSF.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). The HQ is compared to a hazard index of 1E+00 (or simply, 1) which indicates that the exposure is below a level that is likely to cause adverse health effects even in the most sensitive members of the population. For example, if the HQ >1E+00 (is greater than 1), there may be concern for noncarcinogenic adverse health effects. On the other hand, if the HQ <1E+00 (is less than 1), the exposure is very unlikely to result in noncarcinogenic adverse health effects.

Although carcinogenic risk and noncarcinogenic hazard estimates are presented numerically, there are uncertainties associated with each component of the risk assessment process.

Because conservative assumptions were used in each component of the risk assessment, the actual adverse effects to human health are very unlikely to exceed the estimates of human health risks and hazards.

In addition, soil lead concentrations were compared to a lead soil screening value of 840 mg/kg. This value is based primarily on the results of using conservative assumptions in modeling lead concentrations in the blood of human receptors at the PSF. Concentration levels less than this are considered protective of human health for sites evaluated in this RI.

As a preliminary assessment of a residential scenario, a residential PRG ratio screening assessment was also performed for all Main Installation RI sites. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of each component of risk assessment that was performed in the other scenarios assessed in this RI report. In contrast, the other scenarios assessed in this RI are based on conservative, but

more realistic exposure assumptions based on the planned future uses and site conditions at the PSF. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

The findings of the human health risk assessment for each Main Installation RI site are summarized in section 15.1 of this Executive Summary.

3.5.2 Interpreting Ecological Risk Assessment Results

The ecological risk assessment for the Main Installation RI follows USEPA guidance and includes the following components:

- **Problem Formulation:** Summarizes information pertinent to the assessment of ecological risk, including a description of ecological receptors (plants or animals exposed to contamination), site conditions, and selection of chemicals of concern.
- **Exposure Analysis:** Evaluates which of the exposure pathways presented in the site conceptual model are actually complete and are quantifiable for the media investigated.
- **Stress Response Analysis.** Describes the ecological health effects caused by each of the COCs.
- **Risk Characterization:** Presents site-specific risk results and uncertainty analysis.

For each of the identified fill sites, landfills, or areas of concern where chemicals occur in soil, exposure by direct contact (contact of the receptor directly with soil) was evaluated for terrestrial plants and soil invertebrates. In addition, dermal (skin) contact with soils was evaluated for mammals and birds. Exposure due to ingestion of soils was evaluated for mammalian and avian wildlife receptors. Uptake of chemicals from soil by biota was modeled with a food web model so that dietary exposure could be quantitatively evaluated.

Ecological receptors are divided into two broad categories based on habitat type: (1) receptors that occur in terrestrial environments (e.g., terrestrial plants, soil invertebrates, American robin, mourning dove, peregrine falcon, red-tailed hawk, western harvest mouse, valley pocket gopher, and raccoon), and (2) those that live in aquatic habitats (e.g., benthic invertebrates, amphibians, fish, mallard duck, spotted sandpiper, and racoon). These categories overlap in that some receptors may occur in transitional habitats or in more than

one habitat type. Potential impacts of the PSF to aquatic receptors in San Francisco Bay were assessed separately from the RI; (ESAP summary) however, the results of that study have been integrated into the RI characterization of sites adjacent to the Bay.

Determining how exposure occurs and quantifying the extent of exposure constitute a large component of the ecological risk assessment. However, to predict the actual hazard to a receptor, toxicological information relative to the various ecological receptors was obtained. For plants and soil invertebrates, a literature review produced estimates of acceptable soil concentrations for most of the contaminants of concern. For birds and mammals, the literature review resulted in daily intake values (the daily amount of a chemical ingested, expressed in terms of body weight) that would not be likely to produce individual or population health effects for each of the contaminants of concern. The Ambient Water Quality Criteria for the Protection of Freshwater Aquatic Organisms and their uses were used to determine whether or not adverse effects on populations of aquatic life or amphibians would occur due to exposure to water. Sediment Quality Criteria were used to determine adverse effects on populations of aquatic life or amphibians. While the Sediment Quality Criteria appear to specifically determine risks to benthic invertebrates, the results can be inferred to be protective of other species of aquatic life in continuous contact with sediments. Where such toxicity criteria or benchmarks are lacking, ecological risk cannot be quantified.

Risk to ecological receptors is quantified by the Quotient Method, which is similar to the method used to quantify noncarcinogenic risk to human receptors. An exposure estimate is compared to a toxicity criterion and the resulting ratio is called a hazard quotient (HQ), which provides an estimate of potential risk for a specific chemical to a specific receptor. If the HQ is less than 1, it indicates that the chemical presents little or no risk to the receptor. If the HQ exceeds 1, it indicates that the chemical concentration in the environment may have a potential for adverse effects on that receptor. However, there is no direct relationship between the magnitude of the HQ and the magnitude of the adverse effects. For example, an HQ of 100 does not mean that the effects are 100 times more severe than an HQ of 1. In fact, given the uncertainties inherent in risk assessment, as well as the cumulative effects of numerous conservative assumptions, even an HQ of 10 is probably not a strong indicator of ecological risk. However, larger HQs do indicate some greater potential for adverse effects.

In response to concerns expressed by reviewers of the previous RI, low and high HQs are calculated for each COPC and each receptor at each assessed site. The HQ_{Low} is an estimate of ecological hazard based on toxicity criteria that correspond to levels of exposure that have been shown in published studies to cause adverse effects (the TBV_{High}). The HQ_{High} is more conservative because it is based on toxicity criteria that correspond to levels of exposure that have been shown in published studies to cause no adverse effects. These criteria are the TBV_{Low} . In other words, a larger HQ results when a lower (more conservative) toxicity criterion is used. In this RI report, HQ_{Low} values are summed for each receptor at each assessed site to find the total hazard index (HI_{Low}) based on adverse effects criteria. Likewise, HQ_{High} values are summed to find the HI_{High} based on the no adverse effects criteria.

The two HI values represent a range of total estimated ecological risk to a specific ecological receptor from all COPCs at a specific site. This approach is intended to help risk managers make informed decisions on remedial actions at the PSF by using a broad base of scientific information to develop a range of estimated ecological risk. With this information, the risk managers can balance the risk presented by the contaminants with other decision factors such as the destruction of habitat that may be associated with remedial actions.

The findings of the ecological risk assessment are summarized in section 15.2 of this Executive Summary. The Following sections, sections 4 through 14, summarize the site investigation results for each of the Main Installation RI study areas.

4. NIKE FACILITY

The area around the silos at the Nike Facility has been used for storage since the termination of missile activities at the site. Chemical releases from the stored materials to surface sediments on the asphalt have resulted in detectable concentrations of several contaminants of concern, primarily inorganics, total petroleum hydrocarbons (TPH), and polynuclear aromatic hydrocarbons (PAHs). These chemicals have migrated with the sediment into the storm drain system and, in some cases, to the soil below the outfalls outside the perimeter fence. Most of the elevated concentrations are detected in the surface soil and not in subsurface soil.

Rusting metal within the silos has resulted in detectable concentrations of antimony in samples of the standing water in all three silos. The antimony in the silo water does not appear to have been released to the groundwater in the area. The groundwater contained several inorganics, including aluminum, chromium, manganese, mercury, and nickel at concentrations above California primary maximum contaminant levels (MCLs) for drinking water. With the exception of mercury, the elevated concentrations are likely due to the presence of serpentinite bedrock and trace amounts of serpentinite in the other geologic units. Mercury was detected above the California primary MCL in Well NKGW01 during the Follow-on RI and in subsequent sampling conducted by Montgomery Watson, indicating a potential site-related source of mercury that has resulted in detections in storm drain sediment and in groundwater near Silo 2.

5. CRISSY FIELD STUDY AREA

The investigations in the Crissy Field Study Area were designed to assess the chemical impact of army activities at the site. Potential sources were identified, and analytical samples were collected from various media. For the purposes of this RI, the area was divided into five subregions: the Consolidated Motor Pool; the POL Area; Fill Site 7; Buildings 609, 611, and 633; and the Sewer Lift Stations. An additional subregion was added for the BRA to allow evaluation of the proposed future wetland.

5.1 Consolidated Motor Pool

Potential chemical sources evaluated in the Consolidated Motor Pool Area were surface leaks and spills related to vehicle maintenance activities. Both inorganics and organics could have been released by such a source. TPH was the most frequently detected organic compound in soil that will be evaluated in the human health and ecological BRA. The extent of TPH is limited primarily to surface soils located behind Building 643. Two volatile organic compounds (VOCs), several PAHs and phthalates, and one pesticide were also identified as COPCs for both the human health and ecological risk assessments. The extent of PAHs in soil is limited, with detections occurring in soils from 0 to 2 feet below ground surface (bgs) in a small area near the southeast corner of Building 643. A specific source for PAHs, TPH, and inorganic detections in this area is unknown, but it is probably related to accidental surface spill(s).

5.2 POL Area

Because all COPCs in the POL Area are related to releases of petroleum products, analytical results from this area are not incorporated into the human health or ecological BRA in this RI report. Assessment of this site is being conducted by the Sacramento Corps of Engineers under the petroleum cleanup program.

5.3 Fill Site 7

The potential chemical sources evaluated in Fill Site 7 are debris and artificial fill materials. The surface soil at Fill Site 7 contained the majority of inorganic analytes detected above ambient concentrations. Although several inorganic analytes were detected above ambient values in subsurface samples, they were generally not the same inorganics that were detected in the surface soils. This indicates that downward migration of inorganics from surface soils to deeper soils is minimal. The fill material has only a local impact, with the areal extent of ambient exceedences generally defined by adjacent samples (within approximately 300 to 500 feet). Inorganics in groundwater reflect natural weathering processes of serpentinite derived soils, with aluminum, iron, nickel, chromium, manganese, and magnesium occurring throughout the site. Inorganics detected above ambient values in soils were generally absent in groundwater, or occurred at concentrations below primary MCLs and/or Water Quality Objectives for saltwater aquatic life protection. The eastern portion of Fill Site 7, at Wells LF7GW07, LF7GW09, and LF7GW10, was the only area where chemical concentrations in groundwater are generally higher than elsewhere in Fill Site 7. However, these higher groundwater detections do not appear to be derived from leaching of inorganics from fill materials, and may reflect local, natural, hydrogeologic conditions.

Organic compound detections were primarily PAHs in surface soils from the helipad area and total petroleum hydrocarbons in the diesel range (TPH-D) throughout the site. The helipad area was the only portion of Fill Site 7 with elevated concentrations of PAHs. The lateral extent of PAHs in the northwestern portion of the helipad is approximately 125 feet by 125 feet, with a maximum vertical extent of 2 feet. The eastern section of the helipad area had a lateral extent of approximately 100 feet by 100 feet, with a maximum vertical extent of 2 feet. PAH concentrations elsewhere in Fill Site 7 were generally below SDCs. Other organics detected in soil were several organochlorine pesticides in surface soils and a single detection of trichlorofluoromethane. Organic compounds detected in the soil were not detected in groundwater from Fill Site 7, indicating that the fill material and overlying soils are not a potential source of groundwater contamination, and vice versa. The only organics detected in groundwater in more than one location were two final degradation products of trichloroethene (cis-1,2-dichloroethene and vinyl chloride) and 2,4-D.

5.4 Buildings 609, 611, and 633

The potential chemical source evaluated at Building 609 was a pesticide spill that reportedly occurred prior to demolition of the building in 1987. Three pesticides were detected in surface soil samples.

Samples were analyzed for PCBs at Building 611, but there were no detections.

Building 633 was a firing range used for small arms target practice. It is no longer in use. Lead was the only chemical targeted in sample analyses at this site, and concentrations found above ambient were generally limited to the concrete-lined sand pit, which was the receptacle for spent ammunition.

5.5 Sewer Lift Stations

Surface spills from over-flow at two sanitary sewer lift stations were investigated at this site. COPCs were limited to inorganics, as organic compounds were not detected above reporting limits at either of the Sewer Lift Stations.

5.6 Proposed Wetlands Restoration Area

The proposed wetlands restoration area encompasses samples from both the Crissy Field Study Area and the East-of-Mason site. Soil and groundwater sample results from these areas were included in the wetlands evaluation. The list of COPCs for these samples includes inorganics, VOCs, PAHs and other semivolatile organic compounds (SVOCs), and pesticides.

5.7 Potential Impacts to the Bay

Stormwater and bay sediment sample data collected under the ESAP provide additional information on the significance of this pathway and the potential effects on aquatic receptors in the Bay. The storm drains in the POL area are part of the Outfall 10 drainage system. Both stormwater and bay sediment samples associated with this outfall were collected. The analytes detected in the RI storm drain sediment samples were not present at elevated levels in ESAP stormwater or bay sediment samples collected in 1994 and 1995 from Outfall 10.

Bioassay testing data for these media indicated that there was no significant effect of the toxicity of the stormwater or sediments to the tested species. Because the nearshore area is such a dynamic environment, the potential for accumulation of chemicals in the bay sediment is low. As concluded from the ESAP data, the transport of contaminants in sediment and soil from the POL area to the bay via the storm drains is not a significant exposure pathway for aquatic receptors in the bay.

6. BUILDING 900S SERIES STUDY AREA

The investigations in the Building 900s Series Study Area were designed to assess the chemical impact of army activities at the site. Potential sources were identified, and analytical samples were collected from various media. For the purposes of this RI, the area was divided into three subregions: the Vehicle Maintenance Area, the Storage Building Area, and Building 979. The evaluation of groundwater included all three areas. Conclusions for the each subregion and for groundwater are presented in the following four sections.

6.1 Vehicle Maintenance Area

The evaluation of the Vehicle Maintenance Area was subdivided to allow the separate assessment of Building 937, which was treated in greater detail under the IRA.

Potential contaminant sources for Buildings 923 through 935 in the Vehicle Maintenance Area are surface spills or leaks from equipment. The primary source of inorganics in this area was activities such as steam cleaning and the storage of paints and batteries in the vicinity of Buildings 929, 930, and 931. Elevated inorganic detections elsewhere in the Vehicle Maintenance Area suggest other small, isolated sources. The vertical extent of elevated inorganic detections in soil throughout the area is limited, with very few exceedences of ambient values in subsurface samples. In addition, there is no indication that groundwater is impacted by inorganic soil contamination. Several organic compounds were detected in soil from Buildings 923 through 935, but the lateral and vertical extent was limited, indicating that U.S. Army activities have had little impact on the soil.

The potential contaminant sources evaluated at Building 937 are surface spills and USTs. Two USTs, contaminated soil, and petroleum product have been removed from this area as part of the IRA. Though elevated inorganics have been detected at the site and will be evaluated in the risk assessment, a specific source of inorganics is unknown.

BTEX compounds are the most commonly detected organics in soils in the Building 937 Area, with the highest concentrations generally occurring where there is product. Soil samples saturated with petroleum product have been collected outside the area of the

excavation where the underground storage tank was removed and a thin sheen of product has been sometimes observed in Wells 937GW03 and 937GW36. BTEX compounds and TPH are present at high concentrations in shallow groundwater where product is observed. Soil near Well 937GW36 was excavated to the extent possible in 1992 as part of the tank excavation to remove product. The well was installed after soil removal. The only remaining potential source for product at this well is in soil beneath the footings for Building 937. Further excavation here would undermine the structural integrity of the building and is not recommended. The area continues to be evaluated through quarterly groundwater sampling.

6.2 Storage Building Area

The Storage Building Area included four buildings: 949, 950, 973, and 974. These pole-construction buildings, which have been demolished, were used to store a variety of materials over the history of the site, and Building 950 was temporarily used to store hazardous materials. The potential sources evaluated in this area were surface spills and leaks. Numerous inorganics were detected, generally with limited vertical extents. With the exception of lead, elevated detections of inorganics were generally limited to samples collected from building interiors. Organic COPCs identified in this area include several PAHs, phthalates, ppDDE, TPH, and trichlorofluoromethane.

6.3 Building 979

The potential source evaluated at Building 979 was surface spills. Elevated chemical detections in soil are limited to a few inorganics, pesticides at very low concentrations, SVOCs, and TPH. The areal extent of each of these is limited and chemicals in the soil do not appear to impact groundwater.

6.4 Groundwater

The total extent of groundwater contaminated by BTEX, chlorinated compounds, and TPH resulting from releases at Building 937 and 979 has been defined by the investigations in the Building 900s Series Study Area. The chemical sources in each of these areas have been removed. The investigation and quarterly monitoring program show that natural attenuation

is occurring. For BTEX and TPH compounds, there has been minimal migration away from the source area at Building 937. Trends in the distribution of chlorinated compounds over time show a decrease in parent compounds due to degradation. Migration of parent compounds south of Building 937 has not occurred. A few detections of degraded chlorinated compounds have occurred south of Building 937; however, these are isolated occurrences and generally do not exceed primary MCLs.

Inorganic source areas in most of the Building 900s Series Study Area have not been identified for groundwater. Most areas where standards for drinking water and saltwater aquatic life are exceeded are associated with natural weathering processes. Wells 937GW03 and 937GW36, located near Building 937 have contained floating petroleum product. The residual product in these wells is the source of high inorganic concentrations at these locations. Migration of the inorganics from this area is not evident.

6.5 Potential Impacts to the Bay

The transport of potential contaminants to the Bay and the potential impact on aquatic life within the Bay were investigated as part of the ESAP for four primary storm drains in the Building 900s Series Study Area. Stormwater and bay sediment samples, associated with the four outfalls, were analyzed to assess the impact of the storm drains and the potential migration of contaminated groundwater to the Bay. Chemical analyses were performed to measure chemical concentrations in stormwater and bay sediment. Bioassay testing was performed to directly assess adverse effects on aquatic life.

The analytical and bioassay testing data for stormwater indicated potential toxicity at Outfalls 12, 13, and 16, most likely associated with the concentrations of metals in the stormwater. However, only the drainage associated with Outfall 16 is interpreted to be producing higher than expected concentrations of metals for an urban environment. Based on the drain system configuration, the potential source of these metals (arsenic, chromium, and copper) is the Building 979 area, but no confirmation of elevated levels in the soil has been made. Although these concentrations are higher than those reported in the other outfall samples, the calculated annual mass loading of metals to the Bay from this outfall falls at the lower end of the range estimated for each of the other outfalls at the PSF. This is due to the

low amount of flow typically observed at this outfall. This, in combination with potential dilution at the point of discharge, by rainfall and bay water during high tides, and the absence of apparent impacts to biota at the outfall, suggests that toxicity to aquatic life near the Outfall 16 discharge area predicted from these test results is an overestimation.

Chemicals detected in the stormwater do not appear to be incorporated into the sediments adjacent to the outfalls. Analytical and bioassay testing data for sediments indicated that although low levels of PAHs and pesticides were associated with a few samples from Outfalls 12, 13, and 15 (PAHs only), there was no significant effect on the toxicity of the sediments to the tested species. Therefore, it is likely that the toxicity associated with the stormwater is limited to the stormwater and its collection system, with no residual impact on the bay sediments. Furthermore, the PAHs and pesticides detected in the bay sediments may not be associated with the Building 900s Series Study Area, but derived from ubiquitous urban emissions and routine agricultural applications, respectively, on either the PSF or nearby properties.

7. DIRECTORATE OF ENGINEERING AND HOUSING STUDY AREA

The investigations in the Directorate of Engineering and Housing (DEH) Study Area were designed to assess the chemical impact of army activities at the site. Potential sources were identified, and analytical samples were collected from various media. Concern in the DEH Study Area relates, primarily, to chemical concentrations in soil. In the vicinity of Buildings 267, 268, and 287, the COPCs in soil were chromium, copper, cyanide, lead, silver, zinc, organochlorine pesticides (OCPs) and related bis(2-ethylhexyl)phthalate, PAHs, phenol, and toluene. Near Buildings 269 and 293, selenium and OCPs and related compounds were identified as COPCs in soil. The COPCs in soil at Building 283 included cadmium, copper, cyanide, lead, manganese, mercury, zinc, PAHs, phthalate esters, 1,2-dichlorobenzene, 2,4-dichlorophenol, and ppDDD. The COPCs in soil at Building 286 were antimony, copper, manganese, SVOCs, and TPH.

The data from filtered and unfiltered groundwater samples in the DEH Study Area indicate that inorganic analytes are adsorbing to the soil, and concentrations detected in unfiltered samples are associated with suspended sediment. Detections of organic compounds in groundwater samples have generally been limited to chlorinated solvents in the vicinity of Well DEHGW02.

The distribution of target analytes in the sediment samples collected in the DEH Area suggests that chemical transport through the storm drain system is limited. In general, analytes detected in upstream samples are not detected in downstream samples. This conclusion is supported by the sampling conducted in support of the ESAP, which indicated that although the stormwater samples contain the types of analytes detected in the RI storm drain sediment samples, such as PAHs, TPH-D, total petroleum hydrocarbons in the gasoline range (TPH-G), and metals, they have not been translocated into the nearshore sediments. In addition, the analyte detections in the stormwater are primarily associated with sources other than the DEH Study Area.

8. MAIN POST STUDY AREA

The Main Post Study Area is located in the northeastern portion of the PSF. The area is south and west of U.S. Route 101, north of Fill Site 6, and east of the Building 669 site. San Francisco Bay is approximately 1,000 feet north of the Main Post Study Area.

Six sites within the Main Post Study Area have been investigated during the RI: the Building 215 area, the Building 231 area, the Building 1057 area, the Building 1065 area, the Building 1167 area, and the Building 1151 area. Building 1040 was identified as requiring further study; however, the transformer area associated with Building 1040 was remediated prior to the 1992 Supplemental RI field investigation. Therefore, Building 1040 was eliminated from the scope of work for the RI.

8.1 Building 215

The investigative results in the Building 215 area demonstrate that contamination associated with USTs formerly located at this site has been remediated. There were no detections of targeted chemicals in any of the soil samples collected at the site. It is recommended that Well 215GW01 be resampled as part of the site-wide groundwater monitoring program to confirm the presence or absence of 1,2-dichloroethane in the shallow groundwater at this site. All three of the wells have been recommended for a year of quarterly sampling in the Basewide Groundwater Monitoring Program.

Exposure to inorganics, miscellaneous parameters and the two detected organics, 1,2-dichloroethane and chloroform, in groundwater beneath Building 215 will be evaluated in the human health risk assessment. Risk to ecological receptors will not be addressed because of the unlikely existence of an exposure pathway.

The results of field investigations confirm the presence of two primary sources of fuel hydrocarbons in the Building 231 area. Fuel hydrocarbons are known to have leaked from USTs that were removed in 1988 from the parking lot north of Building 231. In addition, soil and groundwater samples indicate a second source of fuel hydrocarbons in the vicinity of the

tanks located between Buildings 231 and 228. Leaks and/or spills of fuel hydrocarbons from these sources have resulted in soil and groundwater contamination at the site.

8.2 Building 231

Petroleum hydrocarbon soil contamination extends from south of Building 231 to the north and east of Building 231. The eastern extent of soil contamination has not been fully defined. Fuel hydrocarbons in groundwater extend from the area of the USTs between Buildings 231 and 228 downgradient to Well 231GW15. Groundwater contamination was found in all three water-bearing zones downgradient of Building 231 in the Follow-on RI, but subsequent monitoring results have not shown any consistent detections in the deep aquifer. However, based on the results of discrete groundwater samples collected from Boring 231SB26, the vertical extent of groundwater contamination has not been delineated.

The Building 231 area will not be considered in the BRA. Given that the COPCs are petroleum hydrocarbons and that the suspected sources are USTs formerly located at the site, the assessment of the need for further investigation of the vertical extent and further investigations or remedial actions will be conducted under the USCOE basewide petroleum cleanup program. A Corrective Action Plan is in preparation. Future sampling of the Building 231 wells is addressed under the Basewide Groundwater Monitoring Program.

In the Building 228 area, the only COPC in soil is bis(2-ethylhexyl) phthalate. It is suspected that this analyte is not site-derived, and the analytical data indicate that the former dry cleaning operations at Building 228 have not impacted soil and groundwater. Subsequent groundwater sampling conducted by Montgomery Watson supports this inference. Bis(2-ethylhexyl)phthalate will, however, be evaluated as a COPC in both the human health (subsurface soil) and ecological risk assessments for the Building 228 site, as all detected organics are considered to be COPCs, unless the data are considered unreliable or affected by blank contamination.

8.3 Building 1057

COPCs in the vicinity of the vault at Building 1057 appear to be limited to the sediment within the vault itself. Although cadmium, lead, mercury, zinc, and TPH-D were detected at

elevated levels in sediment from within the vault, they were not detected at levels of concern in the soil sample collected below the vault. Phthalates, which were detected in the sediment sample at concentrations ranging from 12.3 to 28.4 $\mu\text{g/g}$, were detected at concentrations less than 0.2 $\mu\text{g/g}$ in the soil sample collected 1.6 feet below the vault. The concrete floor of the vault appears to have limited migration of COPCs through the vault to underlying soil. The COPCs detected in the vault may not be related to past activities in Building 1057 but probably resulted from surface water runoff from Birmingham Road north of the vault.

8.4 Building 1065

Soil and groundwater samples were collected to evaluate potential sources of petroleum-related contamination in the Building 1065 area. These potential sources include unsubstantiated underground tank(s) under or near Building 1065 and the above ground fuel oil tank and associated fuel oil distribution lines northwest of Building 1040 and south of Building 1065. TPH-G and TPH-D were detected above SDCs and lead was detected above the drinking water action level in discrete groundwater samples collected both upgradient and downgradient of Building 1065. Analytical data from soil samples are inconclusive as to the source(s) of contamination. TPH (immunoassay) was detected at $>100 \mu\text{g/g}$ in only one soil sample collected immediately south of Building 1065. The vertical and lateral extent of lead and TPH in groundwater have not been fully delineated in either the upgradient or downgradient directions. However, it is possible that the elevated levels of lead in the discrete groundwater samples are associated with the turbid nature of the samples collected using a depth-discrete groundwater sampling device and that groundwater samples, particularly filtered samples, collected from monitoring wells would have significantly reduced lead concentrations.

Building 1065 will not be considered in the BRA. Considering that the primary contaminants at this site are petroleum hydrocarbons and that Building 1065 was formerly a gasoline service station, it has been determined that future investigations of the nature and extent of contamination and any necessary remedial actions will be conducted under the USCOE basewide petroleum cleanup program

8.5 Building 1167

Investigation of potential contamination related to the spray booths at Building 1167 documented the presence of several inorganics at concentrations above ambient in shallow subsurface soil, but no VOCs were detected in any of the soil samples. Detections of lead, mercury, and zinc in the 0.5 feet bgs sample from Boring 1167SB03 were considered to be potentially associated with previous site activities. Migration to deeper soil appears to be limited to 5 feet bgs. However, because the groundwater is shallow in this area (1.5 to 3.5 feet bgs during the field investigation), migration of these inorganics to groundwater is possible. This pathway was not assessed through field sampling; however, any impact of these inorganics on the groundwater is expected to be minimal, based on the minor exceedences (less than an order of magnitude) of ambient values, the relative immobility of inorganics, and the clayey subsurface lithologies which tend to inhibit migration.

8.6 Building 1151

The primary source(s) of contamination at the site was transformers containing PCBs. No contamination was detected associated with the metal paint storage shed. Past transformer operations resulted in leaks and/or spills of PCBs to concrete pads, fence posts, and soils. The transformers containing PCBs were removed following a sampling program in 1987. Assuming that quantities of PCBs leaked or spilled were small, there is little potential for PCB migration downward through the soil column. This is supported by subsequent sampling conducted in 1996 by Montgomery Watson. Further investigation and removal of PCB-contaminated soil is addressed under an EE/CA document which has been accepted by DTSC.

9. FILL SITES AND LANDFILLS

This section describes the RI site investigation results at Fill Site 1 and Landfill 2, Transfer Station, Landfill 4 and Fill Site 5, Fill Site 6, Graded Area 9, and Landfill E.

9.1 Fill Site 1 and Landfill 2

The potential source(s) of contamination at Fill Site 1 and Landfill 2 are debris fill and/or landfill materials deposited during use of the sites. To evaluate the impact of fill material on the environment, surface and subsurface soils, surface water, and groundwater samples were analyzed.

Chemicals detected in debris fill samples at Fill Site 1 include several inorganics above ambient concentrations, several SVOCs at concentrations near the detection limit, and one detection of TPH-D at 10 µg/g. These analytes were either not detected, or had lower concentrations in the underlying native material. Several VOCs, and one SVOC were detected in groundwater, however, VOCs were not detected in any soil samples at the site, and the SVOC detected was not the same as those detected in soils. In addition, the VOC 1,2-dichloroethane was detected in only one sampling round, and the associated parent and breakdown products were not detected in any samples at Fill Site 1. 1,2-Dichloroethane was a common anomaly in groundwater samples collected during the Follow-on RI. Quarterly sampling of these following the Follow-on RI failed to confirm the presence of these compounds.

Soil COPCs identified at Fill Site 1 include all detected organics.

At Landfill 2, analytes detected in debris fill or landfill material include inorganics, several SVOCs, one OCP, and TPH-D. These analytes were not detected or were at lower concentrations in the underlying native material or groundwater except for TPH-D. TPH-D was detected in both native material and groundwater, however, its presence is not believed to be associated with fill due to different chromatogram patterns.

Soil COPCs identified at Landfill 2 include all detected organics and the inorganics antimony, barium, chromium, copper, cyanide, lead, mercury, silver, and zinc.

In surface water from El Polin Spring several inorganics were detected at concentrations exceeding MCLs. Several of these inorganics were also above MCLs in groundwater samples from nearby upgradient wells near the base of Landfill 2. All detected analytes in groundwater and surface water will be assessed as part of the risk assessment.

9.2 Transfer Station

The potential source(s) of contamination at the Transfer Station include leaks and spills during waste transfer operations. The purpose of the RI at the Transfer Station was to investigate if waste transfer activities and the artificial/debris fill used in the construction of the site have had an impact on the environment.

To investigate the potential impact of surface spills associated with waste transfer activities, surface and subsurface soils were collected across the site. Several groups of contaminants were detected in surface soils, including inorganics, VOCs, SVOCs, OCPs, chlorinated herbicides, and TPH-D. Laterally, detections at the surface are generally concentrated near the base of the retaining wall and in the areas where roll-off containers were stored. At this location, concentrations generally decrease with depth.

To investigate the fill material used to level the ground surface during construction of the site, subsurface soil samples were collected from within and beneath the fill material. Target analytes detected in the fill include inorganics, VOCs, SVOCs, pesticides, OCPs, and TPH-D. The number of detections and concentrations were lower in the underlying native material.

Results of the RI sampling indicate that operations at the Transfer Station site have released several groups of contaminants to surface soils at the site and that concentrations generally decrease with depth. The fill material used to level the ground surface does not appear to be impacting the underlying soil.

Soil COPCs identified at the Transfer Station include all detected organics and the inorganics aluminum, barium, lead, mercury, and vanadium.

9.3 Landfill 4 and Fill Site 5

The potential source(s) of contamination at Landfill 4 and Fill Site 5 are debris fill and/or landfill materials deposited during use of the sites. Surface and subsurface soils, and downgradient groundwater were analyzed to evaluate the distribution of target analytes at Landfill 4. At Fill Site 5, surface and subsurface soil were analyzed.

In Landfill 4, pesticides, PCBs, and TPH-D were detected in native materials beneath fill; in general the number of detections and concentrations decreased with depth. Groundwater downgradient of Landfill 4 does not show any impact associated with the fill material. In the Fill Site 5 area, inorganics and TPH-D were reported in native materials.

Soil COPCs identified for Landfill 4 include all detected organics and the inorganics antimony, lead, and mercury. Groundwater COPCs include all detected target analytes.

For Fill Site 5, soil COPCs include all detected organics. Inorganics were not identified as COPCs.

9.4 Fill Site 6

The primary source of contamination at Fill Site 6 is debris fill and artificial fill materials from demolition of the original LAMC. Subsurface soils and groundwater were analyzed to evaluate the distribution of target analytes at the site.

Only inorganic and VOC target analytes were detected in samples of native materials below fill. Concentrations of inorganic analytes generally decreased with depth, with the exception of silver, which was similar in both fill and native material. Two VOCs were detected in native material samples collected during the Initial RI. The detections of these compounds were not confirmed in other samples collected at the site, and were not detected in groundwater. Based on these results, fill material at Fill Site 6 has not had a significant impact on underlying soils or groundwater.

Soil COPCs for Fill Site 6 include all detected organics.

9.5 Graded Area 9

The primary source of contamination at Graded Area 9 is debris fill deposited during leveling of the site. Subsurface soils were analyzed to evaluate the distribution of target analytes at the site.

The lateral and vertical extent of target analytes is sporadic and generally appears to be limited to fill materials. Inorganics were not detected above ambient values in the underlying native material. No VOCs, SVOCs, PCBs, or chlorinated pesticides were reported from a sample of native material below fill. ppDDT was reported in native material below fill, but was not detected in the overlying fill material. TPH-D was reported in both fill and native materials; concentrations of TPH-D decreased with depth. Based on the results of RI sampling at Graded Area 9, debris fill material does not appear to be impacting the underlying native soils.

Soil COPCs identified for Graded Area 9 include all detected organics and the inorganics aluminum and vanadium.

9.6 Landfill E

Debris fill and landfill materials deposited in Landfill E are potential sources of contaminants. Surface and subsurface soil samples and groundwater samples were analyzed to evaluate the distribution of target analytes at the site.

Inorganic analytes, one PCB Aroclor, and TPH-D were reported in native soil underlying fill materials. VOCs, SVOCs, OCPs, and chlorinated herbicides were not reported in samples of native materials below fill.

Soil COPCs identified for Landfill E include all detected organics and the inorganics barium, cadmium, copper, iron, lead, mercury, silver, and zinc.

Manganese and TDS were reported above Secondary MCLs in groundwater samples; manganese was not above ambient values in any soil samples collected at the site. The VOC 1,2-dichloroethane was detected in one well, however, its presence was not confirmed by any other samples collected at the site, or by quarterly groundwater sampling performed

following the RI. PCBs and chlorinated herbicides were not reported in groundwater samples. Bis(2-ethylhexyl)phthalate, beta-BHC, delta-BHC, and TPH-D were reported above MDLs or CRLs in groundwater. The two OCPs detected in groundwater were not detected in overlying soil samples from the same location.

10. MISCELLANEOUS SITES

The Miscellaneous Sites are individual areas not associated with any of the study areas discussed in previous sections. Miscellaneous Sites investigated in the Initial RI field program include Lobos Creek, Mountain Lake, and four buildings: 662, 680, 1244, and 1351. The Fort Point U.S. Coast Guard Station (FPCGS) was added to the RI in the Fall of 1990 when it reverted to PSF control.

10.1 Building 662

Vehicle maintenance operations within and around Building 662 have resulted in the release of COPCs to shallow soils in the area. Contamination associated with the UST and AST locations on the west side of Building 662 will be addressed under the basewide petroleum cleanup program. COPCs associated with stained soil on the south side of Building 662 include lead, zinc, bis(2-ethylhexyl)phthalate, and three PAHs, including chrysene, fluoranthene, and pyrene. These contaminants appear to be limited to above 5.0 feet bgs based on the results of samples collected from Borings 662SB06 and 662SB07. No contamination associated with the hydraulic lifts was found. Groundwater did not appear to be impacted by the soil contaminants in the stained areas, and lead is the only groundwater COPC for the human health risk assessment. The ESAP stormwater and sediment data indicated that there was no significant toxicity to aquatic receptors associated with the outfall that is connected to the storm drain at this site.

10.2 Building 680

Building 680 was used to store electrical equipment including transformers. Transformer leaks have resulted in the presence of detectable concentrations of the PCB Aroclor 1260 in the soils surrounding Building 680. PCBs are evaluated in both the human health and ecological risk assessments.

Further investigation and removal of PCB-contaminated soil is addressed under an EE/CA document which has been accepted by DTSC.

10.3 Building 1244

The only soil COPC detected at the Building 1244 site was lead in soil samples collected within the gravel-filled concrete trench. However, it appears that the concrete floor of the trench is limiting potential downward migration, as lead was not detected in soil samples collected below the concrete floor of the trench.

10.4 Building 1351

To evaluate potential contamination associated with vehicle maintenance activities in and around Building 1351, wipe, surface soil, and subsurface soil samples were collected to the east and northeast of the building. Sampling was focused around a bermed concrete oil-storage pad, an oil/water separator, two wash racks, and the area near the fence southeast of the building. Several inorganics were detected above ambient concentrations and several VOCs and SVOCs were detected at low concentrations in surface and near surface soil. The characterization of part of this site may not be to the extent desired, because the exact location of the degreaser, a potential source of solvents, is unknown. However, because no additional information on the degreaser is available, and the most likely sources of contaminants have been addressed, further investigation at this site is not warranted.

10.5 Fort Point U.S. Coast Guard Station

The investigations in the FPCGS site were designed to assess the chemical impact of U.S. Army activities at the site. Potential sources were identified, and analytical samples were collected from various media. Four potential sources of COPCs were identified at the FPCGS.

A former UST site north of Building 991 was evaluated through collection of soil and groundwater samples in the area. These samples included isolated detections of toluene, trichlorofluoromethane, and TPH, all presumably released by the former tanks and associated piping. Any future investigations of the former UST area north of Building 991 will be managed under the USCG UST management program.

Maintenance activities in Building 995 resulted in the release of PAHs and long-chain hydrocarbons to the paved surface outside a door in the building. Subsurface samples indicated detectable concentrations of TPH in the soil and the groundwater, but migration of the PAHs had not occurred. An AST formally located near Building 996 apparently released toluene, xylene, PAHs, and TPH to the surface soil. Surface soils near an AST at Building 997 contained PAHs and TPH. All of the stains at Building 997 were of limited extent both laterally and vertically, and contaminants detected in surface soil in the area (toluene, TPH, and PAHs) are likely limited to the stained surface soil.

10.6 Lobos Creek

The only COPC detected in sediment samples from Lobos Creek is arsenic, which was elevated in one of the sediment samples. There were no detections of organics and all other inorganics are interpreted to occur at natural concentrations. The source of arsenic is not known; it could be from the PSF, but it is more likely to be the residential area south of the PSF, as more than 90 percent of the Lobos Creek drainage basin is located outside the PSF. The human health risk assessment will assess exposure to arsenic in sediments. The arsenic may be at a level of concern to aquatic receptors, based on comparison to aquatic sediment criteria; its associated risk will be further assessed in the ecological risk assessment.

Water from Lobos Creek contains several inorganic analytes and miscellaneous parameters, but most are at relatively low concentrations. The only organic detected was bis(2-ethylhexyl)phthalate, a common compound associated with plastics and laboratory contaminant, at a concentration less than the MCL. Inorganics or miscellaneous parameters that exceeded MCLs in the surface-water samples were iron (California secondary MCL), manganese (California secondary MCL) and nitrate (USEPA MCL). In addition, elevated coliform levels were reported. The iron and manganese are likely derived from serpentinite. Coliform bacteria and nitrates are commonly present at high levels in urban runoff and can be the result of sources such as vegetation, decaying organic matter, soil, animal feces, and human waste. Sources of nitrates are similar. Therefore, multiple sources on and off of the PSF may be contributing to the elevated levels of nitrate and coliform in Lobos Creek samples. Nearly all of the water in the creek has been historically diverted to the Baker Beach water plant; a minor amount is discharged to the Pacific Ocean when the water plant

is in operation. Comparison to standards for protection of freshwater aquatic life indicates that barium and manganese may be at levels of concern; however, these appear to be naturally occurring concentrations.

10.7 Mountain Lake

Groundwater and surface drainage from the north, east, and southeast contribute to Mountain Lake. This includes the upland areas and the golf course at PSF, as well as offsite areas. Although Mountain Lake is not considered a contaminant source at the PSF, sediment, surface water and discrete groundwater samples were collected to evaluate whether contaminants were present in these media. Detections were evaluated to assess the potential sources of the analytes.

Aldrin and lindane were found at concentrations of 0.003 $\mu\text{g/g}$ in sediment samples collected from the south edge of Mountain Lake during the Initial RI in 1990, but not in Supplemental RI samples collected in 1992. These pesticides were not found in water or sediment samples taken from Lobos Creek, indicating that the distribution is limited. Additionally, the source of the pesticides may be from areas south of the PSF, as a majority of the watershed is south of the lake.

Several naturally occurring constituents in surface water were found above human health criteria. These included manganese, detected above the California primary MCL, TDS, and coliform. Heptachlor and barium were above ecological criteria in surface water samples. None of these are believed to be derived from U.S. Army activities at the PSF. Detections of TPH-D may be associated with stormwater runoff from Highway 1.

Nitrates were detected above the USEPA MCL of 10,000 $\mu\text{g/L}$ in one of the four discrete groundwater samples but decreased below the MCL with depth. Nitrate levels in Mountain Lake surface-water samples were a minimum of an order of magnitude lower than in the groundwater samples. Sources on and off of the PSF may be contributing to the elevated levels of nitrate.

11. GOLDEN GATE BRIDGE HIGHWAY AND TRANSPORTATION DISTRICT STUDY AREA

This section summarizes the results of RI activities at the four areas of investigation at the GGBHTD Study Area. Any further evaluation of the site will be addressed by the GGBHTD. A risk assessment of the site is not included in this RI report, and the site will not be addressed in the Main Installation FS.

11.1 Transformer Area

A concrete-floored powerhouse building in the Transformer Area formerly housed a transformer that contained PCBs. Spills or leaks are potential release mechanisms. Two of the three wipe samples taken on the floor of the building had a detection of Aroclor 1260. The concrete floor of the building has no visible cracks or staining. It is unlikely that this compound will impact underlying soils or groundwater.

11.2 Underground Storage Tank Area

Compounds associated with fuel leaks, solvents, and pesticides from groundskeeping were detected near the USTs and some have migrated to the water-bearing zone. There are no drinking water MCLs for the solvents or pesticides detected here. The BTEX concentrations detected in the groundwater are above the MCLs. The groundwater is limited in vertical and aerial extent. The production rates, as determined from recharge rates, for Wells GGGW02 and GGGW03 are 96 gpd and 5 gpd, respectively. These rates are less than the production rate of 200 gpd for a designated drinking water aquifer as specified in State Water Resources Control Board Resolution 88-63. Also the TDS, 887,000 µg/L, measured at the site exceeds the California recommended secondary MCL for a drinking water aquifer. Overfill protection and inventory control procedures meet current State requirements.

11.3 Paint Operations Area

The compounds detected in the Paint Operations Area are related primarily to spills or leaks from fuel or waste oil storage, solvents used during cleaning of paint equipment and former groundskeeping practices. These compounds are limited in extent, with some found only in

the sediments or upper soil samples. Concentrations of di-n-butylphthalate, which was found in only one boring, increased with depth. TPH-D increased with depth in only one boring. Surface-water runoff has transported some compounds to sewers, but there is very little migration to the subsurface soils. Wastewaters from the equipment washing area are now directed to pre-treatment systems which discharge to the sanitary sewer after treatment. The storm drain is permitted under the SWRCB's general NPDES stormwater permit for industrial facilities.

11.4 Bone Yard Storage Area

The compounds detected in the Bone Yard Storage Area are limited in extent and are possibly related to isolated fuel spills, the storage of asphalt, painting operations, and former groundskeeping practices. Surface-water runoff has transported some compounds to sewers, but there is very little migration to the subsurface.

The sites within the GGBHTD Study Area are all being assessed under the GGBHTD Program and not in Main Installation RI risk assessment.

12. BAKER BEACH STUDY AREA

This section summarizes the evaluation of results for the Baker Beach Study Area.

The potential source(s) of contamination evaluated in the Baker Beach Study Area are debris fill and/or landfill materials deposited at the sites. Due to geographical separation, each of four disturbed areas was evaluated individually within the study area.

At all four disturbed areas, target analytes appear to be confined to the disturbed area. Samples collected downhill of the disturbed areas generally had either no detections or lower concentrations of target analytes than those detected in the fill material. The vertical extent of chemicals is limited due to shallow bedrock throughout the Baker Beach Study Area. Groundwater was only observed at a small seep in Disturbed Area 1, and was not detected in any borings at any of the disturbed areas.

COPCs identified in Disturbed Area 1 fill material include inorganics, VOCs, SVOCs, OCPs, PCBs, and TPH-D. Detections of these compounds were discontinuous, both laterally and vertically. Laterally, several inorganics including lead, appear to be defined by a mounded area of landfill material located in the center of the disturbed area. Inorganics and TPH-D were detected in groundwater from a seep near the center of the disturbed area. Sediment collected at the seep contained inorganics, OCPs, PCBs, and TPH-D. At Disturbed Area 2, the identified COPCs included the inorganic beryllium, several VOCs, SVOCs, OCPs, and TPH-D. These analytes were detected in both fill and underlying native material samples, but detections were both laterally and vertically discontinuous at the site. Inorganics, SVOCs, OCPs, and TPH-D were identified as COPCs in Disturbed Area 3. Only OCPs, and TPH-D were considered COPCs in Disturbed Area 4.

13. BATTERY HOWE/WAGNER

This section summarizes the site investigation results for the Battery Howe/Wagner Study Area.

The potential source(s) of contamination investigated at Battery Howe/Wagner are debris/artificial fill materials deposited during construction of the site. In order to evaluate the impact of fill material on the environment, surface and subsurface soils, and groundwater samples were analyzed.

COPCs identified in soil at Battery Howe/Wagner include inorganics, VOCs, SVOCs, and TPH-D. Detections of these compounds were discontinuous, both laterally and vertically. Debris fill material encountered during drilling was not a clearly identifiable source of these analytes. Concentrations of inorganics are elevated in both the fill and underlying native material, possibly due to the presence of serpentinite. VOCs and SVOCs are limited to samples collected from within the fill material. TPH-D was detected in both fill and underlying native material.

Target analytes detected in groundwater include inorganics, VOCs, and TPH-D. Like the soil COPCs, the sources of these compounds is unclear. Several inorganics were detected above Primary and Secondary MCLs. Most detections were only slightly above MCLs, and were consistently lower in the filtered samples, indicating that the results are heavily influenced by the presence of sediment in the samples. VOCs detected above MCLs during the RI include carbon tetrachloride and 1,2-dichloroethane. The presence of carbon tetrachloride was confirmed in the subsequent quarterly sampling performed by Montgomery Watson. However, the extent of this compound appears to be limited to the area near Well HWGW01. The presence of 1,2-dichloroethane was not confirmed by the quarterly sampling. TPH-D was detected in one RI sample.

14. MISCELLANEOUS FOLLOW-ON SITES

This section presents the site investigation results for the Miscellaneous Follow-on RI Sites.

The Miscellaneous Follow-on RI Sites are:

- Building 302
- Building 669
- Building 1245
- Building 1369
- Building 1388
- Building 1750
- East of Mason (EOM)

The Miscellaneous Follow-on RI Sites are sites that were not investigated prior to the Follow-on RI. They are not associated with any of the study areas discussed in previous sections.

14.1 Building 302

The northern portion of Building 302 is used to store the herbicides, pesticides and fertilizers used at the golf course. Consequently, the primary suspected contaminants at the Building 302 site were OCPs and chlorinated herbicides. Two herbicides, Dicamba and 2,4-D, were detected at concentrations below the SDCs. No OCPs were detected. The only inorganics detected above ambient that were considered as COPCs for the BRA are cyanide and mercury.

14.2 Building 669

Based on observations made during drilling, little or no ash deposits are present in the shallow subsurface in the vicinity of Building 669. The source of the elevated concentrations of lead detected in the 1.3 to 2 feet bgs interval of the CalTrans boring is unknown. Further investigation of this site may be warranted to assess the source and extent of elevated lead concentrations. The U.S. Army will review available information and contact CalTrans to see if any additional information is available. If warranted, the U.S. Army will consider

taking a limited number of samples to assess the source and extent of lead. However, under the future use recreational scenario, there would be no exposure pathway to human receptors because elevated concentrations of lead were in subsurface soil. Potential ecological receptor exposures are possible. Because no analytical data were collected under the RI, Building 669 is not included in the risk assessment except to evaluate the effects of the PSF water supply on the industrial worker in the area.

14.3 Building 1245

The analytical data indicate the presence of dieldrin, ppDDT, ppDDE, fluoranthene, and pyrene in low concentrations in subsurface soil adjacent to Building 1245. The primary sources identified at Building 1245 were associated with the storage of materials and potential releases through spillage or leakage. However, the pesticides may be from routine applications, and the PAHs may be associated with ubiquitous urban sources. Phthalates, which are commonly associated with plastics and common laboratory contaminants, were detected at low concentrations and are not likely to be related to activities at the site. Although the data indicate that SDCs are not exceeded and that concentrations decrease with depth, these compounds are considered COPCs for both the human health and ecological risk assessments.

14.4 Building 1369

The presence of elevated lead concentration in the vicinity of Building 1369 is limited to a shallow soil sample (0.5-foot bgs) from one boring with a concentration of 365 $\mu\text{g/g}$. The presence of lead above ambient fill concentrations only occurred in this sample and in the 2.0-foot bgs sample from this boring. Surrounding surface soil samples indicate that the elevated lead concentrations are confined to a small area below the end of the drainage pipe. Lead is evaluated as a subsurface soil COPC in the human health risk assessment and as a soil COPC in the ecological risk assessment.

14.5 Building 1388

Soil sampling in the Building 1388 area was conducted in the areas with visible staining and where ASTs were formerly located. The results of chemical analysis of these soil samples indicate that TPH above the SDC is limited to soil directly below the stained asphalt in the immediate vicinity of Boring 1388SB05. The TPH will be assessed in the BRA.

14.6 Building 1750

Results of soil-gas sampling and confirmation soil sampling indicate that none of the hydrocarbons analyzed were detected. Therefore, no further investigation of the hydrocarbon sources is recommended for the Building 1750 site and the site is not included in the risk assessment except to evaluate the effects of the PSF water supply on the industrial worker in the area.

The investigation of the firing range adjacent to and within the Building 1750 site is being conducted by the USCOE under a separate program; any additional conclusions or remedial actions will be based upon the information presented in the final report for that effort.

14.7 East of Mason

The investigations in the EOM Study Area were designed to assess the chemical impact of U.S. Army activities at the site. The potential source investigated through sampling at this site was artificial fill material. There were no inorganic COPCs identified in soil, and a comparison of filtered and unfiltered groundwater results indicates that most of the inorganics detected in unfiltered samples are associated with particulate matter. There were few organic detections in either soil or groundwater. In fact, the only organic compound detected in any of the nine discrete groundwater samples was bis(2-ethylhexyl)phthalate, which is a common laboratory contaminant. The impact of army activities at this site appears to be minimal.

15. BASELINE RISK ASSESSMENT

A baseline risk assessment (BRA) was conducted to evaluate potential human health and ecological risks associated with exposure to site-related chemicals in soil, groundwater, sediments, and surface water at the PSF. The BRA for the PSF study areas is divided into two major sections, the human health risk assessment (section 15.1) and the ecological risk assessment (section 15.2). Each section identifies chemicals of concern (COCs) from the COPCs for relevant populations, assesses exposure pathways and toxicity of COCs, and quantifies the risks associated with potential exposures to these chemicals. The BRA evaluates site-specific risks for areas within the PSF. The approach to risk assessment is based on USEPA guidance.

Sites within each study area were evaluated separately for both the human health and ecological risk assessments. Because of the different habitat requirements and behavior of human and ecological receptors, the sites for each evaluation were not necessarily the same. For the human health risk assessment (HHRA), sites within each study area were evaluated under future industrial or recreational land use scenarios, depending on the land use designated in the NPS *General Management Plan Amendment (GMPA)*. Because the PSF has been transferred to the NPS as of October 1, 1994, only the future land uses were evaluated in the human health risk assessment for this BRA.

Both the human health and the ecological risk assessments for the PSF study areas and sites are organized and discussed in subsections according to the four steps common to most risk assessments:

- Identification of COCs
- Exposure assessment
- Toxicity assessment
- Risk characterization.

15.1 Human Health Risk Assessment Summary

This risk assessment was conducted to evaluate potential human health risks associated with exposure to site-related chemicals in soil, groundwater, sediments, and surface water at the

PSF. For the Main Installation RI, the PSF was divided into 11 study areas as described in this Executive Summary. Area designations were based on future site land uses and on analytes identified by available sampling data. The risk assessment included identification of COCs, exposure assessment, toxicity assessment, and risk characterization.

COCs were identified on the basis of several nature and extent characteristics. Substances were selected for inclusion in the risk evaluations for each site when the maximum detected value was greater than the respective residential USEPA Region IX PRG or California MCL, was not an essential nutrient, and was detected above the CRL at a frequency greater than 5 percent. A variety of inorganics, VOCs, SVOCs, PAHs, PCBs, pesticides, and water quality parameters were subjected to the COC screening process for soil, sediment, surface water, and groundwater at all RI sites where COCs were identified.

No air sampling was conducted in this investigation. However, the air pathway may be expected to contribute only a minor amount to total site risks as most of the study sites are either paved or heavily covered with vegetation, thus reducing the potential for dusts to become airborne.

Two categories of land-use scenarios were considered in the risk assessment. Sites within each study area were evaluated separately under industrial or recreational land use scenarios, depending on the predominant potential future land use of each site from the GMPA

Where appropriate, the following exposure pathways were considered:

- Ingestion of and dermal contact with soil
- Ingestion of and dermal contact with drinking water
- Ingestion of and dermal contact with surface water
- Ingestion of and dermal contact with sediment
- Ingestion of and dermal contact with groundwater.

RME estimates of lifetime cancer risk were calculated for each of the land-use scenarios described above. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health (Federal Register 56(20):3535, Wednesday, January 30, 1991). This risk range was used as a basis for comparison of risk estimates calculated for carcinogens identified at the PSF. Noncarcinogenic effects were compared to a hazard index

of 1E+00, which indicates that the exposure is below a level that is likely to cause adverse health effects even in the most sensitive members of the population. Lead was compared with the lead soil screening value of 840 mg/kg for industrial and recreational land use scenarios.

Maximum detected lead values in surface soil was greater than the lead soil screening value of 840 mg/kg for the following sites:

- Nike Facility silo/storage area (2143 mg/kg)
- Crissy Field Study Area Building 640/643 (1430 mg/kg)
- Building 900s Series Study Area Building 923 Area (4700 mg/kg) and Buildings 950/973/974 (4000 mg/kg)
- DEH Study Area Building 283 (1200 mg/kg)
- Baker Beach Study Area Disturbed Area 1 (2050 mg/kg).

Sites assessed for carcinogenic risk with estimated total cancer risks less than 1E-06 are listed below by study area.

Crissy Field Study Area

- Building 640/643
- Proposed wetlands restoration area.

Building 900s Series Study Area

- Groundwater
- Building 937.

Fill Sites and Landfills

- El Polin Spring
- Landfill 4
- Landfill E.

Miscellaneous Sites

- Lobos Creek.

Baker Beach Study Area

- Disturbed Area 1

- Disturbed Area 3
- Disturbed Area 4.

There were several sites with COCs not considered carcinogenic which indicates that exposure to the COCs at these sites is unlikely to result in excess cancer risk. Four sites, the Nike Facility silo/storage area and groundwater; DEH Study Area Buildings 269/293, and Fill Site 6 have estimated total carcinogenic risks greater than or equal to 1E-04.

Ingestion of the PSF water supply and dermal contact during showering was assumed in all industrial, institutional, and commercial/office land use scenarios. Three COCs (lead, manganese, and nitrate) were identified in the COPC screening for the PSF water supply. These COCs are not considered carcinogenic and result in a total hazard index of 5E-01. This indicates that it is unlikely that exposure to the PSF water supply to industrial worker will result in an excess cancer risk or noncarcinogenic adverse health effects.

The likelihood that actual cancer risks are underestimated is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values. USEPA's Guidelines for Carcinogen Risk Assessment states that ". . . the linearized multistage procedure leads to a plausible upper limit to the risk that is consistent with proposed mechanisms of carcinogenesis The true value of the risk is unknown, and may be as low as zero." (Fed. Reg. 51, 185:33992-34054, 1986).

Estimated noncarcinogenic chemical-specific HIs exceed or are equal to 1E+00 for the assessed future land use scenarios for the sites listed below.

- Nike Facility silo/storage area (arsenic 1E+00)
- Nike Facility Groundwater (manganese - 2E+00)
- Building 269/293 in the DEH Study Area(chlordane - 7E+00)
- Fill Site 6 (several inorganics ranging from 1E+00 to 1E+01)
- Landfill E (silver 2E+00)
- FPCGS [n-hexane and naphthalene (TPH-gas fractions) both 1E+00].

15.2 Ecological Risk Assessment Summary

There are several general conclusions which can be made from the risk assessment results.

These are:

- Dermal exposure never results in HQs in excess of 1 for birds or mammals.
- Large raptors, as represented by the red-tailed hawk, do not appear to be at risk at any of the sites.
- Drinking water ingestion does not produce HQs greater than 1 for any of the receptors investigated.

Although HIs (sum of chemical specific HQs) were presented in the RI to visually present risks for each receptor by site, cumulative HIs are not realistic. The assumption is that all toxicity is additive; this is a crude assumption at best. Therefore, the conclusions focus on the results of the ERA as indicated by the sum of the pathway HQs, and for total exposure that exceeds 1.

The magnitude of the HQ does not relate directly to the magnitude of risk in a linear manner, i.e., a HQ of 100 does not infer a 100 fold increase in adverse effects. One reason for this is because the HQ is based on single point estimates derived from multiple different studies, and not a dose response curve from one study. In fact, given the known uncertainties inherent in the risk assessment, as well as the cumulative effects of numerous conservative assumptions, even an HQ of 10 probably is not a strong indicator of ecological risk. However, larger HQs do indicate some greater potential for adverse effects.

The HQs are based on TBVs which contain several orders of magnitude of applied uncertainty factors (i.e., because the true toxicity values are unknown, ones much lower were used in the risk assessment). Application of uncertainty factors makes some of the TBVs very low; for example, the TBV_{Low} for the peregrine falcon is in the range of that required for avian nutrition.

Many of the sites and areas within the PSF present no or minimal risk to ecological receptors under the exposure scenarios evaluated. Out of approximately 42 sites evaluated, many have HQs that exceed 1 for the TBV_{Low} which may warrant further investigation or evaluation of data.

These sites are:

Nike Facility	Landfill E
Nike Swale	Graded Area 9
Crissy Field Building 640/643	Building 662
Fill Site 7/EOM Shoreline	Building 680
Building 609	Building 1351
Crissy Field Building 633	FPCGS
Crissy Field Future Wetland	Baker Beach DA1 Outside the Mounded Landfill Material Area
Crissy Field Sewer Lift Station 1	Baker Beach DA1 Mounded Landfill Material Area
Crissy Field Sewer Lift Station 2	Baker Beach DA1 Seep
Building 900 Series Study Area	Baker Beach DA3
DEH	Baker Beach DA4
Main Post Building 1151	Battery Howe /Wagner
Main Post Building 1167	Building 302
Landfill 2	Building 1369
Transfer Station	Mountain Lake
Landfill 4	Lobos Creek
Fill Site 5	

However, at some of these locations, the area is so highly disturbed by current and/or projected future human use, that there is very little likelihood of ecological receptors utilizing the location with any frequency. If receptors do not exist, the estimated risk results are improbable at best. The locations identified as lacking in natural habitat are:

Building 609	Building 662
Building 1167	Building 680
Building 1151	FPCGS

Those locations that might have adequate habitat to support ecological receptors, and where the HQs for at least one receptor exceed 1 based on the TBV_{High} , are considered candidates for further evaluation of the data. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others.

These sites are:

HQs >1 for the TBV _{Low}	HQs >1 for the TBV _{High}	Evaluate Further?
Nike Facility	Nike Facility	Yes
Nike Swale		No
Crissy Field Building 640/643	Building 640/643	Maybe
Fill Site 7/EOM Shoreline	Fill Site 7/EOM Shoreline	Yes
Crissy Field Building 633	Building 633	Maybe
Crissy Field Wetland (Terrestrial)		No
Crissy Field Wetland (Aquatic)	Crissy Field Wetland (Aquatic)	Yes
Crissy Field Wetland (Groundwater)	Crissy Field Wetland (Groundwater)	Yes
Crissy Field Sewer Lift Station 1		No
Crissy Field Sewer Lift Station 2	Crissy Field Sewer Lift Station 2	Maybe
Building 900s	Building 900s	Maybe
DEH	DEH	Done
Landfill 2	Landfill 2	Yes
Transfer Station	Landfill 3	Yes
Landfill 4	Landfill 4	Yes
Fill Site 5		No
Graded Area 9	Graded Area 9	Yes
Landfill E	Landfill E	Yes
Building 1351	Building 1351	Maybe
Baker Beach DA1- Outside Mounded Landfill Material Area	Baker Beach DA1 Outside the Mounded Landfill Material Area	Yes
Baker Beach DA1 Mounded Landfill Material Area	Baker Beach DA1 Mounded Landfill Material Area	Yes
Baker Beach DA1 Seep	Baker Beach DA1 Seep	Maybe
Lobos Creek	Lobos Creek	Yes
Mountain Lake	Mountain Lake	No-No Army Sources
Baker Beach Disturbed Area 2		No
Baker Beach Disturbed Area 3	Baker Beach Disturbed Area 3	Yes
Baker Beach Disturbed Area 4		No
Battery Howe /Wagner	Battery Howe /Wagner	Yes
Building 302		No
Building 1369		No

15.2.1 Comparison of Risk Assessment Results to the Assessment and Measurement Endpoints

The risk assessment results were further evaluated by consideration of the results compared to the assessment endpoints considered important for the PSF. The potential effects on the assessment endpoints are discussed below.

15.2.1.1 Ability of the Crissy Field Study Area to Serve as Suitable Wetland Habitat as a Future Use

There are several significant results of the ERA for Crissy Field. These are:

- There were HQs above 1 for copper, manganese, and mercury, as well as ppDDE, ppDDT, and dieldrin, when the current soil concentrations (to a depth of 15 feet) were assumed to represent future sediment concentrations. The risks were for benthic invertebrates and were based on the sediment quality criteria.
- In order to perform the ERA for the future wetland, it was assumed that groundwater wells in the area would discharge to surface water. Under scenarios considering zero, 50%, and 90% dilution of the groundwater by Bay water, groundwater exposure point concentrations resulted in risks to aquatic life. Only the chronic criteria were used as the basis of estimating risks.

While these results suggest a potential for risk to future aquatic receptors in the wetland, the ERA for this future use is very uncertain. The actual future sediment concentrations are unknown, as soils are likely to be moved during wetland construction. Groundwater wells that were used to project an exposure point concentration may in fact not discharge to surface water. Even if the wells do discharge to surface water, influx from the Bay cannot be determined at this point in time. While three dilution scenarios were examined, these may not represent reality since the volume of water contributed by the Bay relative to that from groundwater is unknown. The ERA recommends that if the wetland is constructed, sampling be performed, to include sediment and water analyses after the wetland becomes stabilized. The absence of critical habitat is a more compelling risk than any hypothetical risks due to theoretical chemical contamination.

15.2.1.2 Survivability and Reproduction of Populations of Avifauna (passerines, raptors)

At some locations, avian receptor HQs were high, indicating a potential for adverse effects on avian populations. The HQs are discussed for the American robin and the mourning dove below.

For passerine birds feeding primarily on invertebrates, represented by the American robin, the locations producing potential risks are summarized. Assessments of whether or not

habitat exists and if further evaluation appears warranted on the basis of risks to this receptor are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others.

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility	Nike Facility	Yes	Yes
Building 640/643	Building 640/643	Maybe	Maybe
FS7/EOM Shoreline	FS7/EOM Shoreline	Yes	Yes
Crissy Field Future Wetland		Yes	No
Building 609		No	No
Building 633	Building 633	Maybe	Maybe
Sewer Lift Station 1		Yes	No
Sewer Lift Station 2	CFSL2	Maybe	Maybe
Building 900s	Building 900s	Maybe	Maybe
DEH	DEH	Yes	Done
Building 1151	Building 1151	No	No
Building 1167	Building 1167	No	No
Landfill 2	Landfill 2	Yes	Yes
Transfer Station	Landfill 3	Yes	Yes
Landfill 4	Landfill 4	Yes	Yes
Fill Site 5		Yes	No
Graded Area 9	Graded Area 9	Yes	Yes
Landfill E	Landfill E	Yes	Yes
Building 662		No	No
Building 680	Building 680	No	No
Building 1351	Building 1351	Maybe	Maybe
FPCGS		No	No
BBDA1-Outside Mounded Landfill Area	BBDA1-Outside Mounded Landfill Area	Yes	Yes
BBDA1 - Mounded Landfill Area	BBDA1 - Mounded Landfill Area	Yes	Yes
BBDA2		Yes	No
BBDA3	BBDA3	Yes	Yes
BBDA4		Yes	No
Battery Howe/Wagner	Battery Howe/Wagner	Yes	Yes
Building 302		Yes	No
Building 1369		Yes	No

BBDA = Baker Beach Disturbed Area

For ground feeding herbivorous birds, represented by the mourning dove, the locations producing risk are summarized below. Assessments of whether or not habitat exists and if further evaluation appears warranted are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others.

These sites are:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility	Nike Facility	Yes	Yes
Building 640/643	Building 640/643	Maybe	Maybe
FS7/EOM Shoreline		Yes	No
Building 633	Building 633	Maybe	Maybe
Sewer Lift Station 1		Yes	No
Sewer Lift Station 2	Sewer Lift Station 2	Maybe	Maybe
Building 900s	Building 900s	Maybe	Maybe
DEH	DEH	Yes	Done
Building 1151		No	No
Building 1167		No	No
Landfill 2		Yes	No
Landfill 3	Landfill 3	Yes	Yes
Landfill 4	Landfill 4	Yes	Yes
Graded Area 9	Graded Area 9	Yes	Yes
Landfill E		Yes	No
Building 662		No	No
Building 680		No	No
Building 1351		Yes	No
FPCGS		No	No
BBDA1-Outside Mounded Landfill	BBDA1-Outside Mounded Landfill	Yes	Yes
BBDA1 - Mounded Landfill Area	BBDA1 - Mounded Landfill Area	Yes	Yes
BBDA3	BBDA3	Yes	Yes
Battery Howe/Wagner	Battery Howe/Wagner	Yes	No
Building 1369		Yes	No

For the peregrine falcon, the locations that have HQs in excess of 1 are presented below.

Assessments of whether or not habitat exists and if further evaluation appears warranted are also presented:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike		Yes	No
Building 900		No	No
DEH		No	Done

For the mallard duck, the results of the ERA are summarized below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented.

These sites are:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike swale		No	No
Crissy Field Future Wetland (0%)		Yes	No
Crissy Field Future Wetland (50%)		Yes	No
Lobos Creek	Lobos Creek	Yes	Yes
Mountain Lake	Mountain Lake	No	No (No army sources)

For the western sandpiper, the results of the ERA are presented below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented. These sites are:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike swale		Yes	No
Crissy Field Future Wetland (0%)		Yes	No
Crissy Field Future Wetland (50%)		Yes	No
Building 900s	Building 900	Yes	Yes
Lobos Creek	Lobos Creek	Yes	Yes
Mountain Lake	Mountain Lake	No	No (No Army sources)

15.2.1.3 Survivability and Reproduction of Special Status Species and Plant Communities

The risk at Fill Site 5 is considered to be minimal, and special status plant species currently occur in the vicinity. This indicates that Fill Site 5 is not having an adverse effect on special status plants. In addition, the size of Fill Site 5 is 0.8 ac, and the native communities grow on the outskirts of this area, making contact with fill materials unlikely. Any human actions in the area would need to avoid the plant communities.

The Baker Beach Study Area may be a potential threat to plant species in some areas, primarily Disturbed Area 1 and the mounded refuse area within Disturbed Area 1. Disturbed Areas 2, 3, and 4 are unlikely to have effects on plant communities, although HQs for plants for antimony, cobalt, chromium, iron, nickel, lead, and zinc exceed 1 for the TBV_{Low} at

Baker Beach Disturbed Areas 2 and 3. The evidence suggests that Baker Beach is not affecting plant communities, as special status species are currently growing there. The native plants associated with serpentinite outcrops may require high metal concentrations.

The results of the risk assessment do not indicate any adverse effects on the cultural forest in most locations. The results of the comparison of exposure to the TBVs for plants and soil fauna are summarized below.

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike	Nike	Yes	Yes
Fillsite 7/EOM Shoreline	Fillsite 7/EOM Shoreline	Yes	Yes
Building 640/643	Building 640/643	Maybe	Maybe
Crissy Field Future Wetland	Crissy Field Future Wetland	Maybe	Maybe
Building 633		Maybe	No
Crissy Field Sewer Lift Station 1		Maybe	No
Crissy Field Sewer Lift Station 2		Maybe	No
DEH	DEH	Yes	Done
Building 1167	Building 1167	No	No
Landfill 2	Landfill 2	Yes	Yes
Transfer Station	Transfer Station	Yes	Yes
Landfill 9	Landfill 9	Yes	Yes
Landfill E	Landfill E	Yes	Yes
Building 662		No	No
Building 1351	Building 1351	Maybe	Maybe
Building 900s Series	Building 900s Series	Yes	Yes
FPCGS	FPCGS	No	No
Baker Beach DA1 Mounded Landfill Area	Baker Beach DA1 Mounded Landfill Area	Yes	Yes
Baker Beach DA1- Outside the Mounded Landfill Area	Baker Beach DA1- Outside the Mounded Landfill Area	Yes	Yes
Baker Beach DA3	Baker Beach DA3	Yes	Yes
Building 302		Yes	No
Battery Howe/Wagner	Battery Howe/Wagner	Yes	Yes

15.2.1.4 Survivability and Reproduction of Populations of Small Mammals that could Serve as Prey for Raptors and Other Predators

For the western harvest mouse, the results of the ERA are presented below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others.

These sites are:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility	Nike Facility	Yes	Yes
Sewer Lift Station 2	Sewer Lift Station 2	Maybe	Maybe
Building 640/643	Building 640/643	Maybe	Maybe
Building 633		Yes	No
Building 900		Yes	No
DEH	DEH	Yes	No
Landfill 2		Yes	No
Transfer Station	Transfer Station	Yes	Yes
Landfill 4		Yes	No
Graded Area 9	Graded Area 9	Yes	Yes
Building 680		No	No
Building 1351		No	No
BBDA1-Outside Mounded Landfill	BBDA1-Outside Mounded	Yes	Yes
BBDA1-Mounded Landfill Area	BBDA1-Mounded Landfill Area	Yes	Yes
BBDA3		Yes	No

For the valley pocket gopher, the results of the ERA are presented below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others. These sites are:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility		Yes	No
Building 640/643		Maybe	Maybe
Building 633		Yes	No
Sewer Lift Station 2	Sewer Lift Station 2	Maybe	Maybe
Building 900		Yes	No
DEH		Yes	No
Transfer Station	Transfer Station	Yes	Yes
Landfill 4		Yes	No
Graded Area 9	Graded Area 9	Yes	Yes
BBDA1-Outside Mounded Landfill		Yes	No
BBDA1-Mounded Landfill Area		Yes	No
BBDA3		Yes	No

15.2.2 Recommendations

Based on the body of ecological risk assessment results generated in this RI, the following general recommendations are presented.

- Any further efforts should focus only on COPCs that produced HQs greater than 1 based on comparison to the TBV_{High} , as these are the most likely contaminants of concern.
- Evaluation should be focused only on sites that contain adequate habitat.
- Evaluation should be focused only on receptors where there are potential risks.
- Evaluation should be focused only on sites where there are known army-related sources.
- Monte Carlo Uncertainty Analysis may be appropriate for identifying appropriate, site-specific, PRGs.

Results of the dietary ingestion pathway should be viewed with caution, as this pathway is more uncertain since the food web model was calibrated with literature-based information.

**Final
Remedial Investigation Report
Presidio Main Installation**

Presidio of San Francisco

**Volume I
Text**

Contract No. DAAA15-90-D-0018
Task Order 0002, Data Item A009

Prepared by

 **DAMES & MOORE**

Prepared for

**U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland 21010-5401**

January 1997

REPORT CERTIFICATION

This report is the Final Remedial Investigation Report, Presidio Main Installation, Presidio of San Francisco, dated January 1997.

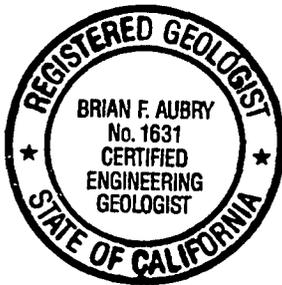
The geologic and hydrogeologic content of this report has been reviewed by Brian F. Aubry, California Registered Geologist (#4637). The geologic and hydrogeologic content of this report is prepared in accordance with current standard professional practice, and no warranty is expressed or implied.



Brian F. Aubry
Senior Geologist
California Registered Geologist, #4637
Certified Engineering Geologist, #1631

1/15/97

Date



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TABLE OF CONTENTS

	Page
1. INTRODUCTION	1-1
1.1 PURPOSE OF THE REMEDIAL INVESTIGATION	1-1
1.2 BACKGROUND ON THE REMEDIAL INVESTIGATION PROGRAM	1-2
1.2.1 Prior and Concurrent Environmental Programs	1-3
1.2.1.1 Programs by the U.S. Army Corps of Engineers	1-3
1.2.1.2 Programs by Other Agencies	1-4
1.2.2 Field Programs and Graphic Overview for This RI	1-6
1.2.2.1 Initial RI Field Program	1-7
1.2.2.2 Supplemental RI Field Program	1-7
1.2.2.3 Follow-on RI Field Program	1-8
1.2.2.4 Graphic Overview of the Study Areas	1-10
1.3 REPORT ORGANIZATION	1-10
1.3.1 Report Outline: Final Remedial Investigation Report Presidio Main Installation, Presidio of San Francisco	1-12
1.3.2 Index of Study Areas, Buildings, and Sites, with Section Numbers	1-13
2. BACKGROUND	2-1
2.1 HISTORICAL BACKGROUND AND STUDY AREAS	2-1
2.1.1 Study Areas	2-2
2.1.2 Areas Excluded from the RI	2-5
2.2 DEMOGRAPHY AND LAND USE	2-7
2.3 PHYSICAL SETTING	2-8
2.3.1 Meteorological Conditions	2-9
2.3.2 Topography	2-10
2.3.3 Surface-Water Hydrology	2-10
2.3.4 Regional Geology	2-11
2.3.4.1 Franciscan Formation	2-12
2.3.4.2 Dune Sand	2-14
2.3.4.3 Slope Debris and Ravine Fill	2-14

2.3.4.4 Beach Deposits	2-14
2.3.4.5 Bay Muds	2-15
2.3.4.6 Structural Setting	2-15
2.3.5 Regional Hydrogeology	2-16
2.3.5.1 Groundwater Occurrence and Movement	2-18
2.3.5.2 Hydraulic Characteristics of Geologic Units	2-20
2.3.5.3 Estimated Well Yields	2-22
2.3.6 Beneficial Use and Hydrogeology of Groundwater Areas	2-23
2.3.6.1 Lobos Creek Groundwater Area	2-25
2.3.6.2 West Valley Groundwater Area	2-26
2.3.6.3 Northeastern Groundwater Area	2-28
2.3.6.4 Crissy Field Groundwater Area and Sea Water Intrusion	2-31
2.3.7 Regional Groundwater Chemistry	2-38
2.3.8 Water Supply and Use	2-39
3. INVESTIGATION METHODS	3-1
3.1 SITE CONCEPTUAL MODEL	3-1
3.2 FIELD INVESTIGATIONS	3-3
3.2.1 Geophysical Survey Methods	3-4
3.2.1.1 Resistivity Sounding Methods	3-5
3.2.1.2 Electromagnetic Survey Methods	3-7
3.2.2 Wipe Sampling	3-8
3.2.3 Sediment Sampling	3-9
3.2.4 Borehole Drilling	3-10
3.2.4.1 Hand-Auger Drilling	3-10
3.2.4.2 Power-Auger Drilling	3-11
3.2.4.3 Hollow-Stem Auger Drilling	3-11
3.2.4.4 Mud-Rotary Drilling	3-12
3.2.4.5 Geoprobe Boring	3-13
3.2.4.6 Cone Penetrometer Testing	3-13
3.2.5 Soil Sampling Methods	3-14
3.2.5.1 Test Pit Sampling	3-14
3.2.5.2 Surface Soil Sampling	3-15
3.2.5.3 Soil Boring Sampling	3-15
3.2.6 Monitoring Well Installation	3-16

3.2.7 Temporary Piezometers	3-18
3.2.8 Well Development Methods	3-18
3.2.9 Groundwater Level Measurement Methods.....	3-19
3.2.10 Water Sampling Methods.....	3-19
3.2.10.1 Groundwater Sampling from Monitoring Wells.....	3-20
3.2.10.2 Groundwater Sampling with Geoprobe Rig.....	3-21
3.2.10.3 Groundwater Sampling with Mud-Rotary Drill Rig.....	3-21
3.2.10.4 Groundwater Sampling with the Cone Penetrometer Testing Rig	3-22
3.2.10.5 Surface Water	3-22
3.2.11 Product Layer.....	3-23
3.2.12 Soil-Gas Survey	3-24
3.2.13 Sample Locations and Surveying.....	3-25
3.2.14 Sample Handling and Photographs	3-26
3.2.15 Decontamination Methods and Approved Water Sources	3-27
3.2.16 Investigation Derived Waste.....	3-29
3.3 LABORATORY PROCEDURES	3-29
3.3.1 Initial and Supplemental RI.....	3-29
3.3.2 Follow-on RI	3-33
3.4 DATA MANAGEMENT AND TABLE GENERATION.....	3-36
3.5 LABORATORY QUALITY ASSURANCE AND QUALITY CONTROL PROGRAM, PROCEDURES, AND RESULTS	3-40
3.5.1 Laboratory Audits	3-40
3.5.2 Initial and Supplemental RI.....	3-40
3.5.3 Follow-on RI.....	3-43
3.5.3.1 Data Review and Validation	3-43
3.5.3.1.1 Field Data Review.....	3-43
3.5.3.1.2 Organic Data Review	3-44
3.5.3.1.3 Inorganic Data Review.....	3-45
3.5.3.1.4 Data Validation.....	3-46
3.5.3.1.5 Part 1 - 100 Percent Review of Data Packages.....	3-47
3.5.3.1.6 Part 2 - Rigorous Data Validation Program.....	3-47
3.5.3.1.7 Part 3 - Comparison of Electronic and Hard Copy Data.....	3-48
3.5.3.2 Summary of Data Validation Program for the Follow-on RI.....	3-49
3.5.3.2.1 Organics	3-49
3.5.3.2.2 Metals.....	3-50
3.5.3.2.3 Conventional Analyses.....	3-50

3.6 FIELD QUALITY CONTROL SAMPLES, RESULTS, AND INTERPRETATION	3-51
3.6.1 Rinse Blanks	3-51
3.6.1.1.1 Initial and Supplemental RI	3-52
3.6.1.1.2 Follow-on RI	3-52
3.6.2 Trip Blanks	3-53
3.6.2.1.1 Initial and Supplemental RI	3-53
3.6.2.1.2 Follow-on RI	3-53
3.6.3 Field Blanks	3-53
3.6.3.1.1 Initial and Supplemental RI	3-54
3.6.3.1.2 Follow-on RI	3-54
3.6.4 Method Blanks	3-54
3.6.5 Duplicates	3-54
3.6.5.1.1 Initial and Supplemental RI	3-55
3.6.5.1.2 Follow-on RI	3-56
3.6.6 Split Sample Data	3-56
3.6.6.1.1 Supplemental RI	3-56
3.6.6.1.2 Follow-on RI	3-57
3.6.7 XRF Confirmation Samples	3-58
3.6.8 Immunoassay Confirmation	3-58
3.6.9 Conclusions	3-59
3.7 CONTAMINANT IDENTIFICATION PROCESS AND AMBIENT SOIL CONCENTRATIONS	3-59
3.7.1 Overview of Regional Soil Concentrations	3-61
3.7.2 PSF Ambient Soil Evaluation	3-63
3.7.2.1 Step 1 - Soils Description and Data Compilation	3-64
3.7.2.1.1 Soils Description	3-64
3.7.2.1.2 Statistical Comparisons	3-65
3.7.2.1.3 Data Compilation	3-67
3.7.2.2 Step 2 - Risk-based Screening of Potential Contaminants	3-68
3.7.2.3 Step 3 - Ambient Soil Concentration Estimation	3-69
3.7.2.4 Step 4 - Determination of Ambient Exceedences by Study Area	3-75
3.7.2.5 Step 5 - Comparisons of Investigative Samples to Ambient Concentrations	3-75
3.7.2.6 Step 6 - Spatial Analysis	3-76
3.7.3 Chromium Oxidation States	3-77
3.7.3.1 Hexavalent Chromium in Soil	3-77
3.7.3.2 Hexavalent Chromium in Water	3-78

3.7.4 Metals Mobility	3-81
3.7.5 Interpretation of Filtered and Unfiltered Water Results	3-83
3.8 SAMPLING DECISION CRITERIA AND REGULATORY LEVELS	3-84
3.9 RISK ASSESSMENT	3-88
3.9.1 Human Health Evaluation	3-88
3.9.2 Ecological Evaluation	3-90
4. NIKE FACILITY	4-1
4.1 AREA DESCRIPTION	4-1
4.1.1 Location and Physical Features	4-1
4.1.2 History and Land Use	4-3
4.2 SAMPLE LOCATION RATIONALE	4-4
4.3 HYDROGEOLOGIC SETTING	4-5
4.3.1 Soils and Geology	4-6
4.3.2 Hydrology	4-7
4.4 ANALYTICAL RESULTS	4-9
4.4.1 Building 1450 and Surrounding Structures	4-9
4.4.2 Storage Areas and Storm Drain System	4-11
4.4.2.1 Initial RI Results	4-12
4.4.2.2 Supplemental and Follow-on RI Results	4-13
4.4.2.2.1 Silo 1 Area	4-14
4.4.2.2.2 Silo 2 Area	4-15
4.4.2.2.3 Silo 3 Area	4-17
4.4.3 Silo Water	4-18
4.4.4 Groundwater	4-19
4.5 RESULTS EVALUATION	4-20
4.5.1 Nature and Extent	4-22
4.5.1.1 Building 1450 and Surrounding Structures	4-22
4.5.1.2 Storage Areas and Storm Drain System	4-24
4.5.1.2.1 Silo 1 Area	4-24
4.5.1.2.2 Silo 2 Area	4-27
4.5.1.2.3 Silo 3 Area	4-30
4.5.1.3 Silo Water	4-30

4.5.1.4 Groundwater	4-31
4.5.2 Contaminant Mobility and Migration Pathways	4-34
4.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY	4-35
4.6.1 Conclusions	4-36
4.6.2 Risk Assessment Summary.....	4-36
4.6.2.1 Human Health	4-37
4.6.2.1.1 Quantification of Carcinogenic Risks	4-39
4.6.2.1.2 Quantification of Noncarcinogenic Effects.....	4-39
4.6.3 Ecological.....	4-40
5. CRISSY FIELD STUDY AREA	5-1
5.1 AREA DESCRIPTION.....	5-1
5.1.1 Location and Physical Features	5-1
5.1.1.1 Consolidated Motor Pool Area	5-3
5.1.1.2 Petroleum, Oil, and Lubricants Area	5-4
5.1.1.3 Fill Site 7	5-5
5.1.1.4 Buildings 609, 611, and 633	5-6
5.1.1.5 Sewer Lift Stations	5-6
5.1.2 Previous and Ongoing Environmental Investigations	5-7
5.1.2.1 Previous Investigations	5-7
5.1.2.2 Ongoing Investigations.....	5-8
5.2 SAMPLE LOCATION RATIONALE.....	5-9
5.3 GEOLOGIC SETTING.....	5-12
5.3.1 Soil and Geology.....	5-12
5.3.2 Hydrogeology	5-16
5.4 ANALYTICAL RESULTS	5-19
5.4.1 Consolidated Motor Pool Area	5-20
5.4.1.1 Wipe and Sediment Samples	5-20
5.4.1.2 Surface and Subsurface Soil Samples.....	5-22
5.4.2 Petroleum, Oil, and Lubricants Area.....	5-25
5.4.2.1 Surface and Subsurface Soil Samples.....	5-26
5.4.2.2 Groundwater Samples.....	5-28
5.4.3 Fill Site 7	5-30

5.4.3.1 Sediment Samples	5-32
5.4.3.2 Surface Soil Samples	5-34
5.4.3.3 Subsurface Soil Samples	5-36
5.4.3.4 Groundwater Samples	5-39
5.4.4 Buildings 609, 611, and 633	5-43
5.4.5 Sewer Lift Stations	5-44
5.5 RESULTS EVALUATION.....	5-45
5.5.1 Consolidated Motor Pool Area	5-47
5.5.2 Petroleum, Oil, and Lubricants Area	5-50
5.5.3 Fill Site 7	5-54
5.5.3.1 Sediment	5-54
5.5.3.2 Soil	5-57
5.5.3.3 Groundwater	5-66
5.5.4 Buildings 609, 611, and 633	5-74
5.5.5 Sewer Lift Stations	5-74
5.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY	5-76
5.6.1 Conclusions	5-76
5.6.1.1 Consolidated Motor Pool	5-76
5.6.1.2 POL Area	5-77
5.6.1.3 Fill Site 7	5-77
5.6.1.4 Buildings 609, 611, and 633	5-78
5.6.1.5 Sewer Lift Stations	5-78
5.6.1.6 Proposed Wetlands Restoration Area	5-78
5.6.2 Risk Assessment Summary	5-79
5.6.2.1 Human Health	5-80
5.6.2.1.1 Quantification of Cancer Risks	5-81
5.6.2.1.2 Quantification of Noncarcinogenic Effects	5-83
5.6.2.2 Ecological	5-83
5.6.2.2.1 Buildings 640 and 643	5-84
5.6.2.2.2 Building 642	5-85
5.6.2.2.3 Fill Site 7/East of Mason Shoreline Area	5-85
5.6.2.2.4 Future Wetland Area	5-86
5.6.2.2.5 Building 609	5-88
5.6.2.2.6 Building 611	5-88
5.6.2.2.7 Building 633	5-88
5.6.2.2.8 Sewer Lift Stations	5-89
6. BUILDING 900S SERIES STUDY AREA	6-1

6.1 AREA DESCRIPTION	6-1
6.1.1 Location and Physical Features	6-2
6.1.2 History and Use	6-2
6.1.2.1 Vehicle Maintenance Area (Buildings 920 and 923 through 937)	6-3
6.1.2.2 Storage Area (Buildings 949, 950, 973, 974).....	6-6
6.1.2.3 Building 979.....	6-7
6.2 SAMPLE LOCATION RATIONALE.....	6-8
6.3 GEOLOGIC SETTING.....	6-10
6.3.1 Soils and Geology	6-10
6.3.2 Hydrogeology	6-12
6.3.2.1 Water-Bearing Zone/Aquifer.....	6-13
6.3.2.2 Flow Directions and Hydraulic Gradients.....	6-13
6.3.2.3 Tidal Studies	6-17
6.3.2.4 Aquifer Properties	6-19
6.3.2.5 Saltwater/Freshwater Interface and Saltwater Intrusion	6-20
6.4 ANALYTICAL RESULTS	6-23
6.4.1 Vehicle Maintenance Area.....	6-24
6.4.1.1 Buildings 920 through 935.....	6-24
6.4.1.2 Building 937.....	6-31
6.4.1.2.1 Wipe, Sediment, and Surface Soil Sampling Program and Results.....	6-31
6.4.1.2.2 Subsurface Soil Sampling Program and Results.....	6-32
6.4.1.2.3 Groundwater Sampling Program and Results	6-34
6.4.1.2.4 Product Sampling Program and Results.....	6-51
6.4.2 Storage Area.....	6-51
6.4.2.1 Building 949.....	6-52
6.4.2.2 Buildings 950 and 973	6-53
6.4.3 Building 979 Area.....	6-56
6.4.3.1 Sampling Program.....	6-56
6.4.3.2 Soil Sample Results.....	6-58
6.4.3.3 Inorganic Groundwater Sample Results.....	6-59
6.4.3.4 Organic Groundwater Sample Results.....	6-62
6.4.3.5 Soil-Gas Survey Sample Results	6-65
6.5 RESULTS EVALUATION	6-65
6.5.1 Evaluation of Chemicals in Soil.....	6-65
6.5.1.1 Vehicle Maintenance Area	6-67

6.5.1.2 Storage Area	6-72
6.5.1.3 Building 979	6-76
6.5.2 Fate and Transport of Chemicals in Soil.....	6-76
6.5.3 Nature and Extent/Fate and Transport of Chemicals in Groundwater	6-79
6.5.3.1 Inorganics	6-79
6.5.3.2 Organics	6-81
6.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY	6-91
6.6.1 Conclusions.....	6-91
6.6.1.1 Vehicle Maintenance Area	6-92
6.6.1.2 Storage Building Area	6-93
6.6.1.3 Building 979	6-93
6.6.1.4 Groundwater	6-93
6.6.2 Risk Assessment Summary	6-94
6.6.2.1 Human Health.....	6-95
6.6.2.1.1 Quantification of Cancer Risks.....	6-97
6.6.2.1.2 Quantification of Noncarcinogenic Effects	6-98
6.6.2.2 Ecological.....	6-98
7. DIRECTORATE OF ENGINEERING AND HOUSING STUDY AREA.....	7-1
7.1 AREA DESCRIPTION	7-1
7.1.1 Location and Physical Features.....	7-2
7.1.2 History and Land Use	7-2
7.1.3 Previous Investigations	7-5
7.2 SAMPLE LOCATION RATIONALE	7-6
7.3 HYDROGEOLOGIC SETTING.....	7-7
7.3.1 Geology and Soil	7-7
7.3.2 Hydrology	7-9
7.4 ANALYTICAL RESULTS.....	7-10
7.4.1 Building Wipe Sampling Results.....	7-11
7.4.2 Sediment Sampling Results.....	7-12
7.4.3 Soil Sampling Results.....	7-13
7.4.4 Groundwater Sampling Results.....	7-19
7.5 RESULTS EVALUATION.....	7-21

7.5.1 Sediment	7-22
7.5.2 Soil and Groundwater	7-24
7.5.2.1 Inorganic Constituents	7-26
7.5.2.2 Organic Compounds	7-33
7.5.2.2.1 Buildings 267, 268, and 287	7-33
7.5.2.2.2 Buildings 269 and 293	7-34
7.5.2.2.3 Building 283	7-35
7.5.2.2.4 Building 286	7-35
7.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY	7-36
7.6.1 Conclusions	7-36
7.6.2 Risk Assessment Summary	7-37
7.6.2.1 Human Health	7-38
7.6.2.1.1 Quantification of Cancer Risks	7-39
7.6.2.1.2 Quantification of Noncarcinogenic Effects	7-40
7.6.2.2 Ecological	7-40
8. MAIN POST STUDY AREA	8-1
8.1 BUILDING 215	8-2
8.1.1 Area Description	8-2
8.1.2 Sample Location Rationale	8-3
8.1.3 Geologic Setting	8-4
8.1.4 Analytical Results	8-5
8.1.5 Results Evaluation	8-6
8.1.6 Conclusions and Risk Assessment Results	8-7
8.1.6.1 Conclusions	8-7
8.1.6.2 Risk Assessment Summary	8-8
8.1.6.2.1 Quantification of Cancer Risks	8-9
8.1.6.2.2 Quantification of Noncarcinogenic Effects	8-10
8.2 BUILDING 231 AREA	8-10
8.2.1 Area Description	8-10
8.2.1.1 Physical Setting	8-10
8.2.1.2 History and Land Use	8-11
8.2.1.3 Previous Investigations	8-12
8.2.1.4 Ongoing Investigations	8-13
8.2.2 Sample Location Rationale	8-14
8.2.3 Hydrogeologic Setting	8-15

8.2.3.1 Geology	8-15
8.2.3.2 Hydrology	8-17
8.2.4 Analytical Results	8-19
8.2.4.1 Soil Sample Results	8-19
8.2.4.2 Groundwater Sample Results	8-21
8.2.5 Results Evaluation	8-24
8.2.5.1 Soil Evaluation	8-25
8.2.5.2 Groundwater Evaluation	8-26
8.2.6 Conclusions and Risk Assessment Summary	8-28
8.2.6.1 Conclusions	8-28
8.2.6.2 Risk Assessment Summary	8-29
8.2.6.2.1 Human Health	8-30
8.2.6.2.1.1 Quantification of Cancer Risks	8-31
8.2.6.2.1.2 Quantification of Noncarcinogenic Effects	8-31
8.2.6.2.2 Ecological	8-31
8.3 BUILDING 1057	8-32
8.3.1 Area Description	8-32
8.3.2 Sample Location Rationale	8-33
8.3.3 Geologic Setting	8-33
8.3.4 Analytical Results	8-34
8.3.5 Results Evaluation	8-35
8.3.6 Conclusions and Risk Assessment Summary	8-36
8.3.6.1 Conclusions	8-36
8.3.6.2 Risk Assessment Summary	8-36
8.3.6.2.1 Quantification of Cancer Risks	8-38
8.3.6.2.2 Quantification of Noncarcinogenic Effects	8-38
8.4 BUILDING 1065	8-38
8.4.1 Area Description	8-39
8.4.2 Sample Location Rationale	8-39
8.4.3 Hydrogeologic Setting	8-40
8.4.4 Analytical Results	8-41
8.4.5 Results Evaluation	8-42
8.4.6 Conclusions	8-44
8.5 BUILDING 1167	8-45
8.5.1 Area Description	8-45

8.5.2 Sample Location Rationale.....	8-46
8.5.3 Geologic Setting.....	8-47
8.5.4 Analytical Results.....	8-47
8.5.5 Results Evaluation.....	8-48
8.5.6 Conclusions and Risk Assessment Summary.....	8-50
8.5.6.1 Conclusions.....	8-50
8.5.6.2 Risk Assessment Summary.....	8-51
8.5.6.2.1 Human Health.....	8-51
8.5.6.2.1.1 Quantification of Cancer Risks.....	8-53
8.5.6.2.1.2 Quantification of Noncarcinogenic Effects.....	8-53
8.5.6.2.2 Ecological.....	8-53
8.6 BUILDING 1151.....	8-55
8.6.1 Area Description.....	8-55
8.6.2 Sample Location Rationale.....	8-55
8.6.3 Geologic Setting.....	8-56
8.6.4 Analytical Results.....	8-56
8.6.5 Results Evaluation.....	8-57
8.6.6 Conclusions and Risk Assessment Summary.....	8-58
8.6.6.1 Conclusions.....	8-58
8.6.6.2 Risk Assessment Summary.....	8-58
8.6.6.2.1 Human Health.....	8-59
8.6.6.2.1.1 Quantification of Cancer Risks.....	8-60
8.6.6.2.1.2 Quantification of Noncarcinogenic Effects.....	8-60
8.6.6.2.2 Ecological.....	8-60
9. FILL SITES AND LANDFILLS.....	9-1
9.1 FILL SITE 1 AND LANDFILL 2.....	9-2
9.1.1 Area Description.....	9-2
9.1.1.1 Location and Physical Features.....	9-2
9.1.1.2 History and Land Use.....	9-3
9.1.2 Sample Location Rationale.....	9-3
9.1.3 Geologic Setting.....	9-5
9.1.4 Hydrogeology.....	9-6
9.1.5 Analytical Results.....	9-8
9.1.5.1 Fill Site 1 Soil Sampling Results.....	9-8
9.1.5.2 Landfill 2 Soil Sampling Results.....	9-9

9.1.5.3 Fill Site 1 Groundwater Sampling Results.....	9-11
9.1.5.4 Landfill 2 Surface-Water/Groundwater Sampling Results	9-12
9.1.6 Results Evaluation.....	9-14
9.1.6.1 Fill Site 1 Results Evaluation	9-15
9.1.6.2 Landfill 2 Results Evaluation	9-18
9.1.7 Conclusions and Risk Assessment Summary	9-22
9.1.7.1 Conclusions	9-22
9.1.7.2 Risk Assessment Summary.....	9-23
9.1.7.2.1 Human Health.....	9-24
9.1.7.2.1.1 Quantification of Cancer Risks	9-25
9.1.7.2.1.2 Quantification of Noncarcinogenic Effects.....	9-26
9.1.7.2.2 Ecological.....	9-26
9.2 TRANSFER STATION.....	9-28
9.2.1 Area Description	9-29
9.2.1.1 Location and Physical Features	9-29
9.2.1.2 History and Land Use.....	9-29
9.2.2 Sample Location Rationale	9-30
9.2.3 Geologic Setting	9-30
9.2.4 Analytical Results.....	9-31
9.2.5 Results Evaluation.....	9-33
9.2.6 Conclusions and Risk Assessment Summary	9-37
9.2.6.1 Conclusions	9-37
9.2.6.2 Risk Assessment Summary.....	9-38
9.2.6.2.1 Human Health.....	9-38
9.2.6.2.1.1 Carcinogenic Risk	9-39
9.2.6.2.1.2 Non-carcinogenic Risk	9-40
9.2.6.2.2 Ecological.....	9-40
9.3 LANDFILL 4 AND FILL SITE 5	9-41
9.3.1 Area Description	9-41
9.3.1.1 Location and Physical Features	9-42
9.3.1.2 History and Land Use.....	9-42
9.3.2 Sample Location Rationale	9-43
9.3.3 Geologic Setting and Hydrogeology	9-44
9.3.3.1 Landfill 4 Soils and Geology	9-44
9.3.3.2 Landfill 4 Hydrogeology.....	9-45
9.3.3.3 Fill Site 5 Soils and Geology	9-46

9.3.4 Analytical Results	9-47
9.3.4.1 Landfill 4 Soil Sampling Results	9-47
9.3.4.2 Landfill 4 Groundwater Sampling Results	9-50
9.3.4.3 Fill Site 5 Soil Sampling Results	9-50
9.3.5 Results Evaluation	9-51
9.3.5.1 Landfill 4 Results Evaluation	9-52
9.3.5.2 Fill Site 5 Results Evaluation	9-55
9.3.6 Conclusions and Risk Assessment Summary	9-56
9.3.6.1 Conclusions	9-56
9.3.6.2 Risk Assessment Summary	9-57
9.3.6.2.1 Human Health	9-57
9.3.6.2.1.1 Quantification of Cancer Risks	9-58
9.3.6.2.1.2 Quantification of Noncarcinogenic Effects	9-59
9.3.6.2.2 Ecological	9-59
9.4 FILL SITE 6	9-60
9.4.1 Area Description	9-61
9.4.1.1 Location and Physical Features	9-61
9.4.1.2 History and Land Use	9-61
9.4.2 Sample Location Rationale	9-61
9.4.3 Geologic Setting	9-62
9.4.4 Analytical Results	9-63
9.4.4.1 Soil Sampling Results	9-63
9.4.4.2 Discrete Groundwater Sampling Results	9-64
9.4.5 Results Evaluation	9-65
9.4.6 Conclusions and Risk Assessment Summary	9-67
9.4.6.1 Conclusions	9-67
9.4.6.2 Risk Assessment Summary	9-67
9.4.6.2.1 Carcinogenic Risk	9-69
9.4.6.2.2 Non-carcinogenic Risk	9-70
9.5 GRADED AREA 9	9-70
9.5.1 Area Description	9-70
9.5.1.1 Location and Physical Features	9-70
9.5.1.2 History and Land Use	9-70
9.5.2 Sample Location Rationale	9-71
9.5.3 Geologic Setting	9-71
9.5.4 Analytical Results	9-72

9.5.5 Results Evaluation	9-73
9.5.6 Conclusions and Risk Assessment Summary	9-74
9.5.6.1 Conclusions	9-74
9.5.6.2 Risk Assessment Summary.....	9-75
9.5.6.2.1 Human Health.....	9-75
9.5.6.2.1.1 Carcinogenic Risks.....	9-76
9.5.6.2.1.2 Non-carcinogenic Risks.....	9-76
9.5.6.2.2 Ecological.....	9-76
9.6 LANDFILL E.....	9-78
9.6.1 Area Description	9-78
9.6.1.1 Location and Physical Features	9-78
9.6.1.2 History and Land Use.....	9-78
9.6.2 Sample Location Rationale	9-79
9.6.3 Geologic Setting	9-79
9.6.4 Hydrogeology	9-81
9.6.5 Analytical Results.....	9-83
9.6.5.1 Soil Sampling Results	9-83
9.6.5.2 Groundwater Sampling Results	9-86
9.6.6 Results Evaluation.....	9-88
9.6.7 Conclusions and Risk Assessment Summary	9-93
9.6.7.1 Conclusions	9-93
9.6.7.2 Risk Assessment Summary.....	9-93
9.6.7.2.1 Human Health.....	9-94
9.6.7.2.1.1 Carcinogenic Risk	9-95
9.6.7.2.1.2 Non-carcinogenic Risk	9-95
9.6.7.2.2 Ecological.....	9-96
10. MISCELLANEOUS SITES	10-1
10.1 BUILDING 662.....	10-1
10.1.1 Area Description.....	10-1
10.1.2 Sample Location Rationale	10-2
10.1.3 Geologic Setting	10-3
10.1.4 Analytical Results.....	10-4
10.1.4.1 Building 662 UST/AST Area	10-5
10.1.4.2 South Perimeter of Building 662.....	10-5
10.1.4.3 Hydraulic Lift Area.....	10-6

10.1.4.4 Downgradient Groundwater	10-6
10.1.5 Results Evaluation	10-7
10.1.5.1 Building 662 UST/AST area	10-7
10.1.5.2 South Perimeter of Building 662	10-8
10.1.5.3 Hydraulic Lift Area	10-9
10.1.5.4 Downgradient Groundwater	10-9
10.1.6 Conclusions and Risk Assessment Summary	10-9
10.1.6.1 Conclusions	10-10
10.1.6.2 Risk Assessment Summary	10-10
10.1.6.2.1 Human Health	10-11
10.1.6.2.1.1 Quantification of Cancer Risks	10-12
10.1.6.2.1.2 Quantification of Noncarcinogenic Effects	10-13
10.1.6.2.2 Ecological	10-13
10.2 BUILDING 680	10-14
10.2.1 Area Description	10-14
10.2.2 Sample Location Rationale	10-15
10.2.3 Geologic Setting	10-16
10.2.4 Analytical Results	10-16
10.2.5 Results Evaluation	10-16
10.2.6 Conclusions and Risk Assessment Summary	10-18
10.2.6.1 Conclusions	10-18
10.2.6.2 Risk Assessment Summary	10-18
10.2.6.2.1 Human Health	10-19
10.2.6.2.1.1 Quantification of Cancer Risks	10-20
10.2.6.2.1.2 Quantification of Noncarcinogenic Effects	10-20
10.2.6.2.2 Ecological	10-20
10.3 BUILDING 1244	10-21
10.3.1 Area Description	10-22
10.3.2 Sample Location Rationale	10-23
10.3.3 Geologic Setting	10-23
10.3.4 Analytical Results	10-24
10.3.5 Results Evaluation	10-24
10.3.6 Conclusions and Risk Assessment Summary	10-25
10.3.6.1 Conclusions	10-26
10.3.6.2 Risk Assessment Summary	10-26
10.3.6.2.1 Human Health	10-26

10.3.6.2.1.1 Quantification of Cancer Risks	10-27
10.3.6.2.1.2 Quantification of Noncarcinogenic Effects.....	10-27
10.3.6.2.2 Ecological	10-27
10.4 BUILDING 1351	10-27
10.4.1 Area Description.....	10-28
10.4.2 Sample Location Rationale	10-29
10.4.3 Geologic Setting	10-30
10.4.4 Analytical Results.....	10-30
10.4.5 Results Evaluation.....	10-33
10.4.5.1 Inorganic Ambient Evaluation	10-34
10.4.5.2 Organic Compound Evaluation.....	10-37
10.4.6 Conclusions and Risk Assessment Summary	10-38
10.4.6.1 Conclusions	10-38
10.4.6.2 Risk Assessment Summary.....	10-38
10.4.6.2.1 Human Health.....	10-39
10.4.6.2.1.1 Quantification of Cancer Risks	10-40
10.4.6.2.1.2 Quantification of Noncarcinogenic Effects.....	10-40
10.4.6.2.2 Ecological.....	10-41
10.5 FORT POINT U.S. COAST GUARD STATION	10-42
10.5.1 Area Description.....	10-42
10.5.2 Sample Location Rationale	10-44
10.5.3 Hydrogeologic Setting.....	10-45
10.5.3.1 Soils and Geology	10-45
10.5.3.2 Hydrology.....	10-46
10.5.4 Analytical Results.....	10-46
10.5.4.1 UST Area North of Building 991.....	10-47
10.5.4.2 Building 995	10-49
10.5.4.3 Building 996	10-51
10.5.4.4 Building 997	10-53
10.5.4.5 Inland Well CGGW01.....	10-54
10.5.5 Results Evaluation.....	10-54
10.5.5.1 Underground Storage Tanks	10-56
10.5.5.2 Building 995	10-59
10.5.5.3 Building 996	10-60
10.5.5.4 Building 997	10-61
10.5.6 Conclusions and Risk Assessment Summary	10-61

10.5.6.1 Conclusions	10-61
10.5.6.2 Risk Assessment Summary	10-62
10.5.6.2.1 Human Health	10-63
10.5.6.2.1.1 Quantification of Cancer Risks	10-64
10.5.6.2.1.2 Quantification of Noncarcinogenic Effects	10-64
10.5.6.2.2 Ecological	10-64
10.6 LOBOS CREEK	10-66
10.6.1 Area Description	10-66
10.6.2 Sample Location Rationale	10-68
10.6.3 Hydrogeologic Setting	10-68
10.6.4 Analytical Results	10-69
10.6.5 Results Evaluation	10-70
10.6.6 Conclusions and Risk Assessment Summary	10-73
10.6.6.1 Conclusions	10-73
10.6.6.2 Risk Assessment Summary	10-74
10.6.6.2.1 Human Health	10-75
10.6.6.2.1.1 Quantification of Cancer Risks	10-76
10.6.6.2.1.2 Quantification of Noncarcinogenic Effects	10-77
10.6.6.2.2 Ecological	10-77
10.7 MOUNTAIN LAKE	10-78
10.7.1 Area Description	10-79
10.7.2 Sample Location Rationale	10-80
10.7.3 Hydrogeologic Setting	10-80
10.7.4 Analytical Results	10-81
10.7.5 Results Evaluation	10-83
10.7.5.1 Nature and Extent	10-84
10.7.5.2 Fate and Transport	10-87
10.7.6 Conclusions and Risk Assessment Summary	10-89
10.7.6.1 Conclusions	10-89
10.7.6.2 Risk Assessment Summary	10-90
10.7.6.2.1 Human Health	10-90
10.7.6.2.1.1 Quantification of Cancer Risks	10-92
10.7.6.2.1.2 Quantification of Noncarcinogenic Effects	10-92
10.7.6.2.2 Ecological	10-92
11. GOLDEN GATE BRIDGE HIGHWAY AND TRANSPORTATION DISTRICT	11-1
11.1 AREA DESCRIPTION	11-1

11.1.1 Location and Physical Features	11-1
11.1.2 Site History and Land Use	11-2
11.1.2.1 Transformer Area	11-2
11.1.2.2 Underground Storage Tank Area	11-2
11.1.2.3 Paint Operations Area	11-3
11.1.2.4 Bone Yard Storage Area	11-4
11.1.3 Previous Investigations	11-5
11.2 SAMPLE LOCATION RATIONALE	11-5
11.2.1 Transformer Area	11-6
11.2.2 Underground Storage Tank Area	11-6
11.2.3 Paint Operations Area	11-6
11.2.4 Bone Yard Storage Area	11-7
11.3 GEOLOGIC SETTING	11-8
11.3.1 Soils and Geology	11-8
11.3.2 Area Hydrogeology	11-9
11.4 ANALYTICAL RESULTS	11-10
11.4.1 Transformer Area	11-10
11.4.2 Underground Storage Tank Area	11-10
11.4.3 Paint Operations Area	11-12
11.4.4 Bone Yard Storage Area	11-13
11.4.5 RESULTS EVALUATION	11-14
11.4.6 Transformer Area	11-14
11.4.7 Underground Storage Tank Area	11-14
11.4.8 Paint Operations Area	11-15
11.4.9 Bone Yard Storage Area	11-17
11.5 CONCLUSIONS AND RECOMMENDATIONS	11-18
11.5.1 Transformer Area	11-19
11.5.2 Underground Storage Tank Area	11-19
11.5.3 Paint Operations Area	11-19
11.5.4 Bone Yard Storage Area	11-20
12. BAKER BEACH STUDY AREA	12-1

12.1 AREA DESCRIPTION	12-1
12.1.1 Location and Physical Features	12-1
12.1.2 History and Land Use.....	12-2
12.2 SAMPLE LOCATION RATIONALE	12-3
12.3 GEOLOGIC SETTING.....	12-4
12.4 ANALYTICAL RESULTS	12-5
12.4.1 Disturbed Area 1.....	12-6
12.4.1.1 Disturbed Area 1a.....	12-10
12.4.2 Disturbed Area 2.....	12-10
12.4.3 Disturbed Area 3.....	12-11
12.4.4 Disturbed Area 4.....	12-13
12.5 RESULTS EVALUATION	12-14
12.5.1 Disturbed Area 1.....	12-15
12.5.1.1 Disturbed Area 1a.....	12-18
12.5.2 Disturbed Area 2.....	12-19
12.5.3 Disturbed Area 3.....	12-22
12.5.4 Disturbed Area 4.....	12-24
12.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY	12-26
12.6.1 Conclusions	12-26
12.6.2 Risk Assessment Summary.....	12-26
12.6.2.1 Human Health	12-27
12.6.2.1.1 Quantification of Cancer Risks.....	12-29
12.6.2.1.2 Quantification of Noncarcinogenic Effects.....	12-30
12.6.2.2 Ecological.....	12-30
13. BATTERY HOWE/WAGNER.....	13-1
13.1 AREA DESCRIPTION	13-1
13.1.1 Location and Physical Features	13-1
13.1.2 History and Land Use.....	13-2
13.2 SAMPLE LOCATION RATIONALE.....	13-3
13.3 GEOLOGIC SETTING.....	13-4

13.3.1 Soil and Geology	13-4
13.3.2 Hydrogeology	13-5
13.4 ANALYTICAL RESULTS	13-7
13.5 RESULTS EVALUATION	13-12
13.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY	13-16
13.6.1 Conclusions	13-16
13.6.2 Risk Assessment Summary	13-17
13.6.2.1 Human Health	13-17
13.6.2.2 Ecological	13-19
14. MISCELLANEOUS FOLLOW-ON RI SITES	14-1
14.1 BUILDING 302	14-1
14.1.1 Area Description	14-1
14.1.2 Sample Location Rationale	14-2
14.1.3 Geologic Setting	14-3
14.1.4 Analytical Results	14-3
14.1.5 Results Evaluation	14-4
14.1.6 Conclusions and Risk Assessment Summary	14-5
14.1.6.1 Conclusions	14-5
14.1.6.2 Risk Assessment Summary	14-5
14.1.6.2.1 Human Health	14-6
14.1.6.2.2 Ecological	14-6
14.2 BUILDING 669	14-7
14.2.1 Area Description	14-7
14.2.2 Sample Location Rationale	14-8
14.2.3 Geologic Setting	14-9
14.2.4 Analytical Results	14-9
14.2.5 Results Evaluation	14-10
14.2.6 Conclusions and Risk Assessment Summary	14-10
14.3 BUILDING 1245	14-11
14.3.1 Area Description	14-11
14.3.2 Sample Location Rationale	14-11

14.3.3 Geologic Setting.....	14-12
14.3.4 Analytical Results	14-12
14.3.5 Results Evaluation	14-12
14.3.6 Conclusions and Risk Assessment Summary.....	14-13
14.3.6.1 Conclusions	14-13
14.3.6.2 Risk Assessment Summary	14-13
14.3.6.2.1 Human Health.....	14-14
14.3.6.2.1.1 Quantification of Cancer Risks.....	14-15
14.3.6.2.1.2 Quantification of Noncarcinogenic Effects	14-15
14.3.6.2.2 Ecological	14-15
14.4 BUILDING 1369	14-16
14.4.1 Area Description	14-16
14.4.2 Sample Location Rationale.....	14-17
14.4.3 Geologic Setting.....	14-17
14.4.4 Analytical Results	14-17
14.4.5 Results Evaluation	14-18
14.4.6 Conclusions and Risk Assessment Summary.....	14-18
14.4.6.1 Conclusions	14-18
14.4.6.2 Risk Assessment Summary	14-19
14.4.6.2.1 Human Health	14-19
14.4.6.2.1.1 Quantification of Cancer Risks.....	14-20
14.4.6.2.1.2 Quantification of Noncarcinogenic Effects	14-20
14.4.6.2.2 Ecological	14-20
14.5 BUILDING 1388	14-21
14.5.1 Area Description	14-21
14.5.2 Sample Location Rationale.....	14-22
14.5.3 Geologic Setting.....	14-22
14.5.4 Analytical Results	14-23
14.5.5 Results Evaluation	14-23
14.5.6 Conclusions and Risk Assessment Summary.....	14-23
14.5.6.1 Conclusions	14-23
14.5.6.2 Risk Assessment Summary	14-24
14.5.6.2.1 Human Health	14-24
14.5.6.2.1.1 Quantification of Cancer Risks.....	14-25
14.5.6.2.1.2 Quantification of Noncarcinogenic Effects	14-26
14.5.6.2.2 Ecological	14-26

14.6 BUILDING 1750	14-27
14.6.1 Site Description	14-27
14.6.2 Sample Location Rationale	14-28
14.6.3 Geologic Setting	14-28
14.6.4 Analytical Results	14-29
14.6.5 Results Evaluation	14-29
14.6.6 Conclusions and Risk Assessment Summary	14-29
14.7 EAST-OF-MASON	14-30
14.7.1 Area Description	14-30
14.7.2 Sampling Location Rationale	14-31
14.7.3 Hydrogeologic Setting	14-31
14.7.4 Analytical Results	14-33
14.7.4.1 Soil Samples	14-33
14.7.4.2 Groundwater Samples	14-34
14.7.5 Results Evaluation	14-35
14.7.6 Conclusions and Risk Assessment Summary	14-38
14.7.6.1 Conclusions	14-38
14.7.6.2 Risk Assessment Summary	14-38
14.7.6.2.1 Human Health	14-39
14.7.6.2.1.1 Quantification of Cancer Risks	14-40
14.7.6.2.1.2 Quantification of Noncarcinogenic Effects	14-40
14.7.6.2.2 Ecological	14-40
15. BASELINE RISK ASSESSMENT	15-1
15.1 HUMAN HEALTH RISK ASSESSMENT	15-2
15.1.1 Identification of Chemicals of Concern	15-4
15.1.2 Exposure Assessment	15-8
15.1.2.1 Identification and Characterization of Exposed Populations	15-8
15.1.2.2 Evaluation of Exposure Pathways	15-10
15.1.2.2.1 Overview of Exposure Pathways by Environmental Medium	15-11
15.1.2.2.1.1 Soil	15-11
15.1.2.2.1.2 Groundwater	15-14
15.1.2.2.1.3 Surface Water	15-17
15.1.2.2.1.4 Sediment	15-18
15.1.2.2.1.5 Air	15-18
15.1.2.2.2 Summary of Exposure Pathways by Study Area	15-19
15.1.2.2.2.1 Nike Facility	15-19

- 15.1.2.2.2 Crissy Field Study Area 15-20
- 15.1.2.2.2.3 Building 900s Series Study Area 15-23
- 15.1.2.2.2.4 DEH Study Area 15-27
- 15.1.2.2.2.5 Main Post Study Area 15-30
- 15.1.2.2.2.6 Fill Sites and Landfills 15-33
- 15.1.2.2.2.7 Miscellaneous Sites 15-35
- 15.1.2.2.2.8 GGBHTD Study Area 15-38
- 15.1.2.2.2.9 Baker Beach Study Area 15-38
- 15.1.2.2.2.10 Battery Howe/Wagner 15-39
- 15.1.2.2.2.11 Miscellaneous Follow-on Sites 15-40
- 15.1.2.3 Quantification of Exposure 15-43
 - 15.1.2.3.1 Ingestion of Soil 15-45
 - 15.1.2.3.2 Dermal Contact with Soil 15-46
 - 15.1.2.3.3 Ingestion of Drinking Water 15-47
 - 15.1.2.3.4 Dermal Contact with Drinking Water 15-47
 - 15.1.2.3.5 Ingestion of Surface Water 15-48
 - 15.1.2.3.6 Dermal Contact with Surface Water 15-48
 - 15.1.2.3.7 Ingestion of Sediment 15-48
 - 15.1.2.3.8 Dermal Contact with Sediments 15-49
 - 15.1.2.3.9 Ingestion of Groundwater 15-49
 - 15.1.2.3.10 Dermal Contact with Groundwater 15-50
 - 15.1.2.3.11 Inhalation of Dust 15-50
- 15.1.3 Toxicity Assessment 15-51
 - 15.1.3.1 Toxicity Assessment for Exposure Routes With No USEPA-Derived Toxicity Values 15-52
- 15.1.4 Risk Characterization 15-54
 - 15.1.4.1 Nike Facility 15-56
 - 15.1.4.1.1 Quantification of Cancer Risks 15-56
 - 15.1.4.1.2 Quantification of Noncarcinogenic Effects 15-57
 - 15.1.4.2 Crissy Field Study Area 15-57
 - 15.1.4.2.1 Quantification of Cancer Risks 15-57
 - 15.1.4.2.2 Quantification of Noncarcinogenic Effects 15-59
 - 15.1.4.3 Building 900s Series Study Area 15-59
 - 15.1.4.3.1 Quantification of Cancer Risks 15-59
 - 15.1.4.3.2 Quantification of Noncarcinogenic Effects 15-60
 - 15.1.4.4 DEH Study Area 15-61
 - 15.1.4.4.1 Quantification of Cancer Risks 15-61
 - 15.1.4.4.2 Quantification of Noncarcinogenic Effects 15-62
 - 15.1.4.5 Main Post Study Area 15-62
 - 15.1.4.5.1 Quantification of Cancer Risks 15-62
 - 15.1.4.5.2 Quantification of Noncarcinogenic Effects 15-63
 - 15.1.4.6 Fill Sites and Landfills 15-63
 - 15.1.4.6.1 Quantification of Cancer Risks 15-63
 - 15.1.4.6.2 Quantification of Noncarcinogenic Effects 15-65
 - 15.1.4.7 Miscellaneous Sites 15-65
 - 15.1.4.7.1 Quantification of Cancer Risks 15-66
 - 15.1.4.7.2 Quantification of Noncarcinogenic Effects 15-67

15.1.4.8 Baker Beach Study Area	15-68
15.1.4.8.1 Quantification of Cancer Risks.....	15-68
15.1.4.8.2 Quantification of Noncarcinogenic Effects	15-69
15.1.4.9 Battery Howe/Wagner	15-69
15.1.4.10 Miscellaneous Follow-On Sites.....	15-70
15.1.4.10.1 Quantification of Cancer Risks.....	15-70
15.1.4.10.2 Quantification of Noncarcinogenic Effects	15-70
15.1.4.11 Risk Characterization for Lead	15-71
15.1.4.12 Uncertainties	15-72
15.1.4.12.1 Uncertainties Associated with Identification of COCs.....	15-73
15.1.4.12.2 Uncertainties Associated with Exposure Assessment	15-74
15.1.4.12.3 Uncertainties Associated with Toxicity Assessment.....	15-77
15.1.4.12.4 Uncertainties Associated with Risk Characterization.....	15-78
15.1.5 Summary and Conclusions.....	15-79
15.2 ECOLOGICAL RISK ASSESSMENT	15-82
15.2.1 Problem Formulation	15-82
15.2.1.1 Description of Biota	15-85
15.2.1.2 Key Receptors.....	15-90
15.2.1.3 Description of Study Area and Site Conditions.....	15-93
15.2.1.4 Selection of COPCs.....	15-101
15.2.2 Exposure Analysis	15-102
15.2.2.1 Exposure Pathways	15-103
15.2.2.2 Exposure Point Concentrations	15-106
15.2.2.3 Exposure Intakes.....	15-106
15.2.2.3.1 Chemical Intake due to Ingestion of Soil or Sediment	15-108
15.2.2.3.2 Chemical Intake due to Ingestion of Water.....	15-110
15.2.2.3.3 Chemical Intake Due to Dermal Exposure.....	15-111
15.2.2.3.4 Chemical Intake Due to Ingestion of Dietary Items.....	15-111
15.2.2.3.5 Terrestrial Food Web	15-113
15.2.2.3.6 Aquatic Food Web	15-114
15.2.3 Stress Response Assessment	15-116
15.2.3.1 Ecotoxicological Data	15-116
15.2.3.1.1 Metals.....	15-119
15.2.3.1.2 Pesticides and PCBs.....	15-125
15.2.3.1.3 TPH.....	15-125
15.2.3.2 Uncertainty Factors	15-126
15.2.3.3 Final TBVs	15-127
15.2.3.4 Aquatic Life and Amphibians	15-127
15.2.4 Risk Characterization	15-128
15.2.4.1 Uncertainty Analysis	15-128
15.2.4.2 Ecological Risk at Each of the RI Sites	15-130

15.2.4.2.1 Nike Facility.....	15-132
15.2.4.2.2 Crissy Field Study Area.....	15-134
15.2.4.2.2.1 Petroleum, Oil, and Lubricants Area (Buildings 640/643 and 642).....	15-135
15.2.4.2.2.2 Fill Site 7/East of Mason.....	15-135
15.2.4.2.2.3 Crissy Field Future Wetland.....	15-136
15.2.4.2.2.4 Buildings 609 and 633.....	15-139
15.2.4.2.2.5 Sewer Lift Stations.....	15-140
15.2.4.2.3 Building 900s Series Study Area.....	15-141
15.2.4.2.4 DEH Study Area.....	15-143
15.2.4.2.5 Main Post Study Area.....	15-144
15.2.4.2.6 Fill Site 1.....	15-145
15.2.4.2.7 Landfill 2.....	15-146
15.2.4.2.8 El Polin Spring.....	15-146
15.2.4.2.9 Transfer Station.....	15-147
15.2.4.2.10 Landfill 4 and Fill Site 5.....	15-148
15.2.4.2.11 Graded Area 9.....	15-149
15.2.4.2.12 <u>Landfill E</u>	15-150
15.2.4.2.13 Miscellaneous Sites.....	15-150
15.2.4.2.13.1 Building 662.....	15-151
15.2.4.2.13.2 Building 680.....	15-151
15.2.4.2.13.3 Building 1351.....	15-152
15.2.4.2.13.4 Fort Point U.S. Coast Guard Station (FPCGS).....	15-153
15.2.4.2.13.5 Lobos Creek.....	15-154
15.2.4.2.13.6 Mountain Lake.....	15-155
15.2.4.2.14 Baker Beach Study Area.....	15-156
15.2.4.2.14.1 Baker Beach DA1 Outside the Mounded Landfill Material Area... ..	15-156
15.2.4.2.14.2 Baker Beach Disturbed Area 1 Mounded Landfill Material Area... ..	15-157
15.2.4.2.14.3 Baker Beach Disturbed Area 1 Seep.....	15-158
15.2.4.2.14.4 Baker Beach Disturbed Area 1a.....	15-159
15.2.4.2.14.5 Baker Beach Disturbed Area 2.....	15-159
15.2.4.2.14.6 Baker Beach Disturbed Area 3.....	15-159
15.2.4.2.14.7 Baker Beach Disturbed Area 4.....	15-160
15.2.4.2.15 Battery Howe/ Wagner.....	15-160
15.2.4.2.16 Miscellaneous Follow on RI Sites.....	15-161
15.2.4.2.16.1 Building 302.....	15-161
15.2.4.2.16.2 Building 669.....	15-162
15.2.4.2.16.3 Building 1245.....	15-162
15.2.4.2.16.4 Building 1369.....	15-162
15.2.4.2.16.5 Building 1388.....	15-162
15.2.4.2.16.6 Building 1750.....	15-163
15.2.5 Conclusions.....	15-163
15.2.5.1 Comparison of Risk Assessment Results to the Assessment and Measurement Endpoints.....	15-165
15.2.5.1.1 Ability of the Crissy Field Study Area to serve as suitable wetland habitat as a future use.....	15-166
15.2.5.1.2 Survivability and reproduction of populations of avifauna (passerines, raptors).....	15-166
15.2.5.1.3 Survivability and reproduction of special status species and plant communities.....	15-169

15.2.5.1.4 Survivability and reproduction of populations of small mammals that could serve as prey for raptors and other predators.....	15-170
15.2.5.2 Recommendations	15-172
15.3 GLOSSARY OF RISK ASSESSMENT TERMS.....	15-172

LIST OF APPENDICES

- Appendix A background/psf water supply
- Appendix B Nike Facility
- Appendix C Crissy Field Study Area
- Appendix D Building 900s Series Study Area
- Appendix E DEH Study Area
- Appendix F Main Post Study Area
- Appendix G Fill Sites and Landfills
- Appendix H Miscellaneous Sites
- Appendix I Golden Gate Bridge Highway and Transportation: District (GGBHTD) Study Area
- Appendix J Baker Beach Study Area
- Appendix K Battery Howe/Wagner
- Appendix L Miscellaneous Follow-on Sites
- Appendix M Physical Properties Data
- Appendix N Geophysical Data
- Appendix O Well and Sample Data
- Appendix P Transducer Study
- Appendix Q Metals Mobility
- Appendix R IRA Data
- Appendix S Soil Gas Survey Report
- Appendix T Quality Assurance / Quality Control Program
- Appendix U Risk Assessment Calculation Documentation

LIST OF TABLES

Table 2.3-1	Total and Average Precipitation Data for Presidio of San Francisco, 1951 - 1991
Table 2.3-2	Well Yield Calculations
Table 2.3-3	Summary of Estimated Well Yields for PSF RI Sites
Table 3.2-1	Summary of Source Water Sample Detections, Initial RI
Table 3.2-2	Summary of Groundwater Sample Detections, PSF Supply Wells, Supplemental RI
Table 3.3-1	Target Analyte List, Analytical Methods, and Reporting Limits for Wipe Samples, Initial and Supplemental RI
Table 3.3-2	Target Analyte List, Analytical Methods, and Reporting Limits for Soil Samples, Initial RI
Table 3.3-3	Target Analyte List, Analytical Methods, and Reporting Limits for Water Samples, Initial RI
Table 3.3-4	Target Analyte List, Analytical Methods, and Reporting Limits for Product Samples, Initial RI
Table 3.3-5	Target Analyte List, Analytical Methods, and Reporting Limits for Soil Samples, Feasibility Study
Table 3.3-6	Target Analyte List, Analytical Methods, and Reporting Limits for Soil Samples, Supplemental RI
Table 3.3-7	Target Analyte List, Analytical Methods, and Reporting Limits for Water Samples, Supplemental RI
Table 3.3-8	Target Analyte List, Analytical Methods, and Reporting Limits for Soil Samples, Follow-on RI
Table 3.3-9	Target Analyte List, Analytical Methods, and Reporting Limits for Water Samples, Follow-on RI
Table 3.4-1	Data Types, Sources and Destinations, Main Installation RI
Table 3.6-1	Organic Analyses Field QC Blank Summary, Initial and Supplemental RI
Table 3.6-2	Inorganic Analyses Field QC Blank Summary, Initial and Supplemental RI
Table 3.6-3	Summary of Rinse and Trip Blank Detections, Follow-on RI

Table 3.6-4	Results affected by Rinse or Trip Blank Contamination, Follow-on RI
Table 3.6-5	Results affected by Method Blank Contamination, Initial and Supplemental RI
Table 3.6-6	Results affected by Method Blank Contamination, Follow-on RI
Table 3.6-7	Comparison of Investigative and State Split Results, Pesticides in Groundwater, Well DEHW03, Follow-on RI
Table 3.6-8	Comparison of Investigative and State Split Results, Pesticides in Groundwater, Well LF7GW06, Follow-on RI
Table 3.6-9	Comparison of Investigative and State Split Results, PCBs in Groundwater, Wells DEHW03 and LF7GW06, Follow-on RI
Table 3.6-10	Comparison of Investigative and State Split Results, TPH in Groundwater, Wells DEHW03 and LF7GW06, Follow-on RI
Table 3.6-11	Comparison of Investigative and State Split Results, Inorganics in Groundwater, Well DEHW03, Follow-on RI
Table 3.6-12	Comparison of Investigative and State Split Results, Inorganics in Groundwater, Well LF7GW06, Follow-on RI
Table 3.6-13	Comparison of Investigative and State Split Results, Background Soil Samples, Follow-on RI
Table 3.7-1	Regional Background/Ambient Soil Concentrations
Table 3.7-2	Background Metals: ANOVA by Soil Type
Table 3.7-3	Ambient Metal Concentrations in Beach/Dune Deposits
Table 3.7-4	Ambient Metal Concentrations in Colma Formation
Table 3.7-5	Ambient Metal Concentrations in Serpentinite
Table 3.7-6	Ambient Metal Concentrations in Fill Materials
Table 3.7-7	Ambient Concentrations for the PSF
Table 3.7-8	Ambient Exceedences by Study Area - Beach/Dune Deposits
Table 3.7-9	Ambient Exceedences by Study Area - Colma Formation
Table 3.7-10	Ambient Exceedences by Study Area - Serpentinite
Table 3.7-11	Ambient Exceedences by Study Area - Fill Materials

Table 3.7-12	Hexavalent Chromium Results for Groundwater
Table 3.7-13	Filtered Versus Unfiltered Inorganics Concentrations in Groundwater
Table 3.8-1	Sampling Decision Criteria for Soil Samples
Table 3.8-2	Sampling Decision Criteria for Water Samples/California Primary Maximum Contaminant Levels
Table 3.8-3	Summary of Soil Reporting Limits Exceeding SDCs, Follow-on RI
Table 3.8-4	Summary of Water Reporting Limits Exceeding SDCs, Follow-on RI
Table 3.8-5	California Secondary Maximum Contaminant Levels
Table 3.8-6	California Enclosed Bays and Estuaries Water Quality Objectives for Saltwater Aquatic Life Protection
Table 3.8-7	Summary of Freshwater and Sediment Criteria for Protection of Aquatic Life
Table 4.4-1	Summary of Wipe Sample Detections for Building 1450, Nike Facility, Initial RI
Table 4.4-2	Summary of Sediment Sample Detections, Nike Facility, Initial RI
Table 4.4-3	Summary of Soil Boring Sample Detections, Buildings 1450 and 1451, Nike Facility, Follow-on RI
Table 4.4-4	Summary of Soil Boring Sample Detections, Nike Facility, Supplemental RI
Table 4.4-5	Summary of Sediment Sample Detections, Drainage Ditch, Nike Facility, Follow-on RI
Table 4.4-6	Summary of Sediment Sample Detections Associated with Sediment Samples NISD10 and NISD11, Nike Facility, Follow-on RI
Table 4.4-7	Summary of Soil Boring Sample Detections, Drainage Ditch, Nike Facility, Follow-on RI
Table 4.4-8	Summary of Soil Boring Sample Detections Associated with Boring NKSB01, Nike Facility, Follow-on RI
Table 4.4-9	Summary of Soil Boring Sample Detections Associated with Sediment Samples NISD10 and NISD11, Nike Facility, Follow-on RI
Table 4.4-10	Summary of Surface-Water Sample Detections, Nike Facility, Initial RI
Table 4.4-11	Summary of Surface-Water Sample Detections, Nike Facility, Follow-on RI

Table 4.4-12	Summary of Groundwater Sample Detections, Nike Facility, Supplemental RI
Table 4.4-13	Summary of Groundwater Sample Detections, Nike Facility, Follow-on RI
Table 5.4-1	Summary of Wipe Sample Detections, Consolidated Motor Pool Area, Initial RI
Table 5.4-2	Summary of Sediment Sample Detections, Buildings 637 and 640, Initial RI
Table 5.4-3	Summary of Sediment Sample Detections, Building 637 Area, Montgomery Watson
Table 5.4-4	Summary of Stormwater Sample Detections from Storm Drains, Building 637 Area, Montgomery Watson
Table 5.4-5	Summary of Soil Boring Sample Detections, Consolidated Motor Pool Area, Initial RI
Table 5.4-6	Summary of Soil Boring Sample Detections, Building 642, Follow-on RI
Table 5.4-7	Summary of Surface Soil Sample Detections, POL and Consolidated Motor Pool Areas, Initial RI
Table 5.4-8	Summary of Soil Boring Sample Detections, Building 643, Supplemental RI
Table 5.4-9	Summary of Surface Soil Sample Detections, POL and Consolidated Motor Pool Areas, Feasibility Study
Table 5.4-10	Summary of Soil Boring Sample Detections, Building 643, Follow-on RI
Table 5.4-11	Summary of Soil Boring Sample Detections, POL Area, Initial RI
Table 5.4-12	Summary of Soil Boring Sample Detections, Building 637 Area, Montgomery Watson
Table 5.4-13	Summary of Groundwater Sample Detections, POL and Consolidated Motor Pool Areas, Initial RI
Table 5.4-14	Summary of Groundwater Sample Detections, Building 637 Area, Montgomery Watson
Table 5.4-15	Summary of Sediment Sample Detections, Fill Site 7, Supplemental RI
Table 5.4-16	Summary of Surface Soil Sample Detections, Fill Site 7, Initial RI
Table 5.4-17	Summary of Soil Boring Sample Detections, Fill Site 7, Supplemental RI

- Table 5.4-18 Summary of Soil Boring Sample Detections, Helipad Area, Fill Site 7, Follow-on RI
- Table 5.4-19 Summary of Soil Boring Sample Detections Associated with Boring LF7SB07, Fill Site 7, Follow-on RI
- Table 5.4-20 Summary of Test Pit Soil Sample Detections, Fill Site 7, Initial RI
- Table 5.4-21 Summary of Soil Boring Sample Detections Associated with Well LF7GW09, Fill Site 7, Follow-on RI
- Table 5.4-22 Summary of Soil Boring Sample Detections Associated with Well LF7GW08, Fill Site 7, Follow-on RI
- Table 5.4-23 Summary of Soil Boring Sample Detections, Fill Site 7, Initial RI
- Table 5.4-24 Summary of Groundwater Sample Detections, Fill Site 7, Initial RI
- Table 5.4-25 Summary of Groundwater Sample Detections, Fill Site 7, Supplemental RI
- Table 5.4-26 Summary of Groundwater Sample Detections, Fill Site 7, Follow-on RI
- Table 5.4-27 Summary of Filtered and Unfiltered Metals Detections in Groundwater, Fill Site 7, Supplemental RI
- Table 5.4-28 Summary of Discrete Groundwater Sample Detections Associated with Well LF7GW08, Follow-on RI
- Table 5.4-29 Summary of Discrete Groundwater Sample Detections Associated with Well LF7GW09, Follow-on RI
- Table 5.4-30 Comparison of Filtered and Unfiltered Discrete Groundwater Sample Results for Lead, Follow-on RI
- Table 5.4-31 Summary of Surface Soil Sample Detections, Building 609, Initial RI
- Table 5.4-32 Summary of Soil Boring Sample Detections, Building 633, Follow-on RI
- Table 5.4-33 Summary of Soil Boring Sample Detections, Crissy Field Sewer Lift Station, Follow-on RI
- Table 5.4-34 Summary of Discrete Groundwater Sample Detections, Crissy Field Sewer Lift Station, Follow-on RI
- Table 6.1-1 Summary of 1984 Groundwater Sample Detections, Building 900s Series Study Area, USAEHA
- Table 6.1-2 Summary of Soil Boring Sample Detections, Fall 1991 and 1992, Building 937, IRA

Table 6.1-3	Target Analyte List, Building 937 Area, IRA
Table 6.3-1	Calculated Hydraulic Gradients and Tidal Heights, Building 900s Series Study Area
Table 6.3-2	Calculated Hydraulic Conductivity, Building 900s Series Study Area
Table 6.4-1	Summary of Soil Boring Sample Detections, Building 920, Follow-on RI
Table 6.4-2	Summary of Wipe Sample Detections, Buildings 924, 929-931, 933-935, 937, Initial RI
Table 6.4-3	Summary of Sediment Sample Detections for Storm Drains, Building 900s Series Study Area, Initial RI
Table 6.4-4	Summary of Surface Soil Sample Detections, Buildings 923 and 924, Initial RI
Table 6.4-5	Summary of Surface Soil Sample Detections, Building 900s Series Study Area, Feasibility Study
Table 6.4-6	Summary of Soil Boring Sample Detections, Building 900s Series Study Area, Feasibility Study
Table 6.4-7	Summary of Soil Boring Sample Detections, Buildings 923, 924, 926, 927, 929, 930, 931, and 933, Follow-on RI
Table 6.4-8	Summary of the Wipe Sample Detections, Building 926, Initial RI
Table 6.4-9	Summary of Soil Boring Sample Detections, Building 927, Follow-on RI
Table 6.4-10	Summary of Surface Soil Sample Detections, Buildings 929, 930, 931, 933 and 935, Initial RI
Table 6.4-11	Summary of Soil Boring Sample Detections, Buildings 931 and 950, Supplemental RI
Table 6.4-12	Summary of Soil Sample Detections, Building 937, Initial RI
Table 6.4-13	Summary of Groundwater Sample Detections, Building 900s Series Study Area, Initial RI
Table 6.4-14	Summary of Groundwater Sample Detections, Building 937 Area, RI and IRA
Table 6.4-15	Summary of Free Product Sample Detections, Building 937 Area, Initial RI
Table 6.4-16	Summary of Free Product Sample Detections for Fall 1991, Building 937 Area, IRA

Table 6.4-17	Summary of Soil Boring Sample Detections, Building 949, Follow-on RI
Table 6.4-18	Summary of Surface Soil Sample Detections, Buildings 950 and 973, Initial RI
Table 6.4-19	Summary of Soil Boring Sample Detections, Buildings 950 and 973, Follow-on RI
Table 6.4-20	Summary of Soil Boring Sample Detections, Building 979 Area, Initial RI
Table 6.4-21	Summary of Groundwater Sample Detections, Building 979 Area, Initial RI
Table 6.4-22	Summary of Soil Boring Sample Detections, Building 979, Supplemental RI
Table 6.4-23	Summary of Soil Boring Sample Detections, Building 979, Follow-on RI
Table 6.4-24	Summary of Groundwater Sample Detections, Building 979, Supplemental RI
Table 6.4-25	Summary of Filtered and Unfiltered Metals Detections in Groundwater, Building 979 Area, Supplemental RI
Table 6.4-26	Summary of Groundwater Sample Detections, Building 979 Area, Follow-on RI
Table 6.4-27	Summary of Discrete Groundwater Sample Detections, Building 979, Follow-on RI
Table 6.5-1	Product Thickness, Building 937 Area
Table 7.4-1	Summary of Wipe Sample Detections, Building 283, DEH Study Area, Initial RI
Table 7.4-2	Summary of Sediment Sample Detections, DEH Study Area, Initial RI
Table 7.4-3	Summary of Sediment Sample Detections, Building 286, Follow-on RI
Table 7.4-4	Summary of Surface Soil Sample Detections, Buildings 268 and 283, DEH Study Area, Initial RI
Table 7.4-5	Summary of Soil Sample Detections, Buildings 268 and 283, DEH Study Area, Initial RI
Table 7.4-6	Summary of Soil Sample Detections, Building 269, Initial RI
Table 7.4-7	Summary of Surface Soil Sample Detections, Building 293, DEH Study Area, Initial RI

Table 7.4-8	Summary of Soil Boring Sample Detections, DEH Study Area, Supplemental RI
Table 7.4-9	Summary of Soil Boring Sample Detections, Building 268, Follow-on RI
Table 7.4-10	Summary of Soil Boring Sample Detections, Building 269, Follow-on RI
Table 7.4-11	Summary of Soil Boring Sample Detections Associated with Boring 268SO09, Building 286, Follow-on RI
Table 7.4-12	Summary of Soil Boring Sample Detections, Building 286, Follow-on RI
Table 7.4-13	Summary of Soil Boring Sample Detections, Building 293, Follow-on RI
Table 7.4-14	Summary of Soil Boring Sample Detections, Total Organic Carbon Analysis, DEH Study Area, Follow-on RI
Table 7.4-15	Summary of Soil Boring Sample Detections, Building 267, Follow-on RI
Table 7.4-16	Summary of Soil Boring Sample Detections, Building 287, Follow-on RI
Table 7.4-17	Summary of Groundwater Sample Detections, DEH Study Area, Supplemental RI
Table 7.4-18	Summary of Filtered and Unfiltered Metal Detections in Groundwater, DEH Study Area, Supplemental RI
Table 7.4-19	Summary of Groundwater Sample Detections, DEH Study Area, Follow-on RI
Table 7.4-20	Summary of Discrete Groundwater Sample Detections, Building 286, Follow-on RI
Table 7.4-21	Summary of Discrete Groundwater Sample Detections Associated with Boring 268SO09, Building 286, Follow-on RI
Table 7.4-22	Summary of Discrete Groundwater Sample Detections, Building 287, Follow-on RI
Table 7.4-23	Summary of Discrete Groundwater Sample Detections Associated with Well DEHGW02, DEH Study Area, Follow-on RI
Table 7.5-1	Comparison of Filtered and Unfiltered Discrete Groundwater Sample Results for Lead, Follow-on RI
Table 8.1-1	Summary of Groundwater Sample Detections, Building 215, Follow-on RI
Table 8.2-1	Underground Storage Tanks Located in the Vicinity of Buildings 228/231

Table 8.2-2	Screened Intervals of Building 231 Wells
Table 8.2-3	Comparison of Potentiometric Head in Building 231 Well Clusters
Table 8.2-4	Summary of Soil Boring Sample Detections, Building 231, Initial RI
Table 8.2-5	Summary of Soil Sample Detections, Building 231 Area, IRA
Table 8.2-6	Summary of Soil Boring Sample Detections, Building 228, Follow-on RI
Table 8.2-7	Summary of Soil Boring Sample Detections, Former UST Site, Building 231, Follow-on RI
Table 8.2-8	Summary of Groundwater and Free Product Sample Detections, Buildings 228/231, Initial RI
Table 8.2-9	Summary of Groundwater Sample Detections, Building 231, IRA
Table 8.2-10	Summary of Discrete Groundwater Sample Detections, Former UST Site, Building 231, Follow-on RI
Table 8.2-11	Summary of Discrete Groundwater Sample Detections, Downgradient of Former UST Site, Building 231, Follow-on RI
Table 8.2-12	Summary of Discrete Groundwater Sample Detections, Building 231 Area, Follow-on RI
Table 8.2-13	Summary of Detections, Tank Samples, Building 231 Area, IRA
Table 8.3-1	Summary of Sediment Sample Detections, Building 1057 Site, Follow-on RI
Table 8.3-2	Summary of Soil Boring Sample Detections, Building 1057 Site, Follow-on RI
Table 8.4-1	Summary of Soil Boring Sample Detections, Building 1065 Site, Follow-on RI
Table 8.4-2	Summary of Discrete Groundwater Sample Detections, Building 1065 Site, Follow-on RI
Table 8.5-1	Summary of Soil Boring Sample Detections, Building 1167 Site, Follow-on RI
Table 8.6-1	Summary of Soil Sample Detections, Building 1151 Site, Initial RI
Table 8.6-2	Summary of Soil Boring Sample Detections, Building 1151 Site, Follow-on RI
Table 9.0-1	Summary of Fill Sites and Landfills

Table 9.1-1	Summary of Surface Soil Sample Detections, Fill Site 1, Initial RI
Table 9.1-2	Summary of Test Pit Soil Sample Detections, Fill Site 1 and Landfill 2, Initial RI
Table 9.1-3	Summary of Soil Boring Sample Detections, Fill Site 1 and Landfill 2, Supplemental RI
Table 9.1-4	Summary of Soil Boring Sample Detections Associated with Test Pits LF2TP01 and LF2TP02, Landfill 2, Follow-on RI
Table 9.1-5	Summary of Soil Boring Sample Detections, Landfill 2, Follow-on RI
Table 9.1-6	Summary of Groundwater Sample Detections, Fill Site 1 and Landfill 2, Initial RI
Table 9.1-7	Summary of Groundwater Sample Detections, Fill Site 1 and Landfill 2, Supplemental RI
Table 9.1-8	Summary of Discrete Groundwater Sample Detections, Fill Site 1, Follow-on RI
Table 9.1-9	Summary of Filtered and Unfiltered Metals Detections in Groundwater, Fill Site 1 and Landfill 2, Supplemental RI
Table 9.1-10	Summary of Surface-Water Sample Detections, El Polin Spring, Initial RI
Table 9.1-11	Summary of Surface-Water Sample Detections, El Polin Spring, Follow-on RI
Table 9.1-12	Summary of Groundwater Sample Detections, Landfill 2, Follow-on RI
Table 9.2-1	Summary of Surface Soil Sample Detections, Transfer Station, Initial RI
Table 9.2-2	Summary of Soil Boring Sample Detections, Transfer Station Site, Supplemental RI
Table 9.2-3	Summary of Soil Boring Sample Detections, Transfer Station Site, Follow-on RI
Table 9.3-1	Summary of Surface Soil Sample Detections Landfill 4 and Fill Site 5, Initial RI
Table 9.3-2	Summary of Test Pit Soil Sample Detections, Landfill 4, Initial RI
Table 9.3-3	Summary of Soil Boring Sample Detections, Landfill 4 and Fill Site 5, Initial RI
Table 9.3-4	Summary of Soil Boring Sample Detections, Landfill 4, Supplemental RI

Table 9.3-5	Summary of Soil Boring Sample Detections Associated with Test Pit LF4TP01, Landfill 4, Follow-on RI
Table 9.3-6	Summary of Soil Boring Sample Detections Associated with Test Pit LF4TP05, Landfill 4, Follow-on RI
Table 9.3-7	Summary of Discrete Groundwater Sample Detections, Landfill 4, Follow-on RI
Table 9.3-8	Summary of Test Pit Sample Detections, Fill Site 5, Initial RI
Table 9.4-1	Summary of Soil Boring Sample Detections, Fill Site 6, Initial RI
Table 9.4-2	Summary of Soil Boring Sample Detections Associated with Soil Boring LF6SO03, Fill Site 6, Follow-on RI
Table 9.4-3	Summary of Soil Boring Sample Detections, Total Organic Carbon Analysis, Fill Site 6, Follow-on RI
Table 9.4-4	Summary of Discrete Groundwater Sample Detections, Fill Site 6, Follow-on RI
Table 9.5-1	Summary of Test Pit Soil Sample Detections, Graded Area 9, Initial RI
Table 9.5-2	Summary of Soil Boring Sample Detections, Graded Area 9, Supplemental RI
Table 9.6-1	Summary of Soil Boring Sample Detections, Landfill E, Supplemental RI
Table 9.6-2	Summary of Soil Boring Sample Detections, Landfill E, Follow-on RI
Table 9.6-3	Summary of Test Pit Soil Sample Detections, Landfill E, Initial RI
Table 9.6-4	Summary of Soil Boring Sample Detections, Landfill E, Feasibility Study
Table 9.6-5	Summary of Soil Boring Sample Detections, Lead Evaluation, Landfill E, Follow-on RI
Table 9.6-6	Summary of Groundwater Sample Detections, Landfill E, Supplemental RI
Table 9.6-7	Summary of Discrete Groundwater Sample Detections, Landfill E, Follow-on RI
Table 10.1-1	Summary of Surface Soil Sample Detections, Building 662, Initial RI
Table 10.1-2	Summary of Soil Boring Sample Detections Associated with Surface Soil Samples 662SS01 and 662SS02, Building 662, Follow-on RI
Table 10.1-3	Summary of Soil Boring Sample Detections, Building 662, Follow-on RI

Table 10.1-4	Summary of Discrete Groundwater Sample Detections, Building 662, Follow-on RI
Table 10.2-1	Summary Wipe Sample Detections, Building 680, Initial RI
Table 10.2-2	Summary of Surface Soil Sample Detections, Building 680, Initial RI
Table 10.2-3	Summary of Soil Boring Sample Detections, Building 680, Initial RI
Table 10.3-1	Summary of Wipe Sample Detections, Building 1244, Initial RI
Table 10.3-2	Summary of Soil Boring Sample Detections, Building 1244, Follow-on RI
Table 10.4-1	Summary of Wipe Sample Detections, Building 1351, Initial RI
Table 10.4-2	Summary of Surface Soil Sample Detections, Building 1351, Initial RI
Table 10.4-3	Summary of Soil Boring Sample Detections, Building 1351, Initial RI
Table 10.4-4	Summary of Soil Boring Sample Detections, Building 1351, Follow-on RI
Table 10.5-1	Summary of Soil Boring Sample Detections, Fort Point Coast Guard Station, Supplemental RI
Table 10.5-2	Summary of Discrete Groundwater Sample Detections, Fort Point Coast Guard Station, Follow-on RI
Table 10.5-3	Summary of Soil Boring Sample Detections, Fort Point Coast Guard Station, Initial RI
Table 10.5-4	Summary of Surface Soil Sample Detections, Fort Point Coast Guard Station, Initial RI
Table 10.5-5	Summary of Soil Boring Sample Detections, Building 995, Fort Point Coast Guard Station, Follow-on RI
Table 10.5-6	Summary of Groundwater Sample Detections, Fort Point Coast Guard Station, Supplemental RI
Table 10.5-7	Summary of Groundwater Sample Detections, Fort Point Coast Guard Station, Follow-on RI
Table 10.5-8	Summary of Soil Boring Sample Detections, Building 996, Fort Point Coast Guard Station, Follow-on RI
Table 10.5-9	Comparison of California Secondary Maximum Contaminant Levels (MCLs) and Groundwater Detections, Fort Point Coast Guard Station
Table 10.6-1	Summary of Sediment Sample Detections, Lobos Creek, Initial RI

Table 10.6-2	Summary of Surface-Water Sample Detections, Lobos Creek, Initial RI
Table 10.6-3	Summary of Filtered and Unfiltered Metals Detections in Surface Water, Lobos Creek, Supplemental RI
Table 10.7-1	Summary of Groundwater Sample Detections, Golf Course Irrigation Well 316GW01
Table 10.7-2	Summary of Sediment Sample Detections, Mountain Lake, Initial RI
Table 10.7-3	Summary of Surface Water Sample Detections, Mountain Lake, Initial RI
Table 10.7-4	Summary of Filtered and Unfiltered Metal Detections in Surface Water, Mountain Lake, Supplemental RI
Table 10.7-5	Summary of Surface-Water Sample Detections, Mountain Lake, Follow-on RI
Table 10.7-6	Summary of Discrete Groundwater Sample Detections, Mountain Lake, Follow-on RI
Table 11.4-1	Summary of Wipe Sample Detections, GGBHTD Study Area, Supplemental RI
Table 11.4-2	Summary of Soil Boring Sample Detections, UST Area, GGBHTD Study Area, Supplemental RI
Table 11.4-3	Summary of Groundwater Sample Detections, UST Study Area, Supplemental RI
Table 11.4-4	Summary of Sediment Sample Detections, Paint Operations Area, GGBHTD Study Area, Supplemental RI
Table 11.4-5	Summary of Soil Boring Sample Detections, Paint Operations Area, GGBHTD Study Area, Supplemental RI
Table 11.4-6	Summary of Sediment Sample Detections, Bone Yard, GGBHTD Study Area, Supplemental RI
Table 11.4-7	Summary of Soil Boring Sample Detections, Bone Yard, GGBHTD Study Area, Supplemental RI
Table 12.4-1	Summary of Soil Boring Sample Detections, Disturbed Area 1, Baker Beach Study Area, Supplemental RI
Table 12.4-2	Summary of Soil Boring Sample Detections, Disturbed Area 1, Baker Beach Study Area, Follow-on RI

Table 12.4-3	Summary of Surface-Water Sample Detections, Disturbed Area 1, Baker Beach Study Area, Supplemental RI
Table 12.4-4	Summary of Sediment Sample Detections, Disturbed Area 1, Baker Beach Study Area, Supplemental RI
Table 12.4-5	Summary of Soil Boring Sample Detections, Disturbed Area 2, Baker Beach Study Area, Supplemental RI
Table 12.4-6	Summary of Soil Boring Sample Detections, Disturbed Area 3, Baker Beach Study Area, Supplemental RI
Table 12.4-7	Summary of Soil Boring Sample Detections, Disturbed Area 3, Baker Beach Study Area, Follow-on RI
Table 12.4-8	Summary of Soil Boring Sample Detections, Disturbed Area 4, Baker Beach Study Area, Supplemental RI
Table 13.4-1	Summary of Soil Boring Sample Detections, Battery Howe/Wagner, Supplemental RI
Table 13.4-2	Summary of Soil Boring Sample Detections Associated with Boring HWSB04, Battery Howe-Wagner, Follow-on RI
Table 13.4-3	Summary of Soil Boring Sample Detections Associated with Boring HWSB05, Battery Howe-Wagner, Follow-on RI
Table 13.4-4	Summary of Groundwater Sample Detections, Battery Howe/Wagner, Supplemental RI
Table 13.4-5	Summary of Groundwater Sample Detections, Battery Howe-Wagner, Follow-on RI
Table 13.4-6	Summary of Discrete Groundwater Sample Detections Associated with Well HWGW01, Battery Howe-Wagner, Follow-on RI
Table 14.1-1	Summary of Soil Boring Sample Detections, Building 302, Follow-on RI
Table 14.3-1	Summary of Soil Boring Sample Detections, Building 1245, Follow-on RI
Table 14.4-1	Summary of Soil Boring Sample Detections, Building 1369, Follow-on RI
Table 14.5-1	Summary of Soil Boring Sample Detections, Building 1388, Follow-on RI
Table 14.6-1	Summary of Soil Boring Sample Detections, Building 1750, Follow-on RI
Table 14.7-1	Summary of Soil Boring Sample Detections, East of Mason Site, Follow-on RI

Table 14.7-2	Summary of Discrete Groundwater Sample Detections, East of Mason Site, Follow-on RI
Table 15.1-1	Screening of Chemicals of Concern for the Nike Facility--Building 1450/1451
Table 15.1-2	Screening of Chemicals of Concern for the Nike Facility--Silo/Storage Area
Table 15.1-3	Screening of Chemicals of Concern for the Nike Facility--Groundwater
Table 15.1-4	Screening of Chemicals of Concern for the Crissy Field Study Area--Building 609
Table 15.1-5	Screening of Chemicals of Concern for the Crissy Field Study Area--Building 633
Table 15.1-6	Screening of Chemicals of Concern for the Crissy Field Study Area--Building 640/643
Table 15.1-7	Screening of Chemicals of Concern for the Crissy Field Study Area--Building 642
Table 15.1-8	Screening of Chemicals of Concern for the Crissy Field Study Area--Fill Site 7
Table 15.1-9	Screening of Chemicals of Concern for the Crissy Field Study Area--Proposed Wetlands Restoration Area
Table 15.1-10	Screening of Chemicals of Concern for the Crissy Field Study Area--Sewer Lift Station
Table 15.1-11	Screening of Chemicals of Concern for the Building 900s Series Study Area--Building 923Area
Table 15.1-12	Screening of Chemicals of Concern for the Building 900s Series Study Area--Building 937
Table 15.1-13	Screening of Chemicals of Concern for the Building 900s Series Study Area--Building 949
Table 15.1-14	Screening of Chemicals of Concern for the Building 900s Series Study Area--Building 950/973/974
Table 15.1-15	Screening of Chemicals of Concern for the Building 900s Series Study Area--Groundwater
Table 15.1-16	Screening of Chemicals of Concern for the DEH Study Area--Building 267/268/287

- Table 15.1-17 Screening of Chemicals of Concern for the DEH Study Area–Building 269/293
- Table 15.1-18 Screening of Chemicals of Concern for the DEH Study Area–Building 283
- Table 15.1-19 Screening of Chemicals of Concern for the DEH Study Area–Building 286
- Table 15.1-20 Screening of Chemicals of Concern for the Main Post Study Area–Building 215
- Table 15.1-21 Screening of Chemicals of Concern for the Main Post Study Area–Building 228
- Table 15.1-22 Screening of Chemicals of Concern for the Main Post Study Area–Building 1057
- Table 15.1-23 Screening of Chemicals of Concern for the Main Post Study Area–Building 1151/1152
- Table 15.1-24 Screening of Chemicals of Concern for the Main Post Study Area–Buildings 1167
- Table 15.1-25 Screening of Chemicals of Concern for Fill Sites and Landfills–Fill Site 1
- Table 15.1-26 Screening of Chemicals of Concern for Fill Sites and Landfills–Landfill 2
- Table 15.1-27 Screening of Chemicals of Concern for Fill Sites and Landfills–El Polin Spring
- Table 15.1-28 Screening of Chemicals of Concern for Fill Sites and Landfills–Transfer Station
- Table 15.1-29 Screening of Chemicals of Concern for Fill Sites and Landfills–Landfill 4
- Table 15.1-30 Screening of Chemicals of Concern for Fill Sites and Landfills–Fill Site 5
- Table 15.1-31 Screening of Chemicals of Concern for Fill Sites and Landfills–Fill Site 6
- Table 15.1-32 Screening of Chemicals of Concern for Fill Sites and Landfills–Landfill E
- Table 15.1-33 Screening of Chemicals of Concern for the Miscellaneous Sites–Building 662
- Table 15.1-34 Screening of Chemicals of Concern for the Miscellaneous Sites–Building 680

- Table 15.1-35 Screening of Chemicals of Concern for the Miscellaneous Sites–Building 1244
- Table 15.1-36 Screening of Chemicals of Concern for the Miscellaneous Sites–Building 1351
- Table 15.1-37 Screening of Chemicals of Concern for the Miscellaneous Sites–FPCGS
- Table 15.1-38 Screening of Chemicals of Concern for the Miscellaneous Sites–Lobos Creek
- Table 15.1-39 Screening of Chemicals of Concern for the Miscellaneous Sites–Drinking Water Source
- Table 15.1-40 Screening of Chemicals of Concern for the Miscellaneous Sites–Mountain Lake
- Table 15.1-41 Screening of Chemicals of Concern for the Baker Beach Study Area–Disturbed Area 1a
- Table 15.1-42 Screening of Chemicals of Concern for the Baker Beach Study Area–Disturbed Area 1
- Table 15.1-43 Screening of Chemicals of Concern for the Baker Beach Study Area–Disturbed Area 2
- Table 15.1-44 Screening of Chemicals of Concern for the Baker Beach Study Area–Disturbed Area 3
- Table 15.1-45 Screening of Chemicals of Concern for the Baker Beach Study Area–Disturbed Area 4
- Table 15.1-46 Screening of Chemicals of Concern for the Miscellaneous Follow-on Sites–Building 1245
- Table 15.1-47 Screening of Chemicals of Concern for the Miscellaneous Follow-on Sites–Building 1369
- Table 15.1-48 Screening of Chemicals of Concern for the Miscellaneous Follow-on Sites–Building 1388
- Table 15.1-49 Screening of Chemicals of Concern for the Miscellaneous Follow-on Sites–EOM
- Table 15.1-50 Chemicals of Concern for the Study Areas
- Table 15.1-51 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Nike Facility–Silo/Storage Area

- Table 15.1-52 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Nike Facility–Groundwater
- Table 15.1-53 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Crissy Field Study Area–Building 640/643
- Table 15.1-54 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Crissy Field Study Area–Fill Site 7
- Table 15.1-55 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Crissy Field Study Area–Proposed Wetlands Restoration Area
- Table 15.1-56 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Crissy Field Study Area–Sewer Lift Station
- Table 15.1-57 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Building 900s Series Study Area–Building 923Area
- Table 15.1-58 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Building 900s Series Study Area–Building 937
- Table 15.1-59 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Building 900s Series Study Area–Building 950/973/974
- Table 15.1-60 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Building 900s Series Study Area–Groundwater
- Table 15.1-61 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the DEH Study Area–Building 267/268/287
- Table 15.1-62 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the DEH Study Area–Building 269/293
- Table 15.1-63 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the DEH Study Area–Building 283
- Table 15.1-64 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the DEH Study Area–Building 286
- Table 15.1-65 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Main Post Study Area–Building 215

- Table 15.1-66 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Main Post Study Area–Building 1151/1152
- Table 15.1-67 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Fill Sites and Landfills–Landfill 2
- Table 15.1-68 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Fill Sites and Landfills–El Polin Spring
- Table 15.1-69 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Fill Sites and Landfills–Transfer Station
- Table 15.1-70 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Fill Sites and Landfills–Landfill 4
- Table 15.1-71 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Fill Sites and Landfills–Fill Site 6
- Table 15.1-72 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Fill Sites and Landfills–Landfill E
- Table 15.1-73 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–Building 662
- Table 15.1-74 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–Building 680
- Table 15.1-75 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–Building 1351
- Table 15.1-76 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–FPCGS
- Table 15.1-77 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–Lobos Creek
- Table 15.1-78 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–Drinking Water Source
- Table 15.1-79 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Sites–Mountain Lake
- Table 15.1-80 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Baker Beach Study Area–Disturbed Area 1a

- Table 15.1-81 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Baker Beach Study Area–Disturbed Area 1
- Table 15.1-82 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Baker Beach Study Area–Disturbed Area 2
- Table 15.1-83 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Baker Beach Study Area–Disturbed Area 3
- Table 15.1-84 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Baker Beach Study Area–Disturbed Area 4
- Table 15.1-85 Maximum Detected Values, 95 Percent UCL, and Exposure Point Concentrations for COCs at the Miscellaneous Follow-on Sites–EOM
- Table 15.1-86 Risk Assessment Scenarios and Planned NPS Land Use Classifications
- Table 15.1-87 Residential PRG Ratios Assessment Media Assessed
- Table 15.1-88 Soil Ingestion Exposure Algorithm
- Table 15.1-89 Soil Dermal Exposure Algorithm
- Table 15.1-90 Drinking Water Ingestion Exposure Algorithm
- Table 15.1-91 Drinking Water Dermal Exposure Algorithm
- Table 15.1-92 Surface Water Ingestion Exposure Algorithm
- Table 15.1-93 Surface Water Dermal Exposure Algorithm
- Table 15.1-94 Sediment Ingestion Exposure Algorithm
- Table 15.1-95 Sediment Dermal Exposure Algorithm
- Table 15.1-96 Groundwater Ingestion Exposure Algorithm
- Table 15.1-97 Groundwater Dermal Exposure Algorithm
- Table 15.1-98 Toxicological and Chemical Parameters
- Table 15.1-99 Derivation of Toxicity Values for Dermal Exposure to Chemicals
- Table 15.1-100 Cancer Risk Estimates for the Nike Facility
- Table 15.1-101 Hazard Indices Greater than 1E+00 for the Nike Facility
- Table 15.1-102 Cancer Risk Estimates for the Crissy Field Study Area

- Table 15.1-103 Hazard Indices Greater than 1E+00 for the Crissy Field Study Area
- Table 15.1-104 Cancer Risk Estimates for the Building 900s Series Study Area
- Table 15.1-105 Hazard Indices Greater than 1E+00 for the Building 900s Series Study Area
- Table 15.1-106 Cancer Risk Estimates for the DEH Study Area
- Table 15.1-107 Hazard Indices Greater than 1E+00 for the DEH Study Area
- Table 15.1-108 Cancer Risk Estimates for the Main Post Study Area
- Table 15.1-109 Hazard Indices Greater than 1E+00 for the Main Post Study Area
- Table 15.1-110 Cancer Risk Estimates for the Fill Sites and Landfills
- Table 15.1-111 Hazard Indices Greater than 1E+00 for the Fill Sites and Landfills
- Table 15.1-112 Cancer Risk Estimates for the Miscellaneous Sites
- Table 15.1-113 Hazard Indices Greater than 1E+00 for the Miscellaneous Sites
- Table 15.1-114 Cancer Risk Estimates for the Baker Beach Study Area
- Table 15.1-115 Hazard Indices Greater than 1E+00 for the Baker Beach Study Area
- Table 15.1-116 Cancer Risk Estimates for the Miscellaneous Follow-on Sites
- Table 15.1-117 Hazard Indices Greater than 1E+00 for the Miscellaneous Follow-on Sites
- Table 15.1-118 Pb6 Modeling Results of Lead Soil Levels (mg/kg) Resulting in 10 µg/dl Blood Lead in 95th Percentile of Children
- Table 15.1-119 Summary of HHRA for PSF Study Areas and Sites
- Table 15.2-1 Assessment and Measurement Endpoints for the Ecological Risk Assessment
- Table 15.2-2 Summary of Ecological Data Pertinent to the Ecological Risk Assessment
- Table 15.2-3 Exposure Pathways Quantitatively Evaluated in the Risk Assessment
- Table 15.2-4 Summary Statistics for Soils at the Nike Facility
- Table 15.2-5 Summary Statistics for Soils at Buildings 640 and 643, Consolidated Motor Pool Area, Crissy Field Study Area

- Table 15.2-6 Summary Statistics for Soils at Building 642, Consolidated Motor Pool Area, Crissy Field Study Area
- Table 15.2-7 Summary Statistics for Soils in the Fill Site 7/East of Mason Shoreline Area
- Table 15.2-8 Summary Statistics for Crissy Field Future Wetland Area Soils
- Table 15.2-9 Summary Statistics for Crissy Field Future Wetland Area Groundwater
- Table 15.2-10 Summary Statistics for Soils at Building 609, Crissy Field Study Area
- Table 15.2-11 Summary Statistics for Soils at Building 633, Crissy Field Study Area
- Table 15.2-12 Summary Statistics for Soils at Crissy Field Sewer Lift Station 1
- Table 15.2-13 Summary Statistics for Soils at Crissy Field Sewer Lift Station 2
- Table 15.2-14 Summary Statistics for Soils at the Building 900s Series Study Area
- Table 15.2-15 Summary Statistics for Soils at the DEH Study Area
- Table 15.2-16 Summary Statistics for Soils at Building 228, Main Post Study Area
- Table 15.2-17 Summary Statistics for Soils at Building 1167 Site, Main Post Study Area
- Table 15.2-18 Summary Statistics for Soils at Building 1151 Site, Main Post Study Area
- Table 15.2-19 Summary Statistics for Soils at Fill Site 1, Fill Sites and Landfills
- Table 15.2-20 Summary Statistics for Soils at Landfill 2, Fill Sites and Landfills
- Table 15.2-21 Summary Statistics for El Polin Spring Surface Water, Fill Sites and Landfills
- Table 15.2-22 Summary Statistics for Soils at the Transfer Station Site, Fill Sites and Landfills
- Table 15.2-23 Summary Statistics for Soils at Landfill 4, Fill Sites and Landfills
- Table 15.2-24 Summary Statistics for Soils at Fill Site 5, Fill Sites and Landfills
- Table 15.2-25 Summary Statistics for Soils at Graded Area 9, Fill Sites and Landfills
- Table 15.2-26 Summary Statistics for Soils at Landfill E, Fill Sites and Landfills

- Table 15.2-27 Summary Statistics for Soils at Building 662, Miscellaneous Sites
- Table 15.2-28 Summary Statistics for Soils at Building 680, Miscellaneous Sites
- Table 15.2-29 Summary Statistics for Soils at Building 1351, Miscellaneous Sites
- Table 15.2-30 Summary Statistics for Soils at Fort Point Coast Guard Station, Miscellaneous Sites
- Table 15.2-31 Summary Statistics for Lobos Creek Sediments and Surface Water, Miscellaneous Sites
- Table 15.2-32 Summary Statistics for Mountain Lake Sediments and Surface Water, Miscellaneous Sites
- Table 15.2-33 Summary Statistics for Soils at Disturbed Area 1 Outside Mounded Landfill Material Area, Baker Beach Study Area
- Table 15.2-34 Summary Statistics for Soils at Disturbed Area 1 Mounded Landfill Material Area, Baker Beach Study Area
- Table 15.2-35 Summary Statistics for Sediment and Surface Water at Disturbed Area 1 Seep, Baker Beach Study Area
- Table 15.2-36 Summary Statistics for Soils at Disturbed Area 1a, Baker Beach Study Area
- Table 15.2-37 Summary Statistics for Soils at Disturbed Area 2, Baker Beach Study Area
- Table 15.2-38 Summary Statistics for Soils at Disturbed Area 3, Baker Beach Study Area
- Table 15.2-39 Summary Statistics for Soils at Disturbed Area 4, Baker Beach Study Area
- Table 15.2-40 Summary Statistics for Soils at Battery Howe/Wagner
- Table 15.2-41 Summary Statistics for Soils at Building 302, Miscellaneous Follow-on RI Sites
- Table 15.2-42 Summary Statistics for Soils at Building 1245, Miscellaneous Follow-on RI Sites
- Table 15.2-43 Summary Statistics for Soils at Building 1369, Miscellaneous Follow-on RI Sites

- Table 15.2-44 Summary Statistics for Soils at Building 1388, Miscellaneous Follow-on RI Sites
- Table 15.2-45 Exposure Parameters for the Ecological Receptors
- Table 15.2-46 Final Bioaccumulation Factors for Terrestrial Receptors at PSF
- Table 15.2-47 Final Bioconcentration Factors for Aquatic Receptors at PSF
- Table 15.2-48 Summary of Toxicity Information for Mammals and Birds
- Table 15.2-49 Toxicity Benchmark Values for Plants and Soil Fauna
- Table 15.2-50 Application of Intertaxon Uncertainty Factors to TBV-Low and TBV-High
- Table 15.2-51 Final TBV-Low Values Used in the Ecological Risk Assessment
- Table 15.2-52 Final TBV-High Values Used in the Ecological Risk Assessment
- Table 15.2-53 Summary of Criteria for the Protection of Aquatic Life
- Table 15.2-54 Toxicity Benchmark Values for Amphibians
- Table 15.2-55 Hazard Indices for Exposure to Shallow Soils (<3 ft) at the Nike Facility
- Table 15.2-56 Hazard Indices for Modeled Aquatic Exposures South of the Nike Facility
- Table 15.2-57 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Buildings 640 and 643, Consolidated Motor Pool Area, Crissy Field Study Area
- Table 15.2-58 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 642, Consolidated Motor Pool Area, Crissy Field Study Area
- Table 15.2-59 Hazard Indices for Exposure to Shallow Soils (<3 ft) in the Fill Site 7/East of Mason Shoreline Area
- Table 15.2-60 Hazard Indices for Wetland Receptors Exposed to Soils (<15 ft) in Crissy Field Future Wetland Area
- Table 15.2-61 Hazard Indices for Terrestrial Receptors Exposed to Soils (<15 ft) in Crissy Field Future Wetland Area
- Table 15.2-62a Hazard Indices for Water Exposure at the Crissy Field Future Wetland Area: Zero Dilution Scenario

- Table 15.2-62b Hazard Indices for Water Exposure at the Crissy Field Future Wetland Area: 50 Percent Dilution Scenario
- Table 15.2-62c Hazard Indices for Water Exposure at the Crissy Field Future Wetland Area: 90 Percent Dilution Scenario
- Table 15.2-63 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 609, Crissy Field Study Area
- Table 15.2-64 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 633, Crissy Field Study Area
- Table 15.2-65 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Crissy Field Sewer Lift Station 1
- Table 15.2-66 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Crissy Field Sewer Lift Station 2
- Table 15.2-67 Hazard Indices for Exposure to Shallow Soils (<3 ft) at the Building 900s Series Study Area
- Table 15.2-68 Hazard Indices for Exposure to Shallow Soils (<3 ft) at the DEH Study Area
- Table 15.2-69 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 228, Main Post Study Area
- Table 15.2-70 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 1167 Site, Main Post Study Area
- Table 15.2-71 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 1151 Site, Main Post Study Area
- Table 15.2-72 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Fill Site 1, Fill Sites and Landfills
- Table 15.2-73 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Landfill 2, Fill Sites and Landfills
- Table 15.2-74 Hazard Indices for Receptors Exposed to Water and Sediment at El Polin Spring, Fill Sites and Landfills
- Table 15.2-75 Hazard Indices for Exposure to Shallow Soils (<3 ft) at the Transfer Station Site, Fill Sites and Landfills
- Table 15.2-76 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Landfill 4, Fill Sites and Landfills

- Table 15.2-77 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Fill Site 5, Fill Sites and Landfills
- Table 15.2-78 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Graded Area 9, Fill Sites and Landfills
- Table 15.2-79 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Landfill E, Fill Sites and Landfills
- Table 15.2-80 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 662, Miscellaneous Sites
- Table 15.2-81 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 680, Miscellaneous Sites
- Table 15.2-82 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 1351, Miscellaneous Sites
- Table 15.2-83 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Fort Point Coast Guard Station, Miscellaneous Sites
- Table 15.2-84 Hazard Indices for Receptors Exposed to Water and Sediments at Lobos Creek, Miscellaneous Sites
- Table 15.2-85 Hazard Indices for Receptors Exposed to Water and Sediments at Mountain Lake, Miscellaneous Sites
- Table 15.2-86 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Disturbed Area 1 Outside Mounded Landfill Material Area, Baker Beach Study Area
- Table 15.2-87 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Disturbed Area 1 Mounded Landfill Material Area, Baker Beach Study Area
- Table 15.2-88 Hazard Indices for Receptors Exposed to Water and Sediments at Disturbed Area 1 Seep, Baker Beach Study Area
- Table 15.2-89 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Disturbed Area 1a, Baker Beach Study Area
- Table 15.2-90 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Disturbed Area 2, Baker Beach Study Area
- Table 15.2-91 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Disturbed Area 3, Baker Beach Study Area
- Table 15.2-92 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Disturbed Area 4, Baker Beach Study Area

- Table 15.2-93 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Battery Howe/Wagner
- Table 15.2-94 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 302, Miscellaneous Follow-on RI Sites
- Table 15.2-95 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 1245, Miscellaneous Follow-on RI Sites
- Table 15.2-96 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 1369, Miscellaneous Follow-on RI Sites
- Table 15.2-97 Hazard Indices for Exposure to Shallow Soils (<3 ft) at Building 1388, Miscellaneous Follow-on RI Sites

LIST OF FIGURES

- Figure 1.1-1 PSF Site Location Map
- Figure 1.2-1 Remedial Investigation Study Area/Site Locations and Sample History, Presidio of San Francisco
- Figure 2.3-1 Average Total Monthly Precipitation for 1951 - 1994, San Francisco, California
- Figure 2.3-2 Potentiometric Surface Map of First Encountered Groundwater, Presidio of San Francisco
- Figure 2.3-3 Surface Geology Map, Presidio of San Francisco
- Figure 2.3-4 Structure Contour Map of the Bedrock Surface, Presidio of San Francisco
- Figure 2.3-5 Regional Cross Section Location Map, Presidio of San Francisco
- Figure 2.3-6 Regional Cross Section A-A', Presidio of San Francisco
- Figure 2.3-7 Regional Cross Section B-B', Presidio of San Francisco
- Figure 2.3-8 Generalized Geology Showing Major Shear Zones & Fold Axes
- Figure 2.3-9 Crissy Field Groundwater Area Water Table Elevation Map, Presidio of San Francisco
- Figure 2.3-10 Schematic Illustration of a Coastal Aquifer
- Figure 2.3-11 Crissy Field Groundwater Area TDS Isoconcentration Map, Presidio of San Francisco
- Figure 2.3-12 Crissy Field Groundwater Area Electrical Conductivity Map, Presidio of San Francisco
- Figure 2.3-13 General Mineral Characteristics of Surface Water & Groundwater, Presidio of San Francisco
- Figure 3.1-1 Conceptual Site Model for Human Receptors at the Presidio of San Francisco
- Figure 3.1-2 Conceptual Site Model for Ecological Receptors at the Presidio of San Francisco
- Figure 3.2-1 Resistivity Schematic and Electrode Configuration
- Figure 3.2-2 Typical Monitoring Well Construction

- Figure 3.2-3 Background Soil and PSF Water Supply Sample Locations
- Figure 3.4-1 Data Management Flow Scheme
- Figure 3.7-1 Summary of Process of Identifying Inorganic COCs in Soil and Sediment
- Figure 3.7-2 Method for Performing Statistical Comparisons of Background Chemical Data
- Figure 4.1-1 Nike Facility Study Area and Cross Section Location Map
- Figure 4.1-2 Nike Facility, Drainage Structures, Wipe, Sediment, and Surface Water Sample Locations
- Figure 4.1-3 Nike Facility, Missile Silo Plan Map
- Figure 4.1-4 Nike Facility, Cross Section A-A'
- Figure 4.1-5 Nike Facility, Cross Section B-B'
- Figure 4.2-1 Nike Facility, Monitoring Well and Soil Boring Location Map
- Figure 4.3-1 Nike Facility, Cross Section C-C'
- Figure 4.3-2 Nike Facility, Potentiometric Surface Map
- Figure 4.5-1 Nike Facility, Concentrations of Chromium in Soil
- Figure 4.5-2 Nike Facility, Concentrations of Copper in Soil
- Figure 4.5-3 Nike Facility, Concentrations of Cyanide in Soil
- Figure 4.5-4 Nike Facility, Concentrations of Lead in Soil
- Figure 4.5-5 Nike Facility, Concentrations of Manganese in Soil
- Figure 4.5-6 Nike Facility, Concentrations of Mercury in Soil
- Figure 4.5-7 Nike Facility, Concentrations of Nickel in Soil
- Figure 4.5-8 Nike Facility, Concentrations of Zinc in Soil
- Figure 4.5-9 Nike Facility, Concentrations of Benzo(a)pyrene in Soil
- Figure 4.5-10 Nike Facility, Concentrations of Benzo(a)anthracene in Soil
- Figure 4.5-11 Nike Facility, Concentrations of PCB-1260 in Soil
- Figure 4.5-12 Nike Facility, Concentrations of Antimony in Groundwater and Surface Water

- Figure 4.5-13 Nike Facility, Concentrations of Chromium in Groundwater and Surface Water
- Figure 4.5-14 Nike Facility, Concentrations of Lead in Groundwater and Surface Water
- Figure 4.5-15 Nike Facility, Concentrations of Manganese in Groundwater and Surface Water
- Figure 4.5-16 Nike Facility, Concentrations of Mercury in Groundwater and Surface Water
- Figure 4.5-17 Nike Facility, Concentrations of Nickel in Groundwater and Surface Water
- Figure 5.1-1 Crissy Field Study Area
- Figure 5.1-2 Crissy Field Study Area, Test Pit, Soil Boring, Monitoring Well & Cross Section Locations
- Figure 5.1-3 Historical Wetlands, Presidio of San Francisco
- Figure 5.1-4 Crissy Field Study Area, Storm Drain and Sediment, Wipe, and Surface Soil Sample Locations
- Figure 5.1-5 POL Area, Montgomery Watson Soil Boring Locations
- Figure 5.3-1 Crissy Field Study Area, Cross Section A-A'
- Figure 5.3-2 Crissy Field Study Area, Cross Section B-B'
- Figure 5.3-3 Crissy Field Study Area, Debris Fill Isopach
- Figure 5.3-4 Crissy Field Study Area, Potentiometric Surface Map, Low Tide, November 1992
- Figure 5.3-5 Crissy Field Study Area, Potentiometric Surface Map, High Tide, November 1992
- Figure 5.3-6 Crissy Field Study Area, Potentiometric Surface Map, High Tide, March 1995
- Figure 5.3-7 Crissy Field Study Area, Potentiometric Surface Map, Low Tide, March 1995
- Figure 5.5-1 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Aluminum in Soil
- Figure 5.5-2 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Arsenic in Soil

- Figure 5.5-3 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Barium in Soil
- Figure 5.5-4 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Beryllium in Soil
- Figure 5.5-5 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Cadmium in Soil
- Figure 5.5-6 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Chromium in Soil
- Figure 5.5-7 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Cobalt in Soil
- Figure 5.5-8 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Copper in Soil
- Figure 5.5-9 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Iron in Soil
- Figure 5.5-10 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Lead in Soil
- Figure 5.5-11 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Manganese in Soil
- Figure 5.5-12 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Mercury in Soil
- Figure 5.5-13 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Nickel in Soil
- Figure 5.5-14 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Vanadium in Soil
- Figure 5.5-15 Crissy Field Study Area, Consolidated Motor Pool, POL Area, and Buildings 609 and 633, Concentrations of Zinc in Soil
- Figure 5.5-16 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Aluminum in Soil
- Figure 5.5-17 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Arsenic in Soil
- Figure 5.5-18 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Barium in Soil

- Figure 5.5-19 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Beryllium in Soil
- Figure 5.5-20 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Cadmium in Soil
- Figure 5.5-21 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Chromium in Soil
- Figure 5.5-22 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Cobalt in Soil
- Figure 5.5-23 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Copper in Soil
- Figure 5.5-24 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Iron in Soil
- Figure 5.5-25 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Lead in Soil
- Figure 5.5-26 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Manganese in Soil
- Figure 5.5-27 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Mercury in Soil
- Figure 5.5-28 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Nickel in Soil
- Figure 5.5-29 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Vanadium in Soil
- Figure 5.5-30 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Zinc in Soil
- Figure 5.5-31 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Benzo(a)pyrene in Soil
- Figure 5.5-32 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of ppDDE in Soil
- Figure 5.5-33 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of ppDDT in Soil
- Figure 5.5-34 Crissy Field Study Area, Fill Site 7 and Sewer Lift Stations, Concentrations of Endrin in Soil
- Figure 5.5-35 Crissy Field Study Area, Concentrations of Aluminum in Groundwater

- Figure 5.5-36 Crissy Field Study Area, Concentrations of Chromium in Groundwater
- Figure 5.5-37 Crissy Field Study Area, Concentrations of Copper in Groundwater
- Figure 5.5-38 Crissy Field Study Area, Concentrations of Lead in Groundwater
- Figure 5.5-39 Crissy Field Study Area, Concentrations of Nickel in Groundwater
- Figure 5.5-40 Crissy Field Study Area, Concentrations of Vanadium in Groundwater
- Figure 5.5-41 Crissy Field Study Area, Concentrations of Zinc in Groundwater
- Figure 5.5-42 Crissy Field Study Area, Concentrations of Vinyl Chloride in Groundwater
- Figure 6.1-1 Building 900s Study Area
- Figure 6.1-2 Building 900s Series Study Area, Wipe Sample, Storm Drain, & Sediment Sample Locations
- Figure 6.1-3 Building 900s Series Study Area, Stained Areas
- Figure 6.1-4 Building 900s Series Study Area, 1984 and 1986 Monitoring Well Locations
- Figure 6.1-5 Building 900s Series Study Area, Soil Boring Locations
- Figure 6.1-6 Building 937 IRA Soil Samples and Excavation Locations
- Figure 6.2-1 Building 900s Series Study Area, Current Shallow Monitoring Wells and Discrete Groundwater Sample Locations
- Figure 6.2-2 Building 900s Series Study Area, Current Intermediate and Deep Monitoring Wells and Discrete Groundwater Sample Locations
- Figure 6.2-3 Building 900s Series Study Area, Surface Soil Sample Locations
- Figure 6.3-1 Building 900s Series Study Area, Cross Section Location Map
- Figure 6.3-2 Building 900s Series Study Area, Cross Section A-A'
- Figure 6.3-3 Building 900s Series Study Area, Cross Section B-B'
- Figure 6.3-4 Building 900s Series Study Area, Cross Section C-C'
- Figure 6.3-5 Building 900s Series Study Area, Bedrock Structure Contour Map
- Figure 6.3-6 Building 900s Series Study Area, Potentiometric Surface Map, Shallow Monitoring Wells, Higher-High Tide, 1992

- Figure 6.3-7 Building 900s Series Study Area, Potentiometric Surface Map, Shallow Monitoring Wells, Lower-Low Tide, 1992
- Figure 6.3-8 Building 900s Series Study Area, Potentiometric Surface Map, Shallow Monitoring Wells, Higher-High Tide, 1995
- Figure 6.3-9 Building 900s Series Study Area, Potentiometric Surface Map, Shallow Monitoring Wells, Lower-Low Tide, 1995
- Figure 6.3-10 Building 900s Series Study Area, Potentiometric Surface Map, Deep Monitoring Wells, Higher-High Tide, 1992
- Figure 6.3-11 Building 900s Series Study Area, Potentiometric Surface Map, Deep Monitoring Wells, Lower-Low Tide, 1992
- Figure 6.3-12 Building 900s Series Study Area, Potentiometric Surface Map, Deep Monitoring Wells, Higher-High Tide, 1995
- Figure 6.3-13 Building 900s Series Study Area, Potentiometric Surface Map, Deep Monitoring Wells, Lower-Low Tide, 1995
- Figure 6.3-14 Building 900s Series Study Area, Average Stage Ratios, RI Tidal Studies 1,2, & 3
- Figure 6.3-15 Building 900s Series Study Area, Specific Conductance and Water Level Hydrographs, IRA Tidal Study 1
- Figure 6.3-16 Building 900s Series Study Area, Estimated Hydraulic Conductivity
- Figure 6.5-1 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Aluminum in Soil
- Figure 6.5-2 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Arsenic in Soil
- Figure 6.5-3 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Barium in Soil
- Figure 6.5-4 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Cadmium in Soil
- Figure 6.5-5 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Chromium in Soil
- Figure 6.5-6 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Copper in Soil
- Figure 6.5-7 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Lead in Soil

- Figure 6.5-8 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Manganese in Soil
- Figure 6.5-9 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Mercury in Soil
- Figure 6.5-10 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Nickel in Soil
- Figure 6.5-11 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of Zinc in Soil
- Figure 6.5-12 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of ppDDD in Soil
- Figure 6.5-13 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of ppDDE in Soil
- Figure 6.5-14 Building 900s Series Study Area, Vehicle Maintenance Area, Concentrations of ppDDT in Soil
- Figure 6.5-15 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Aluminum in Soil
- Figure 6.5-16 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Antimony in Soil
- Figure 6.5-17 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Arsenic in Soil
- Figure 6.5-18 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Cadmium in Soil
- Figure 6.5-19 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Chromium in Soil
- Figure 6.5-20 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Copper in Soil
- Figure 6.5-21 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Cyanide in Soil
- Figure 6.5-22 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Iron in Soil
- Figure 6.5-23 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Lead in Soil

- Figure 6.5-24 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Manganese in Soil
- Figure 6.5-25 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Mercury in Soil
- Figure 6.5-26 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Nickel in Soil
- Figure 6.5-27 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Thallium in Soil
- Figure 6.5-28 Building 900s Series Study Area, Storage Area and Building 979, Concentrations of Zinc in Soil
- Figure 6.5-29 Building 900s Series Study Area, Concentrations of Aluminum in Shallow Groundwater
- Figure 6.5-30 Building 900s Series Study Area, Concentrations of Aluminum in Intermediate and Deep Groundwater
- Figure 6.5-31 Building 900s Series Study Area, Concentrations of Antimony in Shallow Groundwater
- Figure 6.5-32 Building 900s Series Study Area, Concentrations of Antimony in Intermediate and Deep Groundwater
- Figure 6.5-33 Building 900s Series Study Area, Concentrations of Cadmium in Shallow Groundwater
- Figure 6.5-34 Building 900s Series Study Area, Concentrations of Cadmium in Intermediate and Deep Groundwater
- Figure 6.5-35 Building 900s Series Study Area, Concentrations of Chromium in Shallow Groundwater
- Figure 6.5-36 Building 900s Series Study Area, Concentrations of Chromium in Intermediate and Deep Groundwater
- Figure 6.5-37 Building 900s Series Study Area, Concentrations of Copper in Shallow Groundwater
- Figure 6.5-38 Building 900s Series Study Area, Concentrations of Copper in Intermediate and Deep Groundwater
- Figure 6.5-39 Building 900s Series Study Area, Concentrations of Lead in Shallow Groundwater

- Figure 6.5-40 Building 900s Series Study Area, Concentrations of Lead in Intermediate and Deep Groundwater
- Figure 6.5-41 Building 900s Series Study Area, Concentrations of Manganese in Shallow Groundwater
- Figure 6.5-42 Building 900s Series Study Area, Concentrations of Manganese in Intermediate and Deep Groundwater
- Figure 6.5-43 Building 900s Series Study Area, Concentrations of Nickel in Shallow Groundwater
- Figure 6.5-44 Building 900s Series Study Area, Concentrations of Nickel in Intermediate and Deep Groundwater
- Figure 6.5-45 Building 900s Series Study Area, Concentrations of Thallium in Shallow Groundwater
- Figure 6.5-46 Building 900s Series Study Area, Concentrations of Zinc in Shallow Groundwater
- Figure 6.5-47 Building 900s Series Study Area, Concentrations of Zinc in Intermediate and Deep Groundwater
- Figure 6.5-48 Building 900s Study Area, Sum of Concentrations of BTEX Species, Well Cluster 937GW31, 937GW36, 937GW41
- Figure 6.5-49 Building 900s Study Area, Sum of Concentrations of BTEX Species, Coastal Wells 937GW07, 937GW08, 937GW10, 937GW15, 937GW16, 937GW17, 937GW23, 937GW24, 937GW35, 937GW39
- Figure 6.5-50 Building 900s Study Area, Sum of Concentrations of Parent Compounds: TCE, PCE, 111TCA, 11DCA; Well Cluster 937GW06, 937GW32/32R, 937GW42
- Figure 6.5-51 Building 900s Study Area, Sum of Concentrations of Parent Compounds: TCE, PCE, 111TCA, 11DCA; Well Cluster 937GW31, 937GW36, 937GW41
- Figure 6.5-52 Building 900s Study Area, Sum of Concentrations of Chlorinated Degradation Products: 12DCE, cis/trans-12DCE, and VC; Well Cluster 937GW06, 937GW32/32R, 937GW42
- Figure 6.5-53 Building 900s Study Area, Sum of Concentrations of Chlorinated Degradation Products: 12DCE, cis/trans-12DCE, and VC; Well Cluster 937GW31, 937GW36, 937GW41

- Figure 6.5-54 Building 900s Study Area, Sum of Concentrations of Chlorinated Degradation Products: 12DCE, cis/trans-12DCE, and VC; Well Cluster 937GW28, 937GW40, 937GW43
- Figure 6.5-55 Building 900s Study Area, Sum of Concentrations of Chlorinated Degradation Products: 12DCE, cis/trans-12DCE, and VC; Well Cluster 937GW12, 937GW38
- Figure 6.5-56 Building 900s Study Area, Sum of Concentrations of Chlorinated Degradation Products: 12DCE, cis/trans-12DCE, and VC; Coastal Wells 937GW07, 937GW08, 937GW10, 937GW15, 937GW16, 937GW17, 937GW23, 937GW24, 937GW35, 937GW39
- Figure 6.5-57 Building 900s Study Area, Sum of Concentrations of Chlorinated Degradation Products: 12DCE, cis/trans-12DCE, and VC; Shallow Wells 937GW01, 937GW22, 937GW28, 937GW33
- Figure 6.5-58 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Well Cluster 937GW06, 937GW32/32R, 937GW42
- Figure 6.5-59 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Well Cluster 937GW31, 937GW36, 937GW41
- Figure 6.5-60 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Well Cluster 937GW28, 937GW40, 937GW43
- Figure 6.5-61 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Well Cluster 937GW12, 937GW38
- Figure 6.5-62 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Well Cluster 937GW15, 937GW29
- Figure 6.5-63 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Coastal Wells 937GW07, 937GW08, 937GW10, 937GW15, 937GW16, 937GW17, 937GW23, 937GW24, 937GW35, 937GW39
- Figure 6.5-64 Building 900s Study Area, Concentrations of Total Petroleum Hydrocarbon, Shallow Wells 937GW01, 937GW22, 937GW28, 937GW33
- Figure 6.5-65 Building 900s Series Study Area, Sum of Concentrations of BTEX Compounds in Shallow Groundwater
- Figure 6.5-66 Building 900s Series Study Area, Sum of Concentrations of BTEX Compounds in Intermediate and Deep Groundwater
- Figure 6.5-67 Building 900s Series Study Area, Sum of Concentrations of Parent Chlorinated Compounds in Shallow Groundwater

- Figure 6.5-68 Building 900s Series Study Area, Sum of Concentrations of Parent Chlorinated Compounds in Intermediate Groundwater
- Figure 6.5-69 Building 900s Series Study Area, Sum of Concentrations of Parent Chlorinated Compounds in Deep Groundwater
- Figure 6.5-70 Building 900s Series Study Area, Sum of Concentrations of Chlorinated Degradation Products in Shallow Groundwater
- Figure 6.5-71 Building 900s Series Study Area, Sum of Concentrations of Chlorinated Degradation Products in Intermediate Groundwater
- Figure 6.5-72 Building 900s Series Study Area, Sum of Concentrations of Chlorinated Degradation Products in Deep Groundwater
- Figure 6.5-73 Building 900s Series Study Area, Concentrations of TPH-D in Shallow Groundwater
- Figure 6.5-74 Building 900s Series Study Area, Concentrations of TPH-D in Intermediate and Deep Groundwater
- Figure 6.5-75 Building 900s Series Study Area, Concentrations of Trichloroethene in Shallow Groundwater
- Figure 6.5-76 Building 900s Series Study Area, Concentrations of Trichloroethene in Intermediate and Deep Groundwater
- Figure 6.5-77 Building 900s Series Study Area, Concentrations of cis-1,2-Dichloroethene in Shallow Groundwater
- Figure 6.5-78 Building 900s Series Study Area, Concentrations of cis-1,2-Dichloroethene in Intermediate and Deep Groundwater
- Figure 6.5-79 Building 900s Series Study Area, Concentrations of Vinyl Chloride in Shallow Groundwater
- Figure 6.5-80 Building 900s Series Study Area, Concentrations of Vinyl Chloride in Intermediate and Deep Groundwater
- Figure 7.1-1 Directorate of Engineering and Housing Study Area, Wipe, Sediment & Surface Soil Sample Locations
- Figure 7.3-1 Directorate of Engineering and Housing Study Area, Soil Boring, Monitoring Well and Cross Section Locations
- Figure 7.3-2 Directorate of Engineering and Housing Study Area, Debris Fill Isopach
- Figure 7.3-3 Directorate of Engineering and Housing Study Area, Cross Section A-A'

- Figure 7.3-4 Directorate of Engineering and Housing Study Area, Cross Section B-B'
- Figure 7.3-5 Directorate of Engineering and Housing Study Area, Potentiometric Surface Map, High Tide, March 1995
- Figure 7.3-6 Directorate of Engineering and Housing Study Area, Potentiometric Surface Map, Low Tide, March 1995
- Figure 7.3-7 Directorate of Engineering and Housing Study Area, Potentiometric Surface Map, Low Tide, November 1992
- Figure 7.3-8 Directorate of Engineering and Housing Study Area, Potentiometric Surface Map, High Tide, November 1992
- Figure 7.5-1 Directorate of Engineering and Housing Study Area, Concentrations of Aluminum in Soil
- Figure 7.5-2 Directorate of Engineering and Housing Study Area, Concentrations of Antimony in Soil
- Figure 7.5-3 Directorate of Engineering and Housing Study Area, Concentrations of Arsenic in Soil
- Figure 7.5-4 Directorate of Engineering and Housing Study Area, Concentrations of Barium in Soil
- Figure 7.5-5 Directorate of Engineering and Housing Study Area, Concentrations of Beryllium in Soil
- Figure 7.5-6 Directorate of Engineering and Housing Study Area, Concentrations of Cadmium in Soil
- Figure 7.5-7 Directorate of Engineering and Housing Study Area, Concentrations of Chromium in Soil
- Figure 7.5-8 Directorate of Engineering and Housing Study Area, Concentrations of Copper in Soil
- Figure 7.5-9 Directorate of Engineering and Housing Study Area, Concentrations of Cyanide in Soil
- Figure 7.5-10 Directorate of Engineering and Housing Study Area, Concentrations of Iron in Soil
- Figure 7.5-11 Directorate of Engineering and Housing Study Area, Concentrations of Lead in Soil
- Figure 7.5-12 Directorate of Engineering and Housing Study Area, Concentrations of Manganese in Soil

- Figure 7.5-13 Directorate of Engineering and Housing Study Area, Concentrations of Mercury in Soil
- Figure 7.5-14 Directorate of Engineering and Housing Study Area, Concentrations of Nickel in Soil
- Figure 7.5-15 Directorate of Engineering and Housing Study Area, Concentrations of Silver in Soil
- Figure 7.5-16 Directorate of Engineering and Housing Study Area, Concentrations of Zinc in Soil
- Figure 7.5-17 Directorate of Engineering and Housing Study Area, Concentrations of Aldrin in Soil
- Figure 7.5-18 Directorate of Engineering and Housing Study Area, Concentrations of Chlordane in Soil
- Figure 7.5-19 Directorate of Engineering and Housing Study Area, Concentrations of Dieldrin in Soil
- Figure 7.5-20 Directorate of Engineering and Housing Study Area, Concentrations of Endrin in Soil
- Figure 7.5-21 Directorate of Engineering and Housing Study Area, Concentrations of Heptachlor in Soil
- Figure 7.5-22 Directorate of Engineering and Housing Study Area, Concentrations of Arsenic in Groundwater
- Figure 7.5-23 Directorate of Engineering and Housing Study Area, Concentrations of Cadmium in Groundwater
- Figure 7.5-24 Directorate of Engineering and Housing Study Area, Concentrations of Chromium in Groundwater
- Figure 7.5-25 Directorate of Engineering and Housing Study Area, Concentrations of Copper in Groundwater
- Figure 7.5-26 Directorate of Engineering and Housing Study Area, Concentrations of Lead in Groundwater
- Figure 7.5-27 Directorate of Engineering and Housing Study Area, Concentrations of Zinc in Groundwater
- Figure 7.5-28 Directorate of Engineering and Housing Study Area, Concentrations of Trichloroethene in Groundwater
- Figure 8.0-1 Main Post Study Areas

- Figure 8.1-1 Main Post Study Area, Building 215, Sample Locations and Potentiometric Surface Map
- Figure 8.2-1 Main Post Study Area, Building 231, Sample, Cross Section & Tank Locations
- Figure 8.2-2 Main Post Study Area, Building 231, Cross Section A-A'
- Figure 8.2-3 Main Post Study Area, Building 231, Cross Section B-B'
- Figure 8.2-4 Main Post Study Area, Building 231, Potentiometric Surface Map, Shallow Monitoring Wells, 1995
- Figure 8.2-5 Main Post Study Area, Building 231, Potentiometric Surface Map, Intermediate Monitoring Wells, 1995
- Figure 8.2-6 Main Post Study Area, Building 231, Potentiometric Surface Map, Deep Monitoring Wells, 1995
- Figure 8.3-1 Main Post Study Area, Building 1057, Sample Locations
- Figure 8.4-1 Main Post Study Area, Building 1065, Sample and Cross Section Locations
- Figure 8.4-2 Main Post Study Area, Building 1065, Cross Section A-A'
- Figure 8.5-1 Main Post Study Area, Building 1167, Sample Locations
- Figure 8.6-1 Main Post Study Area, Building 1151, Sample Locations
- Figure 9.1-1 Fill Site 1 and Landfill 2, Sample and Cross Section Locations
- Figure 9.1-2 Fill Site 1, Cross Section A-A'
- Figure 9.1-3 Fill Site 1, Cross Section B-B'
- Figure 9.1-4 Landfill 2, Cross Section C-C'
- Figure 9.1-5 Landfill 2, Cross Section D-D'
- Figure 9.1-6 Fill Site 1 and Landfill 2, Debris Fill and Landfill Material Isopachs
- Figure 9.1-7 Fill Site 1 and Landfill 2, Potentiometric Surface Map, September 1992
- Figure 9.1-8 Fill Site 1 and Landfill 2, Potentiometric Surface Map, March 1995
- Figure 9.1-9 Fill Site 1 and Landfill 2, Concentrations of Antimony in Soil
- Figure 9.1-10 Fill Site 1 and Landfill 2, Concentrations of Arsenic in Soil
- Figure 9.1-11 Fill Site 1 and Landfill 2, Concentrations of Barium in Soil

- Figure 9.1-12 Fill Site 1 and Landfill 2, Concentrations of Chromium in Soil
- Figure 9.1-13 Fill Site 1 and Landfill 2, Concentrations of Copper in Soil
- Figure 9.1-14 Fill Site 1 and Landfill 2, Concentrations of Iron in Soil
- Figure 9.1-15 Fill Site 1 and Landfill 2, Concentrations of Lead in Soil
- Figure 9.1-16 Fill Site 1 and Landfill 2, Concentrations of Manganese in Soil
- Figure 9.1-17 Fill Site 1 and Landfill 2, Concentrations of Mercury in Soil
- Figure 9.1-18 Fill Site 1 and Landfill 2, Concentrations of Nickel in Soil
- Figure 9.1-19 Fill Site 1 and Landfill 2, Concentrations of Selenium in Soil
- Figure 9.1-20 Fill Site 1 and Landfill 2, Concentrations of Silver in Soil
- Figure 9.1-21 Fill Site 1 and Landfill 2, Concentrations of Vanadium in Soil
- Figure 9.1-22 Fill Site 1 and Landfill 2, Concentrations of Zinc in Soil
- Figure 9.1-23 Fill Site 1 and Landfill 2, Concentrations of ppDDT in Soil
- Figure 9.1-24 Fill Site 1 and Landfill 2, Concentrations of Barium in Groundwater and Surface Water
- Figure 9.1-25 Fill Site 1 and Landfill 2, Concentrations of Cadmium in Groundwater and Surface Water
- Figure 9.1-26 Fill Site 1 and Landfill 2, Concentrations of Chromium in Groundwater and Surface Water
- Figure 9.1-27 Fill Site 1 and Landfill 2, Concentrations of Copper in Groundwater and Surface Water
- Figure 9.1-28 Fill Site 1 and Landfill 2, Concentrations of Lead in Groundwater and Surface Water
- Figure 9.1-29 Fill Site 1 and Landfill 2, Concentrations of Manganese in Groundwater and Surface Water
- Figure 9.1-30 Fill Site 1 and Landfill 2, Concentrations of Nickel in Groundwater and Surface Water
- Figure 9.2-1 Transfer Station Site, Sample Locations and Cross Section Locations
- Figure 9.2-2 Transfer Station Site, Cross Section A-A'

- Figure 9.2-3 Transfer Station Site, Cross Section B-B'
- Figure 9.2-4 Transfer Station Site, Debris Fill Isopach
- Figure 9.2-5 Transfer Station Site, Concentrations of Aluminum in Soil
- Figure 9.2-6 Transfer Station Site, Concentrations of Barium in Soil
- Figure 9.2-7 Transfer Station Site, Concentrations of Iron in Soil
- Figure 9.2-8 Transfer Station Site, Concentrations of Lead in Soil
- Figure 9.2-9 Transfer Station Site, Concentrations of Manganese in Soil
- Figure 9.2-10 Transfer Station Site, Concentrations of Mercury in Soil
- Figure 9.2-11 Transfer Station Site, Concentrations of Benzo(a)anthracene in Soil
- Figure 9.2-12 Transfer Station Site, Concentrations of Benzo(a)pyrene in Soil
- Figure 9.3-1 Landfill 4 and Fill Site 5, Sample and Cross Section Locations
- Figure 9.3-2 Landfill 4, Cross Section A-A'
- Figure 9.3-3 Landfill 4, Cross Section B-B'
- Figure 9.3-4 Fill Site 5, Cross Section C-C'
- Figure 9.3-5 Fill Site 5, Cross Section D-D'
- Figure 9.3-6 Landfill 4, Landfill Material Isopach
- Figure 9.3-7 Landfill 4, Debris Fill Isopach
- Figure 9.3-8 Fill Site 5, Debris Fill Isopach
- Figure 9.3-9 Landfill 4, Concentrations of Aluminum in Soil
- Figure 9.3-10 Landfill 4, Concentrations of Iron in Soil
- Figure 9.3-11 Landfill 4, Concentrations of Lead in Soil
- Figure 9.3-12 Landfill 4, Concentrations of Manganese in Soil
- Figure 9.3-13 Landfill 4, Concentrations of Aldrin in Soil
- Figure 9.3-14 Landfill 4, Concentrations of Chlordane in Soil
- Figure 9.3-15 Landfill 4, Concentrations of Dieldrin in Soil

- Figure 9.3-16 Landfill 4, Concentrations of Heptachlor in Soil
- Figure 9.3-17 Landfill 4, Concentrations of Heptachlor Epoxide in Soil
- Figure 9.3-18 Fill Site 5, Concentrations of Aluminum in Soil
- Figure 9.3-19 Fill Site 5, Concentrations of Chromium in Soil
- Figure 9.3-20 Fill Site 5, Concentrations of Iron in Soil
- Figure 9.3-21 Fill Site 5, Concentrations of Lead in Soil
- Figure 9.3-22 Fill Site 5, Concentrations of Manganese in Soil
- Figure 9.3-23 Fill Site 5, Concentrations of Vanadium in Soil
- Figure 9.3-24 Fill Site 5, Concentrations of Chlordane in Soil
- Figure 9.3-25 Fill Site 5, Concentrations of Dieldrin in Soil
- Figure 9.3-26 Fill Site 5, Concentrations of Heptachlor in Soil
- Figure 9.4-1 Fill Site 6, Sample & Cross Section Locations
- Figure 9.4-2 Fill Site 6, Cross Section A-A'
- Figure 9.4-3 Fill Site 6, Cross Section B-B'
- Figure 9.4-4 Fill Site 6, Debris Fill Isopach
- Figure 9.4-5 Fill Site 6, Concentrations of Aluminum in Soil
- Figure 9.4-6 Fill Site 6, Concentrations of Barium in Soil
- Figure 9.4-7 Fill Site 6, Concentrations of Cadmium in Soil
- Figure 9.4-8 Fill Site 6, Concentrations of Chromium in Soil
- Figure 9.4-9 Fill Site 6, Concentrations of Lead in Soil
- Figure 9.4-10 Fill Site 6, Concentrations of Nickel in Soil
- Figure 9.4-11 Fill Site 6, Concentrations of Vanadium in Soil
- Figure 9.4-12 Fill Site 6, Concentrations of Aluminum in Groundwater
- Figure 9.4-13 Fill Site 6, Concentrations of Barium in Groundwater
- Figure 9.4-14 Fill Site 6, Concentrations of Chromium in Groundwater

- Figure 9.4-15 Fill Site 6, Concentrations of Lead in Groundwater
- Figure 9.4-16 Fill Site 6, Concentrations of Nickel in Groundwater
- Figure 9.5-1 Graded Area 9, Sample and Cross Section Locations
- Figure 9.5-2 Graded Area 9, Cross Section A-A'
- Figure 9.5-3 Graded Area 9, Debris Fill Isopach
- Figure 9.6-1 Landfill E, Sample and Cross Section Locations
- Figure 9.6-2 Landfill E, Cross Section A-A'
- Figure 9.6-3 Landfill E, Cross Section B-B'
- Figure 9.6-4 Landfill E, Debris Fill Isopach
- Figure 9.6-5 Landfill E, Landfill Material Isopach
- Figure 9.6-6 Landfill E, Potentiometric Surface Map, October 1992
- Figure 9.6-7 Landfill E, Potentiometric Surface Map, March 1995
- Figure 9.6-8 Landfill E, Concentrations of Aluminum in Soil
- Figure 9.6-9 Landfill E, Concentrations of Antimony in Soil
- Figure 9.6-10 Landfill E, Concentrations of Arsenic in Soil
- Figure 9.6-11 Landfill E, Concentrations of Barium in Soil
- Figure 9.6-12 Landfill E, Concentrations of Beryllium in Soil
- Figure 9.6-13 Landfill E, Concentrations of Cadmium in Soil
- Figure 9.6-14 Landfill E, Concentrations of Chromium in Soil
- Figure 9.6-15 Landfill E, Concentrations of Copper in Soil
- Figure 9.6-16 Landfill E, Concentrations of Iron in Soil
- Figure 9.6-17 Landfill E, Concentrations of Lead in Soil
- Figure 9.6-18 Landfill E, Concentrations of Manganese in Soil
- Figure 9.6-19 Landfill E, Concentrations of Mercury in Soil
- Figure 9.6-20 Landfill E, Concentrations of Nickel in Soil

- Figure 9.6-21 Landfill E, Concentrations of Silver in Soil
- Figure 9.6-22 Landfill E, Concentrations of Vanadium in Soil
- Figure 9.6-23 Landfill E, Concentrations of Zinc in Soil
- Figure 9.6-24 Landfill E, Concentrations of Benzo(a)pyrene in Soil
- Figure 9.6-25 Landfill E, Concentrations of Indeno(1,2,3-cd)pyrene in Soil
- Figure 9.6-26 Landfill E, Concentrations of Alpha-bhc in Soil
- Figure 9.6-27 Landfill E, Concentrations of ppDDT in Soil
- Figure 9.6-28 Landfill E, Concentrations of Aluminum in Groundwater
- Figure 9.6-29 Landfill E, Concentrations of Barium in Groundwater
- Figure 9.6-30 Landfill E, Concentrations of Chromium in Groundwater
- Figure 9.6-31 Landfill E, Concentrations of Lead in Groundwater
- Figure 9.6-32 Landfill E, Concentrations of Nickel in Groundwater
- Figure 10.1-1 Miscellaneous Sites, Building 662, Sample Locations
- Figure 10.2-1 Miscellaneous Sites, Building 680, Sample Locations
- Figure 10.3-1 Miscellaneous Sites, Building 1244, Sample Locations
- Figure 10.4-1 Miscellaneous Sites, Building 1351, Sample and Cross Section Locations
- Figure 10.4-2 Miscellaneous Sites, Building 1351, Cross Section A-A'
- Figure 10.4-3 Miscellaneous Sites, Building 1351, Concentrations of Aluminum in Soil
- Figure 10.4-4 Miscellaneous Sites, Building 1351, Concentrations of Barium in Soil
- Figure 10.4-5 Miscellaneous Sites, Building 1351, Concentrations of Beryllium in Soil
- Figure 10.4-6 Miscellaneous Sites, Building 1351, Concentrations of Cadmium in Soil
- Figure 10.4-7 Miscellaneous Sites, Building 1351, Concentrations of Chromium in Soil
- Figure 10.4-8 Miscellaneous Sites, Building 1351, Concentrations of Copper in Soil
- Figure 10.4-9 Miscellaneous Sites, Building 1351, Concentrations of Iron in Soil
- Figure 10.4-10 Miscellaneous Sites, Building 1351, Concentrations of Lead in Soil

- Figure 10.4-11 Miscellaneous Sites, Building 1351, Concentrations of Manganese in Soil
- Figure 10.4-12 Miscellaneous Sites, Building 1351, Concentrations of Nickel in Soil
- Figure 10.4-13 Miscellaneous Sites, Building 1351, Concentrations of Vanadium in Soil
- Figure 10.4-14 Miscellaneous Sites, Building 1351, Concentrations of Zinc in Soil
- Figure 10.5-1 Miscellaneous Sites, Fort Point U.S. Coast Guard Station, Sample & Cross Section Locations
- Figure 10.5-2 Miscellaneous Sites, Fort Point U.S. Coast Guard Station, Cross Section A-A'
- Figure 10.5-3 Miscellaneous Sites, Fort Point U.S. Coast Guard Station, Cross Section B-B'
- Figure 10.5-4 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Aluminum in Soil
- Figure 10.5-5 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Cadmium in Soil
- Figure 10.5-6 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Benzo(b)fluoranthene in Soil
- Figure 10.5-7 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Benzo(k)fluoranthene in Soil
- Figure 10.5-8 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Aluminum in Groundwater
- Figure 10.5-9 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Antimony in Groundwater
- Figure 10.5-10 Miscellaneous Sites, Fort Point U. S. Coast Guard Station, Concentrations of Cadmium in Groundwater
- Figure 10.6-1 Miscellaneous Sites, Mountain Lake & Lobos Creek, Watershed Boundaries
- Figure 10.6-2 Miscellaneous Sites, Lobos Creek Surface Drainage Basin
- Figure 10.6-3 Miscellaneous Sites, Mountain Lake, Lobos Creek & Source Water Areas, Sample Locations
- Figure 11.1-1 GGBHTD Study Area, Sample & Cross Section Locations
- Figure 11.3-1 GGBHTD Study Area, Cross Section A-A'

- Figure 11.3-2 GGBHTD Study Area, Potentiometric Surface Map
- Figure 12.0-1 Baker Beach - Disturbed Areas 1 and 2, Sample Locations
- Figure 12.0-2 Baker Beach - Disturbed Areas 3 and 4, Sample Locations
- Figure 12.5-1 Baker Beach Study Area, Disturbed Area 1, Concentrations of Aluminum in Soil
- Figure 12.5-2 Baker Beach Study Area, Disturbed Area 1, Concentrations of Antimony in Soil
- Figure 12.5-3 Baker Beach Study Area, Disturbed Area 1, Concentrations of Barium in Soil
- Figure 12.5-4 Baker Beach Study Area, Disturbed Area 1, Concentrations of Beryllium in Soil
- Figure 12.5-5 Baker Beach Study Area, Disturbed Area 1, Concentrations of Chromium in Soil
- Figure 12.5-6 Baker Beach Study Area, Disturbed Area 1, Concentrations of Copper in Soil
- Figure 12.5-7 Baker Beach Study Area, Disturbed Area 1, Concentrations of Iron in Soil
- Figure 12.5-8 Baker Beach Study Area, Disturbed Area 1, Concentrations of Lead in Soil
- Figure 12.5-9 Baker Beach Study Area, Disturbed Area 1, Concentrations of Manganese in Soil
- Figure 12.5-10 Baker Beach Study Area, Disturbed Area 1, Concentrations of Mercury in Soil
- Figure 12.5-11 Baker Beach Study Area, Disturbed Area 1, Concentrations of Nickel in Soil
- Figure 12.5-12 Baker Beach Study Area, Disturbed Area 1, Concentrations of Selenium in Soil
- Figure 12.5-13 Baker Beach Study Area, Disturbed Area 1, Concentrations of Silver in Soil
- Figure 12.5-14 Baker Beach Study Area, Disturbed Area 1, Concentrations of Vanadium in Soil
- Figure 12.5-15 Baker Beach Study Area, Disturbed Area 1, Concentrations of Zinc in Soil
- Figure 13.1-1 Battery Howe/Wagner, Sample Locations

- Figure 13.3-1 Battery Howe/Wagner, Cross Section A-A'
- Figure 13.3-2 Battery Howe/Wagner, Cross Section B-B'
- Figure 13.3-3 Battery Howe/Wagner, Debris Fill Isopach
- Figure 13.3-4 Battery Howe/Wagner, Potentiometric Surface Map, September 1992
- Figure 13.3-5 Battery Howe/Wagner, Potentiometric Surface Map, March 1995
- Figure 13.5-1 Battery Howe/Wagner, Concentrations of Aluminum in Soil
- Figure 13.5-2 Battery Howe/Wagner, Concentrations of Arsenic in Soil
- Figure 13.5-3 Battery Howe/Wagner, Concentrations of Barium in Soil
- Figure 13.5-4 Battery Howe/Wagner, Concentrations of Beryllium in Soil
- Figure 13.5-5 Battery Howe/Wagner, Concentrations of Cadmium in Soil
- Figure 13.5-6 Battery Howe/Wagner, Concentrations of Chromium in Soil
- Figure 13.5-7 Battery Howe/Wagner, Concentrations of Copper in Soil
- Figure 13.5-8 Battery Howe/Wagner, Concentrations of Manganese in Soil
- Figure 13.5-9 Battery Howe/Wagner, Concentrations of Mercury in Soil
- Figure 13.5-10 Battery Howe/Wagner, Concentrations of Nickel in Soil
- Figure 13.5-11 Battery Howe/Wagner, Concentrations of Vanadium in Soil
- Figure 13.5-12 Battery Howe/Wagner, Concentrations of Cadmium in Groundwater
- Figure 13.5-13 Battery Howe/Wagner, Concentrations of Chromium in Groundwater
- Figure 13.5-14 Battery Howe/Wagner, Concentrations of Manganese in Groundwater
- Figure 13.5-15 Battery Howe/Wagner, Concentrations of Nickel in Groundwater
- Figure 14.1-1 Miscellaneous Follow-on Sites, Building 302, Sample Locations
- Figure 14.2-1 Miscellaneous Follow-on Sites, Building 669, Sample Locations
- Figure 14.3-1 Miscellaneous Follow-on Sites, Building 1245, Sample Locations
- Figure 14.4-1 Miscellaneous Follow-on Sites, Building 1369, Sample Locations
- Figure 14.5-1 Miscellaneous Follow-on Sites, Building 1388, Sample Locations

- Figure 14.6-1 Miscellaneous Follow-on Sites, Building 1750, Sample Locations
- Figure 14.7-1 Miscellaneous Follow-on Sites, East of Mason, Sample Locations
- Figure 14.7-2 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Aluminum in Soil
- Figure 14.7-3 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Arsenic in Soil
- Figure 14.7-4 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Chromium in Soil
- Figure 14.7-5 Miscellaneous Follow-on Sites, East of Mason, Concentrations Copper in Soil
- Figure 14.7-6 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Lead in Soil
- Figure 14.7-7 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Manganese in Soil
- Figure 14.7-8 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Mercury in Soil
- Figure 14.7-9 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Nickel in Soil
- Figure 14.7-10 Miscellaneous Follow-on Sites, East of Mason, Concentrations of ppDDE in Soil
- Figure 14.7-11 Miscellaneous Follow-on Sites, East of Mason, Concentrations of ppDDT in Soil
- Figure 14.7-12 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Arsenic in Groundwater
- Figure 14.7-13 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Cadmium in Groundwater
- Figure 14.7-14 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Chromium in Groundwater
- Figure 14.7-15 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Copper in Groundwater
- Figure 14.7-16 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Lead in Groundwater

- Figure 14.7-17 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Manganese in Groundwater
- Figure 14.7-18 Miscellaneous Follow-on Sites, East of Mason, Concentrations of Nickel in Groundwater
- Figure 15.1-1 The Four Principal Steps of a Baseline Risk Assessment
- Figure 15.1-2 Crissy Field Wetlands Restoration Area—Surface Soil and Soil Boring Sample Locations within Risk Assessment Area
- Figure 15.1-3 Crissy Field Wetlands Restoration Area—Groundwater Sample Locations within Risk Assessment Area
- Figure 15.2-1 Terrestrial Food Web Showing Fractions of Dietary Items for Presidio of San Francisco Receptors
- Figure 15.2-2 Aquatic Food Web Showing Fractions of Dietary Items for Presidio of San Francisco Receptors
- Figure 15.2-3 Hazard Indices for the Nike Facility
- Figure 15.2-4 Hazard Indices for Modeled Aquatic Exposures South of the Nike Facility
- Figure 15.2-5 Hazard Indices for Buildings 640 and 643, Consolidated Motor Pool Area, Crissy Field Study Area
- Figure 15.2-6 Hazard Indices for Building 642, Consolidated Motor Pool Area, Crissy Field Study Area
- Figure 15.2-7 Hazard Indices for the Fill Site 7/East of Mason Shoreline Area
- Figure 15.2-8 Hazard Indices for Wetland Receptors Exposed to Soils in the Crissy Field Future Wetland Area
- Figure 15.2-9 Hazard Indices for Terrestrial Receptors Exposed to Soils in the Crissy Field Future Wetland Area
- Figure 15.2-10a Hazard Indices for Water Exposure at the Crissy Field Future Wetland Area: Zero Dilution Scenario
- Figure 15.2-10b Hazard Indices for Water Exposure at the Crissy Field Future Wetland Area: 50 Percent Dilution Scenario
- Figure 15.2-10c Hazard Indices for Water Exposure at the Crissy Field Future Wetland Area: 90 Percent Dilution Scenario
- Figure 15.2-11 Hazard Indices for Building 609, Crissy Field Study Area

- Figure 15.2-12 Hazard Indices for Building 633, Crissy Field Study Area
- Figure 15.2-13 Hazard Indices for Crissy Field Sewer Lift Station 1
- Figure 15.2-14 Hazard Indices for Crissy Field Sewer Lift Station 2
- Figure 15.2-15 Hazard Indices for the Building 900s Series Study Area
- Figure 15.2-16 Hazard Indices for the DEH Study Area
- Figure 15.2-17 Hazard Indices for Building 228, Main Post Study Area
- Figure 15.2-18 Hazard Indices for the Building 1167 Site, Main Post Study Area
- Figure 15.2-19 Hazard Indices for the Building 1151 Site, Main Post Study Area
- Figure 15.2-20 Hazard Indices for Fill Site 1, Fill Sites and Landfills
- Figure 15.2-21 Hazard Indices for Landfill 2, Fill Sites and Landfills
- Figure 15.2-22 Hazard Indices for El Polin Spring, Fill Sites and Landfills
- Figure 15.2-23 Hazard Indices for the Transfer Station Site, Fill Sites and Landfills
- Figure 15.2-24 Hazard Indices for Landfill 4, Fill Sites and Landfills
- Figure 15.2-25 Hazard Indices for Fill Site 5, Fill Sites and Landfills
- Figure 15.2-26 Hazard Indices for Graded Area 9, Fill Sites and Landfills
- Figure 15.2-27 Hazard Indices for Landfill E, Fill Sites and Landfills
- Figure 15.2-28 Hazard Indices for Building 662, Miscellaneous Sites
- Figure 15.2-29 Hazard Indices for Building 680, Miscellaneous Sites
- Figure 15.2-30 Hazard Indices for Building 1351, Miscellaneous Sites
- Figure 15.2-31 Hazard Indices for Fort Point Coast Guard Station, Miscellaneous Sites
- Figure 15.2-32 Hazard Indices for Lobos Creek, Miscellaneous Sites
- Figure 15.2-33 Hazard Indices for Mountain Lake, Miscellaneous Sites
- Figure 15.2-34 Hazard Indices for Disturbed Area 1 Outside Mounded Landfill Material Area, Baker Beach Study Area

Figure 15.2-35 Hazard Indices for Soil Exposure at Disturbed Area 1 Mounded Landfill Material Area, Baker Beach Study Area

Figure 15.2-36 Hazard Indices for Receptors Exposed to Water and Sediments at Disturbed Area 1 Seep, Baker Beach Study Area

Figure 15.2-37 Hazard Indices for Disturbed Area 1a, Baker Beach Study Area

Figure 15.2-38 Hazard Indices for Disturbed Area 2, Baker Beach Study Area

Figure 15.2-39 Hazard Indices for Disturbed Area 3, Baker Beach Study Area

Figure 15.2-40 Hazard Indices for Disturbed Area 4, Baker Beach Study Area

Figure 15.2-41 Hazard Indices for Battery Howe/Wagner

Figure 15.2-42 Hazard Indices for Building 302, Miscellaneous Follow-on RI Sites

Figure 15.2-43 Hazard Indices for Building 1245, Miscellaneous Follow-on RI Sites

Figure 15.2-44 Hazard Indices for Building 1369, Miscellaneous Follow-on RI Sites

Figure 15.2-45 Hazard Indices Building 1388, Miscellaneous Follow-on RI Sites

LIST OF ACRONYMS AND ABBREVIATIONS

AAFES	Army Air Force Exchange Service
ABS	soil absorption
ac	acre(s)
AET	apparent effects threshold
AGM	adjusted geometric mean
ALARA	As Low As Reasonably Achievable
ANL	Argonne National Laboratory
ARAR	Applicable or Relevant and Appropriate Requirement
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
AUF	area use factor
BAF	bioaccumulation factor
BCF	bioconcentration factor
bgs	below ground surface
BRA	baseline risk assessment
BTEX	benzene, toluene, ethylbenzene, and xylene
C	Celsius
Cal EPA	California Environmental Protection Agency
CBP	Cooper-Bredehoeft-Papadopulos method
CDI	chronic daily intake
CEQ	Council on Environmental Quality
CEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CERFA	Community Environmental Response Facilitation Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
Cg	concentration in the gas phase
CGLS	Coast Guard Lifeboat Station

cm ²	square centimeter(s)
cm ³	cubic centimeter(s)
C-O-C	chain-of-custody
COC	chemical of concern
COD	criteria of detection
COPC	chemical of potential concern
CPT	cone penetrometer testing
CQI	continuous quality improvement
CRL	certified reporting limit
CRWQCB	California Regional Water Quality Control Board
CSF	Cancer Slope Factor
DA	Disturbed Area
DEH	Directorate of Engineering and Housing
DL	Detection Limit
DOT	U. S. Department of Transportation
DPDO	Defense Property Disposal Office
DQO	Data Quality Objective
DRMO	Defense Reutilization and Marketing Office
DTSC	Department of Toxic Substances Control
EC	electrical conductivity
ECD	electron capture detector
ECJC	E.C. Jordan Company
EIS	environmental impact statement
ELCD	electrolytic conductivity detector
EM	electromagnetic
EOD	Explosive Ordnance Demolition
EOM	East of Mason
EPA	U.S. Environmental Protection Agency
ESAP	Environmental Sampling and Analysis Program
ESE/D	Environmental Science & Engineering, Inc. - Denver
ESE/G	Environmental Science & Engineering, Inc. - Gainesville

EST	Environmental Support Technologies
F	Fahrenheit
FDS	fuel distribution system
FID	flame-ionization detector
FOD	frequency of detection
FPALDR	Fuel Product Action Level Development Report
FPCGS	Fort Point U. S. Coast Guard Station
FPLSS	Fort Point Life-Saving Station
Fs	friction
FS	Feasibility Study
ft	foot or feet
ft bgs	feet below ground surface
ft-mll	feet-mean-lower low water
gal	gallon(s)
GC/MS	Gas Chromatography/Mass Spectrometry
GG3	Gossen Goehm-3 instrument
GGBHTD	Golden Gate Bridge Highway & Transportation District
GGNRA	Golden Gate National Recreation Area
GMP	General Management Plan
gpd	gallons per day
gpm	gallons per minute
GPR	ground penetrating radar
GT	greater than
HEAST	Health Effects Assessment Summary Tables and Supplements
HI	hazard index
HLA	Harding Lawson Associates
HQ	hazard quotient
HSA	hollow-stem auger
HSDB	Hazardous Substances Database
IEUBK	integrated exposure uptake biokinetic
IFC	Integrated Fire Control

in	inch or inches
IRA	Interim Remedial Action
IRDMIS	Installation Restoration Data Management Information System
IRIS	Integrated Risk Information System
kg	kilogram
Kh	Henry's Law Constant
km	kilometers
LAIR	Letterman Army Institute of Research
LAMC	Letterman Army Medical Center
LCL	Lower Confidence Limit
LOAEL	lowest-observed-adverse-effects level
LT	less than
m	meter
MBAS	methyl blue active substances
MCL	maximum contaminant level
MDEP	Massachusetts Department of Environmental Protection
MDL	method detection limit
meq/L	milliequivalents per liter
mg	milligram
Mg-HCO ₃	magnesium-bicarbonate
mg/kg bw/d	milligram chemical per kilogram body weight per day
mg/L	milligrams per liter
mi	mile(s)
mi ²	square mile(s)
mL/hr	milliliters per hour
mm	millimeter(s)
mmho/m	millimhos per meter
mph	miles per hour
m/s	meters per second
mS/m	millisiemens per meter
mybp	million years before present

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NFG	National Functional Guidelines
NOAEL	no-observed-adverse-effects level
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NTAM	Non-THAMA Approved Method
OCP	organochlorine pesticides
OD	outside diameter
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PA	Preliminary Assessment
PAH	polynuclear aromatic hydrocarbons
PCA	tetrachloroethane
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PHSH	Public Health Service Hospital
PID	photoionization detector
PLL	Presidio Lower Low
POL	petroleum, oil, and lubricant
ppDDD	2,2-bis(p-chlorophenyl)-1,1-dichloroethane
ppDDE	2,2-bis(p-chlorophenyl)-1,1-dichloroethene
ppDDT	2,2-bis(p-chlorophenyl)-1,1-trichloroethane
ppm	parts per million
PRG	preliminary remediation goal
PSF	Presidio of San Francisco
psi	pounds per square inch
PVC	polyvinyl chloride
QA	Quality Assurance
QAP	Quality Assurance Plan
Qc	cone bearing

QC	Quality Control
QCP	Quality Control Plan
R&D	research and development
RAGS	Risk Assessment Guidance for Superfund
RfD	reference dose
RI	Remedial Investigation
RL	Reporting Limit
RLSA	R.L. Stollar & Associates
RME	reasonable maximum exposure
RPD	relative percent difference
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Authorization Act
SCS	U.S. Soil Conservation Service
SDC	sample decision criteria
SDP	Sampling Design Plan
STLC	Soluble Threshold Limit Concentration
SGWPCR	Soil and Groundwater Pollution Characterization Report
SVOC	semivolatile organic compound
TBV	toxicity benchmark value
TCE	trichloroethene
TDS	total dissolved solids
THM	trihalomethane
TIC	tentatively identified compound
TP	technical plan
TPH	total petroleum hydrocarbon
TPH-D	total petroleum hydrocarbon - diesel fraction
TPH-G	total petroleum hydrocarbon - gasoline fraction
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
U	pressure
U/BK	uptake/biokinetic

UCL95	upper confidence limit on the 95th percentile
USAEC	U.S. Army Environmental Center
USAEHA	U.S. Army Environmental Hygiene Agency
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USCOE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	underground storage tank
VOC	volatile organic compound
XRF	X-Ray Fluorescence
yd	yard(s)
yd ²	square yard(s)
yd ³	cubic yard(s)
WET	waste extraction test
WGCEP	Working Group on California Earthquake Probabilities
WJE	Watkins-Johnson Environmental, Inc.
μg	microgram
$\mu\text{g}/\text{dL}$	microgram per deciliter
$\mu\text{g}/\text{L}$	micrograms per liter
$\mu\text{g}/\text{m}^3$	micrograms per cubic meter
$\mu\text{S}/\text{cm}$	microSiemen per centimeter



1. INTRODUCTION

This Final Remedial Investigation (RI) Report presents the results of an investigation conducted at the Main Installation of the Presidio of San Francisco (PSF). The investigation was conducted under the direction of the U.S. Army Environmental Center (USAEC). The RI report was prepared under contract No. DAAA15-90-D-0018 with USAEC by Dames & Moore, which also participated in the investigation. The report describes RI activities conducted at the Main Installation of the PSF, presents the data collected for the Main Installation, and provides interpretations and conclusions drawn from these data.

The following introductory sections present the purpose of the investigation, provide background information on the RI program, and explain how the eight volumes of the full RI report are organized.

1.1 PURPOSE OF THE REMEDIAL INVESTIGATION

The purpose of the RI was to characterize the nature and extent of contamination resulting from U.S. Army activities at the PSF and to assess associated risks to human health and/or the environment. When the PSF was closed as a U.S. Army base and was transferred in 1994 to the National Park Service (NPS), it was required by the Base Closure and Realignment Act to undergo environmental studies. The Main Installation RI is one of the environmental studies initiated by the U.S. Army.

Because the PSF is so valuable for its scenic beauty and recreational use, the U.S. Army, the NPS, the State of California, and the general public want to ensure that the area is not a risk to either human health or the environment. For a location map of the PSF, which comprises 1,416 acres at the northern tip of the San Francisco Peninsula, see Figure 1.1-1. (Note: All figures referenced in this introduction are found in Volume III.)

The specific objectives of the PSF RI are to

- Identify and characterize potential sources of contamination at Main Installation sites
- Define the concentrations and distribution of chemicals of potential concern in environmental media

- Evaluate the risks to human health and the environment which may be posed by these chemicals.

In addition, data from the investigation will support the Main Installation Feasibility Study (FS). The FS will identify procedures to mitigate environmental contaminants that present an unacceptable risk to human health or the environment.

The RI was conducted in accordance with the U.S. Environmental Protection Agency (USEPA) guidance for activities performed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA), the National Environmental Policy Act of 1969 (NEPA), and the President's Council on Environmental Quality 40 Code of Federal Regulations 1500-1508. The investigative approach was based on recommendations in the USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (1988).

Furthermore, the procedures used in this RI are consistent with the Department of the U.S. Army policy of integrating the NEPA and CERCLA processes. Local and State environmental policies, laws, and regulations were also followed in conducting the RI.

1.2 BACKGROUND ON THE REMEDIAL INVESTIGATION PROGRAM

In December 1988, the U.S. Secretary of Defense's Commission on Base Realignments and Closures recommended closure of the PSF. The PSF was transferred to the National Park Service (NPS) on October 1, 1994, under Public Law 92-589, and became part of the Golden Gate National Recreation Area (GGNRA). Before the property could be transferred, however, the Base Closure and Realignment Act required that environmental studies be performed.

To manage the Base Realignment and Closure Environmental Restoration Program, the USAEC, formerly U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), has been assigned to plan, implement, and direct the U.S. Department of the Army Environmental Program. Thus, USAEC is responsible for conducting the environmental

investigations necessary to transfer the PSF to the NPS. The Sacramento District Corps of Engineers is assigned to conduct any required remediation.

An Enhanced Preliminary Assessment (PA), was conducted by Argonne National Laboratory (ANL) in 1989. The purpose of the PA was to characterize environmentally significant operations, identify areas requiring immediate remedial actions, and evaluate areas that may need further investigations. The assessment was based on a review of available site records, aerial photographs, data from regulatory agencies, interviews with PSF personnel, and observations made during visits to the site. The conclusions of the Enhanced PA stated that the PSF does not present an "imminent or substantial threat to human health or the environment" and that emergency actions are not warranted. However, the Enhanced PA did identify areas potentially impacted by U.S. Army activities and recommended additional studies in these areas. Information gathered during the Enhanced PA was used to develop work plans for this RI/FS.

1.2.1 Prior and Concurrent Environmental Programs

Several environmental programs which are separate from this RI have been performed or are currently being conducted at the PSF. These environmental programs address known and potential contamination issues which, with two exceptions, are not addressed in this Main Installation RI. The two exceptions are the Marine Ecological Sampling and Analysis and the U.S. Army's investigation of two RI study areas.

1.2.1.1 Programs by the U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USCOE) has the lead role in a number of completed and ongoing environmental programs at the PSF.

Environmental Impact Statement. Based on the data presented in the Enhanced PA, USCOE prepared an Environmental Impact Statement (EIS) (USCOE, 1991). The EIS focused on the economic impacts of the closure of the base.

Firing Ranges. Under the direction of the USCOE, several sites at the PSF which have been used as small arms firing ranges have been investigated. Some of these firing range sites are

located along the San Francisco Bay and some are located in inland areas. The final characterization report and remedial action plan for the firing range sites are expected to be issued in 1997.

Lead Contamination. The occurrence of lead-based paint in soils near all residential buildings constructed before 1978 has been investigated by USCOE. The U.S. Army is evaluating the need to remediate soil where elevated lead concentrations have been detected.

Petroleum Cleanup. USCOE is also conducting a petroleum cleanup program at PSF to correct petroleum contamination in soil and groundwater (Montgomery Watson 1995e). Under this program, an extensive underground piping system used by the U.S. Army to distribute heating oil to many of the buildings at the PSF is being removed. At the time of this writing, about half of the fuel distribution system has been removed. The remainder of the fuel distribution system is expected to be removed or closed in place in 1997. The investigation and removal of underground storage tanks (USTs) and above ground storage tanks (ASTs) is ongoing. All indoor storage tanks have already been removed. Monthly updates on the progress and status of the petroleum cleanup program are available to the public at the monthly Restoration Advisory Board (RAB) meetings. Information on the schedule and location of the RAB meetings can be obtained by contacting the BRAC Public Affairs Office at (415) 289-7407.

Groundwater monitoring. Under the direction of the USCOE, Montgomery Watson is monitoring groundwater at nearly 200 PSF monitoring wells quarterly. This program includes monitoring wells installed under the Main Installation RI. The monitoring results are presented in quarterly reports and annual summary reports.

Historical Research. The USCOE is currently pursuing additional historical information. If information is obtained to identify additional target areas for environmental investigation, these areas will not be added to this RI but will be addressed in subsequent investigations.

1.2.1.2 Programs by Other Agencies

Additional environmental programs at the PSF lead by agencies other than the USCOE include the following:

A Separate RI. Completely separate from the RI for the Main Installation is an RI conducted by the U.S. Army at the PSF for the former Public Health Services Hospital (PHSH) (RLSA, 1992d). This successful PHSR RI led to a final Record of Decision (ROD) for PHSR, including Landfill 8 and Landfill 10 (USAEC, 1995). Groundwater monitoring and other actions stipulated by the PHSR ROD are currently being implemented by the USCOE. The location of the PHSR within the PSF is shown in Figure 1.2-1.

A Remedial Action Plan. For the Directorate of Engineering and Housing (DEH), the Presidio Base Closure Team (BCT) is developing a Remedial Action Plan (RAP). The BCT includes the U.S. Army, regulatory agencies and the NPS. The RAP will be submitted for public review and comment. After incorporation of public comments and the U.S. Army's responses, a final Record of Decision (ROD) will be issued.

An Engineering Evaluation/Cost Analysis. An Engineering Evaluation/Cost Analysis (EE/CA) for polychlorinated biphenyl (PCB) contaminated soils at Building 680 and an area between Buildings 1151 and 1152 has undergone public review. The U.S. Army is currently reviewing public comments and will issue a final EE/CA in early 1997.

Plan for Removing Contaminated Soil. The California Department of Transportation has prepared a removal action work plan for an area beneath the Route 101 Presidio Viaduct and the Route 1 Presidio Viaduct Ramp (California Department of Transportation, 1995). This work plan focuses on soil which is contaminated with lead and chromium from past sandblasting and repainting activities associated with maintenance of the viaduct structures. All remediation activities associated with the maintenance of the Presidio viaduct are the responsibility of the California Department of Transportation.

A Survey for Explosives. Watkins-Johnson Environmental, Inc. (WJE) conducted a survey of magazines and coastal fortifications which included visual inspections and wipe sampling for compounds associated with explosives. A draft report of the results of the survey has been prepared by Dames & Moore and submitted to USAEC for review.

Groundwater Remediation. In 1994, WJE initiated an interim remedial action at Building 937 to remove a source of chlorinated solvents and petroleum contamination. This action

also included the installation and operation of an innovative technology to remediate volatile hydrocarbon contamination in groundwater. A draft report of the effectiveness of the groundwater remediation system has been prepared by Dames & Moore and submitted to USAEC for review.

Marine Ecological Sampling and Analysis. Under the direction of the USAEC, Dames & Moore conducted the Marine Ecological Sampling and Analysis Program (ESAP) to assess potential adverse impacts to the San Francisco Bay (Dames & Moore, 1996a). Dames & Moore assessed the chemical quality of stormwater that flows from the PSF to the San Francisco Bay and the chemical quality of the bay sediment near the stormwater outfalls. Toxicity bioassays were performed to determine whether marine biota are being adversely affected by potentially hazardous chemical contaminants transported from the PSF to the San Francisco Bay via groundwater or surface water runoff. Results of the ESAP are integrated into this RI as they relate to RI sites along the San Francisco Bay shoreline.

Other RI Study Areas. Under the Main Installation RI program, the U.S. Army has also investigated the Golden Gate Bridge, Highway, and Transportation District (GGBHTD) Study Area and the Fort Point U.S. Coast Guard Station; the results of these investigations are included in this RI report. However, because GGBHTD and the Coast Guard have been responsible for these areas during the activities which motivated the investigations, the U.S. Army's position is that these two organizations are responsible for evaluating the remedial alternatives and conducting remediation at these sites.

1.2.2 Field Programs and Graphic Overview for This RI

The contract under which this RI was performed was initially between USAEC and R.L. Stollar and Associates Inc. (RLSA). The USAEC contract was transferred in 1990 to Watkins-Johnson Environmental, Inc. (WJE) when that company acquired RLSA. On January 1, 1995, Dames & Moore acquired WJE, including the USAEC RI/FS contract. To account for changes in ownership, references in this RI report to previous versions of the RI and to supporting documents show RLSA and WJE as the preparers.

To obtain data required to meet the RI objectives, three field programs were conducted under the RI. Each field program's activities and results are referred to in this report as the Initial RI, Supplemental RI, or Follow-on RI. The following sections list the study areas for each field program and briefly describe the investigation. These descriptions are followed by a graphic overview of the sites investigated in each field program.

1.2.2.1 Initial RI Field Program

The Initial RI field program, which was conducted in 1990, included the following study areas and sites:

- Nike Facility
- Crissy Field Study Area, including Fill Site 7
- Building 900s Series Study Area
- Directorate of Engineering and Housing (DEH) Study Area
- Main Post Study Area, including Buildings 215, 231, and 1151
- Fill Sites and Landfills
- Miscellaneous Sites, including Buildings 662, 680, 1244, and 1351; Fort Point Coast Guard Station (FPCGS); Lobos Creek; and Mountain Lake.

The locations of these sites are shown in Figure 1.2-1.

The investigations of these sites were conducted according to the Technical Plan prepared by E.C. Jordan Company (ECJC) (1990a), which presents the rationale, approach, and proposed program. the following plans:

- Final Sampling Design Plan (SDP) (ECJC, 1990b)
- Final Quality Control Plan (QCP) (ECJC, 1990c)
- Draft Final Supplement to the Quality Assurance Plan (QAP) (RLSA, 1990)
- Accident Prevention and Safety Plan (ECJC, 1990d).

1.2.2.2 Supplemental RI Field Program

In response to identified data deficiencies, the Supplemental RI field program was conducted in 1992. The Supplemental RI field program included three new study areas:

- GGBHTD Study Area

- Baker Beach Study Area
- Battery Howe/Wagner.

The data collected in the new study areas are presented in Sections 11, 12, and 13 of this RI report.

Under the Supplemental RI field program, additional data were also collected from all of the previously studied areas with the exception of the Main Post Study Area, Fill Site 6, and several of the Miscellaneous Sites (see Figure 1.2-1). The additional data have been incorporated into each of the study area results sections. Furthermore, a survey of the magazines and coastal fortifications was conducted to evaluate the condition of the structures and assess the potential for residues of explosive material. The survey results have been submitted as a draft report to USAEC for review. Additional sampling in support of the FS was also conducted under the Supplemental RI field program.

The Supplemental RI Field program was developed after PAs were completed (RLSA, 1992a). The procedures followed in the Supplemental RI field program are described in the Sample Design Plan (RLSA, 1992e), the Quality Control Plan (RLSA, 1992c), and the Accident Prevention and Safety Plan (RLSA, 1992f).

1.2.2.3 Follow-on RI Field Program

A third field program, the Follow-on RI, was conducted in 1994 and 1995 to address concerns of the California Environmental Protection Agency (CEPA), NPS, and other parties in response to the Revised Draft Final Remedial Investigation Report, Presidio Main Installation PSF (WJE, 1993a). The specific purpose of the Follow-on RI was to fill technical data gaps that were identified in several of the existing study areas. To address these deficiencies, additional samples were collected in the following study areas and sites:

- Nike Facility
- Crissy Field Study Area
- Building 900s Series Study Area
- DEH Study Area
- Main Post Study Area, including Buildings 231, 1057, 1065, and 1167

- Fill Sites 1, 5, and 6
- Landfills 2, 4, and E
- Transfer Station
- Baker Beach
- Battery Howe/Wagner
- Miscellaneous Sites, including Buildings 662, 1151, 1244, and 1351; FPCGS; and Mountain Lake.

The additional data collected for these areas and sites under the Follow-on RI field program have been incorporated into each of the existing study areas as appropriate.

The Follow-on RI field program also included investigations at 17 new sites. The sites were added to the Follow-on RI field program as a consequence of the following events:

- Review of the Revised Draft Final Remedial Investigation Report, Presidio Main Installation, Presidio of San Francisco (WJE, 1993a)
- An inspection of the PSF including PSF buildings by the U.S. Army and NPS in 1994
- Review of historical facility maps
- Interviews by the NPS (HLA, 1994)
- Review of the Community Environmental Response Facilitation Act (CERFA) Report (TETC, 1994). The CERFA investigation involved the review of existing investigation documents; USEPA, state, and county regulatory records; environmental data bases; and title documents. Interviews and visual inspections of the PSF were also conducted, as were visual inspections and data base searches for surrounding properties.

The new sites include Buildings 267, 286, 287, 302, 633, 669, 920, 1057, 1065, 1167, 1245, 1369, 1388, 1750, two sewer lift stations near the Crissy Field Study Area, and the East of Mason (EOM) site, which is east of the Crissy Field Study Area (Figure 1.2-1). The data collected at these sites are incorporated into Section 14. of this RI report, Miscellaneous Follow-on Sites.

The procedures used in the Follow-on RI field program are described in the Sampling Design Plan (WJE, 1994a) and the Quality Assurance/Quality Control Plan (WJE, 1994b).

1.2.2.4 Graphic Overview of the Study Areas

The boundaries of investigated areas are shown in Figure 1.2-1, which is color coded to indicate the general locations where non-groundwater sampling was performed in each RI field program. To indicate where groundwater sampling was performed in each RI field program, Figure 1.2-1 also provides table.

The map is keyed on geographical and physical features such as buildings, rather than the actual sample locations. For example, in the DEH Study Area, investigations in the vicinity of Building 268 were conducted under the Initial and Supplemental RI, and therefore the building is yellow in Figure 1.2-1. The actual sample locations were outside of the building and are shown in the RI section on the DEH Study Area (Section 7, Figures 7.1-1 and 7.3-1).

1.3 REPORT ORGANIZATION

Volume I (this volume) of the Final Remedial Investigation Report contains the text of the report. It includes sections for the site background, investigative methods, results, Baseline Risk Assessment (BRA), and a reference section. The results sections are organized by study areas. Each study area includes one or more investigated sites grouped by physical similarity, geographic proximity, and the field program in which the sites were added to the RI. The section titles for the RI study areas are as follows:

- Nike Facility
- Crissy Field Study Area
- Building 900s Series Study Area
- Directorate of Engineering and Housing Study Area
- Main Post Study Area
- Fill Sites and Landfills
- Miscellaneous Sites
- Golden Gate Bridge, Highway, and Transportation District Study Area
- Baker Beach Study Area
- Battery Howe/Wagner

- Miscellaneous Follow-on Sites.

The structure of the study area sections varies somewhat because of fundamental differences between study areas; however, the following topics are covered for each RI study area and site:

- Area description
- Sample location rationale
- Geologic setting
- Analytical results
- Results evaluation
- Conclusions.

The remaining seven volumes in this RI report contain information as follows: Volume II contains the tables referenced in Volume I. Volumes III, IV, and V contain the figures referenced in Volume I. Volumes VI through VIII contain supporting documentation for the RI in Appendices A through U.

Appendix A contains field data sheets for the background soils and PSF water supply investigations. Appendices B through L contain the field data sheets for each of the study areas. Appendices M through U contain survey data, results of physical soils testing, geophysical and analytical data, continuous water level monitoring data from the Building 900s Series Study Area, fate and transport information, analytical data collected under an IRA in the Building 900s Series Study Area, results from soil-gas surveys, and quality assurance information for chemical analyses. Appendix U contains the calculation spreadsheets for the BRA.

The following report outline shows section and Appendix titles for all eight report volumes and is included in the introduction section of each volume of this RI report.

1.3.1 Report Outline: Final Remedial Investigation Report Presidio Main Installation, Presidio of San Francisco

The following outline lists the major sections in each of the eight volumes of this RI report.

VOLUME I TEXT

1. Introduction
2. Background
3. Investigation Methods
4. Nike Facility
5. Crissy Field Study Area
6. Building 900s Series Study Area
7. Directorate of Engineering and Housing Study Area
8. Main Post Study Area
9. Fill Sites and Landfills
10. Miscellaneous Sites
11. Golden Gate Bridge Highway and Transportation District Study Area
12. Baker Beach Study Area
13. Battery Howe/Wagner
14. Miscellaneous Follow-on Sites
15. Baseline Risk Assessment
16. References

VOLUME II TABLES

1. Introduction
2. Background
3. Investigation Methods
4. Nike Facility
5. Crissy Field Study Area
6. Building 900s Series Study Area
7. Directorate of Engineering and Housing Study Area
8. Main Post Study Area
9. Fill Sites and Landfills
10. Miscellaneous Sites
11. Golden Gate Bridge Highway and Transportation District Study Area
12. Baker Beach Study Area
13. Battery Howe/Wagner
14. Miscellaneous Follow-on Sites
15. Baseline Risk Assessment

VOLUME III FIGURES SECTIONS 1-5

1. Introduction
2. Background
3. Investigation Methods
4. Nike Facility
5. Crissy Field Study Area

VOLUME IV FIGURES SECTION 6

- Introduction
6. Building 900s Series Study Area

VOLUME V FIGURES SECTIONS 7-15

- Introduction
7. Directorate of Engineering and Housing Study Area
 8. Main Post Study Area
 9. Fill Sites and Landfills
 10. Miscellaneous Sites
 11. Golden Gate Bridge Highway and Transportation District Study Area
 12. Baker Beach Study Area
 13. Battery Howe/Wagner
 14. Miscellaneous Follow-on Sites
 15. Baseline Risk Assessment

VOLUME VI APPENDICES A-F

- Introduction
- A Background/PSF Water Supply
 - B Nike Facility
 - C Crissy Field Study Area
 - D Building 900s Series Study Area
 - E DEH Study Area
 - F Main Post Study Area

VOLUME VII APPENDICES G-Q

- Introduction
- G Fill Sites and Landfills
 - H Miscellaneous Sites
 - I Golden Gate Bridge Highway and Transportation District Study Area
 - J Baker Beach Study Area
 - K Battery Howe/Wagner
 - L Miscellaneous Follow-on Sites
 - M Physical Properties Data
 - N Geophysical Data
 - O Well and Sample Data
 - P Transducer Study
 - Q Fate and Transport Data

VOLUME VIII APPENDICES R-U

- Introduction
- R IRA Data
 - S Soil Gas Data
 - T QA/QC Program
 - U Risk Calculation Spreadsheets

1.3.2 Index of Study Areas, Buildings, and Sites, with Section Numbers

The following index shows where each study area, building, and site is discussed in the RI report. Note, however, that although all listed items are discussed, not all listed items are areas which were investigated in this RI. The index can also be cross referenced with Figure 1.2-1.

For space requirements in the index, and for brevity in the rest of this RI report, the Golden Gate Bridge, Highway, and Transportation District Study Area is abbreviated as GGBHTD Study Area. For the same reasons, the Directorate of Engineering and Housing Study Area is abbreviated as DEH Study Area.

Study Area/Building/Site	RI Report Section
Baker Beach Study Area.....	12. Baker Beach Study Area
Battery Howe/Wagner	13. Battery Howe/Wagner
Bone Yard Area	11. GGBHTD Study Area
Bridge District Area (see GGBHTD Study Area).....	11. GGBHTD Study Area
Building 1029.....	8. Main Post Study Area
Building 1040.....	8. Main Post Study Area
Building 1057.....	8. Main Post Study Area
Building 1065.....	8. Main Post Study Area
Building 1151.....	8. Main Post Study Area
Building 1152.....	8. Main Post Study Area
Building 1153.....	8. Main Post Study Area
Building 1167.....	8. Main Post Study Area
Building 1244.....	10. Miscellaneous Sites
Building 1245.....	14. Miscellaneous Follow-on Sites
Building 1285.....	13. Battery Howe/Wagner
Building 1287.....	13. Battery Howe/Wagner
Building 1351.....	10. Miscellaneous Sites
Building 1369.....	14. Miscellaneous Follow-on Sites
Building 1388.....	14. Miscellaneous Follow-on Sites
Building 1450.....	4. Nike Facility
Building 1451.....	4. Nike Facility
Building 1750.....	14. Miscellaneous Follow-on Sites
Building 201	8. Main Post Study Area
Building 205 (see Sewer Lift Station 2).....	5. Crissy Field Study Area
Building 206	8. Main Post Study Area
Building 207	8. Main Post Study Area
Building 208	8. Main Post Study Area
Building 215	8. Main Post Study Area
Building 228	8. Main Post Study Area
Building 229	8. Main Post Study Area

Study Area/Building/Site	RI Report Section
Building 230.....	8. Main Post Study Area
Building 231.....	8. Main Post Study Area
Building 267.....	7. DEH Study Area
Building 268.....	7. DEH Study Area
Building 269.....	7. DEH Study Area
Building 269.....	7. DEH Study Area
Building 283.....	7. DEH Study Area
Building 285.....	7. DEH Study Area
Building 286.....	7. DEH Study Area
Building 287.....	7. DEH Study Area
Building 293.....	7. DEH Study Area
Building 302.....	14. Miscellaneous Follow-on Sites
Building 609.....	5. Crissy Field Study Area
Building 611.....	5. Crissy Field Study Area
Building 633.....	5. Crissy Field Study Area
Building 634.....	5. Crissy Field Study Area
Building 637.....	5. Crissy Field Study Area
Building 638.....	5. Crissy Field Study Area
Building 640.....	5. Crissy Field Study Area
Building 642.....	5. Crissy Field Study Area
Building 643.....	5. Crissy Field Study Area
Building 645 (see Sewer Lift Station 1).....	5. Crissy Field Study Area
Building 661.....	10. Miscellaneous Sites
Building 662.....	10. Miscellaneous Sites
Building 663.....	10. Miscellaneous Sites
Building 664.....	10. Miscellaneous Sites
Building 665.....	10. Miscellaneous Sites
Building 669.....	14. Miscellaneous Follow-on Sites
Building 680.....	10. Miscellaneous Sites
Building 900s Series Study Area.....	6. Building 900s Series Study Area
Building 920.....	6. Building 900s Series Study Area
Building 923.....	6. Building 900s Series Study Area
Building 924.....	6. Building 900s Series Study Area
Building 925.....	6. Building 900s Series Study Area
Building 926.....	6. Building 900s Series Study Area
Building 927.....	6. Building 900s Series Study Area
Building 929.....	6. Building 900s Series Study Area
Building 930.....	6. Building 900s Series Study Area
Building 931.....	6. Building 900s Series Study Area
Building 933.....	6. Building 900s Series Study Area
Building 934.....	6. Building 900s Series Study Area
Building 937.....	6. Building 900s Series Study Area
Building 949.....	6. Building 900s Series Study Area
Building 950.....	6. Building 900s Series Study Area
Building 973.....	6. Building 900s Series Study Area
Building 974.....	6. Building 900s Series Study Area

Study Area/Building/Site	RI Report Section
Building 976	6. Building 900s Series Study Area
Building 979	6. Building 900s Series Study Area
Building 979 Area	6. Building 900s Series Study Area
Building 991	10. Miscellaneous Sites
Building 992	10. Miscellaneous Sites
Building 993	10. Miscellaneous Sites
Building 994	10. Miscellaneous Sites
Building 995	10. Miscellaneous Sites
Building 996	10. Miscellaneous Sites
Building 997	10. Miscellaneous Sites
Building 998	10. Miscellaneous Sites
Building 999	10. Miscellaneous Sites
Consolidated Motor Pool	5. Crissy Field Study Area
Crissy Field Study Area	5. Crissy Field Study Area
Directorate of Engineering and Housing Study Area	7. DEH Study Area
Disturbed Area 1	12. Baker Beach
Disturbed Area 2	12. Baker Beach
Disturbed Area 3	12. Baker Beach
Disturbed Area 4	12. Baker Beach
Disturbed Area E (see Landfill E)	9. Fill Sites and Landfills
East of Mason	14. Miscellaneous Follow-on Sites
Fill Site 1	9. Fill Sites and Landfills
Fill Site 5	9. Fill Sites and Landfills
Fill Site 6	9. Fill Sites and Landfills
Fill Site 7	5. Crissy Field Study Area
Fill Sites and Landfills	9. Fill Sites and Landfills
Fort Point U.S. Coast Guard Station (FPCGS)	10. Miscellaneous Sites
GGBHTD Study Area	11. GGBHTD Study Area
Graded Area 9	9. Fill Sites and Landfills
Landfill 1 (see Fill Site 1)	9. Fill Sites and Landfills
Landfill 2	9. Fill Sites and Landfills
Landfill 3 (see Transfer Station)	9. Fill Sites and Landfills
Landfill 4	9. Fill Sites and Landfills
Landfill 5 (see Fill Site 5)	9. Fill Sites and Landfills
Landfill 6 (see Fill Site 6)	9. Fill Sites and Landfills
Landfill 7 (see Fill Site 7)	5. Crissy Field Study Area
Landfill 9 (see Graded Area 9)	9. Fill Sites and Landfills
Landfill E	9. Fill Sites and Landfills
Letterman Army Institute of Research	2. Background
Letterman Army Medical Center	2. Background
Lobos Creek	10. Miscellaneous Sites
Main Post Study Area	8. Main Post Study Area
Miscellaneous Follow-on Sites	14. Miscellaneous Follow-on Sites
Miscellaneous Sites	10. Miscellaneous Sites
Mountain Lake	10. Miscellaneous Sites
Nike Facility	4. Nike Facility

Study Area/Building/Site	RI Report Section
Paint Operations Area.....	11. GGBHTD Study Area
POL Area.....	5. Crissy Field Study Area
Sewer Lift Station 1.....	5. Crissy Field Study Area
Sewer Lift Station 2.....	5. Crissy Field Study Area
Silo 1.....	4. Nike Facility
Silo 2.....	4. Nike Facility
Silo 3.....	4. Nike Facility
Transfer Station.....	9. Fill Sites and Landfills
Transformer Area.....	11. GGBHTD Study Area
UST Area.....	11. GGBHTD Study Area
Vehicle Maintenance Area.....	6. Building 900s Series Study Area

2. BACKGROUND

This section presents the history of the PSF and RI study areas, ongoing investigations, demography and land use, and physical setting. This information provides a context for understanding the remainder of the RI Report, particularly the sections on assessing human and ecological risk.

2.1 HISTORICAL BACKGROUND AND STUDY AREAS

The PSF is located in the City of San Francisco, at the northern tip of the San Francisco Peninsula (Figure 1.2-1). The PSF occupies approximately 1,416 acres (ac) and is bounded by San Francisco Bay on the north and the Pacific Ocean on the west. The northern portion of the PSF consists of the Fort Point Historic Site and the Golden Gate Bridge and its toll plaza. On October 1, 1994, the PSF, exclusive of the Golden Gate Bridge area, was irrevocably permitted to the U.S. Department of Interior in accordance with Public Law 92-589, and became part of the Golden Gate National Recreation Area (GGNRA) under the management of the National Park Service (NPS).

The PSF was established in 1776 as a military garrison by the government of Spain. It was formally ceded to the United States from Mexico in 1848. The PSF has served as a mobilization and embarkation point during several overseas conflicts, a medical debarkation center, and a coastal defense for the San Francisco Bay area. Prior to the transfer of the property to the Department of the Interior, the PSF was a multimission installation with various military activities conducted under separate commanders stationed as tenants or satellites on PSF. Industrial operations performed at PSF included maintenance and repair of motor vehicles, aircraft, and base facilities.

For purposes of the Main Installation RI, the PSF has been divided into 11 study areas (Figure 1.2-1), which are listed below.

- Nike Facility
- Crissy Field Study Area
- Building 900s Series Study Area

- DEH Study Area
- Main Post Study Area, which includes Buildings 215, 228, 231, 1057, 1065, 1151, and 1167
- Fill Sites and Landfills, which includes Fill Site 1, Landfill 2, Transfer Station, Landfill 4, Fill Site 5, Fill Site 6, Graded Area 9, and Landfill E
- Miscellaneous Sites, which includes Buildings 662, 680, 1244, 1351, Lobos Creek, Mountain Lake, and the Fort Point U.S. Coast Guard Station (FPCGS)
- GGBHTD Study Area
- Baker Beach Study Area
- Battery Howe/Wagner
- Miscellaneous Follow-on Sites, which includes Buildings 302, 669, 1245, 1369, 1388, 1750, and East of Mason (EOM)

Target sites within the study areas were identified in the Enhanced PA and supplemental evaluations. With the exception of Fill Sites, Miscellaneous Sites, and Miscellaneous Follow-on Sites, the target sites were grouped into study areas on the basis of proximity. A brief description of each study area is presented in the following.

2.1.1 Study Areas

The Nike Facility. Located in the southwestern portion of PSF, the Nike Facility was constructed in 1955 as a launch site for the Nike Ajax missile. No nuclear weapons were stored at this location. The Nike Facility is approximately 11 ac and includes Buildings 1450 and 1451, as well as three missile silos with associated underground facilities. Nike Ajax operations ceased in 1964, and the area has since been used for storage of various supplies and equipment, maintenance of electrical equipment, and administrative offices. A detailed description of the Nike Facility, including analytical results, is in Section 4.0 of this RI report.

The Crissy Field Study Area. Located along San Francisco Bay and the northern boundary of the PSF. The Crissy Field Study Area was used during the early 1900s as an airfield and for aircraft maintenance. Since the 1930s, the area has been used for vehicle and equipment maintenance, materials storage, petroleum oil and lubrication (POL) management, and other

functions including the commissary and the post exchange. The Crissy Field Study Area includes the POL Area, the Consolidated Motor Pool Area, Buildings 609 and 611, two sewer lift stations, and Fill Site 7. A detailed description of the Crissy Field Study Area is in Section 5 of this RI report.

The Building 900s Series Study Area. Located west of the Crissy Field Study Area is the Building 900 Series Study Area. The area has been used since the early part of the century for airplane and vehicle maintenance. Several underground storage tanks (USTs) were located in the area. USTs and associated piping at Building 937 were believed to be the source of free petroleum product apparently floating on the groundwater. Investigations of the area were conducted prior to the initiation of the RI (Stetson Engineers, Inc., 1986, and U.S. Army Environmental Hygiene Agency, 1984). An Interim Remedial Action (IRA) is underway in this area to remove contaminant sources associated with Building 937. Two USTs, soil, and product adjacent to the Building have been removed as part of the IRA. In addition, a pilot-scale program to remove volatile organic compounds and chlorinated solvents from the groundwater was installed in August 1994. A detailed description of the Building 900s Series Study Area, including sampling results, is in Section 6.0 of this RI report. Results of current IRA at the site are addressed in several reports (Watkins-Johnson Environmental, Inc., 1993c, d, e). The report evaluating the effectiveness of the pilot-scale remedial system is in progress.

The DEH Study Area. Located in the northeastern corner of the PSF, the DEH Study Area was used as an administrative, storage, and maintenance facility. It included maintenance garages (Buildings 268 and 283), a print shop (Building 285), and pesticide storage buildings (Buildings 287 and 293). All buildings in the DEH Study Area have been demolished by the NPS in preparation for planned reuse of the area. Sampling results and a detailed description of the DEH Study Area are presented in Section 7.0 of this RI report.

The Main Post Study Area. Located in the east-central portion of the PSF, the Main Post Study Area includes Buildings 215, 228, 231, 1057, 1065, 1151, and 1167. Past operations in this area included two gasoline stations, a dry cleaner, and a power plant. Several USTs and associated contaminated soil were removed in the vicinity of Buildings 228 and 231 as

part of the COE UST removal program and earlier installation efforts. An IRA has been implemented at Building 231 to remediate soil and groundwater contamination associated with the UST system. Recent operations in the study area include a tire store, a car wash, a restaurant, and a bank. Sampling results and a detailed description of the Main Post Study Area are in Section 8.0 of this RI report.

Fill Sites and Landfills. Several fill sites and landfills have been identified at the PSF through a review of historical information and aerial photographs (Argonne National Laboratory, 1989). The majority of these fill sites are small and located in upland portions of the PSF. Documentation of materials disposed at each site is limited. Based on current investigations, regular use of the fill sites and landfills was discontinued prior to 1982. Post-closure plans have not been prepared for these sites. A transfer station for solid waste generated at the site was initially referred to as Landfill 3 based upon the Enhanced PA. It is now referred to as the Transfer Station. A detailed description of the fill sites and landfills, including sampling results, is in Section 9.0 of this RI report.

Miscellaneous Sites. Several locations where field investigations were conducted during the Initial and/or Supplemental RIs were not readily placed in any of the study areas discussed previously. These locations have been grouped into the Miscellaneous Sites. Locations include an automobile hobby shop (Building 662), a transformer storage area (Building 680), a field printing plant (Building 1244), a vehicle maintenance shop (Building 1351) and the FPCGS. Surface-water investigations conducted at Mountain Lake and Lobos Creek also are included as part of the Miscellaneous Sites. A detailed description of Miscellaneous Sites investigations and sampling results are in Section 10.0 of this RI report.

The Golden Gate Bridge, Highway and Transportation District Study Area. The Golden Gate Bridge, Highway and Transportation District (GGBHTD) Study Area is a portion of land at the southern end of the Golden Gate Bridge. This area was permitted to the GGBHTD from the U.S. Army in the early 1930s and was included in the recent property transfer to the Department of Interior. The GGBHTD now leases the property and continues to use it as headquarters for bridge operations and maintenance facilities. The U.S. Army conducted no operations in the permitted area during this period. An evaluation of current

and historical waste management practices at the GGBHTD identified four main areas to be evaluated: Bone Yard, transformer, UST, and Paint Operations areas. A detailed description of the GGBHTD Study Area, including sampling results, is in Section 11.0 of this RI report.

The Baker Beach Study Area. The Baker Beach Study Area consists of four disturbed areas west of Lincoln Boulevard along the Pacific Ocean. The disturbed areas consist of fill material and debris from road construction and erosion control deposited from the top of the cliffs overlooking the Pacific Ocean. The areas were intermittently active from 1946 to 1973. A detailed description of the Baker Beach Study Area, including analytical results, is in Section 12.0 of this RI report.

The Battery Howe/Wagner Study Area. The Battery Howe/Wagner Study Area consists of the vicinity of the former mortar battery. The contents of the fill associated with battery construction were suspected to contain debris fill and other unknown constituents. A detailed description of the Battery Howe/Wagner Study Area, including analytical results, is in Section 13.0 of this RI report.

Miscellaneous Follow-on Sites. Several locations were added to the RI/FS in response to regulatory and public comments on the Revised Draft Final version of the RI (Watkins-Johnson Environmental, Inc., 1993a). Where appropriate, the new locations were incorporated into the existing RI study areas described above. Locations that were not readily placed into one of the existing study areas have been grouped into the Miscellaneous Follow-on Sites. Miscellaneous Follow-on Sites include a pesticide storage area (Building 302), incinerator disposal site (Building 669), flammable material storage area (Building 1245), a firing range (Building 1369), an above-ground storage tank (AST) site (Building 1388), a motor pool (Building 1750), and EOM. Detailed descriptions and analytical results for each of these locations are in Section 14.0 of this RI report.

2.1.2 Areas Excluded from the RI

The Letterman Army Institute of Research (LAIR) and Letterman Army Medical Center (LAMC) are not included in the RI/FS because the Enhanced PA determined that they neither required additional characterization nor represented a significant potential for future

chemical releases. This conclusion was confirmed by subsequent sampling in the area by the NPS (Dames & Moore, 1995a). A brief summary of the use and decommissioning of these facilities and the investigation by the NPS follows.

Activities at the LAMC (located in Building 1100 and surrounding 1000 series buildings) included medical and dental care, environmental health services, and occupational health services to active and retired military personnel and their families. LAMC also provided veterinary services. The main LAIR facility was Building 1110, completed in 1976, and adjacent 1000 series buildings. The mission of LAIR was to conduct general military research in the areas of nutrition, dermatology, infectious diseases, effects of military lasers, and experimental psychology. Chemical or biological warfare research were never conducted at the facility.

There were two Nuclear Regulatory Commission (NRC) licenses for the use of radioactive materials, one for LAMC and one for LAIR. Decommissioning of these facilities and termination of the NRC licenses was handled by the U.S. Army in accordance with 10 CFR 30.36. Decommissioning work performed included disposal of radioactive materials and byproducts and a certification of disposal; removal of radioactive contamination to levels As Low as Reasonably Achievable (ALARA); and a survey for radioactive materials.

Decontamination of the LAIR facility included:

- Cleaning all lab areas (including drawers, cabinets, closets, etc.) following decontamination procedures certified by researchers to remove any materials that were used.
- Monitoring for mercury vapors and checking all standard laboratory sinks for mercury residues. The traps of several sinks that had traces of mercury were removed and disposed of as hazardous wastes.
- Cleaning and closing the perchloric acid fume hoods.
- Decontaminating the veterinary lab. The fume hood was sterilized and shipped to a facility in Texas.

Additional environmental investigations of the LAMC and LAIR facilities were conducted by the NPS. Phase I of their investigations included site reconnaissance; records search;

interviews with owners, occupants, and former employees; and a review of available documents. NPS conclusions were that the integrity of the wastewater system was uncertain and that sampling of groundwater was needed to satisfy concerns of prospective tenants/lenders and to establish a baseline groundwater quality. Phase II included installation and sampling of eight monitoring wells (MW-1 through MW-8). Samples were analyzed for inorganics, volatile organic compounds (VOC)s, semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), gross alpha/beta radiation, and gamma radiation. In addition, four soil samples (Borings B-1, B-2, MW-6, and MW-8) and four discrete groundwater samples (Borings B-1, B-2, B-3, and B-4) were collected and analyzed for VOCs and tentatively identified compounds (TICs).

Sample locations and analytical results from the NPS investigations at LAMC and LAIR are included in Appendix A and summarized in this section. There were no detections of VOCs or TICs in the soil or discrete groundwater samples, except for one TIC detection of 1,2,4-trimethylbenzene at 5.7 µg/kg in the soil sample and one chloroform detection of 45 µg/L in the groundwater sample from Boring B-2. Groundwater samples from monitoring wells had few detections of organic compounds. Chloroform was detected in one well (Well MW-3), bis(2-ethylhexyl)phthalate in three wells (Wells MW-1, MW-2, and MW-3), and diethylphthalate in one well (Well MW-2). These three compounds are common laboratory contaminants. Several other SVOCs were detected, but at concentrations below drinking water standards. Organochlorine pesticides, PCBs, TPH-diesel (TPH-D), and TPH-gasoline (TPH-G) were below the reporting limit in all groundwater samples. Inorganic detections above drinking water maximum contaminant levels (MCLs) were aluminum, chromium (total), iron, manganese, and nickel in unfiltered samples. Concentrations of these constituents were all below MCLs in the associated filtered samples. Gross alpha, gross beta, and the gamma scan results were all below MCLs.

2.2 DEMOGRAPHY AND LAND USE

The PSF lies within the 46.4 square mile (mi²) area of the City and County of San Francisco. According to the 1990 census results, the population of San Francisco was 723,959 in 1990, which is a 6.6-percent increase from the 1980 population. The densely populated Richmond

District, a residential neighborhood of one- and two-family houses, is located along the southern boundary of the PSF. The densely populated Marina District of the city is located along the eastern boundary of the PSF.

The NPS currently reports that 256 residences on the PSF are occupied by military personnel and 77 residences are occupied by persons who are employed by either the NPS or organizations with an NPS relationship. The commissary and main exchange are currently in operation. The Officers' Club is currently being used as a community hall.

The PSF, when under the U.S. Army's jurisdiction, was open to civilians, with numerous trails and roads used extensively by the public for hiking, bicycling, and other forms of recreation. The NPS continues to allow recreational use of the PSF. The City and County of San Francisco built and operates the 6-ac Julius Kahn Public Playground along the southern boundary of the PSF. The Presidio Golf Course is currently open to the public. Prior to the transfer of the PSF to the NPS, the 100-ac Baker Beach area, located along the northwest portion of the PSF, and 45 ac of the northern beach (Crissy Field Study Area) adjacent to the San Francisco Bay, were permitted to the GGNRA. Approximately 11.5 ac of the PSF at the southern end of the Golden Gate Bridge, consisting of toll plaza roadway and equipment and maintenance areas was permitted to the GGBHTD by the U.S. Army.

2.3 PHYSICAL SETTING

Information about the physical setting of the PSF provides a basis for understanding additional data collected during the RI, the relationships among that data, and the significance of the data for risk assessment. This section describes physical characteristics of the PSF, including the following :

- Meteorological conditions
- Topography
- Surface-water hydrology
- Regional geology
- Regional groundwater hydrology
- Hydrogeology of groundwater areas

- Regional groundwater chemistry
- Water supply and use.

2.3.1 Meteorological Conditions

The Pacific Ocean and San Francisco Bay have a strong influence on the climate of the PSF. The temperature is moderate; winter months are characterized by rain and mild temperatures, and spring is usually sunny and mild. Fog often occurs in summer when warm, moist air is cooled by cold ocean water along the coast.

Prevailing winds are from the north and northwest. The mean wind speed is 8.7 miles per hour (mph) based on data recorded between 1951 and 1964 at Mission Dolores (Ruffner, 1985). Gale force winds associated with Pacific storms of short duration may occur.

The nearest weather station is located near Mission Dolores in the Mission District of San Francisco, approximately 3 mi southeast of the PSF site. The climatological data provided by this station is for 1951 through 1980 (Ruffner, 1985). Based on this 30-year record, the mean annual temperature is 56.7 degrees Fahrenheit (°F), with the warmest mean monthly temperatures of 59.6°F, 62.4°F, and 61.6°F occurring in August, September, and October, respectively. Mean minimum temperatures range from 46.2°F in January to 55.8°F in September, and mean maximum temperatures range from 56.1°F in January to 68.9°F in September. The daily relative humidity varies from 66 to 85 percent according to data recorded from 1951 to 1972.

Precipitation averages were computed using 43 years of data from 1951 to 1994 from the Mission Dolores weather station. The average annual rainfall is 19.5 inches (in). Ninety percent of the rainfall on the San Francisco area occurs from November to April, which averages a total of 17.5 in. During the remainder of the year, May through October, the average rainfall is 2.0 in. (Figure 2.3-1). A comparison of selected precipitation data for Mission Dolores weather station is presented in Table 2.3-1.

2.3.2 Topography

Elevations at the PSF range from sea level along the northern and western boundaries to approximately 400 feet (ft) above Presidio lower-low water (ft-PLL). The topographic high point is located adjacent to the Presidio Golf Course in the south-central portion of the PSF. The topography of the PSF is shown on Figure 2.3-2.

The northern area along San Francisco Bay is a flat low-lying area developed on fill material. Before filling operations of the early 1900s, much of this area consisted of interior marshlands with a sand spit. In contrast, the western boundary along the Pacific Ocean is very steep with slopes of about 50 percent. Baker Beach, at the base of these steep slopes, is a relatively narrow strip of land. The interior portions of the PSF, including the eastern and southern boundaries, are characterized by gently rolling to hilly topography. Slopes in the western half of the PSF are typically about 20 percent. Slopes in the eastern half, where most buildings are located, are typically about five percent.

2.3.3 Surface-Water Hydrology

Surface water from the PSF drains to the San Francisco Bay or to the Pacific Ocean. There are few perennial surface-water features at the PSF. The only stream with significant perennial flow is Lobos Creek, which flows along the PSF's southern boundary and drains into the Pacific Ocean (Figure 2.3-2). Mountain Lake is located near the southern boundary of the PSF, within the upper reaches of the Lobos Creek drainage. El Polin Spring is located in the southeastern portion of the PSF and flows to a nearby storm drain which drains to the San Francisco Bay. Stormwater runoff from developed portions of the installation is collected by a system of swales and storm drains and routed to the Pacific Ocean or the San Francisco Bay.

Several surface-water divides cross the PSF and delineate groundwater basins. The principal divide separates the drainage between San Francisco Bay (Marina groundwater basin) and the Pacific Ocean (Lobos Creek Groundwater Basin and Coastal Bluffs Groundwater Basin) (Figure 2.3-2). The Lobos Creek drainage comprises a significant portion of the Pacific Ocean drainage on the PSF.

Flow in Lobos Creek is derived principally from groundwater. Approximately 85 percent of the surface drainage area that flows to Lobos Creek is located in the City and County of San Francisco south of the PSF. Except during periods of rainfall and runoff, discharge of Lobos Creek is relatively uniform. Historical flow measurements in the vicinity of Lincoln Boulevard have ranged from 1.2 to 2.1 million gallons per day (gpd) (Nolte & Associates, 1993). No sanitary sewers are known to discharge to Lobos Creek. A storm-drain line originating near Building 1794 may discharge into Lobos Creek approximately 800 ft upstream from where the creek discharges to the ocean. Nearly all water in Lobos Creek is diverted to the PSF water treatment plant when it is in operation. The PSF water plant is located in the 1770 series of buildings in the extreme southwestern portion of the site. Lobos Creek water that is not diverted at the water plant is released to the Pacific Ocean. Section 10.6 of this RI report provides a detailed description of the hydrology and water quality of Lobos Creek.

Mountain Lake is located east of the former Public Health Service Hospital (PHSH) property, adjacent to Park-Presidio Boulevard (Figure 2.3-2). Topographic maps indicate that the average surface elevation of Mountain Lake is approximately 130 ft-PLL. The maximum depth of the lake is approximately 15 ft (ANL, 1989). Surface runoff and groundwater seepage are the sources of water to Mountain Lake. At normal stage, Mountain Lake does not discharge directly to Lobos Creek. Water leaves Mountain Lake primarily by groundwater seepage and evaporation. A detailed description of Mountain Lake, including its water quality, is provided in Section 10.7 of this RI report.

2.3.4 Regional Geology

This section describes the geologic units at the PSF and summarizes its structural setting. The surface geology of the PSF is shown in Figure 2.3-3. This discussion of regional geology incorporates RI results and information from other sources.

Much of the PSF is covered by unconsolidated deposits of sand, silt, and clay. These unconsolidated deposits overlie the geologically complex Franciscan Formation, an assemblage of mafic volcanic rocks, metamorphic rocks, graywacke sandstone, shale, and

siltstone. Artificial fill deposits are present at numerous locations, particularly along the San Francisco Bay.

Elevations of the PSF bedrock surface, based upon RI results and other information sources, are shown on a bedrock structure contour map (Figure 2.3-4). Figure 2.3-5 indicates the traces of two cross sections that extend across the site and shows the locations of all RI soil borings and monitoring wells. The two cross sections (Figures 2.3-6 and 2.3-7) illustrate the geology in the major RI study areas at the PSF.

Soil units defined and mapped by the U.S. Soil Conservation Service (SCS) (Kashiwagi and Hokholt, 1985) are discussed for each RI site in sections 4.0 through 14.0 of this RI report. The SCS soil units are referenced in this RI report because they provide information on soil ecological characteristics. The SCS soil units do not necessarily correspond to the geologic units used in this RI report to characterize the PSF's hydrogeology and contaminant occurrences.

The following sections describe each of the geologic units identified at the PSF.

2.3.4.1 Franciscan Formation

The Franciscan Formation is exposed along much of western California. The rocks of the Franciscan Formation have been through multiple episodes of folding and shearing. The age of this geologic unit ranges from Late Jurassic which is about 155 million years before present (mybp) to Late Cretaceous, about 80 mybp (Schlocker, 1974).

In the San Francisco area, the Franciscan Formation consists of an approximately 10,000-ft thick sequence of predominantly graywacke sandstone, with shale, siltstone, radiolarian chert, and altered ultramafic rocks (predominantly serpentinite) (Schlocker, 1974). In some locations, the lithology may consist predominantly of altered ultramafic intrusives. Along the western boundary of PSF minor outcroppings of Franciscan chert, shale, sandstone and greenstone (basalt) occur as cliffs along the Pacific Ocean. Outcrops in the rest of the installation consist primarily of serpentinitized ultramafic intrusives and coherent blocks of hard rock (silica-carbonate) in a matrix of sheared shale and serpentine. Serpentinite

metamorphic rock is the principal rock type that underlies the unconsolidated sedimentary units that cover much of the PSF.

Serpentinite consists of altered and unaltered pyroxene (MgSiO_3) and olivine $[(\text{Mg, Fe}) \text{SiO}_4]$. Alteration of pyroxene and olivine minerals formed the fibrous serpentine minerals and clays. Trace minerals in the serpentine include magnetite (Fe_2O_3), nickel-bearing kaolinitic clays (nontronite $[\text{H}_4\text{Fe}_2\text{SiO}_9]$) and chromite ($\text{FeO Cr}_2\text{O}_3$) as small veinlets, masses and weathering rinds.

The semi-quantitative chemical composition of the serpentinite and associated nontronite are greater than 10 percent by weight silica and magnesium, and 7 percent by weight iron. Trace element concentrations include nickel (.3 percent) and chromium (.07 percent) (Schlocker, 1974), suggesting that natural background concentrations of nickel and chromium in overlying soils are relatively high.

The Colma Formation is present in the southern and southeastern part of the PSF, where it rests unconformably on the Franciscan Formation. The Colma Formation consists of unconsolidated fine to medium sand with moderate amounts of silt and clay. The unit is believed to have been deposited in estuarine and coastal environments during the Pleistocene epoch, 0.01 to 1.6 mybp (Schlocker, 1974). Generally yellow to reddish brown, in some locations the formation has a gray to black hue. Data on the thickness of the Colma Formation are limited because few wells penetrate the entire unit. Observed thickness is approximately 80 ft in the Landfill E vicinity, but maximum thickness may reach 300 ft (Schlocker, 1974). The Colma Formation consists principally of locally derived rock fragments (25 to 60 percent), quartz (10 to 70 percent), and feldspar (5 to 20 percent). Heavy minerals make up approximately 10 to 25 percent of the sand grains. The heavy-mineral constituents consist mainly of ferro-magnesium silicates, with pyroxene and hornblende being the major constituents. Trace minerals include the following:

- 2 to 6 percent sphene (Ca, TiSiO_5)
- 1 to 6 percent monazite $[(\text{Ce, La})\text{PO}_4]$
- 2 to 3 percent ilmenite (TiO)
- 1 to 13 percent magnetite (Fe_2O_3)

- 2 to 3 percent chromite (Fe, Cr₂O₃).

Minor mineralogical constituents comprising less than 1 percent of the heavy mineral suite were also identified (Schlocker, 1974).

2.3.4.2 Dune Sand

Dune sand forms the surficial deposits throughout most of the southwestern and central PSF. These deposits consist of highly permeable and well-sorted sand typically characterized as fine- to medium-grained. The thickness of surficial dune sand deposits typically is less than 100 ft (Schlocker, 1974). Dune sands in the area consist principally of locally derived rock fragments (10 to 40 percent), quartz (25 to 30 percent) and feldspar (35 to 60 percent). Heavy minerals make up approximately 15 to 28 percent of the sand fraction. The heavy mineral suite is similar to that of the Colma Formation, consisting of pyroxene, hornblende, and the following:

- 2 to 6 percent sphene
- 0.5 to 3 percent monazite
- 7 to 22 percent ilmenite
- 1 to 13 percent magnetite
- 2 to 22 percent chromite.

The dune sands are likely derived from modern beach deposits along the San Francisco Bay and Pacific Ocean shorelines and the Colma Formation.

2.3.4.3 Slope Debris and Ravine Fill

Slope debris and ravine fill form the surficial deposits in upland areas north and east of areas covered by dune sand. These deposits consist of angular rock fragments in a matrix of sand, silt, and clay. The deposits are generally derived from underlying bedrock. In many areas the unit is thin; however, maximum thickness in valley bottoms may be as much as 150 ft (Argonne National Laboratory, 1989).

2.3.4.4 Beach Deposits

Beach deposits and artificial fill form the surficial deposits along San Francisco Bay and at Baker Beach along the Pacific Ocean (Schlocker, 1974). Beach deposits consist of well-

sorted, medium- to coarse-grained sand with some gravel. These deposits are found to be up to 85 ft thick, as indicated in soil boring LF7SB01.

2.3.4.5 Bay Muds

Interbedded within the beach deposits along San Francisco Bay are bay mud layers consisting of organically-rich silty and sandy clay. These bay muds are not surficial deposits on the PSF, so they do not appear on Figure 2.3-3; however, they act as aquitards and confining layers in portions of the site and are pertinent to the discussion of the geology. Two bay mud layers were encountered within approximately 35 ft below ground surface (bgs) in the Fill Site 7 Area and the Building 231 Area (Figure 2.3-6). These bay muds were deposited in the Holocene epoch up to 10,000 years before present (ybp) (Helley and Lajoie, 1979) and are designated young bay mud for purposes of discussion.

An older bay mud layer (hereafter designated old bay mud) that may correspond to Pleistocene age deposits indicated by Helley and Lajoie (1979) was encountered at 85 ft bgs in the Building 231 area. This clay layer was vertically continuous for at least 37 ft and may correlate to deeper clays encountered at similar depths below the Crissy Field Study Area (Figure 2.3-5).

Helley and Lajoie (1979) described the depositional environments of bay muds as “primarily brackish- to salt-water marshes along margins of the bay and in coastal lagoons, similar to the environment that existed the in the Crissy Field area in 1851.” According to Helley and Lajoie, the depositional environments of bay muds also include “...tidally exposed mudflats and beneath the shallow waters of the bay.”

2.3.4.6 Structural Setting

Regional geology of the PSF has been altered substantially by faulting and related structural activity. Situated between two major fault systems, the San Andreas and Hayward/Rodgers Creek, the PSF is located within an active seismic region. The San Andreas fault zone is a major structural feature in California. The fault is located approximately 7 mi to the west of the PSF. The PSF straddles the Fort Point-Potrero Hill-Hunters Point shear zone (Figure

2.3-8). This major shear zone extends to the northwest and southeast of PSF. Evidence of faulting on PSF has been observed only in consolidated bedrock.

2.3.5 Regional Hydrogeology

Three groundwater basins and four groundwater areas have been delineated at the PSF and are shown in Figure 2.3-2. The groundwater basins and groundwater areas shown in Figure 2.3-2 are consistent with those designated by the California Regional Water Quality Control Board in Order No. 96-070, which addresses site cleanup requirements for petroleum impacted soils (California Regional Water Quality Control Board, 1996).

The PSF has been divided into three groundwater basins—the Marina, Lobos Creek, and Coastal Bluffs—based on the primary drainage divides where bedrock topography, which generally follows surface topography, divides groundwater flow in the unconsolidated geologic units that overlie bedrock. Groundwater areas, as defined here, are areas where groundwater occurs which may meet the criteria established in RWQCB Resolution No. 89-39 for evaluating whether groundwater is reasonably expected to constitute a resource for domestic or municipal water supply.

According to Resolution 89-39, groundwater may be excluded as a groundwater resource if any of the following criteria are met.

- Total dissolved solids (TDS) concentrations exceed 3,000 milligrams per liter (mg/L).
- Groundwater does not provide sufficient flow to a well to support an average, sustained yield of 200 gallons per day (gpd).
- Groundwater is contaminated either by natural processes or by human activity, that can not be reasonably treated for domestic use using either Best Management Practices or best economically achievable treatment practices.
- An aquifer is regulated as a geothermal energy-producing source or has been exempted administratively pursuant to Title 40 of the Code of Federal Regulations (CFR), Section 146.4 for underground injection.

Marina Groundwater Basin, which flows to the San Francisco Bay, comprises the West Valley Groundwater Area, the Northeastern Groundwater Area, and the Crissy Field

Groundwater Areas. The Crissy Field Groundwater area includes the low lying area along the San Francisco Bay, where the bedrock surface is generally below sea level, sea water intrusion is evident, and tidal fluctuations affect groundwater levels. The boundaries of the West Valley Groundwater Area and the Northeastern Groundwater Area, shown in Figure 2.3-2, were drawn based on an interpretation of the extent of saturated material overlying bedrock in these upland areas. The boundaries of these two areas do not necessarily indicate the extent of areas which meet the groundwater resource criteria listed above, especially the 200 gpd sustainable yield criterion, given the fact that definitive well yield testing has not been performed in these areas. In addition, the sustainable yield from wells depends, in part, on saturated thickness which varies with wet and dry seasons. Thus, the exact boundaries of areas capable of any specific sustainable yield would not remain constant.

The Lobos Creek Groundwater Basin, which flows to the Pacific Ocean, contains the Lobos Creek Groundwater Area. The boundary of the Lobos Creek Groundwater area shown in Figure 2.3-2 is taken from the California Regional Water Quality Control Board in Order No. 96-070 because sufficient data to interpret the extent of saturated material above bedrock are not available.

The Coastal Bluffs Groundwater Basin occupies the remainder of the PSF along the Pacific Ocean. This basin includes Baker Beach and the steep slopes that face the Pacific Ocean. The slopes are very steep in this part of the PSF with thin accumulations of unconsolidated materials overlying bedrock. Under these conditions, the occurrence of water-saturated conditions in the unconsolidated material is expected to be limited to thin saturated zones in small areas. No specific groundwater areas were identified in the Coastal Bluffs Groundwater Basin during the RI investigation. A perennial seep occurs in the Baker Beach Study Area along the bluffs in Disturbed Area 1 (DA-1). This feature is termed a seep rather than a spring because it emanates from a broad area and consistently shows a very small flow. The flow from this seep has been visually estimated to be less than 1 gallon per minute at the point where it flows over bedrock outcrop at the edge of the beach. The Baker Beach Study Area is described in further detail in Section 12 of this RI report.

A summary of groundwater occurrence and movement at the PSF and a discussion of the hydraulic characteristics of the geologic units are discussed in the following sections. Groundwater occurrence and movement within each of the four groundwater areas are described in Section 2.3.6.

2.3.5.1 Groundwater Occurrence and Movement

Groundwater at the PSF occurs in the unconsolidated sedimentary units that overlie relatively impermeable bedrock. The groundwater investigation at PSF was limited to these unconsolidated deposits. A potentiometric surface map of first encountered groundwater at the PSF is shown on Figure 2.3-2.

Groundwater recharge at the PSF primarily occurs as infiltration and percolation from precipitation and irrigation water. Groundwater discharge primarily occurs as seepage to surface water bodies, including Lobos Creek, Mountain Lake, the Pacific Ocean, and San Francisco Bay. Groundwater also discharges to several springs and seeps at PSF. El Polin Spring is a perennial spring located in the southeastern part of the PSF. A perennial seep is located near the Pacific Ocean in the Baker Beach area in Disturbed Area 1. A spring has been reported at the location of well LF8GW05. Well LF8GW05 is actually a dewatering sump which is used to prevent groundwater from seeping into the basement of Building 1801. An ephemeral spring occurs in response to wet seasons at Landfill 2. Other ephemeral springs may occur at other locations at the PSF, however, they are not well known because they apparently were not flowing when RI sampling teams were in the field and no documentation on other springs is available. Locally, underground utilities such as water lines and storm and sanitary sewers may affect groundwater recharge and discharge, however, the sewer and water distribution systems have recently been upgraded and no instances of underground utilities affecting groundwater recharge or discharge are known.

In areas where groundwater data were not available, the potentiometric contours shown in Figure 2.3-2 were extrapolated, to a reasonable extent, into the vicinity of study areas or regions pertinent to the RI characterization. For example, in the West Valley Groundwater Area, depths to first water in boreholes were used to aid in estimating the potentiometric surface in an area where groundwater data were lacking. Potentiometric contours were not

extrapolated into areas where the presence of groundwater was highly suspect or into regions not pertinent to the investigation. For example, near the Lobos Creek Groundwater Area, potentiometric contours were not extrapolated extensively into regions east and west of the Nike Facility. The area west of the Nike Facility does not contain sites pertinent to this investigation. However, because groundwater flow patterns at the PSF do not always follow surface topography, topographic data were not used to extrapolate potentiometric contours. Potentiometric contours were also not extrapolated extensively to the region east of the Nike Facility because gradients interpreted from groundwater elevation data indicate that groundwater from the Nike Facility does not appear to flow into this eastern region.

In general, groundwater in the unconsolidated units in the PSF occurs as a laterally discontinuous unconfined water-bearing zone that locally may be comprised of several unconsolidated geologic units. Exceptions to this generalization occur in several upland sites, where first groundwater is confined within the Colma Formation, and in the Crissy Field and Building 231 Study Areas, where bay mud deposits act as aquitards and confining layers.

The saturated zone within the unconsolidated sediments is relatively thin or absent near the groundwater basin divide areas and thickens toward San Francisco Bay and the Pacific Ocean. The saturated zone is particularly thick (greater than 40 ft) in the tidal zone of the Building 900s Series, Crissy Field, and DEH Study Areas, where the bedrock surface dips steeply toward the bay (Figure 2.3-4). Large upland areas near the groundwater basin divides are unsaturated or have no permanent water table. These large upland areas may accumulate temporary pockets of groundwater due to infiltration of precipitation and irrigation water. A continuous, extensive water table zone, as is found in the Lobos Creek and El Polin Spring areas, does not occur in the groundwater basin divide areas. Examples of isolated pockets of shallow groundwater occur in the GGBHTD where a very small, isolated, thin saturated zone was identified during the RI and at Landfill 4 where the only groundwater encountered was in a 1-ft thick confined zone downgradient of the landfill (Well LF4GW03).

In general, groundwater movement within the unconsolidated deposits is controlled by bedrock surface topography. For example, flow between groundwater areas, such as the

Northeastern Groundwater Area, the West Valley Groundwater Area, and the Lobos Creek Groundwater Area, is prevented by bedrock highs which physically separate these areas (Figures 2.3-2, 2.3-4, and 2.3-7). However, in the lowlands near San Francisco Bay, groundwater from the Northeastern and West Valley Groundwater Areas flows into the Crissy Field Groundwater Area (Figure 2.3-2) due to the configuration of the bedrock surface (Figure 2.3-4).

Groundwater flow directions generally mimic the unweathered bedrock surface (Figure 2.3-2 and 2.3-4). Surface topography does not always reflect the unweathered bedrock surface. Surface flow, therefore, does not always indicate groundwater flow direction. For example, in the Fill Site 1 area, groundwater flow is toward the northeast while the surface topography would suggest a more northerly groundwater flow direction.

The understanding of groundwater flow in bedrock is limited because the RI field program was directed toward characterizing groundwater in unconsolidated deposits that would be more directly affected by potential contaminant releases at the PSF. No evidence is known which suggests that downward migration of site-related contaminants, by way of groundwater, extends into the relatively impermeable units of the Franciscan Formation at sites addressed in this RI. One of the three bedrock wells on the northeast bank of Mountain Lake (used for irrigation of the Presidio Golf Course), installed to a depth of 155 ft in the sheared Franciscan Formation, yields large quantities of water, 180 gallons per minute (gpm) (Nolte & Associates 1993). This well (316) is further discussed in Section 10.7 and shown on Figure 10.6-3. The other wells were noted to produce 200 to 350 gpm. However, these wells may draw shallow groundwater from both the water table aquifer zone and ultimately Mountain Lake, as indicated by a test well in the vicinity that was installed in the Colma Formation (to a depth of 75 ft) by the NPS (Nolte & Associates, 1993).

2.3.5.2 Hydraulic Characteristics of Geologic Units

Hydraulic conductivity of the geologic units at the PSF has been estimated by conducting instantaneous rising-head (slug) and bailer tests, and by analyzing water level changes that result from tidal fluctuations. Results of these tests are summarized in this section and in the

RI report for the PHS (RLSA, 1992d). The following two sections summarize hydraulic characteristics of bedrock and unconsolidated geologic units.

Bedrock Units. The Franciscan Formation comprises the bedrock at the PSF. Hydraulic conductivity in the Franciscan Formation depends on the geometry and interconnection of fractures and faults and, therefore, is very site specific. Mapping the structural features of the Franciscan Formation is difficult because unconsolidated deposits overlie the Franciscan Formation throughout most of the PSF. Where the Franciscan Formation is highly sheared (Schlocker, 1974), such as near the Presidio Golf Course, hydraulic conductivity may be very large, possibly in excess of 500 ft/day. Otherwise, hydraulic conductivity is likely to be very low and the Franciscan Formation may act as a relatively impermeable barrier to groundwater flow due to the non-porous nature of intrusive units and to the fine-grained nature of clastic units of the formation.

Unconsolidated Units. Several aquifer tests have been conducted in the Colma Formation at the PSF. Three rising head tests at Landfill 8 were conducted in three separate wells that were screened in the Colma Formation, which has variable lithology (RLSA, 1992d). These tests resulted in hydraulic conductivity estimates of 1.6×10^{-1} ft/day, 2.6×10^{-2} ft/day, and 1.5 ft/day. The two wells with relatively low values penetrated material with relatively large amounts of fine sand, silt, and clay, while the well with a relatively large hydraulic conductivity value penetrated mostly dune sand.

No aquifer tests have been conducted solely in the dune sand at the PSF. Well drilling at Landfills 4 and Fill Site 5 indicates that in many upland areas the dune sand is unsaturated. Where saturated, the hydraulic conductivity of dune sand probably exceeds that of the Colma Formation.

Efforts to estimate hydraulic conductivity of beach sands were concentrated in the Building 900s Series Study Area. Bailer tests were conducted. Water level changes that result from tidal fluctuations were analyzed and are discussed in Section 6.0 of this report. Based on these results, hydraulic conductivity of beach sand deposits is estimated to range from 30 to 150 ft per day where the sand is well sorted and silt and clay content is minimal. Hydraulic

conductivity of mixed sand, silt, and clay deposits, typical of deposition in tidal-flat environments, is likely to be at least an order of magnitude smaller.

2.3.5.3 Estimated Well Yields

Estimates of well yield were calculated for inland RI sites where data were available. These estimates are provided to give perspective on areas which may meet the groundwater resource requirement of 200 gpd well yield referenced in California Resolution 89-39. Although sites in the Crissy Field Groundwater Area could have well yields in excess of 200 gpd, well yields were not estimated because of the large saturated thicknesses and sandy lithologies. Calculations for estimating well yield are based on water level drawdown and/or water level recovery data collected during well development and groundwater sampling events from 1992 through 1995. This information was recorded on standard well development data sheets, groundwater sampling field data sheets, or in field logbooks used by sampling personnel. The data sheets are included in this RI in appendices corresponding to the RI sites.

During well development, water was removed from the well typically until it was dewatered. The well was allowed to recover for a measured time interval; then it was dewatered again, and the volume of water removed was recorded. To calculate the well yield, the volume of water removed was divided by the length of time between dewatering events. This type of estimate is not as definitive as a slug test or long-term pumping test because the field measurements are not as strictly controlled and the nature of the stress on the saturated zone is not as well known. For example, because these measurements were recorded on wells that were being developed, rather than fully developed, the well may not be in optimal hydraulic connection with the saturated zone. However, these estimates do give a rough indication of well yield.

During the purging or sampling collection phases of groundwater sampling, data were collected by measuring water levels at recorded time intervals as the well recovered after being dewatered. The water level measurements and well dimensions were used to calculate the volume of water that entered the well. That volume was divided by the time interval to calculate a yield rate. This type of estimate also gives a rough estimate of well yield, but is

not as definitive as slug tests or long-term pumping tests for many of the same reasons as those stated in the preceding paragraph for well development data.

Results of individual well yield calculations are shown in Table 2.3-2. Summary statistics grouped by well and site are shown in Table 2.3-3. The results show average estimated well yields of less than 200 gpd for Battery Howe/Wagner, the Nike Facility, and Landfill 2. Average estimated well yields greater than 200 gpd are found for Fill Site 1, Building 231, and Landfill E. Again, these estimates are approximate relative to more comprehensive testing techniques; however, the results may indicate that some of these sites are not located in areas where groundwater would meet the well yield criterion to be considered a drinking water resource. The well yield estimates are discussed in the descriptions of groundwater areas in the following section of this RI report.

2.3.6 Beneficial Use and Hydrogeology of Groundwater Areas

The San Francisco Regional Water Quality Control Board (SFRWQCB) has adopted a revised Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) which defines beneficial uses and water quality objectives for waters of the State, including surface waters and groundwaters (SFRWQCB, 1995). According to the Basin Plan, the PSF is located in the San Francisco Sands Groundwater Basin, and beneficial uses of groundwater include the following:

- Industrial process water supply
- Industrial service water supply
- Surface water replenishment
- Municipal and domestic supply.

The State has refined these designated beneficial uses for groundwater in each of the basins and groundwater areas defined at the PSF (SFRWQCB, 1996). The PSF groundwater basins and areas and their respective beneficial uses are listed as follows:

Groundwater Basin/Area	Beneficial Use
<u>Lobos Creek Groundwater Basin</u> Lobos Creek Groundwater Area	Municipal Surface Water Ecological
<u>Coastal Bluffs Groundwater Basin</u>	Municipal Recreational Surface Water Ecological
<u>Marina Groundwater Basin</u> West Valley Groundwater Area	Municipal Surface Water
Northeastern Groundwater Area	Municipal Recreational Surface Water Ecological
Crissy Field Groundwater Area	Municipal (low probability for future use) Recreational Surface Water Ecological

Municipal use, as applied here, means the use of groundwater as a source of drinking water for human consumption. Future use of groundwater for municipal water supply in the Crissy Field Groundwater Area was designated "low probability" by the State because sea water intrusion could reach water supply wells, even in areas currently not affected by sea water intrusion. Surface water and groundwater have been used as municipal water supply in the Lobos Creek Groundwater Area. Although not currently in use, the recently upgraded water plant near the mouth of Lobos Creek could be used to purify surface and groundwater to supply potable water to the PSF.

According to the State, the existing beneficial uses of groundwater at PSF include protection of surface water beneficial uses due to groundwater discharge/seepage to the bay and freshwater bodies including Mountain Lake, Lobos Creek, and Tennessee Hollow Corridor. To characterize the interrelationships among specific sites on the PSF, the hydrogeology and beneficial uses of each of the four groundwater areas is summarized in the following

sections. Detailed characterizations of specific sites are included in Sections 4 through 14 of this RI report.

2.3.6.1 Lobos Creek Groundwater Area

The Lobos Creek Groundwater Area includes, or may be affected by, the Nike Facility, Landfill 8, Graded Area 9, Mountain Lake, and Building 1750. Landfill 8 was characterized in the PHSR RI report and is not evaluated in this RI report (RLSA, 1992d). The locations of the sites evaluated in this RI report are shown on the Regional Cross Section Location Map (Figure 2.3-5). The geology and water levels through portions of this groundwater area are shown in Regional Cross Section B-B' (Figure 2.3-7). The potentiometric contours of first groundwater encountered in the area are shown in Figure 2.3-2. The following discussion of groundwater occurrence in this area progresses from upgradient sites to downgradient sites and summarizes potential interrelationships among the sites.

Groundwater Occurrence in the Nike Facility. Groundwater in the northwest part of the Nike Facility occurs as a relatively thin (approximately 2-ft) layer in dune sand, perched on clayey Colma Formation deposits. This thin saturated zone may be seasonal and could be a result of the heavy rains which occurred in the winter of 1994-95. Farther downgradient, in the southern and eastern portions of the site, groundwater is generally unconfined within clayey Colma Formation deposits.

Groundwater Occurrence at Mountain Lake. Downgradient of the Nike Facility, in the Landfill 8 vicinity, groundwater is unconfined in clay, sand, and silt mixtures within the Colma Formation. Just downgradient of Landfill 8, groundwater also flows through the overlying dune sand deposits and intercepts the ground surface at monitoring well LF8GW05. In the Mountain Lake vicinity, groundwater is unconfined within silty sand deposits of the Colma Formation.

Groundwater Occurrence at Building 1750. Groundwater in the vicinity of Building 1750 was not encountered in the dune sand deposits that were penetrated to a maximum depth of 12 ft bgs. However, groundwater is thought to occur beneath the site at a depth of approximately 25 to 30 ft bgs, based on inferred potentiometric contours on Figure 2.3-2. It

is not known whether the Colma Formation is present beneath the dune sand, as it is in upgradient areas. Bedrock occurs at approximately 50 ft bgs; therefore, the estimated saturated thickness of the water-bearing unit at this site is at most 25 ft. Groundwater is probably under unconfined conditions, as at Graded Area 9 and the Nike Facility.

Groundwater Flow Between Sites. It is reasonable to assume, barring any unknown subsurface barrier, that groundwater from the Nike Facility vicinity has the potential to flow into the Landfill 8 vicinity. This groundwater has the potential to eventually flow southeast, towards Mountain Lake and southwest towards Lobos Creek, Building 1750, and the PSF potable supply well field. Mountain Lake and Lobos Creek both appear to be discharge areas from the groundwater basin.

Summary and Evaluation of Beneficial Uses. Groundwater at the most upgradient portions of Nike Facility occurs as a thin layer in dune sand overlying Colma Formation deposits. Further downgradient in the Nike Facility, groundwater occurs in the Colma Formation and flows into the Landfill 8 vicinity and potentially into the Mountain Lake vicinity, extending into the overlying dune sand in some places. Groundwater from Landfill 8 may also flow towards Building 1750. Groundwater below these sites may eventually flow into Lobos Creek and into the vicinity of the potable well field.

Beneficial uses to be protected in the Lobos Creek Groundwater Area include municipal water supply, surface water replenishment, and the ecological conditions of Mountain Lake and Lobos Creek.

2.3.6.2 West Valley Groundwater Area

The West Valley Groundwater Area includes the RI sites of Battery Howe/Wagner and Buildings 662, 669, 680, and 1245. Upgradient of this area, sites where no significant groundwater was found include the Transfer Station, Landfill 4, Fill Site 5, and Buildings 1244, 1351, and 1369. Locations of these sites, both in the area and upgradient of it, are shown on Figure 2.3-5, Regional Cross Section Location Map. The geology and water levels through a portion of this groundwater area are shown in Regional Cross Section B-B' (Figure 2.3-7).

Groundwater Occurrence. Unconfined groundwater was encountered in the slope debris and ravine fill and unconsolidated weathered bedrock deposits in the Battery Howe/Wagner vicinity. The extent of this groundwater is limited to the southeast portion of the Battery Howe/Wagner Study Area (Figures 2.3-2 and 2.3-7). Unconfined groundwater was encountered in dune sand in soil borings 662SB08 and 669D (near Buildings 662 and 669 respectively), which are approximately 1,500 ft downgradient and to the east of Battery Howe/Wagner.

Groundwater Flow Between Sites and Into Other Areas. The potentiometric contours on Figure 2.3-2 suggest that groundwater in weathered bedrock and the slope debris and ravine fill beneath Battery Howe/Wagner could be in communication with groundwater encountered downgradient in the dune sand in the area of Buildings 662 and 669.

Figure 2.3-2 also indicates that groundwater from the West Valley Groundwater Area flows downgradient into the Crissy Field Groundwater Area towards the FPCGS and in the vicinity of the Building 900s Series and Crissy Field Study Areas. It is interpreted that groundwater in the dune sand beneath Buildings 662 and 669 flows into the Crissy Field Groundwater Area. The interpretation of groundwater flow in this area also indicates that groundwater in the vicinity of Battery Howe/Wagner likely flows to the Building 662 and 669 vicinity, and then has the potential to flow into the Crissy Field Groundwater Area, towards the FPCGS and the Building 900s Series and Crissy Field Study Areas. As shown on Figures 2.3-2 and 2.3-7, direct flow of groundwater from Battery Howe/Wagner to the Building 900s Series region appears to be blocked to the northeast by unsaturated clay deposits and bedrock highs.

Summary and Evaluation of Beneficial Uses. Groundwater occurs in the slope debris and ravine fill and unconsolidated weathered bedrock deposits in the Battery Howe/Wagner vicinity and possibly flows downgradient to groundwater encountered in dune sand in the vicinity of Building 662. It appears that groundwater in the West Valley Groundwater Area flows downgradient into the Crissy Field Groundwater Area towards FPCGS and in the vicinity of the Building 900s Series and Crissy Field Study Areas.

Beneficial uses to be protected in the West Valley Groundwater Area include municipal water supply and surface water replenishment. However, the development of municipal water supply in the West Valley Groundwater Area would be inadvisable regardless of any contamination associated with the RI sites because the area is urbanized, groundwater is shallow, sanitary sewers are present, and requirements for surface sanitary seals in water supply wells would likely extend through and block most or all of the saturated zone.

2.3.6.3 Northeastern Groundwater Area

The Northeastern Groundwater Area includes Fill Site 1, Landfill 2, and Landfill E in the uplands region to the south; Fill Site 6, downgradient to the northeast; and Main Post sites including Building 215, a portion of Building 231, and Buildings 1057, 1065, 1151, and 1167. The Building 231 site actually overlaps onto both the Northeastern Groundwater Area and the Crissy Field Groundwater Area. The locations of these sites are shown on Figure 2.3-5, Regional Cross Section Location Map. The geology and water levels through portions of this groundwater area are shown in Regional Cross Section A-A' (Figure 2.3-6). The potentiometric contours of first groundwater encountered in the area are shown in Figure 2.3-2. The following discussion of groundwater occurrence in this area generally progresses from upgradient sites to downgradient sites and summarizes potential interrelationships. Sample depths at Buildings 1057 and 1151 were shallow and entirely within the unsaturated zone; therefore, these sites are excluded from the following discussion of groundwater occurrence.

Groundwater Occurrence at Fill Site 1 and Landfill 2. Fill Site 1 and Landfill 2 are situated in the same vicinity within a subsurface bedrock valley. Landfill 2 is slightly upgradient and cross gradient of Fill Site 1. These sites are located in a region referred to as Tennessee Hollow (Dames & Moore, 1995).

Groundwater is not present in unconsolidated materials in the upper reaches of Landfill 2 at boring LF2GW05 (Figure 2.3-6). The highest occurrence of groundwater at Landfill 2 is found at the base of the Colma Formation in a sand and gravel unit confined by clayey materials (LF2GW04). Groundwater downgradient of Landfill 2 intersects the ground

surface at El Polin Spring. Groundwater beneath Fill Site 1 is unconfined within silty sands of the Colma Formation.

Groundwater Occurrence at Landfill E. Landfill E is situated in a subsurface bedrock valley to the northwest of Fill Site 1 and Landfill 2 (Figure 2.3-4) and is also part of Tennessee Hollow. Groundwater in the upper reaches of the valley is confined near the bottom of the Colma Formation, just above bedrock (DAEGW06). Groundwater further downgradient is unconfined within sandy portions of the Colma Formation.

Groundwater Occurrence at Fill Site 6. Groundwater beneath the Fill Site 6 vicinity, downgradient of Tennessee Hollow, is unconfined and encountered within sand and silty sand deposits of the Colma Formation.

Groundwater Occurrence at Building 231. In the Building 231 vicinity groundwater occurs in three water-bearing zones (designated shallow, intermediate, and deep). The water-bearing zones are primarily beach sand deposits separated from each other by layers of young bay mud, which are laterally continuous throughout the area. The shallow and intermediate water-bearing zones and their respective underlying young bay mud layers comprise approximately the first 30 ft bgs. The deep water-bearing zone extends to 86 ft bgs where an old bay mud layer, at least 35 ft thick, was encountered (231SB26). The shallow zone is unconfined. The intermediate and deep zones are under confined conditions.

Groundwater Occurrence at Building 1065. In the Building 1065 vicinity groundwater was encountered in interlayered beach sand and young bay mud deposits. No wells were installed in this area, but it appears that the uppermost saturated zone is unconfined. It is uncertain if the young bay mud layers are continuous with those found in the Building 231 vicinity or acting as confining layers.

Groundwater Occurrence at Building 1167. In the Building 1167 vicinity groundwater was encountered in beach sand deposits and artificial fill. No wells were installed in this area, but it appears that first groundwater is unconfined. Borehole depths at this site were shallow and it is uncertain if the young bay mud layers found in the Building 231 vicinity are present.

Groundwater Occurrence at Building 215. Beneath the Building 215 vicinity, unconfined groundwater was encountered in sand, silty sand, and clayey sand deposits of the Colma Formation. The interlayered beach sand and young bay mud deposits encountered at the Building 231 site do not extend into this vicinity.

Groundwater Flow Between Sites and Into Other Areas. Groundwater from the Fill Site 1 and Landfill 2 region do not appear to be directly connected to the Landfill E region. Unsaturated clays and a bedrock ridge separate these two regions (Figures 2.3-2 and 2.3-6). As indicated by the potentiometric contours shown on Figure 2.3-2, groundwater from these two regions apparently converges downgradient of Landfill E. Barring any unknown subsurface bedrock high, it is reasonable to assume that groundwater from the Fill Site 1 and Landfill 2 region and the Landfill E region can eventually flow downgradient, through the Colma Formation and undivided surficial deposits, into the Main Post region.

Groundwater from the Northeastern Groundwater Area appears to flow downgradient toward sites in the Crissy Field Groundwater Area. As indicated on Figure 2.3-2, groundwater beneath Fill Site 6 and several Main Post sites including Buildings 1057, 1065, 1151, and 1167, has the potential to flow into the beach sand deposits beneath the DEH Study Area of the Crissy Field Groundwater Area. Groundwater from the Landfills 1 and 2 and Landfill E regions has the potential to eventually flow into the Crissy Field region.

The three water-bearing zones encountered beneath the Building 231 site appear to correlate with those found beneath the Crissy Field Study Area. It appears that as groundwater enters the interlayered beach sand and young bay mud deposits beneath Building 231 and Crissy Field Study Area, some of it becomes confined below the bay mud layers. The extent of these three water-bearing zones in the Crissy Field Groundwater Area is discussed in section 2.3.6.4.

Summary and Evaluation of Beneficial Uses. Groundwater occurs in the Colma Formation in the upland sites Fill Site 1, Landfill 2, and Landfill E. Groundwater appears to flow downgradient from these sites, through Colma Formation deposits, into the Main Post Study Area. Some groundwater becomes confined as it flows into the interlayered beach sand and

bay mud deposits near Building 231. Groundwater from these interlayered deposits and the Colma Formation flows into the Crissy Field Groundwater Area.

Beneficial uses to be protected in the Northeast Groundwater Area include municipal, recreational, surface water replenishment, and ecological. The development of municipal water supply in the Northeastern Groundwater Area would be inadvisable regardless of any contamination associated with the RI sites because the area is urbanized, groundwater is shallow, and sanitary sewers are present. Recreational use would apply to recreational users of the PSF who may come in contact with surface water at El Polin Spring or surface water that could flow in the planned restoration of the Tennessee Hollow riparian habitat. Groundwater in the Northeastern Groundwater Area replenishes surface water flow for a distance of about 100 ft at El Polin Spring. This flow then enters a storm drain which ultimately empties in to the Bay. Depending on the configuration of the restored riparian habitat, groundwater could also replenish surface water flow and support the flora and fauna of that habitat.

2.3.6.4 Crissy Field Groundwater Area and Sea Water Intrusion

The Crissy Field Groundwater Area includes the following study areas and investigation sites from west to east: the Building 900s Series Study Area, FPCGS, Crissy Field Study Area, EOM, DEH, and a portion of the Building 231 area. The water table contours of the Crissy Field Groundwater Area are shown on Figure 2.3-9. Groundwater occurrence, flow, and sea water intrusion in the Crissy Field Groundwater Area are discussed below.

Groundwater Occurrence at Crissy Field Study Area. The hydrostratigraphic units encountered below the Crissy Field Study Area appear to be laterally continuous and several units appear to extend into the Building 231 vicinity. Four water-bearing zones were identified below the Building 637 vicinity in the Crissy Field Study Area (Montgomery Watson, 1995d). The three uppermost water-bearing zones are beach sand deposits separated from each other by two layers of young bay mud (similar to those found at the Building 231 Site). These two young bay mud layers appear to be laterally continuous between the northern coastal portion of Crissy Field Study Area and the Building 637 area to the south. They also appear to be laterally continuous between Crissy Field Study Area and

the Building 231 area as shown on Figure 2.3-6. The lateral continuity of these layers between the Building 637 portion of the Crissy Field Study Area and the Building 231 site is uncertain. Continuity appears to be disrupted by Colma Formation deposits encountered in the vicinity of Building 215. (See Building 215 location in Figure 1.4-1 and Colma Formation in Figure 2.3-3.)

The two uppermost water-bearing zones, designated A1 and A2 respectively by Montgomery Watson (1995d), and their corresponding underlying young bay mud layers, occur within the first 30 ft bgs. These two zones appear to correspond to the shallow and intermediate zones identified in the Building 231 vicinity. A deeper water-bearing zone, designated unit B, extends to 81 ft bgs, near the center of the Crissy Field Study Area (Boring LF7SB01), and may correspond to the deep water-bearing zone found in the Building 231 vicinity. An old bay mud layer was encountered below unit B. This old bay mud may correspond to those found in other borings and to the old bay mud layer encountered in the Building 231 vicinity. A fourth water-bearing zone, unit C, consisting of a silty sand of undetermined thickness, was encountered just below this old bay mud layer. Montgomery Watson (1995d) has characterized unit A1 as unconfined, unit A2 as semi-confined, and unit B as confined.

Groundwater Occurrence in the Building 900s Series Study Area and FPCGS Site.

Groundwater beneath the Building 900s Series Study Area and the FPCGS is unconfined and occurs in beach deposits consisting mostly of sand. The young bay mud layers encountered in the Crissy Field Study Area do not appear to extend west, beneath the FPCGS site or the Building 900s Series Study Areas. Lithologic data in the FPCGS is limited to approximately 30 ft bgs; it is unclear whether the old bay mud layer found beneath Crissy Field Study Area is present beneath the site. This old bay mud layer is not present below the Building 900s Series Study Area. Groundwater from the West Valley Groundwater Area enters the Crissy Field Groundwater Area near the southeast boundary of the Building 900s Series Study Area (Figure 2.3-2).

Groundwater Occurrence in the EOM Site and DEH Study Area. Similar to the Building 900s Series Study Area and the FPCGS, groundwater encountered below the EOM site and DEH Study Area is unconfined and occurs in beach deposits consisting mostly of

sand. Continuous lithologic data are not available below 10 ft in the EOM site; it is unclear whether the young bay mud layers encountered in the Crissy Field Study Area extend east, beneath the EOM vicinity. These young bay mud layers do not extend into the DEH Study Area. Deep lithologic data are limited; it is unclear whether the old bay mud layer found beneath Crissy Field Study Area exists beneath either the EOM site or DEH Study Area. Groundwater from the Northeastern Groundwater Area enters the southern portions of these sites.

Groundwater Flow Between Sites. Water-bearing zones beneath the various sites in the Crissy Field Groundwater Area appear to be in hydraulic communication with each other. That is, there do not appear to be any barriers to inhibit lateral groundwater flow between sites. However, groundwater below each site generally flows towards the Bay, not laterally along the coast between study areas. Tidal fluctuations do affect the direction of groundwater flow to a certain degree, especially during periods of low groundwater levels, but flow is generally towards the Bay.

Summary and Evaluation of Beneficial Uses. Groundwater occurs in beach sand interlayered with bay mud deposits in the Crissy Field Study Area. To the northwest and east of Crissy Field Study Area, in the vicinities of Building 900s Series and DEH Study Areas respectively, groundwater occurs in beach sand deposits devoid of interlayered Bay Mud. Groundwater below the Crissy Field Groundwater Area generally flows towards San Francisco Bay.

Beneficial uses to be protected at the Crissy Field Groundwater Area include municipal (with a low probability of use due to the occurrence of sea water intrusion), recreational, surface water replenishment, and ecological. The recreational, surface water replenishment, and ecological uses apply to the San Francisco Bay and to the wetland restoration planned by the NPS because these surface water bodies receive or would receive groundwater from the Crissy Field Groundwater Area.

Sea Water Intrusion in the Crissy Field Groundwater Area. Groundwater beneath the Crissy Field Groundwater Area encompasses the transition zone between groundwater

recharged from upland areas and a sea water intrusion zone influenced by tidal fluctuations. A schematic illustration of the interface of fresh groundwater and saltwater in a coastal region such as the Crissy Field Groundwater Area is shown in Figure 2.3-10. The position and configuration of the typically wedge-shaped freshwater/saltwater interface changes over time. The position and configuration of the interface is governed by the hydraulic gradient which pushes the lower-density fresh water over the higher-density saltwater that is pushed inland by hydraulic gradients driven by the higher density of the saltwater and by tides. The position of the interface changes as each of the opposing gradients vary.

The extent of sea water intrusion is indicated by the distribution of data concerning total dissolved solids (TDS) and electrical conductivity (EC). The data also show that TDS and EC values tend to increase with depth in many areas. To illustrate sea water intrusion and estimate the areal extent of non-potable water beneath the Crissy Field Groundwater Area, the distribution of TDS and EC data is shown in Figures 2.3-11 and 2.3-12 respectively. Chloride, a major constituent of sea water, tends to mimic the distribution of TDS and EC. As discussed in the following sections and in Section 2.3.7, all of these data aid in evaluating groundwater in the Crissy Field Groundwater Area as a potential drinking water source.

Distribution of Total Dissolved Solids. The distribution of TDS concentrations in the Crissy Field Groundwater Area is shown in Figure 2.3-11. TDS data in the Crissy Field Groundwater Area were obtained from shallow monitoring wells in the DEH, Crissy Field, and Building 900s Series Study Areas and in the FPCGS site. TDS data for deep portions of the aquifer are more limited. The central and northwestern portion of the Building 900s Series Study Area contains wells screened in the shallow, intermediate and deep portions of the water-bearing zone. Data from these wells generally indicate an increase in TDS concentrations with depth and significant sea water intrusion. If more TDS data were available from greater depths, a similar pattern showing an increase in TDS concentrations with depth would likely be seen in the DEH Study Area, EOM site, and the southern portion of the Building 900s Series Study Area.

TDS data indicate that a significant portion of the Building 900s Series Study Area and a portion of the Crissy Field Study Area and Fill Site 7 area are underlain by groundwater

exceeding the regulatory standard of 3,000 mg/L TDS for potential municipal and domestic water supplies required by California State Water Resources Control Board Resolution No. 88-63. Most of the Crissy Field Groundwater Area is underlain by groundwater exceeding the California Department of Health Services recommended secondary maximum contaminant level (MCL) of 500 mg/L (Title 22 CCR Article 16 Section 64449). Concentrations lower than the recommended secondary MCL are "desirable for a higher degree of consumer acceptance" for domestic water supplied to the public.

TDS concentrations above the recommended secondary MCL, but within the range of acceptable levels (upper and short-term secondary MCLs) can be considered in compliance for domestic water supplied to the public only under certain conditions. Concentrations at or above 500 mg/L and below the upper secondary MCL, 1,000 mg/L, are acceptable if it is "neither reasonable nor feasible to provide more suitable waters." Concentrations ranging from 1,000 mg/L to the short-term level, 1,500 mg/L, are "acceptable only for existing systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources."

Lines estimating the areal extent of groundwater exceeding the Resolution 88-63 standard of 3,000 mg/L of TDS and groundwater exceeding the recommended secondary MCL of 500 mg/L for TDS are shown on Figure 2.3-11. These isoconcentration lines are based on the highest TDS concentrations observed, regardless of depth. That is, where data from multiple depths were available, such as the Building 900s Study Area, only the highest TDS concentration (usually from the deepest well) was used to draw the isoconcentration lines. The highest values are used because groundwater extraction would likely draw the high TDS groundwater into a water supply well. Groundwater with TDS concentrations exceeding the upper and short-term secondary MCLs would occur between the two isoconcentration lines on the figure.

Distribution of Electrical Conductivity Values. Figure 2.3-12 shows the EC distribution in groundwater within the Crissy Field Groundwater Area. The data were obtained from calibrated field measurements taken during groundwater sampling. The samples were obtained from monitoring wells and by taking discrete (grab) samples at multiple depths. The

grab sample results are extremely useful when discussing sea water intrusion because they augment data from wells and show the distribution of EC values with depth in areas where these data were previously unavailable. The data on Figure 2.3-12 are posted to show the areal and vertical distribution of EC values. The EC data are presented numerically and graphically with bar graphs for each data point.

For certain sites, including the FPCGS, DEH, and Building 900s Series areas, the data clearly indicate wedge-shaped sea water intrusion and a corresponding trend of increased EC with depth. A pattern of increasing EC with depth was absent in the Fill Site 7 site. Instead, the highest EC values tended to be in the intermediate and sometimes the shallowest groundwater samples. The shallow, intermediate, and deep samples generally correspond to the water-bearing units A1, A2, and B, respectively. These water-bearing units are separated by layers of low permeability young bay mud that are absent in other portions of the Crissy Field Groundwater Area. This vertical heterogeneity, compared to the relative homogeneity of the DEH and Building 900s Series Study Areas, likely controls the complex distribution of EC values beneath Fill Site 7. At most locations, only the uppermost portion of water-bearing unit B was sampled. Deeper samples, like that from discrete Sample 637-23a (67 ft bgs), indicate increasing EC in the lower portions of unit B.

The depth of groundwater sampling at the EOM site was limited to 8 ft bgs because the primary focus of the sampling effort was to characterize the nature and extent of potential contaminants. Therefore, the data are insufficient to show the vertical distribution of EC values. If data were available from greater depths, an increase of EC with depth would probably be evident as seen in the adjacent DEH Study Area where EC values from shallow samples are similar.

EC data indicate that a large percentage of the Crissy Field Groundwater Area is underlain by groundwater that exceeds the regulatory standard of 5,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$) EC for potential municipal or domestic water supplies required by California State Water Resources Control Board Resolution No. 88-63. Most of the Crissy Field Groundwater Area is underlain by groundwater that exceeds the California Department of Health Services recommended secondary MCL of 900 $\mu\text{S}/\text{cm}$ (Title 22 CCR Article 16

Section 64449). Concentrations lower than the recommended secondary MCL are “desirable for a higher degree of consumer acceptance” for domestic water supplied to the public.

EC concentrations above the recommended secondary MCL, but within the range of acceptable levels (upper and short-term secondary MCLs) can be considered in compliance for domestic water supplied to the public only under certain conditions. Concentrations at or above 900 $\mu\text{S}/\text{cm}$ and below the upper secondary MCL, 1,600 $\mu\text{S}/\text{cm}$, are acceptable if it is “neither reasonable nor feasible to provide more suitable waters.” Concentrations ranging from 1,600 $\mu\text{S}/\text{cm}$ to the short-term level, 2,200 $\mu\text{S}/\text{cm}$, are “acceptable only for existing systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources.”

The estimated areal extents of groundwater exceeding the Resolution 88-63 standard of 5,000 $\mu\text{S}/\text{cm}$ EC and the recommended secondary MCL of 900 $\mu\text{S}/\text{cm}$ for EC are shown on Figure 2.3-12. Similar to the TDS data, these lines are based on the largest EC values observed, regardless of depth, because of the probability that the saline water would be drawn into a water supply well. That is, where data from multiple depths were available, only the highest EC concentration (often from the deepest sample) was used in the interpretation. Groundwater with EC exceeding the upper and short-term levels occurs between the two isoconcentration lines.

The 5,000 $\mu\text{S}/\text{cm}$ line is extrapolated between the relatively high EC values at the Fill Site 7 site and the relatively high values at the DEH Study Area. The resulting dashed and inferred line includes the EOM area where only shallow EC data, which were below 5,000 $\mu\text{S}/\text{cm}$, were available. It is reasonable to assume that deeper groundwater beneath the EOM site exhibits EC values greater than 5,000 $\mu\text{S}/\text{cm}$ given that the adjoining areas have similar shallow EC values, higher EC values at depth, and a similar distance from the shoreline. This same rationale was used in extrapolating the 900 $\mu\text{S}/\text{cm}$ line between the Building 900s Series and Crissy Field Study Areas.

In the Building 900s Series Study Area, where there were multilevel data available for both TDS and EC, there is a striking similarity between areas with TDS and EC values exceeding

regulatory standards for potential municipal or domestic water supplies (Figures 2.3-11 and 2.3-12). This similarity indicates that the EC and TDS data correlate well in this area.

Conclusion. Use of groundwater below the Crissy Field Groundwater Area as a potable water supply does not appear to be practical. The data indicate that sea water is intruding beneath fresh groundwater in the area. Most of the area appears to contain groundwater exceeding EC regulatory standards for potential municipal or domestic water supplies and recommended secondary MCLs for EC and TDS. If groundwater were consistently pumped from areas or depths not exceeding regulatory standards and water levels lowered, then further degradation of the groundwater, due to increased sea water intrusion, would likely occur. Groundwater in the Crissy Field Groundwater Area is not considered a likely source of potable water.

2.3.7 Regional Groundwater Chemistry

General water quality at the PSF varies with site-specific natural conditions. In some areas, the major ionic character of groundwater is controlled by the degree of sea water intrusion. For example, groundwater in the Crissy Field Groundwater Area, including the DEH, Crissy Field, and Building 900s Series Study Areas changes from magnesium carbonate-magnesium bicarbonate type waters on the inland side to sodium chloride type water on the Bay side as a result of sea water intrusion. Average cation/anion concentrations from wells and surface waters in each of the study areas are illustrated in Figure 2.3-13.

The distribution of chloride ion concentrations generally mimics that of TDS and EC, which are generally elevated in areas affected by sea water intrusion and tend to increase with depth (Section 2.3.6.4). The recommended secondary MCL for chloride is 250 mg/L, which is exceeded in many of the wells in the Crissy Field Groundwater Area. Upper and short-term levels are 500 and 600 mg/L, respectively.

Groundwater quality at RI sites in upland areas including Fill Site 1, Landfill 2, Landfill E, Building 231, and the Nike Facility and Battery Howe/Wagner Study Areas reflects contact with the bedrock (serpentinite) and unconsolidated materials (Colma Formation and dune sand) that underlie the PSF. The waters in these upland areas are predominantly a $MgCO_3$ -

Mg(HCO₃)₂ type reflecting the soluble major ions in these units. As stated in Section 2.3.4, the underlying rock types are magnesium rich (10 percent by weight). Surface waters in Lobos Creek and Mountain Lake are a MgCO₃ - Mg (HCO₃)₂ type similar to that of the PSF water supply wells in the lower Lobos Creek drainage, reflecting their origin as groundwater uninfluenced by sea water intrusion.

Details of the groundwater types and their effect in each of the study areas are included in each of the study area discussions in sections 4 through 14 of this RI report.

2.3.8 Water Supply and Use

Potable water is supplied to PSF by either the PSF water plant or the City and County of San Francisco water supply. The PSF water plant is located near the mouth of Lobos Creek in Building 1773 and the cluster of buildings surrounding building 1773 (Figure 2.3-2).

When the water plant is in operation, nearly 100 percent of Lobos Creek surface-water flow west of Lincoln Boulevard is diverted to the plant. When the plant was in operation in 1993, 90 percent of the PSF water supply was provided by Lobos Creek. The remaining 10 percent of the water supply was from the water supply well field near the plant and water purchased from the City and County of San Francisco.

One water supply well located near the water plant, Well 13, is currently operational (Figure 3.2-3). Seven water supply wells exist at PSF (Nolte and Associates, 1993). Wells 6 and 13 are the water supply wells which have been most recently used for potable water supply and are discussed further in Section 3.2.15. These wells were sampled to confirm suitability as sources of water for equipment decontamination and drilling in the RI field investigation. Analytical results for Lobos Creek and Mountain Lake are discussed in Sections 10.6 and 10.7, respectively.

Water treatment at the water plant includes pre- and post-chlorination, sedimentation, and filtration. The plant has recently been upgraded to meet current regulatory requirements of the State of California Department of Health Services and EPA Safe Drinking Water Act. At the time of this writing, the PSF was using the same water supply as the City of San Francisco, and the PSF water plant was not in operation.

The PSF golf course is irrigated using a separate water supply that takes water from wells adjacent to Mountain Lake. Water from the lake was once used to irrigate the Presidio Golf Course (Dames & Moore, 1994). The supply of irrigation water is augmented with city water during dry periods (Nolte and Associates, 1993).

3. INVESTIGATION METHODS

This section describes the methods used in the performance of the RI. An objective of the RI was to identify areas of the PSF that pose a threat to human health or the environment. To meet this objective potential sources of contamination were evaluated and the possible release mechanisms, migration pathways, and receptors were identified. This information was incorporated into a generalized conceptual model of the site. Using the conceptual model, the field program requirements were established, including the sample media, numbers of samples, collection locations, analyte suites, analytical methods, sample techniques, and data management and QC procedures. After the field program was completed, analytical and other field data were interpreted to verify or modify the conceptual model. Interpretation of the field program results includes assessment of data quality and comparison of the chemical data to ambient and regulatory levels to gain perspective on the meaning of the results. A Baseline Risk Assessment (BRA) was conducted to estimate risks to human health and the environment in specific exposure scenarios identified at the PSF.

The following sections include a description of the site conceptual model which summarizes the potential contaminant sources, migration and exposure routes. Methods used for field investigation, laboratory analyses, data management, quality assurance and quality control are described. Data interpretation criteria are described, including control sample criteria, ambient concentrations of inorganics in soils, and sampling decision criteria. BRA methods, including human health and ecological risk assessment methods, are also described.

3.1 SITE CONCEPTUAL MODEL

The PSF site conceptual model incorporates the potential contaminant sources, which were evaluated during the Enhanced PA (ANL, 1989), the Supplemental RI PA (RLSA, 1992a), and by regulatory agencies and the public in response to previous versions of this RI. Hydrogeologic data, population information, and land use patterns were also used to identify possible migration pathways and routes of exposure. The model provides a framework for understanding sample results in the context of the environmental setting at the PSF. Figure 3.1-1 illustrates the model for human receptors, and Figure 3.1-2 illustrates the model for ecological receptors.

The potential contaminant sources evaluated in the RI can be categorized as fill materials, underground storage tanks (USTs), above ground storage tanks (ASTs), buildings, storage areas, and maintenance areas. Areas containing fill materials include the landfills, fill sites, and graded areas, portions of the Crissy Field Study Area and the other areas along the San Francisco Bay shoreline, Battery Howe/Wagner, Baker Beach, and some of the building sites. Potential release mechanisms associated with these possible sources include surface-water runoff, infiltration of chemicals from the fill material to underlying soils and groundwater, transport of particulates from the surface, or biotic uptake into lower trophic levels.

USTs were investigated under the RI in the Main Post Study Area, in the POL area of the Crissy Field Study Area, at FPCGS, and at Buildings 937 and 1245. Releases from tanks result from leaks from the tank or piping, or spills during filling operations. These mechanisms could release contaminants to the surface or subsurface soils, sediment, surface water, or groundwater.

Buildings and storage and maintenance areas include motor pools in the DEH, Crissy Field, and Building 900s Series Study Areas, and several of the Miscellaneous Sites; ASTs in the FPCGS and Building 1388, storage areas such as the Bone Yard at the GGBHTD, and Buildings 293 and 302, which were used for pesticide storage. Spills or leaks from these potential sources would affect surface soils or generate residues which workers, residents, visitors, or biota could contact.

Following the releases by surface-water runoff, leaks and spills, infiltration and percolation, particulate transport, and biotic uptake, the soils, sediments, surface water, groundwater, plants and invertebrates may become secondary contaminant sources. As shown in Figures 3.1-1 and 3.1-2, releases from these primary and secondary sources could result in migration of potential contaminants through several media including surface water, sediments, air, particulates, groundwater, soil, vegetables and fruits, invertebrates, birds, and mammals. Sampling media, locations, techniques, and analytical suites were selected after considering these potential sources and potential release mechanisms. The sampling program was designed to provide data that could be used to evaluate these sources and migration mechanisms.

Inhalation of fugitive dust is not likely to be a significant exposure pathway for receptors because most sites are either paved or have significant vegetation. However, some sites adjacent to San Francisco Bay (particularly the Crissy Field Study Area) are likely to have paving removed as part of renovations for recreational use. An analysis is provided in this section 15.1.2.3.1 indicating that the inhalation pathway would also be a negligible contributor to risks for site visitors.

3.2 FIELD INVESTIGATIONS

The field investigation methods that were used during the RI are described in this section. These methods were selected to provide adequate data to evaluate the potential sources and chemical release and transport mechanisms developed in the site conceptual model. Samples were collected according to the detailed procedures specified in work plans for the Initial RI field program conducted in fall 1990, the Supplemental RI field program conducted in summer 1992 and the Follow-on RI field program conducted in the fall and winter of 1994-95. The work plans include the Technical Plan (TP) (ECJC, 1990a), SDPs (ECJC, 1990b; RLSA, 1992e; and WJE, 1994a), QCPs (ECJC, 1990c; RLSA, 1992c; and WJE, 1994b), USATHAMA QAP (1990b), and the Accident Prevention and Safety Plan (RLSA, 1992f). An archaeologist reviewed information on all sites to identify possible cultural resources and was present during field activities in sensitive areas. Written procedures were modified in some cases due to field constraints. These modifications are documented in the method descriptions in this section.

The Supplemental RI field program was conducted almost 2 years after the Initial RI field program. Several of the field techniques were modified based on experience gained during the preceding field program and regulatory requirements. The primary modifications adapted at the start of the Supplemental RI field program (aside from the analytical program discussed in Section 3.3) were the use of brass liners for soil sampling and the elimination of headspace analyses and test pit excavations. The wipe sampling procedures were also improved to provide more comparable data.

A significant change in the technical approach for the Follow-on RI, as compared to the previous field programs, was that many of the investigations were phased. This approach

was selected so that the extent of potential COCs would be well defined by the end of a single field program spanning approximately 3 months. Sample locations, targeted media, and analytical suites for the initial phase of each investigation are summarized in Sampling Design Plan for the Follow-on RI (WJE, 1994a). Analytical results and hydrogeologic data gathered during the initial phase were used to assess whether and where additional sampling was warranted. To implement this approach, chemical and spatial criteria for defining the vertical and lateral extent of potential COCs were developed. Each analytical result was compared to pre-established sampling decision criteria (SDC), which are described in detail in the SDP (WJE, 1994a) and Section 3.8 of this RI report. If chemical concentrations in all analytical samples from a location were below the SDC, then the investigation was complete. Additional sampling was considered if one or more of the samples had chemical concentrations in excess of SDCs.

Spatial criteria were developed for soil and groundwater for Follow-on RI sites that were investigated beyond the planned initial phase. For soil, the vertical and lateral extent of chemicals was considered defined when each detection of concern was underlain by one sample in the vertical direction and surrounded by samples in lateral directions in which the concentration of the target analytes were below the SDCs. The spatial criteria for groundwater investigations were two samples in the vertical direction with concentrations below the SDC and one in surrounding lateral directions. Modifications to this approach were sometimes required due to field conditions, such as buildings, auger refusal, sensitive plant habitats, or site hydrogeologic conditions, such as aquitards. The actual sampling locations, depths, and analytical suites and results for each Follow-on RI site are provided in the site specific portions of the RI (Sections 4 through 14). Distinctions between the different sampling events are not made in the text, as the data from all sampling events are integrated to provide a single cohesive description of the nature and extent of potential chemicals of concern within each study area.

3.2.1 Geophysical Survey Methods

This section describes geophysical survey methods used in the RI. Surface geophysical surveys using resistivity and electromagnetic (EM) methods were conducted at Crissy Field and Battery Howe/Wagner Study Areas and Fill Sites 1 and 5, Landfill 4 and Graded Area

9. Resistivity methods were also used at Fill Site 6 and Landfill 2. These areas were identified as disturbed in aerial photographs interpreted by Rindgen and Sitton (1990). The Enhanced PA (ANL, 1989) identified these areas as containing unknown fill materials. The rationale for the use of resistivity sounding and electromagnetic survey methods is described below, followed by a detailed description of each method.

Initial geophysical surveys, using EM and resistivity methods, were conducted to estimate the aerial and vertical extent of the fill and to confirm the locations of the landfills as identified from the aerial photographs. The results of the geophysical survey were also used to guide subsequent subsurface investigation and to identify test pit, soil boring, and monitoring well locations. The EM method was predominantly used to delineate the horizontal extent of fill materials, to detect subsurface anomalies for further investigation, and to determine if sites had buried utilities and were safe for intrusive investigation. Resistivity soundings and information collected in test pits, soil borings, and monitoring wells were used to estimate the vertical extent of fill. The absolute values of conductivity or resistivity of the subsurface materials were not necessarily diagnostic in themselves, but the variations in conductivity or resistivity, laterally and with depth, were used to characterize the subsurface conditions in the fill areas.

Resistivity may be measured by direct introduction of electrical currents through either wires and electrodes (resistivity method), or antennas and electromagnetic induction (EM method). EM measurements are suitable for rapid profiling since no ground contact is required. Resistivity measurements are slower, more accurate and less affected by interference from metal structures and pipes. Both methods are capable of penetrating to 20 ft bgs.

3.2.1.1 Resistivity Sounding Methods

Resistivity sounding provides a means of determining relative vertical changes in subsurface electrical properties. The method involves the introduction of a measured current through a pair of voltage measuring electrodes (Figure 3.2-1); the measured resistivity is a function of the current, voltage, and electrode geometry. The flow of an induced current will be affected by the resistive properties of the subsurface material. For example, homogeneous subsurface conditions will have uniform current flow distribution. The electrical resistivity results for PSF fill areas were calculated in terms of apparent resistivity. Measured values differ from

the true resistivity due to layering of soils with varying electrical properties and electrode geometry.

The resistivity survey was performed using a Gossen Geohm-3 (GG3) instrument, which was calibrated before the start of each field effort. Steel stakes were driven into the ground and used as electrodes. Cables were attached to the stakes and connected to a GG3. Fresh or saline water was poured into the ground to increase the effective electrode contact when excessively dry soils were encountered. The data are recorded in field logbooks.

The electrode configuration was set up using Schlumberger and Wenner methods. In some areas, both methods were used to improve interpretation. Using the Wenner array (Figure 3.2-1), electric potential electrodes (MN) were centered on a line between the current electrodes (AB). An equal spacing ("A" spacing) was maintained between the electrodes. The depth of penetration is related to the "A" spacing. The electrode separation was expanded to increase the depth of penetration. The "A" spacing used in the landfill areas generally ranged from 1 to 40 ft.

Using the Schlumberger array, four electrodes were placed in a straight line in the same order, AMNB, as is used in the Wenner array; however, the spacing between the potential electrodes (MN) was less than or equal to one tenth of the current electrode spacing (AB). The current electrode spacing was expanded to increase the depth of penetration; the spacing generally ranged from 1 to 40 ft. If necessary, the distance between the potential electrodes was also expanded in order to maintain a measurable potential. The Schlumberger array is usually less susceptible to near surface interferences than the Wenner array. However, the Schlumberger array may be sensitive to the surface conditions around the closely spaced inner electrodes. If the surface is not homogeneous near the potential electrodes, the Wenner array may provide more accurate data.

Current was induced into the ground by the two outer electrodes, which were connected by cables to a current source in the GG3. The potential field was measured by the GG3 voltage meter connected at the two inner electrodes.

As a check of data quality, the resistivity values were plotted on a portable computer at the field site. The data plots were inspected, and measurements were repeated as necessary.

Resistivity values were calculated from the measurement of voltage and current between the current and potential electrodes. The resulting data were analyzed using the computer software program RESIX Plus, written by Interpex Limited. This program estimates thicknesses and resistivity values for a layered earth model that is based on the actual data. Lithologic data results from nearby soil borings and trenches were in some cases used to establish layer thicknesses for the computer simulation. The input values were adjusted until an acceptable model was generated. The program iteratively adjusted the model parameters to a lower sum of squared error using a ridge regression inversion (Interpex Limited, 1988). The accepted model approximates subsurface soil conditions.

3.2.1.2 Electromagnetic Survey Methods

EM profiling allows for rapid acquisition of high-density and high-resolution data. The profiling data are used to map subsurface conductivity changes and delineate spatial anomalies resulting from buried metal. EM measurements are taken with hand-carried antennas operating in the audio-frequency range of the ground inductive response. The EM method is susceptible to noise from a number of sources, including lightning, power lines, radio transmitters, pipes, fences, and buried utilities. The instrument is used to record relative changes in conductivity; therefore, field calibration using a standard is not performed.

The EM surveys were conducted using a Geonics EM-31 instrument and a Polycorder Digital Data Recorder. The EM-31 consists of a 12-ft long polyvinyl chloride (PVC) boom with a control panel and analog meter mounted at its center. Circular coils are contained in the PVC boom; the transmitting coil is in one end and the receiving coil in the other. The Polycorder acquires and records survey data from the EM-31, under control of the geophysicist. These data include both the quadrature-phase (conductivity) and in-phase (buried metal detection) components of the induced magnetic field, as well as field information such as survey line number, starting station, increment, mode of measurement, and comments. The EM meter registers conductivity in mmho/m. The conductivity values are digitally recorded by the Polycorder in mS/m, which is equivalent to mmho/m. The values generated by the EM instrument are a composite response of subsurface conditions in the interval from the surface to the effective depth of the instrument, approximately 20 ft bgs.

The resulting conductivity values are more strongly influenced by materials near the surface than by deeper materials. The instrument is affected by the thickness, depth, and specific conductivities of subsurface materials. In general, increased penetration is achieved in dry, rocky or sandy soils, whereas, the higher electrical conductivity of wet, clayey soils usually results in less penetration.

Grids were established with surveyed corners, marked spacings and traverse lines for each EM study location. The EM profiling was accomplished by fixed-depth EM measurements, with the instrument held hip high along a traverse line. Measurements were recorded at stations for a discrete interval. Continuous measurements were also visually observed along the traverse lines using the instrument's analog conductivity scale.

As a field control against instrument drift, an area was selected where readings were noted by the geophysicist before and after the EM survey for each site. Objects that could interfere with the EM survey were noted on a map of the site grid. At stations where interference was suspected, the instrument was rotated through 90 degrees, using the geophysicist as the pivot point.

The computer program DAT31 was used to download the Polycorder data files to a computer, edit the files, and transform the data into a three-dimensional coordinate format that can be contoured (Geonics Limited, 1991). The conductivity data are contoured and analyzed to differentiate the possible locations of contaminated, landfilled, or disturbed materials (anomalous conductivities) from the undisturbed terrain.

3.2.2 Wipe Sampling

This section describes wipe sampling methods used in the RI. Wipe samples were collected from buildings in the Nike Facility, the Crissy Field Study Area, the Building 900s Series Study Area, the DEH Study Area, and at miscellaneous building areas to characterize potential contaminant sources. The potential sources evaluated were interior floors and walls, and outdoor paved areas that were used for chemical or equipment storage. Samples were generally collected from stained areas or other locations on which spilled materials or residues may have accumulated. The percent recovery of a chemical from a surface onto a

wipe sample is indeterminate. Therefore, the results were used to qualitatively evaluate whether chemical residues were present on surfaces.

The general procedures for wipe sampling are to select a sample area of a specific size, moisten a wipe filter paper with an appropriate solvent to dissolve the target chemicals and thoroughly wipe the area with the filter. Results from the wipe samples are reported in $\mu\text{g}/\text{cm}^2$. Water approved by USATHAMA for decontamination was used as a solvent for metals, hexane for pesticides/PCBs, and methylene chloride for SVOCs.

During the Initial RI field program the surface area that was sampled with the wipe filter paper varied depending on the degree of staining and the roughness of the area to be wiped. Wipe areas ranged from approximately 25 square centimeters (cm^2) to 930 cm^2 . The wipe filter paper was placed in a clean glass sample container. During the last month of the Initial RI field program (after November 1, 1990), additional solvent was put into the sample containers at the request of the analytical laboratory, at Buildings 283, 634, 640, 643, 680, 900, 1244 and 1351 to prevent desiccation.

During the Supplemental RI field program, a square template was used to block off the perimeter of each sample area. All sample areas were 100 cm^2 and were wiped with a 25 cm^2 filter paper.

QC for the wipe procedures included filter/media blanks in which a filter was moistened with the solvent and analyzed, and field blanks in which the edges of the template were wiped with a solvent moistened filter paper.

3.2.3 Sediment Sampling

This section describes methods used to sample sediments in the RI. Sediments were sampled to evaluate whether potential contaminants have been transported from potential source areas by surface-water runoff and to assess the distribution of potential contaminants in the drainage pathways. Sediment samples were collected from inside storm drains or catch basins in the Nike Facility, Crissy Field, Building 900s Series, Main Post, GGBHTD, and DEH Study Areas. Sediments were also sampled from Lobos Creek, Mountain Lake, and a seep at Baker Beach.

Samples were collected from storm drains by removing the drain grate and collecting the accumulated sediment. During the Initial RI field program, sediment was removed from the storm drain with a stainless steel spoon or a trowel. When necessary, samples were placed in a stainless steel bowl and homogenized prior to placement in a glass sample container. This was done quickly to minimize loss of volatile chemicals. Sediment samples collected from Lobos Creek and Mountain Lake were grab samples acquired directly with the sample jar. During the Supplemental and Follow-on RIs, samples were collected in brass liners, unless the sediment layer was too thin. In these cases, samples were collected with a stainless steel spoon and placed in glass jars or brass liners. A Teflon sheet and a plastic cap were placed over the end of the tube to minimize volatilization. Following collection, sample labels were attached to each sample container. Samples were stored in chilled coolers and shipped to the analytical laboratory according to chain-of-custody (C-O-C) procedures.

3.2.4 Borehole Drilling

This section describes borehole drilling methods used in the RI. Two methods were used for drilling boreholes during the Initial and Supplemental RI field programs. Four additional methods were used during the Follow-on RI. For shallow boreholes, and in areas with limited access, hand augers or hand operated power augers were used for drilling. Truck mounted hollow-stem auger (HSA) and mud-rotary drilling rigs were used to drill deeper boreholes for monitoring wells and to collect soil and discrete groundwater samples. Geoprobe sampling and cone penetrometer testing (CPT) were also used to obtain soil samples and discrete groundwater samples. Details on the sampling methods used during drilling are presented in Section 3.2.5. Prior to drilling, local utility companies were contacted, PSF basic information maps were checked, and in some locations an EM survey was conducted or a commercial underground utility locating service was utilized to assure that underground utilities and other subsurface structures were not present at the drilling location. The following sections provide detailed descriptions of drilling methods used in the RI.

3.2.4.1 Hand-Auger Drilling

The hand augers used for drilling were 2- and 4-in diameter, 6-in long stainless steel bucket augers attached to an extension pipe with a T-handle. Boreholes were drilled by applying downward pressure to the T-handle and rotating the auger. The tool was pulled from the hole

at approximately 6-in. intervals to remove the soil cuttings from the auger bucket. In general, hand-augered boreholes ranged from 2- to 6-ft deep within the unsaturated zone. Upon completion of drilling, boreholes were generally backfilled with grout or bentonite.

3.2.4.2 Power-Auger Drilling

Power-auger boreholes were drilled to the desired sample depth with a gasoline-powered steel auger. Soil cuttings are carried up the auger to the ground surface, eliminating the need to remove the tool from the hole while drilling, as is necessary with the hand auger. After reaching the desired sample depth, the augers were removed and soil samples for chemical analysis were collected using a hand driven core sampler lined with brass tubes. Upon completion of drilling, boreholes were backfilled with grout or bentonite. Generally, power-augered boreholes ranged from 2 to 6 ft deep and did not penetrate the saturated zone.

3.2.4.3 Hollow-Stem Auger Drilling

Three types of truck-mounted HSA rigs were used for drilling soil borings and installing monitoring wells: Mobile B-53, Mobile B-61, and a CME-55. A track mounted Rhino all terrain HSA rig was used in areas difficult to access with conventional truck mounted rigs. The drill crew consisted of a California-licensed driller and driller's helper, and was supervised by a hydrogeologist under the direction of a California-registered geologist. The responsibilities of the hydrogeologist included directing field activities and sample collection, documenting field procedures, and describing and recording lithology. During drilling, the ambient air above each borehole and in the breathing zone of on-site personnel was monitored by health and safety personnel. A photo ionization detector (PID) was used to monitor VOC vapors and a combustible gas indicator was used to monitor for explosive conditions in the borehole. During the Initial RI field program, a PID was used to help select samples for VOC analysis. During the Supplemental and Follow-on RIs, samples to be analyzed for VOCs were prescribed in the work plans.

Boreholes were initially advanced using a finger-type drill bit attached to a 6.5-in outside diameter hollow-stem auger. During the Initial RI field program, samples for lithologic description were collected at 5-ft intervals with a split-spoon or continuously with a 5-ft core barrel advanced ahead of the lead auger. Only the continuous sampler was used during the

Supplemental RI and Follow-on RI. The auger and sampler combinations were selected to obtain relatively undisturbed soil samples for lithologic description from discrete depths, identify saturated zones, detect stained zones, and acquire samples for laboratory analysis.

Flowing sands were encountered while drilling in the Building 900s Series and Crissy Field Study Areas, and Landfill E site. If necessary, the HSA was filled with approved water to prevent sands from flowing into the auger. If the pressure head created by the water was insufficient, a mixture of bentonite Fluidville-Mud II and water was used. Lithologic samples were sometimes collected at 10-ft intervals, rather than continuously or at 5-ft intervals. This reduced the number of times the sampler and drilling rods were pulled out of the drill stem, and thus minimized the amount of sand flowing into the augers. Occasionally, sampling with a core barrel or split spoon was not possible because the augers were filled with sand. In these instances, lithology was logged by examining sands on the outside of the augers as they were pulled out of the ground. Upon reaching bedrock, an attempt was always made to obtain a bedrock sample with a split-spoon sampler.

Soil borings were backfilled to ground surface with grout or bentonite chips. A tremie pipe was used to pour grout into portions of the borehole below the water table. In some cases, boreholes were partially backfilled with bentonite chips in order to complete a monitoring well with the screen at the desired depth interval.

When installing a monitoring well, the borehole diameter was enlarged with a 10-in diameter reaming auger fitted with a wooden plug. If necessary, the drill stem was filled with water or a Fluidville-Mud II bentonite slurry during reaming to control flowing sands. After reaming to the total depth, drilling mud was flushed out with approved water, the wood plug was knocked out with the sampling rod, and the well screen and casing were placed in the drill stem.

3.2.4.4 Mud-Rotary Drilling

A Failing 1250 mud-rotary drill rig was utilized to drill borings for lithologic characterization, groundwater characterization, and installation of groundwater monitoring wells. A 5-in outside diameter (OD) hollow end drill bit and hollow stem drill rods were used to drill a pilot boring to collect continuous soil samples for lithologic characterization and

obtain discrete groundwater samples. Continuous soil samples were obtained with the Christensen 94 millimeter (mm) wireline coring system. Methods for obtaining groundwater samples are described in Section 3.2.9.3.

3.2.4.5 Geoprobe Boring

A Geoprobe hydraulic hammer sampling system was used to obtain soil samples and discrete groundwater samples. A 1-in or 1.5-in diameter hollow probe was advanced by utilizing the weight of the Geoprobe apparatus and the truck on which it was mounted, in combination with hydraulic hammer. Drive rods were added as needed to advance the probe depth. This method was used to obtain continuous soil samples for lithologic characterization. Soil and groundwater samples for chemical analysis were also obtained as described in sections 3.2.5.3 and 3.2.10.2, respectively. All holes created by the Geoprobe rig were backfilled with bentonite grout.

3.2.4.6 Cone Penetrometer Testing

A truck mounted CPT rig was utilized to provide hydrogeologic profiling at approximately 250 locations. This method was performed by pushing a cone penetrometer utilizing hollow CPT rods, the weight of a 20 or 25 ton CPT rig, and a hydraulic ram. As the cone penetrometer is advanced, it measures sleeve friction (F_s), cone bearing (Q_c), and dynamic pore water pressure (U). These parameters are measured at 5-cm intervals and automatically recorded in a data acquisition system located in the rig. Plots of Q_c , F_s , U , and friction ratio, as well as the interpreted soil type, are printed during penetration providing real time, relatively continuous, hydrogeologic characterization. CPT was conducted according to American Society for Testing and Materials (ASTM) standard D3441. All borings created by the CPT rig were backfilled with Volclay bentonite grout.

During cone penetration, soil parameters and interpreted soil type were continuously monitored. In order to prevent the penetration of any clay layer with greater than 5-ft thickness, the penetrometer was stopped whenever the cone penetrated 3 ft into a clay. To calibrate the data obtained by CPT and aid in clay layer identification, at least one CPT location in each investigative site was situated adjacent to a continuously cored boring. Soil

and groundwater samples for chemical analysis were also obtained as described in sections 3.2.5.3 and 3.2.10.4, respectively.

3.2.5 Soil Sampling Methods

This section describes soil sampling methods used in the RI. Soil samples from test pits, borings, and surfaces of unpaved areas were used to assess the physical and chemical characteristics of potential contaminant sources. The data are also used to evaluate the importance of the release mechanisms presented in Section 3.1. The number of soil samples collected at each site was specified in the SDPs for each field program (ECJC, 1990b, RLSA, 1992e, and WJE 1994a). In the Initial RI field program, headspace analysis was conducted to assess changes in the relative concentrations of VOCs in the samples collected from different depths. The concentration of VOCs in the jar's airspace was measured with a PID after it was allowed to equilibrate to ambient temperature. In some areas, in order to collect a soil sample from the most contaminated zone sample depths were selected based on the presence of staining, and during the Initial RI field program, the results of headspace analysis of VOCs in the soil. The depths of soil samples collected during the supplemental RI and Follow-on RI were predetermined or based on analytical results, and headspace analyses were not used.

Physical characterization of soils included describing the lithology of natural soils using the Unified Soil Classification System (ASTM, 1987), determining the depth of unsaturated soils, and identifying the nature and extent of fill materials. Fill materials were classified as artificial fill, debris fill, or landfill material. Artificial fill is comprised of locally derived native materials, whereas debris fill and landfill contain anthropogenic materials. Fill consisting of construction materials such as wood, metal, glass, and concrete rubble was classified as debris fill. Materials containing household and/or commercial refuse such as rags, newspapers, shoes, or cans were classified as landfill material. The following sections describe specific soil sampling methods used in the RI.

3.2.5.1 Test Pit Sampling

Test pits were excavated at Landfills 2, 4, and E; Fill Sites 1, 5 and 7; and Graded Area 9 during the Initial RI field program to characterize the nature, extent, and composition of the

fill material. To minimize the generation of investigative waste, test pits were not excavated during the Supplemental or Follow-on RI field programs. Information on the depth of fill material was also used to calibrate the data collected during geophysical surveys, which allowed further definition of the areal and vertical extent of fill. Subsurface soil samples were collected from the test pits to characterize the distribution of chemicals that could potentially migrate to deeper soil, and possibly to groundwater.

Test pits were excavated with a backhoe to depths generally ranging from 2 to 4 ft. During excavation, a site geologist sketched a profile of the test pit showing the depth and lithology of fill and soil materials, and the sample locations. Excavation was stopped if groundwater seeped into the pit and threatened to cause the walls of the pit to collapse. Samples were collected in glass jars directly from the test pit if the pit wall was stable, otherwise they were collected from the backhoe bucket or the pile of excavated material.

3.2.5.2 Surface Soil Sampling

Surface soil samples were collected from the top 0.5 ft of soil to characterize residues in stained areas. During the Initial RI, the samples were collected with a stainless steel spoon or trowel. Both discrete and composite samples were collected. Composite soil samples consisted of fill materials obtained from several locations around a sampling site and mixed in a stainless steel bowl prior to placement in a glass jar. If discrete samples were heterogeneous with respect to grains size, they were homogenized by mixing the soil in a stainless steel bowl. During the Supplemental and Follow-on field programs, most surface soil samples were collected by driving a brass liner in the same manner as subsurface soil samples, which is described below. The exceptions were in areas with loose soils, which would not stay in the sampling device. In these instances, material was placed directly into glass jars or brass liners.

3.2.5.3 Soil Boring Sampling

Soil samples were collected from borings to assess the vertical distribution of chemicals. At least two soil samples were collected from the unsaturated zone at most boring locations. Sample depths were selected on a site-specific basis and are discussed in the sample location rationale section for each study area.

Different soil sampling methods were used during the Initial, Supplemental, and Follow-on RIs. The changes were prompted by discussions with state regulators. Initial RI soil boring samples were collected from a split-spoon sampler or core barrel with a stainless steel spoon or putty knife. Care was taken to assure that soil contacting the metal interior wall of the sampler was not retained for analysis. Volatilization of chemicals was minimized by rapidly placing the soil sample in a glass sample jar. Soil samples from boreholes drilled with a hand auger were collected by emptying the cuttings from the auger into a glass jar.

During the Supplemental and Follow-on RI, all soil boring samples were collected in 1.0 or 1.5-in diameter brass liners to further reduce the possibility of volatilization of chemicals. The liners were cleaned with distilled water and then placed inside a split-spoon sampler, Geoprobe sampler, CPT sampler, or the hand-driven core sampler before driving the sampler through the desired sample interval. To avoid volatilization of chemicals, the ends of the brass liners were covered with a sheet of Teflon film and capped with a plastic lid. Silicon tape was then stretched around the edge of the lid and any portion of the Teflon sheet protruding from bottom of the lid.

3.2.6 Monitoring Well Installation

This section describes monitoring well installation methods used in the RI. To facilitate the installation of permanent, 4-in diameter monitoring wells, pilot boreholes were reamed with a 10-in outside diameter auger or mud-rotary drill bit. For portions of the pilot hole drilled beyond the well completion depth, bentonite was added to seal the base of the borehole prior to reaming. The drilling mud in mud-rotary borings was flushed from the boring prior to the installation of well materials.

Most monitoring wells were constructed with 4-in inner diameter, schedule 40 PVC, threaded, flush-jointed well casing, bottom cap, and screen. The exceptions were four wells in the Building 900s Series Study Area that were installed near an area that contained free product. These wells were constructed with stainless-steel screens and PVC risers to minimize reactions between the screen material and the product. The maximum length of the well screen was 10 ft. For wells screened across the water table, 7 ft of the screen was placed

below the water table and 3 ft of screen extended above the observed water level to allow for tidal and seasonal fluctuations in ground-water levels.

All well parts were steam cleaned with approved water before being placed inside the drill stem of the reaming augers, or the mud lined borehole. The annular space was then filled with #2/12 silica sand from a maximum of 2 ft below to 2 ft above the linear extent of the screen. Sieve analyses were conducted to determine the particle size distribution of 26 soil samples from water-bearing zones at the PSF. These particle size distributions, or gradations, from the water-bearing zones of 12 borings were evaluated to determine the appropriate sand pack size for monitoring wells. These analyses and the sand pack design curves are presented in Appendix M. Lonestar #2/12 was used as filter pack and the design curves show that this size is generally acceptable at PSF. The installed screens have 0.010-in slot size, which is compatible with the Lonestar #2/12 sand.

A seal of 3/8-in diameter bentonite pellets, or medium bentonite chips, was installed above each sand pack and hydrated with distilled water. Depending on well depth, the seal thickness ranged from 1 to 5.5 ft. The bentonite seal was hydrated with distilled water and allowed to set before filling the remaining annular space with grout comprised of powdered bentonite, portland cement and approved water. In accordance with USAEC standards, the grout mix was approximately 20 parts cement by weight and up to one part bentonite, with a maximum of 8 gallons of water per 94-lb bag of cement. Grout was usually tremied into the annular space. However, when grout placement was above the water table and depth to the top of the bentonite seal was sufficiently shallow, the grout mixture was poured through the augers directly into the well annulus. Several of the flush-mounted wells in the Crissy Field Study Area had insufficient space for grout because the water table was shallow. In these instances, several inches of silica sand was placed on top of the bentonite seal before setting the surface completion box. All flush-mounted wells were fitted with a locking expandable seal cap. Weep holes were drilled into traffic boxes of flush mounted wells to prevent seepage of accumulated water into the wells. Seal caps or PVC slip caps were used on wells with above-ground completions. A locking protective steel casing was placed around the wellhead riser of wells with aboveground completions, and 4-in diameter steel posts (usually

four) were installed to protect the wellhead. A generalized monitoring well construction diagram is shown in Figure 3.2-2.

3.2.7 Temporary Piezometers

This section describes the temporary piezometer methods used in the RI. In upland areas of the PSF, there is a potential for relatively thin water-bearing zones and water-bearing zones that recharge slowly. Temporary piezometers were installed during the Follow-on RI at several of the landfills and at the Nike Facility to determine whether groundwater was present in sufficient quantities to warrant installation of a permanent monitoring well and to isolate potential water-bearing zones encountered in a single borehole.

Piezometers were installed in 6- or 8-in boreholes drilled with a HSA drilling rig. One-inch OD, schedule 40 PVC screen and riser were used for piezometer construction. The screen was usually 5-ft long and was installed across the potential water-bearing zone. A Lonestar #2/12 sand filter pack was installed to at least 1 ft above the screen interval. A bentonite chip seal at least 3-ft thick was installed above the sandpack and hydrated with distilled water. All piezometer construction was done inside the augers.

Piezometers were allowed to stand for at least 24 hours (often 48) at which point they were sounded with a water-level measuring device. If no groundwater was present, the piezometer was abandoned by overdrilling to the total depth, removing the casing and construction materials and sealing the borehole to the surface with cement-bentonite grout. If groundwater was present, then a monitoring well was installed and screened in the water-bearing zone.

3.2.8 Well Development Methods

This section describes well development methods used in the RI. Monitoring wells were developed by alternately removing water and surging with a 3.75-in diameter, bottom-filling bailer (stainless steel or PVC) and/or with an electric 3.75-in diameter submersible pump (Grundfos or Standard). Three to six bore volumes of water and five times the volume of any water or drilling fluid added during drilling operations were removed during development.

Field parameters including temperature, pH, turbidity, and specific conductance were monitored as each borehole volume was removed. Development continued until field

parameters were stable, i.e., measurements from three consecutive borehole volumes differed by less than 10 percent. Wells with slow recharge were considered developed after being dewatered twice.

3.2.9 Groundwater Level Measurement Methods

This section describes methods used to measure groundwater levels in the RI. Static water levels in monitoring wells were measured to the nearest 0.01 ft using a Solinst electrical water level sounding instrument. The measurements were taken from a surveyed measuring point, marked on the top of each well, to the top of the water table. These measurements were entered into IRDMIS and the elevation of the water table was calculated by running a program that subtracts the measured depth to water from the elevation of the measuring point. The datum for all measuring-point elevations was Presidio lower low (PLL) water. PLL is a local tidal datum described in section 3.2.13 of this RI report.

An Envirolab DL200 eight-channel datalogger and PT108C 5-pounds per square inch (psi) transducers were used to obtain a continuous record of water level fluctuations during the tidal influence studies in the Building 900s Series Study Area. The datalogger was programmed to record water levels at 15-minute intervals. Calibrated transducers were lowered into the wells approximately 6 to 8 ft below the water table. Water level measurements were obtained with a Solinst at each well immediately before downhole placement of transducers. These data are used to convert the transducer readings to water table elevations. Test durations ranged from 2 to 3 days.

3.2.10 Water Sampling Methods

This section describes water sampling methods used in the RI. Samples of groundwater and surface water were collected to quantify the distribution of chemicals in these media. The data are also used to evaluate the effect of various transport mechanisms on the overall distribution of chemicals in each study area. In addition to sampling groundwater and surface-water bodies, samples of water in the Nike missile silos were collected. Methods used to sample water from monitoring wells, holes drilled by Geoprobe, mud-rotary, and CTP methods, and surface water bodies are described in the following sections.

3.2.10.1 Groundwater Sampling from Monitoring Wells

Groundwater samples from monitoring wells were collected by purging a well to remove stagnant water, monitoring field parameters to document the influx of formation water into the well, and preserving the samples. The procedures used during the Initial RI field program differed slightly from those of the Supplemental and Follow-on RI. These differences are summarized in the following discussion.

Wells were purged and sampled with a PVC, Teflon, or stainless steel bailer attached to a cotton rope, which was discarded after each use. Wells with large volumes of water were sometimes purged with a Grundfos pump during the Supplemental and Follow-on RI. The temperature, pH, and specific conductance were measured in the initial water purged, and in every casing volume thereafter. Dissolved oxygen was monitored at some wells during the initial sampling, and turbidity was added to the list of Supplemental and Follow-on RI field parameters. Instruments were calibrated in the field according to the manufacturers' specifications. Wells were purged until a minimum of five borehole volumes were removed or field parameters, excluding turbidity, were stabilized, i.e., measurements from three consecutive borehole volumes differed by less than 10 percent. The minimum volume of water purged from each well was decreased to three casing volumes for the Supplemental and Follow-on RI field programs.

Wells that dewatered during the Initial RI field program were sampled after they had recharged to static water levels. During the Supplemental RI and Follow-on RI, wells that dewatered were allowed to recover to static water levels and were purged a second time, if recovery was within approximately 1 hour. If recovery was slow, samples were obtained as soon as sufficient water had accumulated.

After purging the well, groundwater samples were collected using equipment and procedures that minimized agitation and volatilization. All groundwater samples were collected in bottles, which were pre-cleaned to USEPA specifications. Bottles were triple rinsed with sample water prior to preserving and filling during the Initial RI field program. Because all bottles were pre-cleaned, this step was not necessary and was not done during the Supplemental and Follow-on RI field programs. Sample bottles were filled from a bailer fitted with a bottom-emptying device. Samples were preserved in the field immediately after

collection. The exceptions were the volatile samples that required no head space in the bottle. These bottles were acidified prior to filling. A peristaltic pump and a disposable 0.45 μm mini-capsule filter were used in the field to filter samples for metal analysis. Alkalinity was measured in the field by titrating a sample during the Initial RI sampling. This analysis was done in an analytical laboratory during the Supplemental and Follow-on RI. As part of the Supplemental and Follow-on sampling programs, field parameters were measured after the entire sample suite had been collected to document whether conditions had changed during sampling.

3.2.10.2 Groundwater Sampling with Geoprobe Rig

Depth discrete groundwater samples were obtained with the Geoprobe rig at certain locations during the Follow-on RI. Samples were obtained by driving a 36-in long, 1-in OD sheathed stainless steel screen point to the desired depth and retracting the sheath. All of the drive rod and sample sheath connections were water tight. Samples were obtained with clean 3/8-in polyethylene tubing lowered through the hollow drive rods. Groundwater enters the tubing through an attached check valve which allows groundwater to rise to the surface as the tubing is oscillated vertically. The tubing was disposed of after all samples from a depth were collected. A peristaltic pump was used to extract groundwater from the sample tubing where appropriate and only when collecting samples for non-volatile analyses (i.e. analyses other than VOCs and TPH-G). Approximately one tubing volume of groundwater was evacuated before sampling. The temperature, pH, turbidity, and specific conductance were measured in the water purged. Precleaned sample containers were filled directly from the sample tubing. Sample container handling, preservation, and filtering were conducted in the same fashion as described in section 3.2.10.1.

3.2.10.3 Groundwater Sampling with Mud-Rotary Drill Rig

Discrete groundwater samples were obtained from selected mud-rotary borings. A one-inch OD by four-inch long stainless steel screen attached to a drive point was lowered into the borehole at chosen depths. The continuous wire wrap screen had 0.010-in or 0.020-in openings which were covered by a protective sleeve. The screen was advanced two to three ft ahead of the drill bit and into undisturbed soil by driving attached hollow stem sample rods. The protective sleeve was then retracted and the screen filled with water. A sample was

collected by lowering a stainless steel bailer through the water-tight sample rods. Sample temperature, pH, turbidity, and specific conductance were measured. Precleaned sample containers were filled directly from the bailer. Sample container handling, preservation, and filtering were conducted in the same fashion as described in section 3.2.10.1.

3.2.10.4 Groundwater Sampling with the Cone Penetrometer Testing Rig

Discrete groundwater samples for chemical analysis were collected using a CPT rig. Each location was adjacent to a point where hydrogeologic conditions were previously characterized by CPT. A cone-tipped sample tool was pushed to the desired sample depth(s) chosen from the adjacent hydrogeologic log. The CPT rods were retracted sufficiently to expose a three to 5-ft long stainless steel screen. A small diameter stainless steel bailer was lowered through the CPT rods to collect all VOC and TPH-G samples. The bailer was repeatedly lowered through the CPT rods until sufficient sample volume was recovered. A peristaltic pump was used to collect non-volatile samples, following procedures described previously in Section 3.2.10.2. Sample temperature, pH, turbidity, and specific conductance were measured. Precleaned sample containers were filled directly from the bailer or peristaltic pump. Sample container handling, preservation, and filtering were conducted in the same fashion as described in Section 3.2.10.1.

3.2.10.5 Surface Water

Surface-water samples were collected from Lobos Creek, El Polin Spring, Mountain Lake, a seep on Baker Beach, and the Nike missile silos. Grab samples of stream, lake and lagoon water were collected directly with the sample bottle. The surface-water samples were collected at a depth of approximately 0.2 ft. Stream samples were collected from the center of the channel with the sampler standing downstream from the submerged sample container; and care was taken to not disturb streambed sediments. Multiple surface-water samples were collected from Lobos Creek. The first sample was collected from the most downstream location; each successive sample was obtained progressively upstream. Lake and lagoon samples were collected from near the shoreline. Field parameters, including pH, specific conductance, and temperature (and dissolved oxygen when possible) were obtained by submerging the instrument probes directly into the water body. Field titrations were also

performed during the Initial RI to determine water alkalinity. This analysis was done in an analytical laboratory for the Supplemental RI and Follow-on RI.

Instantaneous discharge measurements were collected at each sampling location on Lobos Creek using standard U.S. Geological Survey (USGS) monitoring techniques (Rantz, 1982). Low to moderate flow measurements were made with a flow-rated, 100-mm long-throated flume. Higher flows were measured with a Marsh-McBirney Model 201 current meter with a top-setting wading rod. The streamflow was measured in a straight section of channel, free of obstructions, and exhibiting relatively uniform flow conditions.

During the Initial RI and the Supplemental RI samples from seeps and springs were collected by funneling the water into the sample bottles. The funnels were made by cutting off the bottoms of clean plastic sample bottles or distilled water bottles. During the Follow-on RI samples were collected directly with the sample containers. During the Supplemental RI and Follow-on RI, temperature, pH, turbidity, and specific conductance were monitored prior to taking a spring or seep sample.

The Nike missile silos were sampled to evaluate the quality of accumulated water in the three silos. Samples collected from Silo 1 (NISW01) were obtained approximately 1 to 2.5 ft below the water surface through the personnel access hatch above the silo. A 3.75-in diameter PVC bailer attached to a Teflon-coated cable or cotton rope was used to acquire the water. Samples from Silos 2 and 3 (NISW02 and NISW03 respectively) were obtained by the site scientist in level B personal protective equipment from inside the silos. Grab samples were collected directly with the sample containers in these silos. Field parameters including pH, specific conductance, temperature, and dissolved oxygen were measured at all of the sampling locations.

3.2.11 Product Layer

This section describes methods used in the RI to measure layers of petroleum hydrocarbons floating on water in monitoring wells. Wells in the vicinity of Buildings 937, 231, 228, and 637 were checked for the presence of free product using a MMC Flexi-Dip gauging tape or a clear bailer. The tape was also used to measure the amount of product in USTs.

Free-product samples were collected from wells in the Building 900s Series Study Area. The sample was retrieved from the surface of the water table using a 1.65-in outside diameter stainless steel bailer. The bailer was lowered into the well only deep enough to intercept the free product zone. Bailers were also used to collect product samples from USTs.

3.2.12 Soil-Gas Survey

This section describes the methods used to conduct the soil-gas survey at building 1750. Environmental Support Technologies (EST) of Laguna Hills, California was retained by WJE to collect the soil-vapor samples and perform real time analysis of the samples using a field laboratory, under the supervision of a WJE geologist.

Soil-gas sampling was conducted using a horizontal grid system devised for the investigation. Perforated soil probes were installed using a percussion hammer to depths of approximately 5 ft bgs. Once the probe was installed at the desired depth, the probe shaft was withdrawn, leaving the probe point and Teflon sampling tube in the soil. A small amount of silica sand was poured into the probe hole. The remaining open probe hole was back filled with hydrated bentonite grout to the ground surface. The probe point and sampling tube assembly was left as a long-term soil-gas monitoring point. This allowed subsequent soil-gas sampling and analysis, if desired.

Soil-gas samples were collected using a soil-gas sampling system which includes Teflon tubing, a vacuum pump, and an instrumentation assembly. Soil-gas samples were analyzed by direct gas injection into a laboratory-grade, field-operable gas chromatograph (GC). The purge rate and time were adjusted to achieve the optimal purge volume.

Samples were analyzed in the field using one or more field-operable GCs equipped with an electrolytic conductivity detector (ELCD) or electron capture detector (ECD), a PID, and a flame-ionization detector (FID). The PID and ELCD was used in series to analyze for EPA Method 524.2 compounds including halogenated hydrocarbons and BTEX.

Probes and equipment in contact with the soil-gas sample stream were decontaminated prior to sampling. Decontamination of soil-gas sampling equipment was conducted by repeated washing and/or by baking in the GC oven. Washing included the use of a phosphate-free

detergent wash, tap water rinse, organic-free water rinse, followed by air drying. The sample collection system consisted of stainless-steel and Teflon. Portions of the system in contact with the soil-gas sample stream were decontaminated prior to sampling each probe. Each soil-gas sampling syringe was blanked with helium gas before use. Syringes and adapters were cleaned with phosphate-free detergent at the end of each day and baked overnight in the GC oven at a minimum temperature of 80 degrees Celsius (°C).

To avoid potential cross contamination between soil-gas sampling points, EST used dedicated soil-gas probes at each location. Sampling equipment in contact with the gas sample stream was dedicated to each location or was decontaminated by heating at greater than 100 °C for at least 10 minutes.

Prior to sampling from each probe, the syringe used for soil-gas sample collection was filled with ambient air or ultra-high-purity carrier-grade gas from a compressed gas cylinder. The ambient air or high-purity gas was then injected directly into the GC. This sample injection serves as a blank to detect contamination of the syringe to be used for sampling.

3.2.13 Sample Locations and Surveying

The location, ground-surface elevation, and measuring-point elevation of permanent groundwater monitoring wells were surveyed by a California-licensed surveyor. The locations of all Supplemental and Follow-on RI soil borings and surface-soil samples were also surveyed. Instead of surveying, some Initial RI soil-sample locations were mapped using tape measurements from surface landmarks and elevations were interpreted from topographic maps with 5-ft contour intervals. For surveyed points, the elevation of each site was surveyed to the nearest 0.010-ft. The northings and eastings (horizontal coordinates) were surveyed to the nearest 0.10-ft. Coordinates and elevations for all sample points are provided in an electronic format in Appendix O.

All elevation data generated during the RI are based on the Presidio lower low (PLL) water datum. That means that an elevation reported as zero ft PLL is the same elevation as the PLL datum. In previous versions of this RI report, PLL elevation data were incorrectly referred to as mean lower low water (MLLW) data. The PLL datum approximates the elevation of the lower low tide water level in San Francisco Bay at the Presidio. The PLL

datum is based on miscellaneous tidal observations made prior to 1907 and adopted as a standard in March 1907. Elevation control for the RI surveying was established using Tidal Benchmarks 180 and 181. Tidal Benchmarks 180 and 181 are located at FPCGS and have PLL elevations of 13.46 ft and 13.50 ft, respectively. The relationships among five datums which may be used in the San Francisco Bay area are shown below by listing the elevation of Tidal Benchmark 180 relative to PLL and each of the other datums.

TIDAL

BENCHMARK 180

ELEVATION (ft)	DATUM
13.46	PLL - Presidio Lower Low Water Datum of 1907
13.26	MLLW - Mean Lower Low Water Datum in the San Francisco Bay area
13.11	NAVD88 - North American Vertical Datum of 1988
10.40	NVGD29 - National Geodetic Vertical Datum of 1929
1.78	CCSF - City and County of San Francisco Datum

3.2.14 Sample Handling and Photographs

Analytical samples were handled and shipped according to the C-O-C procedures. Computer-generated C-O-C forms and sample labels were printed for each sample. The labels indicate the sample medium, site identification number, analysis requested, sample bottle, preservative, and tag number. The sampler(s) completed the sample labels and C-O-Cs in the field by signing and adding the sample date, time, depth, and technique. Samples in glass bottles were wrapped in protective plastic bubble sheeting before shipping. During collection and transport, all samples were stored in a cooler with water ice or blue ice to chill the samples to 4°C ($\pm 2^\circ\text{C}$). For the Follow-on RI, the target temperature of 4°C was not always reached before the samples reached the laboratory when only a few hours elapsed between sample collection and arrival at the laboratory. However, the laboratory continued cooling the samples in a refrigerator until analysis. All of the laboratories were required to measure and record the temperature of the samples upon receipt.

Photographs were taken during drilling and sampling activities. Samples of pre- and post-development water, and sample water from monitoring wells were taken. Photographs taken during the Initial RI show each retrieved soil interval. During the Supplemental and Follow-on RI, photographs were taken only during drilling if there was something of particular interest, such as a lithologic change or staining. Photographs showing drilling, soil and wipe

sampling locations were taken throughout the RI field programs. Photographs are retained in the project files.

3.2.15 Decontamination Methods and Approved Water Sources

Water used for equipment decontamination and during drilling is referred to as approved or source water. During the Initial and Supplemental RI field programs, approved water was obtained from a well adjacent to Building 1780 at the water plant at Baker Beach. This well had been designated previously by the Presidio as Well 6 (Figure 3.2-3). This source was chosen because it was an easily accessible, nonchlorinated production well. During the Follow-on RI, decontamination water was also obtained from the PSF water-supply distribution system. This additional source was used because it was available at the Sacramento Corps of Engineers decontamination pad located at the PSF, which was used during the Follow-on RI. In addition, the pump rate at the production well (Well 6) was too low to provide the large volumes of water needed for mud-rotary drilling in a timely manner. All equipment that could potentially contact an analytical sample (such as split spoons and stainless steel bailers) was rinsed with distilled water prior to use. As described in this section, source water samples were analyzed to assess the appropriateness of use for decontaminating equipment.

According to USAEHA (1981) the source well is 62 ft deep and yields 25 gpm. Water from this source was approved to supplement the potable water supply when necessary (ANL, 1989). The installation has collected samples from this well periodically since Fall 1989 and analyzed for a list of approximately 80 organic compounds (SEI, 1990). Inorganic compound concentrations have also been analyzed periodically. Methyl tertbutyl ether, a fuel additive, was tentatively identified in three samples from the well during 1989 and 1990. In addition, chloroform, total trihalomethanes, tetrachloroethylene, and carbon disulfide were each detected once in the well at concentrations near the detection limit. The water source was analyzed for all target analytes listed in Section 3.3 during the Initial and Supplemental field programs.

In addition, the other PSF production well which was active at the time (Well 13; Figure 3.2-3), and which could be used as a backup well for decontamination water, was analyzed

during the Supplemental RI. Analytes detected in these samples are summarized in Tables 3.2-1 and 3.2-2. Among inorganics, only arsenic and lead were detected at concentrations greater than the MCL in any of the samples. Arsenic was detected in Well 6 in the first sampling round, but was below the CRL in the two subsequent sampling rounds. Lead was only detected in Well 6 in the sample collected in 1992, but not in two previous samples. No organics were detected in the samples with the exception of TPH-D at 80 $\mu\text{g/L}$ (PSF Well 6) during the RI sampling. The compounds detected or tentatively identified during quarterly sampling conducted by PSF personnel were not detected in the RI samples. Results for unknown compound detections are included in Appendix O. Based on the history of the water source and recent laboratory analyses, Well 6 was accepted by USATHAMA as a satisfactory supply of water for equipment decontamination.

Two analytical samples from the PSF water-supply distribution system were collected by Montgomery Watson on August 5, 1994 and analyzed for VOCs by method 8240 at Quanterra Laboratory. Samples were collected at the Sacramento Corps of Engineers decontamination pad, one prior to passage of the water through the steam cleaner and the other after passage through the steam cleaner. Detections in the first water sample were chloroform at 9.5 $\mu\text{g/L}$ and dibromochloromethane at 35 $\mu\text{g/L}$. Both compounds were also detected in the sample from the steam cleaner, but at lower concentrations (2.3 and 9.4 $\mu\text{g/L}$, respectively). Also detected in the post steam-cleaner sample were bromodichloromethane and bromoform, at 4.0 and 9.3 $\mu\text{g/L}$, respectively.

The detections of trihalomethanes (THM), such as dibromochloromethane, chloroform, bromodichloromethane, and bromoform, are not unexpected, as they are commonly found in treated water supplies, due to the application of disinfectants containing chlorine. Water quality studies at the water plant have indicated that high levels of THM were present in the treated water, likely formed during the reaction of free chlorine with organic compounds during prolonged storage and distribution (USAEHA, 1981).

Equipment used during drilling and excavation of test pits was decontaminated by steam cleaning with approved water. Brushes were used if steam cleaning alone could not remove the dirt or staining. If necessary, a dilute mixture of Alconox was also used. The brass liners

and the split spoons used for gathering samples were cleaned in an Alconox solution and rinsed with distilled water before use.

Bailers and bottom-emptying devices were decontaminated with a dilute Alconox solution followed by a rinse with distilled water during the Initial RI field program. Only distilled water was used for decontamination during the Supplemental RI and Follow-on RI. The Grundfos pump used during the Supplemental RI and Follow-on RI was decontaminated by pumping 10 gallons (gal) of distilled water through the pump and hose.

3.2.16 Investigation Derived Waste

Investigation derived waste was disposed of in accordance with local, State, and Federal regulations. Waste water was stored in 3,000 gal plastic tanks and samples of the water were analyzed for a full suite of chemical parameters. Results were sent to the City and County of San Francisco, Department of Public Works for approval to discharge the water to the San Francisco sanitary sewer system. The water was discharged after a discharge permit was issued. Solid wastes and drilling mud were containerized in drums or roll-off bins. Samples were collected and analytical results reviewed for proper disposal. All solid wastes were disposed of as non-hazardous wastes. The U.S. Army has the manifests for all waste disposal.

3.3 LABORATORY PROCEDURES

This section describes the laboratory procedures and analytical methods used for the RI. The information pertaining to the Initial and Supplemental RI are presented together in Section 3.3.1. The Follow-on RI laboratory information is presented in Section 3.3.2.

3.3.1 Initial and Supplemental RI

Analytical suites for each of the samples were specified in the SDPs (ECJC, 1990b and RLSA, 1992e) for the Initial and Supplemental RI. The target analytes were selected following an evaluation of the current or former operations, the types of chemicals and waste handling procedures used in each building, and the regulatory agency concerns. Historical records were reviewed to identify areas that have been impacted by spills or released wastes.

Analyses were conducted on each sample to verify whether chemicals suspected to be present in the soil, water, or buildings at the site were actually present.

Analyses were performed for inorganics, miscellaneous parameters, VOCs, SVOCs, pesticides, PCBs, chlorinated herbicides, and TPH. Target analytes for each of these methods and each sample matrix type are listed in Tables 3.3-1 through 3.3-7. These tables also indicate the analytical methods and reporting limits for each laboratory contracted to perform the RI analyses. The laboratory instrumentation complied with USAEC and EPA methods. Gas Chromatography/Mass Spectrometry (GC/MS) analyses provided supplementary information on compounds observed as unknowns that are not verified by a standard. Unknowns and tentative identifications are discussed in Section 3.5.

The analytical program for the Initial RI was performed by DataChem Laboratory in Salt Lake City, Utah, and BC Analytical in California. The Supplemental RI analytical program was performed by Environmental Science & Engineering in Denver (ESE/D) and Gainesville, Florida (ESE/G) and Curtis and Tompkins, Ltd. in Berkeley, California. DataChem, ESE/D, and ESE/G provided the USAEC-certified analyses. BC Analytical and Curtis and Tompkins provided EPA SW-846 and EPA Drinking Water analyses. All laboratories were certified by the State of California for hazardous waste and/or drinking water analysis.

USAEC methods are certified on a laboratory specific basis based on the submission of method validation documentation. Certified Reporting Limits (CRLs) for USAEC-certified methods are statistically derived concentrations that represent the value corresponding to a point on a lower confidence limit curve derived from repeated injections of a fully processed sample at multiple concentrations, where the value of Y equals the value of Y on the upper confidence limit curve at X=0. EPA methods employed are taken from SW-846, Test Methods for Evaluating Solid Waste (RCRA methods), and EPA 600 - 4/79/020, Methods for the Chemical Analysis of Water and Wastes. These methods use a method detection limit (MDL) based on statistical interpretation of multiple analyses of fully processed samples representing the students t value at the 99 percent confidence level for the appropriate number of degrees of freedom times the variance of the measurements.

USAEC-certified methods adjust for the analytical accuracy during the reporting process, while EPA methods do not. Another adjustment to the data in IRDMIS is for percent moisture. All laboratories for the Initial and Supplemental RI programs used USAEC-certified methods to determine percent moisture of soils and sediments. The adjustment for moisture is described in the USAEC QAP (1990b). EPA methods allow the data user to determine if moisture content should be included in the final value calculation. For the PSF, the EPA method results were not adjusted for percent moisture. Those samples with greater than 20 percent moisture were listed and assessed as to whether the moisture affected the comparison of sample results from the Initial RI to those of the Supplemental RI. Less than 5 percent of the samples contained greater than 20 percent moisture, and comparison of sample results indicated that the moisture content was not a contributing factor to the overall results.

The USAEC Chemistry Branch assigns unique laboratory-specific codes for all certified methods. Additional method codes include 00 and 99 method designations. The 00 designation is for methods that do not require USAEC certification. These methods are listed in the IRDMIS data dictionary (Section 8.24) and include water and soil characteristics. The 99 method code is for non-USAEC- approved or semi-quantitative screening. Historically, the 99 code has also been applied to data that do not meet the USAEC QA/QC requirements. EPA codes are designated by the universal method name (e.g., EPA SW846-8080 is the pesticide/PCB method for both water and soil) modified by USAEC in IRDMIS to differentiate media types (e.g., 808S for soil).

Analytical certification for USAEC methods included performing the analysis over several days to show proficiency and consistency for the method. The results and written procedure are submitted to USAEC for approval before any samples are accepted for analysis. Once approved, the method is given a unique USAEC code and the laboratory is authorized to analyze samples for that method. If a laboratory fails to show acceptable performance for a method, USAEC can decertify the method and request recertification.

Each analytical method has been proven for a set of target analytes by either the USAEC certification procedure or EPA method validation. When USAEC laboratories were not certified to perform analyses for certain analytes, they signified "requested but not certified" results by using the flag code "R" from the USAEC data dictionary when the laboratories

provided information on analytes not requested under the PSF program, the results were reviewed in the USAEC database, but not addressed in this RI report.

A few of the target analytes could not be reported due to instrument difficulties or method limitations. Benzoic acid in water and soil samples was analyzed for under the semivolatile GC/MS method certified by USAEC; results were often not acceptable due to inherent limitations in the method. Benzoic acid is known to respond poorly to both the USAEC method employed and its EPA counterpart.

PCBs were analyzed in the Initial RI by a USAEC GC/MS method and frequently confirmed by GC. During the Initial RI, the laboratory occasionally provided GC results for PCBs, although they were not always requested. These results are included in the electronic database in Appendix O and are evaluated in the BRA. However, the GC PCB data do not appear on the detection summary tables in Sections 4 through 14 of this RI report. The Supplemental RI activities used a separate PCB method based on the SW846-8080 method by GC. The GC methods for analysis of PCBs are more compound specific and more sensitive, providing lower detection limits.

Modifications to EPA SW-846 Method 8015 were used to quantitate petroleum hydrocarbons during the Supplemental RI, rather than method 418.1 which was used during the Initial RI. Method 8015 is a GC method which provided results for TPH-G and TPH-D. The results give the data user two types of information. First, the results determine whether there are hydrocarbons (anthropogenic and naturally occurring) present with boiling points in the gasoline or diesel range. The method also generates a chromatogram "fingerprint" of the sample. The chromatogram can be used to evaluate whether TPH detections are caused by one source, or more. It can also be compared to standard chromatograms of fuel products to identify the type of source material.

All samples were analyzed by lot. The USAEC lotting system was employed where a lot is the maximum number of samples, including QC, that can be processed in a 24-hour time frame based on the rate limiting step of the method. Lots were assigned to each method according to USAEC protocols described in the QAP (USATHAMA, 1990b).

Assurance of method control for both USAEC and EPA methods was provided by a control charting system. Control charts for USAEC methods were submitted within 5 days of the completion of each lot for approval by the USAEC Chemistry Branch. These control charts tracked the accuracy and precision of the laboratory control spikes, or the surrogate spikes. Precision and accuracy for each lot were plotted on separate control charts as percent recovery and range between daily spikes. The spikes were averaged to reduce the variability of day-to-day recoveries. EPA methods require analysis of a laboratory spike and matrix spikes to indicate the effect of the sample matrix on the target analyte recovery. Control charts contained percent recovery data from laboratory spikes, without averaging. Both types of charts were based on an average recovery for an analyte with warning and control limits at one and two standard deviations.

Laboratory quality control procedures for each lot included one or more of the following depending on the method: tuning or optimizing the instrument, comparing a first calibration to a continuing calibration, analyzing a method blank, duplicate samples, and laboratory spikes. Analytical results above the instrument range were diluted and reanalyzed. If hold times were exceeded and the reanalysis could not be completed, results were reported as greater than (GT) values in the tables and the USAEC database. Should diluting the sample dilute the concentration of the compound of interest to below the CRL or MDL, the detection limit was adjusted to account for the dilution factor. Results are presented as less than (LT) the dilution factor times the CRL or MDL. The laboratories reviewed the analytical data at the bench, group, task manager, and QA manager levels. Data are reported using the USAEC database, IRDMIS.

3.3.2 Follow-on RI

Three laboratories performed analyses for the Follow-on RI. ESE/D was originally contracted to perform the bulk of the analyses with Quality Assurance Laboratory (QAL), San Diego, California, performing a back-up function and providing analysis of certain methods specific to the State of California that ESE was not prepared to perform. Superior Laboratories, San Francisco, California, provided rapid turnaround analyses and close support laboratory functions. Shortly after the submission of the first samples from the Follow-on RI, however, ESE/D experienced a fire that caused the laboratory to be closed.

Thus, the bulk of the analytical work was performed by QAL. After effecting repairs and recertifications, ESE/D was subsequently used for a small portion of the Follow-on RI activities in April of 1995. All laboratories used for the Follow-on RI were certified by the State of California.

The analyses included a variety of wet chemistry parameters, metals by both ICP and atomic absorption methods, VOC, SVOCs, pesticides/PCBs, herbicides, TPH-G, and TPH-D. These analyses, with the exception of the wet chemistry parameters, were performed in both solid and aqueous matrices. The analytical laboratory, method, and reporting limit for solid and aqueous matrices are shown in Tables 3.3-8 through 3.3-9. Under the Follow-on RI, all EPA method results were adjusted for percent moisture. Similar to the Initial and Supplemental RIs, GC/MS analyses for VOCs and SVOCs identified compounds that were not on the target analyte list and were not verified by a standard. These are reported as unknowns.

A number of TPH-G analyses conducted by Superior Laboratory in the Follow-on RI are reported with a detection limit of 50 µg/L. The laboratory was immediately notified that the contract reporting limit was 10 µg/L. Because health-based criteria for TPH-G were not available, the U.S. Army decided to use 50 µg/L as the SDC for those samples.

A number of methods were employed for the specific purpose of attaining lower detection limits than the methods employed during the Initial and Supplemental RI. Further, many analyses were reported to MDLs and even IDLs in certain cases where conventional methods did not provide Practical Quantitation Limits (PQLs) low enough to meet regulatory requirements. Some of the metals results were reported using atomic absorption methods and drinking water methods were employed for some of the VOC analyses.

Specifically, wet chemistry methods from EPA 600 4/79/020 were employed for total dissolved solids [TDS (160.1)], anions (300.0), and total organic carbon [TOC (415.1)]. Wet chemistry methods from SW-846 were employed for hexavalent chromium (Cr VI) and cyanide (9010). A wet chemistry method from Standard Methods for the Analysis of Water and Wastewater was used for alkalinity (2320) in some cases; in others EPA 600 4/79/020 method 310.1 was employed. When lower than normal detection limits were required for

metals, EPA 600 4/79/020 method 249.2 was employed for nickel, SW-846 method 7760 was employed for silver, and SW-846 methods 7041 and 7211 were used for antimony and copper, respectively. As is usual for the analysis of arsenic, lead, selenium, and thallium, atomic absorption methods were employed. These methods were taken from SW-846 and included methods 7060, 7421, 7740, and 7841, again respectively. Some lead results were reported by method 6010. Mercury was analyzed by SW-846 method 7470 for aqueous samples and 7471 for solid samples.

Among the organic analyses, a variety of methods were employed for volatiles including drinking water method 524.2 and SW-846 methods 8010, 8240, and 8260, depending upon the application and detection limit requirements. A modification of SW-846 method 8015 was employed for the analysis of TPH-G and TPH-D. SVOC analyses were performed using SW-846 method 8270. Extractables such as pesticides/PCBs, and herbicides were analyzed by SW-846 methods 8080 and 8150, respectively.

Some methods were modified in order to achieve lower detection limits. The modifications generally entailed increases in initial sample volume or greater than normal concentration of extracts or digestates. Another method modification occasionally employed was the addition of analytes to the method listing. This was accomplished simply by adding the analyte to the initial and continuing calibration standards and ensuring adequate resolution and response of the analyte prior to analysis.

In addition to the fixed-base laboratory methods described above, two field screening technologies were also employed. X-ray fluorescence (XRF) technology was employed for screening samples for antimony, lead, and zinc. Immunoassay test kits were employed for screening samples for TPH content. However, all XRF and immunoassay analyses were conducted by Superior in their analytical laboratory. All of these data were reported into the Non-THAMA Analytical Methods (NTAMs) portion of the IRDMIS database.

Field QC protocols mirrored those of the Initial and Supplemental RI with the additional requirement that confirmatory samples were analyzed in conjunction with the XRF and Immunoassay screening techniques. Assessment of the field and laboratory QC sample results is provide in Section 3.6.

3.4 DATA MANAGEMENT AND TABLE GENERATION

The data management plan was completed in a manner consistent with the provisions of the Technical Plan (ECJC, 1990a) and procedures of the USAEC IRDMIS. The objective of the data management effort was to ensure the field data and analytical results were organized, coded and entered into IRDMIS. Data entered into IRDMIS were checked for errors using IRDMIS programs and custom in-house programs. All data that passed the error check were sent to the U.S. Army. A final objective was the reporting of qualified data to authorized users.

Most of the chemical data were provided electronically by laboratory subcontractors. For the chemical data that were provided in hard copy, the data were transformed to an electronic format, compatible with IRDMIS.

The IRDMIS software is a PC-based application prepared for the USAEC by Potomac Research, Inc. This software is used for all data entry, some data integrity checks, and all data transfer file preparation. IRDMIS is an integrated system for the collection, validation, storage, retrieval, and presentation of chemical, sample location, and geotechnical data. This system uses personal computers and a UNIX-based minicomputer, located at USAEC headquarters at the Aberdeen Proving Ground, Maryland, which serves as the central repository for all electronic data collected for the USAEC. IRDMIS can be used on a PC to detect invalid data, to provide a mechanism for correcting it, and to format data into files for electronic upload to the minicomputer.

There are three levels of data recognized in the IRDMIS system. Level 1 (unofficial data) consists of all data entered on the PC from field logs and from electronic data provided by the analytical laboratory. All data were checked for integrity prior to data evaluation. Data entered at Level 1 were checked using the PC IRDMIS software to verify the correct use and entry of codes per the USAEC data dictionary, for both chain-of-custody data and for analytical data. Chain-of-custody integrity checks verified site IDs, sample data, sample technique, and sample depths. Analytical data completeness checks verified analytical methods requested, individual parameters required, and appropriate detection limits. Any errors found in these checks were logged and verified, as necessary, with the issuing

laboratory prior to editing. Data were edited and rechecked before being sent to the U.S. Army. A data flow diagram (Figure 3.4-1) depicts the general flow and status of data.

Data from USEPA analytical methods (versus USAEC-certified methods) were entered into the Non-THAMA Approved Methods (NTAMs) Database. Similar to data in IRDMIS format for USAEC methods, NTAMs uses algorithms but requires less data. The various types of data and their sources are identified in Table 3.4-1. Approved USEPA methods are entered as method codes for data entry. When data are identified for entry into NTAMs, the software does not check for detection limits and laboratory QC and does not adjust for accuracy. Adjustments for percent moisture and dilution factors are performed on these data as in USAEC-certified methods.

Level 1 data transferred to the USAEC were checked for errors by the U.S. Army's contract data administrator. If errors were detected, the Dames & Moore data manager was notified, corrections were made, and the data were resubmitted to USAEC. Data that passed final error checks were classified as Level 2. The USAEC Chemistry Branch has the authority to qualify the data and may code it as to its usability, for lots and individual parameters, if its review of laboratory QA/QC indicates conditions out of control. Control chart trend analyses were used to qualify USAEC approved methods for Level 2 data. The final qualified Level 2 data are then processed to Level 3. Level 3 data are stored on the U.S. Army's mainframe computer. The Level 3 data may be queried remotely from the USAEC minicomputer and downloaded for reporting, statistical evaluation, or other processing.

Level 3 data downloaded from the IRDMIS Level 3 database were used to create summary tables of analytical results for each study area. Results for each media (wipe, sediment, soil, groundwater, surface water, and product) are reported on separate tables. All groundwater results are for unfiltered samples unless otherwise indicated. The tables are further divided by RI field program, with Initial, Supplemental, and Follow-on RI results shown on separate tables. The specific compounds included in each analytical suite, by field program, are shown in tables in Section 3.3 of this RI report. For the Follow-on RI, the compounds included in an analytical suite depended on which laboratory conducted the analyses. The specific compounds, analytical methods, and laboratory for each Follow-on RI sample are listed by sample ID in Appendix O. Sample suites were often large, including over 50

different analytes of which only a few may have been detected. Therefore, in the interest of clarity, the summary tables provide results only for compounds that were detected above the reporting limit in at least one of the samples appearing on the table. A complete listing of all analytical results is provided in electronic format in Appendix O (Volume VI of this RI report).

Rounding methods applied to sample results varied between the three separate field programs of the RI. During the Initial RI, the laboratory data were not rounded except for reporting purposes. Data were received from the laboratory, processed with the IRDMIS software, and uploaded to the IRDMIS Level 3 database in an unrounded format. The data were then downloaded from the Level 3 database, manually rounded, and entered into tables by a word processor for the RI report. An electronic copy of the unrounded Level 3 data can be found on disk in Appendix O. The rounding scheme used on the report tables is as follows (USATHAMA, 1990b):

- Increase the last significant digit by 1 if the first insignificant digit is greater than 5;
- Retain the last significant digit unchanged if the first insignificant digit is less than 5;
- Retain the last significant digit unchanged if even, or increase it by 1 if odd, if the first insignificant digit is equal to 5.

Between the Initial and Supplemental RI the U.S. Army released a new version of the IRDMIS software. The new version included an algorithm which electronically rounded Level 1 laboratory data prior to storage in Level 3. The rounding scheme was the same as that described above for the Initial RI, however, the Supplemental RI data stored in the U.S. Army's Level 3 database were rounded, whereas, the Initial RI data stored in the same database were not rounded. Dames & Moore's in house copy of Level 3 data also reflects these rounding differences between the Initial and Supplemental RI data. These data can be found on disk in Appendix O. For reporting purposes, the rounded Supplemental RI data were downloaded from Level 3 and entered into new tables which were included in the RI report. The IRDMIS Level 3 database maintains three digits beyond the decimal place regardless of the number of significant figures. Therefore, in the Supplemental RI tables, the data are rounded, but the results contain place holders to three digits beyond the decimal place.

For the Follow-on RI field program, the Level 1 laboratory data from all labs except for QAL were rounded electronically by the PC IRDMIS software prior to becoming Level 3. The Level 3 data were then downloaded and summary tables were electronically generated and included in the report. Because of delays in the validation of data received from QAL, the Level 1 data were used in the Second Revised Draft Final version of this report. In addition, because the QAL data were not processed using the PC IRDMIS software, an in house program was used to duplicate the rounding scheme described above. Once the data were rounded, they were then added to the summary tables along with the rest of the Follow-on RI data. After the Second Revised Draft Final RI was submitted, the Level 1 QAL data were uploaded to the U.S. Army's Level 3 database. Electronic copies of the Level 3 Follow-on data were added to the database tables in Appendix O.

Due to the significant time and costs associated with regenerating all of the RI tables, this version of the RI report uses the existing summary tables that were generated at the time of each phase of field work. The result is that there are minor differences in the way data are presented on tables for different field programs. In addition, Dames & Moore has maintained a database of all Level 3 data generated as part of the RI program. Rather than a complete current download of all data from the U.S. Army's Level 3 database, Dames & Moore's database is a compilation of data downloaded from Level 3 as it existed at the time of each phase of fieldwork. This database was used to construct the analytical data posting maps included in this RI report. Since the completion of the Follow-on RI field program, the U.S. Army has implemented a new rounding scheme which it has applied to all data stored in its Level 3 database (USAEC, 1995). The differences in data values resulting from the different numerical rounding approaches are too small to have any significant effects on the risk assessment results or the conclusions developed in this RI report.

Footnotes on analytical result tables provide information on data quality and usability (Appendix O). The footnotes consist of designated letters which have the same definition for each RI summary table. Footnotes are defined at the bottom of each summary table when the footnote is used to flag data in that table. The footnotes along with their associated definitions are provided in Appendix O. The criteria used to evaluate data quality are described in Sections 3.3 and 3.6.

3.5 LABORATORY QUALITY ASSURANCE AND QUALITY CONTROL PROGRAM, PROCEDURES, AND RESULTS

This section describes the laboratory QA/QC program, procedures, and results. The laboratory auditing program for the three RI field programs is described in Section 3.5.1. The information on the Initial and Supplemental RI are presented together in Section 3.5.2. The Follow-on RI QA/QC program and results are discussed in Section 3.5.3.

3.5.1 Laboratory Audits

Formal audits of the laboratories performing USAEC methods—DataChem, ESE/D, and ESE/G—were performed on an annual basis by the USAEC. The Dames & Moore chemists typically conducted a concurrent audit when PSF data or impacts to PSF data would be discussed. This is documented for audits performed in August 1992 and April 1993 for ESE/D. An informal audit of Sequoia Laboratory was performed in November 1992. Informal lab audits of QAL were performed in March 1993 and in January 1993 by the WJE chemists. Information gathered during the initial visit was used to establish the ability of QAL to perform analytical services for USAEC. Informal audits of QAL and Superior were conducted during the Follow-on RI in December 1994 to verify each laboratory's abilities to perform the contracted work as directed and to communicate any concerns to laboratory management and staff.

3.5.2 Initial and Supplemental RI

Data collection for the initial and supplemental RI required controls for all activities during planning, implementation, and production of data and deliverables. To accomplish these quality goals in an efficient and cost-effective manner, a continuous quality improvement (CQI) effort was applied to all work processes. The QA program at PSF was developed to ensure that technical and quality requirements were met. The PSF QA Program outlines the controls on field, office, and laboratory activities necessary to provide the data quality that complies with appropriate government regulations and USAEC requirements for environmental investigations. Specific guidelines for the QA Program at PSF are fully documented in the QAP (USATHAMA, 1990b), Geotechnical Requirements for Drilling, Monitor Wells, Data Acquisition, and Reports (USATHAMA, 1987), Final Quality Control

Plan (ECJC, 1990c), and Quality Assurance Supplements (RLSA, 1990 and 1992c). The objectives of these plans are to achieve accuracy, precision, and reproducibility.

Certain USAEC and EPA requirements for assessing the validity and usability of the data were employed during the RI. The Initial and Supplemental RI programs chart the recoveries of laboratory spikes and have in place a multi-level data review process consisting of bench level to laboratory QA Officer to Dames & Moore QA Officer to USAEC Chemist. USAEC also reviewed laboratory controls for trends. Data assessment beyond these protocols included verifying receipt of data, omitting data that were not requested for the RI, reviewing hard copy to electronic copy for transcription or analytical error, reviewing unknown compounds and validating data against a set of quality criteria (EPA, 1991a).

USAEC-certified data were elevated to Level 3 in the IRDMIS database once the USAEC Chemistry Branch reviewed control chart submissions. Based on the laboratory and Chemistry Branch review, data were validated by using flag codes to inform the PSF RI team of accepted, rejected, and qualified data. These flag codes were reviewed by the Dames & Moore data users to evaluate usable data for the RI and the risk assessment.

Before sending data for EPA methods to IRDMIS, manual checks were made between the laboratory hard copy and electronic file transfer. After data were accepted to Level 3, the appropriate data set was downloaded from the USAEC database into a working file at Dames & Moore. Data users made certain that data in the database were consistent with data in the hard copy packages. Any inconsistencies or discrepancies were noted and the resolution was documented in the hard copy data package.

In order to meet state regulatory limits, detection limits lower than the CRL or the MDL were identified for certain compounds and elements. The laboratory was asked to provide results between the method detection and instrument detection limit for EPA methods, and between the CRL and Criteria of Detection (COD) for USAEC methods. The COD is one-half the CRL. The analytes evaluated in this manner were dieldrin, heptachlor, chlordane, 1,1,2,2-tetrachloroethane, and phenol. No detections below the reporting limits for these compounds were identified. The database information was not changed to reflect this additional information. ICP metals in water samples were also reviewed for detections

between the CRL and COD. They included chromium, nickel, and zinc. These values were flagged in the USAEC database with a code of "P" indicating an estimated value.

Unknown compounds are those detections that appear in a GC/MS library search analysis at greater than 10 percent of the internal standard area. A maximum of 20 unknowns were reported for each fraction. The laboratory searched a spectral library database of known compounds to identify the unknowns. If a match between the known and unknown was 95 percent or greater, the compound name was to have been reported by the USAEC Test Name. A flag code of "S" would accompany this result. Compounds with less than a 95 percent match would be reported as "unknownNNN" where the NNN represents a scan number or retention time.

When reviewing the list of unknowns, the data users employed a list of criteria to assess whether unknowns were of concern in any one area at the PSF. All unknowns were reviewed, although not necessarily discussed unless the unknowns at the site had a sum greater than 100 µg/g for soils or 100 µg/L for waters; there were more than 25 unknowns per site; or a particular unknown was detected in more than 50 percent of the samples from a study area. All unknown detections are not discussed because the target analyte list was designed to detect contaminants that may be present due to historical activities, potential toxicity due to unknowns is not likely to be significant except at elevated levels, and any of the unknown detections are a confirmation of the presence of hydrocarbons, as reported by TPH, VOC, or SVOC analyses.

Library searches for the initial RI were performed by DataChem. The 95 percent criteria for reporting test names were not used by DataChem. However, the laboratory did supply a list of compound groupings for the unknowns. Generally, the groups of unknown hydrocarbons encompassed straight-chain, unsaturated, (poly)cyclic, oxygenated, nitrogen-containing, and aromatic hydrocarbons.

Data validation was performed on a group of data packages consisting of EPA chlorinated pesticide and herbicide analyses. An abridged version of EPA (1991a) guidelines was employed for the data validation. Appendix T contains a few examples of the data validation sheets. The objective of the validation was to decrease errors resulting from the application

of non-USAEC methods to the USAEC database. Approximately 50 percent of the chlorinated pesticides and 2 percent of the herbicide data packages were validated. Copies of the validation accompanied the hard copy data packages to USAEC Chemistry Branch. Data (field, laboratory, and office) produced under the above guidelines are of known and acceptable quality. They may be qualified using the USAEC flag codes as identified in the IRDMIS Data Dictionary or by footnotes on the data summary tables. Relevant portions of the IRDMIS Data Dictionary are provided in Appendix O.

3.5.3 Follow-on RI

The Follow-on RI was conducted to address data gaps identified after completion of the Initial and Supplemental RI. Quality assurance and quality control requirements applicable to the Follow-on RI are contained in the Quality Assurance/Quality Control Plan (WJE, 1994b). Aside from the specifications provided in the plan for various field and laboratory activities, laboratory audits and data validation were to be performed.

3.5.3.1 Data Review and Validation

The analytical data for the Follow-on RI were reviewed and validated. In the first three sections that follow, a description of this data review process is presented. Based on the findings of this review, additional review and validation efforts were undertaken, as described later in this section.

3.5.3.1.1 Field Data Review

Data review was performed in the field by the Field Chemist on analytical results provided by Superior. The rapid turn around data were used to make decisions in the field as to whether the vertical and lateral extent of chemicals was adequately defined. The data are also used for quantitative evaluations in the BRA.

All sample data were divided into two classifications, organic and inorganic, and two sets of review guidelines were used. Review guidelines for organic analyses were used for methods 8080, 4030, 8010, 8015 (modified), 8080, 8240, 8260, and 8270, while guidelines for inorganic analyses were used for methods 160.1, 6010, 7041, 7060, 7196, 7421, 7470, 7740, 7841, 9010, and XRF. The guidelines for each classification were further broken

down into review checklists, or decision blocks. Depending on the method being reviewed, certain line items on these decision blocks were disregarded as inappropriate. The five checklists for the organic analyses addressed raw data and results, method blanks, matrix spikes, trip and rinse blanks, and completeness. The five checklists for inorganic analyses addressed raw data and results, method blanks, matrix spikes, rinse blanks, and completeness.

The results of field data review were generally positive and the data were found to be usable for their intended purpose, based on the criteria employed for the field review. Following is a summary of the review procedures for organic and inorganic results. The documentation for the field data reviews is maintained by Dames & Moore in the project files, which will be transferred to USAEC at the completion of the PSF project. Copies of the checklists used for the review are provided in Appendix T.

3.5.3.1.2 Organic Data Review

Decision Block I, the first checklist for organic analyses, assessed whether the raw data and electronic data were acceptable and complete. Electronic and raw data were compared and checked for transcription errors. For methods 8080, 8010, 8015-M, 8260, and 8270, electronic data consisted of sample results, surrogate recoveries, laboratory control sample recoveries, matrix spike recoveries, and method blank results. Raw data consisted of chromatograms and integration sheets for analytical samples, method blanks, laboratory control samples, and matrix spike samples. For method 4030, electronic data consisted of sample and method blank results, and raw data consisted of bench notes. Data review was discontinued if any electronic or raw data were missing.

Decision Block II assessed whether method blank data were acceptable. Data review was discontinued if any method blanks were contaminated and analytical samples associated with contaminated method blanks were reanalyzed.

Decision Block III assessed whether matrix spike results were acceptable. Method 4030 had no associated matrix spiking. Particular attention was paid to peak interference and whether recoveries were affected.

Decision Block IV assessed whether trip and rinse blanks were acceptable. Trip blanks were associated only with volatile organic analytes. Data review was discontinued if any trip or rinse blanks were contaminated and analytical samples associated with contaminated trip or rinse blanks were reanalyzed.

3.5.3.1.3 Inorganic Data Review

Decision Block I, the first checklist for inorganic analyses, determined whether the raw data and results were acceptable and complete. Raw data consisted of electronic data as well as raw laboratory data. Electronic and raw data were compared and checked for transcription errors. For all ICP and GFAA methods, electronic data consisted of sample results, laboratory control sample recoveries, matrix spike recoveries, and method blank results. Raw data consisted of instrument printouts for analytical samples, blanks, laboratory control samples, and matrix spike samples. For method 160.1, electronic data consisted of sample results, blanks, and duplicates. Raw data consisted of bench notes. For XRF samples, electronic data consisted of sample results, laboratory control spikes, and blanks, and raw data consisted of bench notes. Data review was discontinued if any electronic or raw data were missing.

Decision Block II assessed whether method blank data were acceptable. Data review was discontinued if any method blanks were contaminated and analytical samples associated with contaminated method blanks were reanalyzed.

Decision Block III assessed whether laboratory control spike and matrix results were acceptable. Relative percent differences (RPD) and percent recoveries were compared to acceptable limits. Raw data were examined for reanalyses if the RPD or percent recoveries were out of specification. Post spike recoveries were checked if percent recoveries were outside of acceptable limits. Results were considered usable if post spike recoveries were within acceptable limits.

Decision Block IV assessed whether rinse blanks were acceptable. Data review was discontinued in any rinse blanks were contaminated. Analytical samples associated with contaminated rinse blanks were reanalyzed.

Decision Blank V checked sample data for completeness. Raw data were checked for comments included by the analyst. Investigative sample absorbencies were compared to instrument standards and blanks. All other appropriate quality assurance criteria were checked for completeness.

3.5.3.1.4 Data Validation

Initially 10 percent of the analytical data received from the fixed laboratories (QAL and ESE/D) were to undergo a data review and completeness check. At the beginning of this process, anomalies were encountered in the analytical data received from QAL. Initially, the principle observation was that there were mismatches between the electronic files in IRDMIS format and the hard copy data provided by the laboratory, due primarily to QAL's unfamiliarity with USAEC reporting requirements, which differ from EPA requirements. In addition, a number of documentary deficiencies were encountered as well as a greater than usual number of QC failures in certain portions of the data set. For these reasons, a more formal validation program was implemented.

Ten percent of the QAL data were processed through an "R-flag review". An R-flag review, or Level II review as it is sometimes called, is an assessment of the documentary compliance of the deliverable to specifications in the project controlling documents coupled with an assessment of five key indicators of data quality: precision, accuracy, calibrations, holding times, and blanks. No attempt is made to review the raw data, but only summary information is utilized to the extent that it is present. Further, the flagging protocols of an R-flag review are such that only "R" and "U" flags would be applied. Data that would be flagged "J" under National Functional Guidelines (NFGs) are not flagged as the intent of the R-flag review is to only identify those data that are unusable. The initial findings of this review were that, one, the data packages were missing substantial portions of the raw data necessary to perform a more complete review, and two, there was a strong likelihood that if a complete validation was performed on the data set in its then current condition, the data would fail to meet generally accepted completeness goals for a number of differing analyses.

Based on this information, a three part program was implemented to more thoroughly assess the data set and to assure that the data set was of a quality level capable of supporting the

goals of the Follow-on RI program, including the baseline risk assessments. The parts of the program were:

- A 100 percent review of the data packages for documentary compliance
- The application of a more rigorous validation program to the data set
- A 100 percent review of the electronic data in comparison to the hard copy data.

Each of these parts is described below.

3.5.3.1.5 Part 1 - 100 Percent Review of Data Packages

The contractual deliverable required of the laboratories was designed for application to the USAEC program and differs significantly with the requirements of a Level IV EPA data deliverable. The USAEC method of batching samples and the QC applied to the batches differs from the strict requirements of the EPA methods used for the Follow-on RI, making it impossible to completely meet both EPA and USAEC requirements in terms of quality control, documentation, and process. Thus, the focus of the deliverable review effort was not to construct a Level IV EPA style deliverable, but to ensure that contract requirements were enforced and that the raw data determined to be indispensable to an acceptable level of data validation were available. This approach was taken to validate the data to meet the requirements of the RI.

With the exception of wet chemistry data, the vast majority of document deficiencies have been resolved to the fullest extent possible. The size of the task, various contractual provisions, and various practical impediments at the laboratory, have not allowed complete assembly of data packages fully compliant with Level IV specifications, for all lots. This difficulty is apparent in a number of the data validation reports in that the validators have been forced to make usability assessments based in some cases on incomplete information. The validators have applied professional judgment based on the review of the entire data set in making these assessments. However, either a Level III or enhanced R-flag review has been completed on all data packages, as described below.

3.5.3.1.6 Part 2 - Rigorous Data Validation Program

Part 2 of the program was the application of a more rigorous data validation program. Ten percent of data that were subject to the R-flag review were reviewed to what has been called

Level III. The Level III review is based on EPA National Functional Guidelines (NFGs) but incorporates a number of modifications designed to accommodate the specifics of the methods employed; provide guidelines for methods not included in the NFGs; provide additional flagging guidance based on various regional modifications to the NFGs; and, is less rigorous than the NFGs with regard to the level of review of calculations. In this case only the calculation of the analytical result was checked, however, 100 percent of the results included in this review process were verified.

The outcome of this review showed that the most widespread problems with the QAL data were not quality control problems in the data but documentary deficiencies. On the basis of this determination, it was decided that the balance of the 90 percent of the QAL data not already reviewed would be processed through formal data validation. However, the level of effort necessary to perform a Level III validation of the entire data set was prohibitive from both a cost and schedule perspective. Therefore, based on the findings of the 10 percent Level III reviews, the R-flag, or Level II validation protocol was modified to encompass additional features such that any significant deficiencies in the data identified in the Level III review would be examined during the R-flag review on the balance of the data. In this manner, any deficiencies that would cause the data to be rejected would be addressed for the entire QAL data set.

With regard to the Superior data, only a 10 percent Level III validation was performed since, 1) the field reviews of this data were generally positive, 2) the 10 percent Level III reviews were generally positive, and 3) many of the results were immunoassay and XRF analyses with a different set of DQOs. The data provided by ESE/D for the April 1995 sampling round was subjected to an initial 10 percent Level III review. Based on those findings, which were very positive, the balance of the data were reviewed only for those items, primarily interference tests, that indicated the potential for rejection of some small portion of the data. Copies of the data validation protocols employed are presented in Appendix T.

3.5.3.1.7 Part 3 - Comparison of Electronic and Hard Copy Data

The final element in the program was the review and reconciliation of the electronic data base. During the validation process 100 percent of the data that were subject to validation were reviewed to ensure that the information in the analytical results field, and a number of

related fields, were correctly reported in the electronic database. The validators forwarded to the data management staff corrections based on that review. These corrections were then incorporated into the electronic database. Finally a series of logical tests were applied to the database to test the database for reasonability, the absence of various contradictions, and the presence of all of the data expected from the Follow-on RI field programs. Based on these tests, a series of inquiries were forwarded to the validators for reconciliation and additional corrections were made on an as needed basis. Final corrections were then implemented as needed.

3.5.3.2 Summary of Data Validation Program for the Follow-on RI

In the following text the quality of the results of the Follow-on RI validation program are discussed in terms of the various factors reviewed during the data validation process.

3.5.3.2.1 Organics

Samples were analyzed for a variety of organic compounds in 5 fractions: VOCs, SVOCs, pesticides/PCBs, herbicides, and TPH-G/D.

Seven percent of the volatile data were identified as unreliable during the data validation process. The majority of these failures were the result of calibration and holding time failures and primarily affected the water analyses by method 524.2 performed by QAL and the rapid turn around time method 8010 analyses from Superior. Significant portions of the volatiles data are also likely to be more biased or variable than normal. However, these data still fall within the definition of useable. Blank contamination was not a significant issue. The semivolatiles data display few failures in QC acceptance criteria. A modest number of data points may be more highly biased or variable than usual, however, less than 1 percent of the data were identified as being unreliable.

Due to a combination of calibration and surrogate failures, 8 percent of the pesticide data were flagged unreliable and a significant portion of the data, perhaps as much as 80 percent, should be considered to have detection limits that are biased low. The herbicide data are generally acceptable with approximately one percent of the data flagged as unreliable and approximately 10 percent flagged as estimated. Less than one percent of the data were impacted by blank contamination. The TPH data displayed good control with approximately

one percent of the data flagged "R", unreliable, less than one percent flagged "J", estimated, and none of the data impacted by blank contamination.

3.5.3.2.2 Metals

A wide variety of metals were analyzed by a large number of differing methods. In general terms the metals data are acceptable with a limited number of exceptions. One of two lots for silver were flagged estimated due to holding time failures. Eight percent of arsenic data were flagged "R", unreliable, primarily due to matrix spike failures. Chromium data were uniformly acceptable. Hexavalent chromium data are useable although some data may be considered estimated due to calibration anomalies. Limitations of the hexavalent chromium data are further discussed in Section 3.7.8. None of the copper data was rejected but 44 percent of the data were flagged "U", due to blank contamination. In a like manner, none of the mercury data was flagged "R" and 24 percent were flagged "U". Nickel, lead, and selenium data displayed only routine failures with less than five percent of any of these data flagged "R". Antimony and thallium displayed significant levels of QC failure with 30 percent and 11 percent of these data flagged "R", respectively. The multi-component ICP analyses displayed good control with only one percent of the data flagged "R" and approximately four percent of the data impacted by blank contamination.

Antimony, arsenic, and thallium data, and to a lesser extent the ICP and selenium data should be used only with a clear understanding of the limitations inherent in the data, as indicated by the footnotes on the tables in Sections 4 through 14. The data user consulted the data validation reports for additional guidance. This information was incorporated into the risk assessment, as data affected by blank contamination were considered non-detects and unreliable data were not used.

3.5.3.2.3 Conventional Analyses

All of the conventional data are usable with the exception of the bromide data in lot BBR and less than one percent of the cyanide data.

3.6 FIELD QUALITY CONTROL SAMPLES, RESULTS, AND INTERPRETATION

This section describes the types of quality control samples collected during the RI and the evaluation of these data. The evaluations for the Initial and Supplemental RI are discussed together, and are followed by a discussion of the Follow-on RI QC sample results. Quality control results were considered during the interpretation of the data from the RI. The QC results describe the data quality and determine how the data can be used.

Field and laboratory quality control samples were taken for the PSF field activities. Specific field quality control samples were used to evaluate potential sources of contamination that might have been introduced during collection or transportation of samples and to assess overall system precision and representativeness. Laboratory QC samples were used to assess precision, accuracy, and representativeness of the data. Contaminated QC blanks were evaluated to determine whether the analytes detected in the investigative samples generally represented field concentrations.

Four types of field QC samples were collected during the Initial and Supplemental phases: equipment rinse blanks, sample replicates, field blanks, and trip blanks. During the Follow-on RI, field QC samples included rinse, field, and trip blanks, field duplicates, and split samples. The analytical results of these QC samples and potential impact on the investigative data are discussed below.

3.6.1 Rinse Blanks

Equipment rinse blanks indicate the effectiveness of field decontamination procedures and were collected prior to reuse of the equipment at the next sampling site. The rinse water was collected after decontamination of sample collection equipment. Clean, distilled water was poured over the decontaminated equipment and into sample bottles. The analytical suites were identical to that of the investigative samples. For wipe samples, the rinse blanks were collected by pouring the wetting agent (water or organic solvent) onto the filter. The filter and liquid were analyzed together. Analytes detected in both the investigative sample and the associated rinse blank are flagged in summary tables and in the electronic database as

affected by blank contamination if the investigative value was not greater than 10 times the value in the rinse blank.

3.6.1.1.1 Initial and Supplemental RI

Rinse blanks for Initial and Supplemental RI were collected at 27 sampling sites for a coverage rate of approximately five percent. The analytes detected in the rinse blank samples collected during the PSF field sampling program are presented in Tables 3.6-1 and 3.6-2. The rinse blanks displayed detections of organic and inorganic target compounds, as well as some VOC non-target compounds designated with an "UNK" prefix. Several target metals were present at low levels, with sodium and lead present in concentrations equivalent to those detected in the field blanks. Results of the rinse blank analyses were compared to the results of investigative samples collected the same day. The following samples had detects for bis(2-ethylhexyl)phthalate that were determined to be non-detections based on the level reported in the sample:

Sample ID	Collection Date	Sample ID	Collection Date
LF9SB01	08/19/92	979GW06	09/01/92
LF7GW05	09/03/92	NKGW01	09/01/92

No other sample results were affected by rinse blank analyses. The rinse blank results indicate that equipment decontamination procedures were adequate to prevent site-to-site cross contamination of field sampling equipment.

3.6.1.1.2 Follow-on RI

Detailed results for rinse blanks are presented in Table 3.6-3. A listing of samples affected by rinse blank contamination is presented in Table 3.6-4. In general terms, the distribution and concentration of contaminants identified in the rinse blanks is not unusual with the exception of a single sample, EOMSB03, which displays unusually high concentrations of various metals. Other analytes and levels of contamination encountered are either easily explained in terms of the field blank data or are well within expectations. Overall, the Follow-on RI decontamination procedures were largely effective.

3.6.2 Trip Blanks

Trip blanks are samples of analyte-free water, provided by the analytical laboratories, that accompany investigative samples through the entire collection, handling, and shipping process. These samples are designed to evaluate VOC contamination introduced during transportation. These trip blanks are sealed at the laboratory and are not opened during the sampling. Analytes detected in both the investigative sample and the associated trip blank are flagged in summary tables and the electronic database as affected by blank contamination if the investigative sample value was not greater than 10 times the value in the trip blank.

3.6.2.1.1 Initial and Supplemental RI

A total of 64 trip blanks were analyzed as part of the Initial and Supplemental RI, giving a total coverage of approximately 10 percent. The analytes detected in trip blank samples collected during the RI are presented in Table 3.6-1.

Results of the trip blank analyses were compared to the results of investigative samples collected the same day. The sample from LF1GW04 collected on September 10, 1992, had a detection for methylene chloride that was determined to be a non-detection based on the level reported in the associated trip blank.

3.6.2.1.2 Follow-on RI

Detailed results for Follow-on RI trip blanks are presented in Table 3.6-3. A listing of samples affected by trip blank contamination is presented in Table 3.6-4. The distribution and concentration of analytes in the trip blanks are entirely routine and there is no evidence of contamination in the transportation process.

3.6.3 Field Blanks

Field blanks are aqueous samples of approved source water used for decontamination that are exposed to the sampling environment to assess incidental or accidental sampling contamination.

3.6.3.1.1 Initial and Supplemental RI

Four field blanks were collected during the Initial and Supplemental RI. The results of the field blank analyses are presented in Tables 3.6-1 and 3.6-2. Results from the field blank data indicate minimal contamination as a result of exposure to the sampling environment. The results of the field blank analyses were not used to correct investigative data.

3.6.3.1.2 Follow-on RI

Field blanks were not collected as part of the Follow-on RI.

3.6.4 Method Blanks

The contractor laboratories were required to analyze method blanks for all analytical methods used for the PSF samples. The method blanks determine the influence of the laboratory environment on investigative samples. The blanks consisted of analyte-free samples that approximated the investigative matrix and were taken through all steps of an analytical procedure including sample preparation, storage, and analysis. Results of the method blanks were compared to the results of investigative samples contained in the same analytical lot. Analytes detected in both the investigative sample and the associated method blank were considered non-detections if the value in the investigative sample was not greater than five times the value in the method blank, except for common laboratory contaminants (methylene chloride, acetone, methylethyl ketone, toluene, and phthalates), for which a 10 times rule was applied. Samples containing analytes that were determined to be non-detections based on the levels reported in the associated method blank are presented in Table 3.6-5 for the Initial and Supplemental RI and in Table 3.6-6 for the Follow-on RI.

3.6.5 Duplicates

Field duplicates are investigative samples that have been split into two or more containers and analyzed for identical compound suites. Each portion was preserved and treated identically throughout the sampling procedure. Duplicates were used to evaluate variability of sample results due to sampling, handling, shipping, storage, preparation, and analysis. The reproducibility of results varied with the type and homogeneity of matrix analyzed.

Since field duplicate results are a measure of precision for both field and laboratory activities, the results may vary more than true laboratory duplicates, which measure only laboratory performance. Soil duplicate results are expected to have a greater variance than water duplicate results due to the heterogeneity of the matrix.

3.6.5.1.1 Initial and Supplemental RI

Duplicate samples were collected for 15 soil samples and six groundwater samples during the Initial and Supplemental RI. The paired analytical results were compared using the relative percent difference (RPD) of each data pair to determine a relationship between the two samples. This statistical calculation is as follows:

$$RPD = \frac{|S - D|}{(S + D) / 2} \times 100 \quad 3.6-1$$

S = first sample value (Original)

D = second sample value (Duplicate)

Paired analytical results used in this statistical study included only those replicate analyses in which at least one positive identification was reported. In general, the RPD values are meant to indicate reproducibility. As there are no review criteria under USAEC for comparability of field duplicate analyses, the guidelines for laboratory duplicates were used as a point of reference. The guidelines for laboratory duplicates are a control limit of ± 20 percent RPD for sample values greater than five times the CRL.

During the initial RI field program, 22 duplicate samples for soil and four duplicate samples for water were analyzed. Two wipe sample duplicates were analyzed. For the supplemental field program, 10 soil pairs (including sediments) and one groundwater pair fit this criteria for various inorganic and organic analytes. At least 6 out of 10 pairs had an acceptable RPD.

The Initial RI results of the statistical analysis indicate that inorganic and organic analyses conducted for water samples were the most reproducible. For the Initial RI, the highest

variabilities were observed for SVOCs and pesticides/PCBs analyzed in soils, and for TPH analyzed in water. Approximately 60 percent of the detection pairs were within 20 RPD.

The same comparison could not be performed for the Supplemental RI water duplicates since only one pair fit the criteria for assessment. Supplemental RI soil duplicates showed average RPDs of less than 30 percent for inorganics. No organic RPDs fit the criteria for determining the average RPD.

The results of the analysis of the Initial and Supplemental RI field QC activities indicated that, with exceptions as noted above, the data were free from gross contamination and that overall system precision was acceptable. No conditions were identified, within the scope of review discussed above, that would cause the data to be unusable.

3.6.5.1.2 Follow-on RI

Other than the Matrix Spike/Matrix Spike duplicates, assessed as part of the laboratory data validation process and discussed previously, field duplicates were not collected as a part of the Follow-on RI.

3.6.6 Split Sample Data

California regulatory agencies collected split samples during the Supplemental and Follow-on RI. Split sample results and Dames & Moore sample result are compared below. A full listing of the State of California results are provided in Appendix O.

3.6.6.1.1 Supplemental RI

During the Supplemental RI, soil sample splits were collected for the State of California at 11 PSF sites. These soil samples were analyzed for various overlapping parameters by Dames & Moore and the State of California. The split ICP metals analyses were reviewed for similarities. In general, the metals data were comparable, with the exception of thallium. The thallium data from the ICP analysis provided by ESE/D indicated concentrations ranging from not detected ($< 14.7 \mu\text{g/g}$) to just above $200 \mu\text{g/g}$. Thallium was not detected in any of the State samples at a detection limit of $15 \mu\text{g/g}$. Review of corrective actions from ESE laboratory and discussions about method control determined that the USAEC-certified method (JS13) was inaccurate for this metal. Problems in the analytical system affected

thallium results. The thallium data soil data from the Supplemental RI do not meet project quality requirements established for the PSF and are considered unusable for the RI process. However, the data are contained in the Level 3 IRDMIS database. A comparison of RI and State results are presented below and the State data are in Appendix O.

SAMPLE LOCATION	DEPTH (ft bgs)	RI RESULT ($\mu\text{g/g}$)	STATE SPLIT SAMPLE RESULT (mg/kg)
LF7GW06	0.0	156	<15.0
LF7GW10	0.7	95.3	<15.0
LF7SB06	2.9	33.6	<15.0
LF7SD06	3.0	97.3	<15.0
LF1SB01	22.5	<14.7	<15.0
DAESB01	21.0	49	<15.0
GGGW01	3.0	97.4	<15.0
GGGW02	13.6	211	<15.0
GGGW03	2.0	83.8	<15.0
GGGW04	2.5	2.5	<15.0
BBSB16	0.0	68.9	<15.0

3.6.6.1.2 Follow-on RI

Duplicate samples were collected from two groundwater monitoring wells and four soil borings that were split between QAL and the State of California during the Follow-on RI. Analyses were performed for pesticides/PCBs, TPH-G and TPH-D, and filtered and unfiltered metals in the groundwater samples. In the soil samples only metals were analyzed. The results of these split sample analyses were compared as a QC check. Sample results were expected to agree to within 20 percent for water samples and 35 percent for soil samples to be considered acceptable. Results that agreed to within 50 percent for water and 100 percent for soils were considered marginal. Results that did not agree to within those expanded criteria were considered unacceptable.

The results of the comparison of the investigative and State split samples are summarized in Tables 3.6-7 through 3.6-13. Results for the groundwater samples were acceptable for all

organic parameters. Sample DEHGW03 displayed significant variability between the results from the two different laboratories in the unfiltered sample for all analytes. All other samples analyzed for metals displayed generally acceptable precision with exceptions for individual metals. The soil samples displayed acceptable or marginal precision for most of the analytes with only occasional RPDs exceeding routine levels. The State reported soil results that were uncorrected for moisture; therefore, the QAL results in Table 3.6-13 are also uncorrected for moisture. The moisture correction is applied to these results in the rest of this RI report.

3.6.7 XRF Confirmation Samples

XRF data for antimony, lead, and zinc were compared to the results of confirmation analyses by atomic absorption and ICP methods. The data were compared using protocols for comparing field duplicates taken from EPA Region II functional guidelines for validation of inorganic data. In this protocol, a relative percent difference (the difference divided by the average multiplied by 100) is calculated using the results of the two analyses. If this result is less than 100 percent for soil samples, the data are taken to display an acceptable match. For purpose of this comparison, if the results of the XRF and confirmation analysis match to within 100 percent, the XRF data are considered confirmed. In the case where non-detects are compared to positive results, the detection limit of the non-detect was used in the calculation of the relative percent difference.

For antimony and zinc, all of the analyses meet the criteria given above. Thus, the XRF data are confirmed. For lead, seven of twenty seven tests failed to meet the criteria given above. There is no apparent pattern to the failures. The XRF results were as often higher than the atomic absorption or ICP results as they were lower. Both instruments display apparent false positives or false negatives in relation to the other. Thus, the XRF lead data are not uniformly confirmed by the atomic absorption results. XRF results were used with caution in decision making.

3.6.8 Immunoassay Confirmation

The same basic rules describes above were applied to the comparison of immunoassay results for total petroleum hydrocarbons to gas chromatographic results. One difference is that the result of the immunoassay was compared to the total of both the diesel and gas

fractions as analyzed by gas chromatography. The eight comparisons provide results that meet the criteria described above. Thus, the immunoassay results are considered confirmed.

3.6.9 Conclusions

The data from the Initial and Supplemental RI were produced by different laboratories using entirely different methods, in many cases, than the data produced for the Follow-on RI. The Initial and Supplemental RI data were reviewed according to procedures appropriate to their methods and have generally been found to be acceptable in terms of precision, accuracy, and representativeness.

Some portions of the Follow-on RI data suffer from documentary and technical deficiencies that require the data user to apply these data cautiously and only with a full knowledge of the limitations defined in the data validation reports. However, this should not be taken as a condemnation of the data set as a whole. A detailed review, such as that presented above, indicates that the deficiencies are limited, in large measure, to clearly definable subsets of the data. Thus, the bulk of the data are acceptable and usable within the scope of the review performed.

Specific areas of concern in the Follow-on RI data include: VOC data by method 524.2 and method 8010; portions of the pesticide/PCB data; the metals arsenic, antimony, and thallium; and, the anion bromide in one analytical lot. With these exceptions, the data are useable for their intended purpose with incidental exceptions well within the normal experience of the validators. With the exception of the wet chemistry data, the vast majority of documentary deficiencies have been resolved to the fullest extent possible.

3.7 CONTAMINANT IDENTIFICATION PROCESS AND AMBIENT SOIL CONCENTRATIONS

Environmental media sampled at the PSF include surface and subsurface soil, groundwater, surface water, and sediments. The contaminant identification process is performed independently for each of these media. Ambient conditions differ from background conditions in that they incorporate anthropogenic influences.

Because inorganic constituents, namely metals, are naturally occurring, the ranges of ambient concentrations are characterized to help assess these chemical constituents as potential contaminants. Ambient conditions have been characterized for metals in soil. For the purpose of discussing the PSF soil data in this RI report, the following definitions apply:

Background: Concentrations representative of naturally occurring levels with no contribution from any anthropogenic sources.

Ambient: Concentrations in soil that have not been influenced by U.S. Army activities but are representative of ubiquitous anthropogenic and natural sources such as common urban activities and natural metals occurrence in geologic formations.

In contrast to inorganics, organic constituents such as petroleum compounds and pesticides do not occur naturally at the PSF and are considered anthropogenic. Ambient organic concentrations for soil were not characterized because, although there is the potential for ambient levels of PAHs and pesticides resulting from fossil fuel emissions and routine pesticide use, respectively, it is not assumed that the ambient levels of these constituents at the PSF are significant. This inference is based on pesticide results from background surface soil samples (Figure 3.2-3) that were collected during the Initial RI which show very few detections at very low concentrations. Also, because of the general absence of PAHs at concentration levels of concern at most of the RI sites, there appears to be little basis for attempting to characterize ambient concentrations of PAHs. Therefore, in this RI report, all detected organic constituents are considered possible site-related contaminants and are characterized in terms of nature and extent and are included in the risk assessment.

Ambient concentrations of chemicals in groundwater, surface water, and sediment were not characterized. However, for perspective, sediment that was collected from open ditches (versus storm drains) or from the Baker Beach seep, Lobos Creek, and Mountain Lake was evaluated based on the ambient soil concentrations. The results of the contaminant identification process for these media are included in the study area sections of this report, Sections 4 through 14.

This section first presents the ranges of background soil concentrations from other studies within the region, along with PSF background and ambient data set ranges (Section 3.7.1). It

is followed by a discussion of the contaminant identification process and ambient concentration development for inorganics in soil at the PSF (Section 3.7.2). This process is outlined in Figure 3.7-1. Section 3.7.3 focuses on one of the inorganics, chromium, because the oxidation states of chromium significantly affect health risk results. The mobility of three of the inorganics (chromium, nickel, and lead) is evaluated in Section 3.7.4. These inorganics were frequently detected above ambient concentrations at the PSF, and the potential risks posed by these metals are controlled largely by their aqueous solubility and mobility. Additionally, Section 3.7.5 presents an evaluation of the inorganics detected in filtered and unfiltered groundwater from the PSF, demonstrating the typical concentration differences between unfiltered and filtered groundwater sample results.

3.7.1 Overview of Regional Soil Concentrations

Characterizing ambient metals concentrations in soils at the PSF is integral to the identification of contaminants of concern for the nature and extent assessment as well as the BRA. Characterizing these ambient conditions is difficult because of the complexity of the physical setting of the PSF. Variability within each of the lithologic units, coupled with a long history of human activity at multiple study areas and the extensive use of fill material in many areas of the PSF contribute to the difficulty. To aid in this evaluation, regional soil concentrations are reviewed.

The ranges of "background" soil concentrations (as defined by the data sources) for various sites located in the San Francisco Bay region are listed in Table 3.7-1 to provide a frame of reference for the concentrations observed from background and investigative sampling at the PSF. These data are used as a frame of reference and not as background or ambient values applied to the PSF, because they generally do not directly correlate with the lithologic units found at the PSF. However, they do provide perspective on concentrations that occur naturally at other nearby sites, which may be geologically similar to PSF lithologic units or fill materials that may have been brought onto the PSF. Table 3.7-1 summarizes data from:

- Northern Santa Clara County
- Union City Pacific States Steel Corporation Site
- San Leandro - Roberts Landing Development Site (Area 2)

- Lawrence Berkeley Laboratory
- A study conducted by the California Department of Soil and Environmental Sciences.

The concentrations listed in Table 3.7-1 for Northern Santa Clara County were presented in a Master's thesis by Scott (1991). They were obtained from pre-existing reports for various environmental investigations to evaluate natural background levels. Results from over 150 samples were assessed and found to be within the low end of the ranges reported by the U.S. Geological Survey in a nation-wide study (Scott, 1991).

Table 3.7-1 also presents the range of concentrations detected in background soil samples from Clear Lake Clay and Rincon Clay Loam. These samples were collected in support of a site wide RI for a Pacific States Steel Corporation in Union City (SEC Donohue, 1992).

The concentrations listed in Table 3.7-1 for the San Leandro area are from ten background soil samples collected in support of the Phase II RI of the Roberts Landing Development Site (Dames & Moore, 1989).

The concentrations listed for the Lawrence Berkeley National Laboratory (LBNL) are the minimum and maximum concentrations as determined from 498 soil samples taken from the borings for 71 monitoring wells (Lawrence Berkeley National Laboratory, 1995). The samples were collected from five geologic categories: Fill and Colluvium, Great Valley Group, Moraga Formation, Orinda Formation, and the San Pablo Group. As noted in Schlocker (1974), fragments of the Great Valley sequence are included in sheared bedrock such as found at the PSF. A statistical estimate of the 95th percentile of each data set was used by LBNL to define background concentration.

The concentrations listed under California Soils are taken from a study performed by the California Department of Soil and Environmental Sciences, Riverside. The study used a total of 50 benchmark soil samples representing 22 soil series, collected throughout California. The sampling sites were mostly from agricultural fields distant from known point sources of contamination, making these concentrations representative of background levels (Bradford et al., 1992). The minimum and maximum concentrations listed in Table 3.7-1 are from four coastal sites listed in the study that were thought to most resemble Bay Area soils, such as the soils found at the PSF.

PSF background and ambient concentration ranges are also presented in Table 3.7-1. As shown in this table, a wide range of metals concentrations in soils occurs naturally in the region. The background and ambient concentrations for the PSF are similar to background concentrations found by others in the region (same order of magnitude), with the exception of chromium, cobalt, magnesium, manganese, and nickel. The relatively higher ambient concentrations of these four inorganics at the PSF are attributed to the Franciscan Formation bedrock at the PSF, which is naturally elevated in these elements. The derivation of the PSF information is discussed in the following section.

3.7.2 PSF Ambient Soil Evaluation

For the PSF, the identification of potential contaminants and the estimation of ambient concentrations were iterative processes using statistical evaluation and professional judgment while recognizing the inherent variability of these naturally occurring constituents. Because the operational history necessary to clearly indicate specific types of inorganic contamination is not available for most RI sites, a conservative approach was adopted. That is, the screening of RI site data against ambient values may result in retaining metals in soils that are not attributable to any known contaminant sources. Given the levels present, and without justification to rationally eliminate these chemicals as possible residuals of past U.S. Army practices, an unacceptable risk to the potentially exposed receptors may result. However, the risk may not be substantially above the risk posed by ambient or background conditions at the PSF or at other sites in the region.

To deal with the complexity and uncertainties, a stepwise process is employed. The goal is to identify inorganic contaminants at the PSF which likely are a result of U.S. Army activities and justify the inclusion of these chemical constituents in the nature and extent assessment and the BRA for the site. The process generally follows an approach recommended by the Region IX USEPA that has been used to evaluate ambient conditions at two other federal sites in the Bay Area. These sites are Mare Island Naval Shipyard in Vallejo, California (Dept. of Navy, 1995a) and Naval Station Treasure Island (Dept. of Navy, 1995b). Final ambient concentration values from these studies were not available at the time of this

writing. The steps employed in assessing ambient inorganic concentrations in soil at the PSF include:

1. soils description and data compilation
2. risk-based screening of potential contaminants
3. ambient soil concentration estimation
4. determination of ambient exceedences by study area
5. comparisons of investigative samples to ambient concentrations
6. spatial analysis

These six steps are discussed in the following subsections. The general procedures for Steps 5 and 6 are presented in Sections 3.7.2.5 and 3.7.2.6, and are discussed on a site-specific basis in the study area sections of this report, Sections 4 through 14.

3.7.2.1 Step 1 - Soils Description and Data Compilation

The purpose of step 1, soils description and data compilation, is to combine the lithologic soil units that exhibit similar soil chemistry thus increasing the number of samples representing each unique chemistry. Background soil samples were collected at the PSF primarily to characterize the inorganic chemical composition of the native lithologic soil units (Figure 3.2-3). This section briefly describes the lithologic units at PSF, presents a statistical comparison of chemical data from the lithologic units, and summarizes how the data were compiled based on the statistical comparison. Appendix A provides summary statistics and box-and-whisker plots for each analyte.

3.7.2.1.1 Soils Description

The native lithologic units that comprise the soils at the PSF are described in detail in Section 2 of this RI report. Background soil samples were collected during the Initial, Supplemental, and Follow-on RIs to characterize the specific lithologies found at the RI sites and study areas. A total of 28 background samples were collected in these lithologic units and analyzed for inorganics. The selection of background soil sample locations was based on the following criteria:

- Samples used in the background evaluation were taken from native materials, in areas where filling was not known to occur.

- Samples were not acquired near any area known or suspected to be a source of target chemical constituents at the PSF.
- To the extent possible, samples were not collected adjacent to major roadways, such as Lincoln Boulevard or Highway 1, and Follow-on RI samples were collected only from the subsurface, to avoid potential anthropogenic influences.
- Samples were taken from native lithologies found at the PSF, including serpentinite from the Franciscan Formation, Colma Formation, and unconsolidated sand units (i.e. beach and dune sand).

Based on investigative and background sampling efforts, the five lithologies identified at the PSF are:

- Beach deposits
- Dune sand
- Colma Formation
- Serpentinite and material known to contain serpentinite
- Fill material undifferentiated by parent lithology.

As part of the background sampling program, five samples were collected from the beach deposits (i.e., beach sand); nine samples were collected from the dune sand; eight samples were collected from the Colma Formation; and six samples were collected from the serpentinite. These lithologies occur within the study areas at the PSF. In addition, single samples of fill and chert gravel and two mixed samples of beach and dune sand were collected from the site; however, they were not used in the background data evaluation.

Some of the site investigative data did not fit clearly into one of these five groups, because they were collected to evaluate the vertical and lateral extent of chemicals, not to assess ambient concentrations. The procedure followed in categorizing these samples is described in step 3 (Section 3.7.2.3).

3.7.2.1.2 Statistical Comparisons

The background sampling results were used to group lithologic units based on the similarities of soil chemistry. Statistical comparisons were performed to evaluate the hypothesis that the lithologic units may exhibit similar geochemical character and could, therefore, be combined

for the summary statistics. The chemical concentrations of some inorganics, such as chromium and nickel, differ greatly in the serpentinite and sedimentary units (see Appendix A). Therefore, analyte concentrations from the serpentinite unit were not included in the statistical comparisons. Fill material was not included in the statistical comparisons because of the limited background data for fill.

The procedure shown in Figure 3.7-2 was used to compare analyte concentrations in the background data sets in the Colma Formation, beach sand, and dune sand lithologies. The percentage of detections in each lithology was determined for each analyte. If the percentage of quantified results for a particular analyte was less than 80 percent, the analyte was not included in the statistical procedure. If the proportion of detections for a particular analyte exceeded 80 percent, an analysis of variance (ANOVA) procedure was performed.

Consistent with USEPA guidance (EPA, 1989a), non-detects in the data were replaced with one-half the detection limit prior to performing the parametric ANOVA. Duplicate sample results were averaged.

ANOVA is the name given to a wide variety of statistical procedures that compare the means of different groups of observations to determine if significant differences exist between them. In this application, the null hypothesis for the parametric ANOVA assumes that the mean analyte concentrations from all lithologies are equal. Hypothesis tests with the parametric ANOVA assume that the errors (residuals) are normally distributed with equal variance. For analytes having greater than 80 percent detections, residuals were tested for normality using the Shapiro-Wilk test (EPA, 1992a) and for homogeneity of variance using Levene's test (EPA, 1992a). If the residuals of the original data did not meet both assumptions, data were transformed using natural logarithms. The Shapiro-Wilk and Levene tests were then performed on the residuals of the log-transformed data. Analytes that were neither normally nor lognormally distributed, as indicated by the Shapiro-Wilk and Levene tests, were evaluated using the nonparametric ANOVA Kruskal-Wallis test. The Kruskal-Wallis test uses the ranks of the data to determine if significant differences exist between group means. In this application, the null hypothesis for the Kruskal-Wallis test assumes that the mean concentrations for the lithologies are equal.

All ANOVA tests (parametric and nonparametric) were conducted at the five percent significance level (Type I error rate). For analytes with significant differences in mean concentrations, multiple-comparison techniques were then used to compare the mean concentrations between each lithology. These comparisons were used to evaluate which lithologies had statistically different analyte concentrations. This was accomplished by calculation of the Bonferroni t-statistic for analytes that were normally or lognormally distributed (EPA, 1989a). Multiple comparisons for analytes tested using the nonparametric Kruskal-Wallis test were conducted by comparing differences in mean ranks of analyte concentrations for each lithology.

Table 3.7-2 summarizes the ANOVA results for the Colma Formation, beach deposits and dune sand. The ANOVA results show no evidence suggesting that the mean concentrations for calcium, copper, and potassium were statistically different for the Colma Formation, beach sand, and dune sand. As illustrated in Figure 3.7-2 where the ANOVA reveals a statistically significant difference for the three soil types, a multiple comparison procedure was performed. Therefore, the multiple comparison procedure was used to performed separate ANOVAs between the following lithologic types:

- Beach deposits and Colma Formation
- Beach deposits and dune sand
- Colma Formation and dune sand.

As illustrated in Table 3.7-2, the multiple comparison tests show no statistical evidence suggesting that the mean background chemical concentrations for the beach deposits and dune sand are different. The Colma Formation is statistically different from both the beach deposits and dune sand. Iron and vanadium are the only exceptions to the second observation for the Colma Formation and dune sand.

3.7.2.1.3 Data Compilation

The results indicated that the distributions of inorganics concentrations in the Colma Formation are statistically distinct from those of the beach and dune category. In addition, the distributions of the inorganic parameter concentrations are found to be statistically the same in the modern beach deposits and the older dune sand that cover a significant portion of the PSF. Therefore, results from the beach deposits are combined with results from dune

sand. As indicated in the previous discussion on statistical comparisons, the distributions of inorganics concentrations in serpentinite materials are different from those of the beach/dune sand and Colma Formation because of greater variance and exceptionally higher ranges in some parameters such as nickel and chromium. Thus, serpentinite materials represent a distinct lithologic group. Samples consisting of fill material are also a distinct lithologic group because the fill material category does not share a completely common origin with any of the other groups.

The output of step 1 resulted in data compilation of the following lithologic groups:

- Beach/dune sand
- Colma Formation
- Serpentinite and material known to contain serpentinite
- Fill material.

Based on these findings, the background data and site data were compiled according to these designations. Appendix O includes computer diskettes containing the chemical concentration data and lithologic group for all samples analyzed for inorganics.

3.7.2.2 Step 2 - Risk-based Screening of Potential Contaminants

Step 2, a risk-based screening of inorganic constituents detected at PSF, was used to help focus the contaminant identification process. The elements calcium, magnesium, potassium, and sodium were eliminated as potential contaminants because they are common rock-forming elements and occur naturally at high levels. This is consistent with Section 5.9.4 of RAGS (EPA, 1989b), which states that chemicals that are essential human nutrients, present only slightly above naturally occurring levels, and toxic only at very high doses need not be considered further in the qualitative risk assessment. These four elements are considered nontoxic to both human and ecological receptors. Additionally, iron is considered nontoxic to humans (EPA, 1989b).

In contrast to the methodology described for the Navy sites (Dept. of Navy, 1995a, 1995b), no further screening against PRGs was performed in this step of the ambient evaluation. There are two reasons for this difference. The first reason is that although other inorganics are not present at the PSF at concentrations of concern to humans (aluminum, barium,

cobalt, cyanide, iron, selenium, and vanadium), all of these occur at concentrations above the lowest ecological PRGs that have been developed for the PSF (DEH decision document, preparation in progress). The second reason is that there are potential additive effects of these analytes which may contribute to the total risk.

3.7.2.3 Step 3 - Ambient Soil Concentration Estimation

This section describes the statistical methods used in step 3 to estimate ambient concentration limits for potential inorganic contaminants in soil identified in steps 1 and 2 of the contaminant identification process. This step, ambient concentration estimation, involves three phases: data set preparation, identification of threshold concentrations, and ambient concentration calculations.

Data Set Preparation. The data sets were prepared for threshold identification as follows:

- Combine the background data set and the site data set into the lithologic groups: beach/dune sand, Colma Formation, serpentinite/material known to contain serpentinite, and fill material. Some of the samples did not fit clearly into one of the four lithologic groups as described below; however, other characteristics were evaluated to assign the samples to the most appropriate group.
- Calculate summary statistics by analyte for each lithologic group. Summary statistics include the maximum, minimum, mean, standard deviation, skewness, kurtosis, and coefficient of variation for the untransformed and transformed data (see Appendix A). The process of estimating ambient metal concentrations must account for metal concentrations reported as non-detect. A value of one-half the reported detection limit (DL) is substituted for each non-detect data point. The frequency distribution that results when many non-detect data points are included as one half the DL is generally bimodal (the non-detect data represent an anomalous peak). In the few cases where detection limits were higher than the highest detection, the data are excluded from the ambient data set. Also, duplicate sample results are averaged for the summary statistics.
- Conduct distributional tests to aid in the decision of the distribution assumption. The normality assumption is tested using the D'Agostino's test for data sets with more than 50 values. For data sets of less than 50 values, testing for normality is performed using the W-test (Gilbert 1987). Negative results for tests of both normal and lognormal data

indicate that nonparametric techniques must be applied to estimate the mean and variance. The tests for normality are performed using statistical analysis software. The output is presented in Appendix A.

- Construct cumulative probability plots of the untransformed and transformed data. These graphs are used to distinguish between populations of ambient concentration data and site-related data. The plots are presented in Appendix A.

Tables 3.7-3 through 3.7-6 present the summary statistics and output of the distributional tests for each lithologic group.

Although the assignment of background samples into lithologic categories was straightforward because the samples were purposefully collected to evaluate typical concentrations for specific lithologic types, the assignment of some of the samples collected to assess the vertical and lateral extent of chemicals is more complex. This is because mixing of lithologies is common near lithologic boundaries and in fill areas. In addition, some of the lithologies identified at the PSF by Schlocker (1974), such as slope debris and ravine fill, are derived from reworking of bedrock and/or unconsolidated deposits. Furthermore, the Franciscan bedrock locally contains rock types other than serpentinite, such as chert, shale, silt, graywacke sandstone, and greenstone (basalt).

The approach taken in assigning these samples to lithologic categories was to consider site specific information, such as the location of the sample in regional setting, soil type of shallower and deeper soil samples, and prominent composition. The appropriateness of the assignment of these samples was further evaluated in the spatial analysis, by reassessing the lithologic assignment for samples exceeding the corresponding ambient values.

Identification of a Threshold. For the second phase of step 3, normal and lognormal cumulative probability plots for each potential contaminant and lithologic group were constructed (Dept. of the Navy, 1995a). The plots were used to visually select a threshold concentration representing ambient conditions, and to visually identify outliers that represent potential contamination. The assumed distribution for evaluating the plots was based on the results of distributional tests discussed in the data set preparation phase. The recommended

distribution from the statistics output was used. The distributional assumption for each data set are listed in Tables 3.7-3 through 3.7-6.

Analyte specific data sets which exhibit a bimodal distribution result in a cumulative probability plot that has two apparent segments, each with a different slope. The segment with the largest concentration values are considered to represent a potentially contaminated group of samples. The segment with smaller concentration values is considered to potentially represent the distribution of ambient values. The threshold concentration value at the inflection point where the slope of the plot abruptly changes was interpreted to approximate the upper end of the ambient population distribution. Threshold values are not interpreted from probability plots where the inflection point is not clearly discernible. The threshold values are listed for each lithologic group in Tables 3.7-3 through 3.7-6. The cumulative probability plots with the threshold values are presented in Appendix A. For those analytes with very low detection frequencies, a threshold value was not selected.

When one or more inflection points were noted, the data above and below the inflection point(s) were evaluated to assess whether these points represented non-detects, lithologic variations, or potential contamination from U.S. Army activities. The background sample data were useful in this assessment because they were purposefully collected to avoid anthropogenic sources, and therefore, represent background conditions. The plots for the other lithologic groups were also considered. For some analytes, such as chromium, cobalt, manganese, and nickel, concentrations in serpentinite samples exceeded the other lithologies. This is consistent with the known composition of the bedrock. In some cases, concentrations in the fill samples were obviously higher than the other lithologies. This is not unexpected, as some of the fill may not be from the PSF. For example, much of Crissy Field contains fill material dredged from San Francisco Bay. In addition, the number of samples in the fill category is greater than any of the other categories, which would tend to result in a wider range of concentrations. Comparison to Bay Area background concentrations provided additional perspective in evaluating data above and below the inflection points.

Estimation of Ambient Concentration. In the third phase of step 3, the threshold values identified in phase 2 were used to estimate ambient concentration limits (Dept. of the Navy, 1995a). If a threshold value was distinguishable, the data above the threshold were excluded

and the 80 percent lower confidence limit (LCL) of the 95th percentile of the remaining data set was calculated (Dept. of the Navy, 1995a). This procedure is applied instead of using the threshold value because there may be some overlap between the population representing ambient conditions and the population representing potential contamination. The LCL of the 95th percentile is considered an estimate of the ambient concentration upper range. The number of values identified above the threshold value, along with summary statistics for the ambient data set are provided in Tables 3.7-3 through 3.7-6. The 95th percentile value and the LCL value are also presented. The analytes (i.e., data points) with concentrations greater than the LCL and corresponding study areas were retained for further evaluation in step 4 (Section 3.7.2.4). A summary table presenting the ambient concentrations for each lithologic group is included as Table 3.7-7.

For those analytes with very low detection frequencies for which threshold values were not selected, such as antimony, the analyte detection limit was considered the ambient concentration limit. That is, any detection was considered to be potential contamination. Because samples were collected under different field programs, reporting limits varied for each analyte.

For those analytes without a discernible threshold value (i.e., there is no apparent contaminant population significantly elevated above ambient concentrations), a conservative estimate of the ambient population was made by calculating the 80 percent LCL on the 95th percentile and estimating the 95th percentile for each analyte in each lithologic group. It is conservatively assumed that data points above the LCL represent potential contamination. The analytes and corresponding study areas are retained for further evaluation in step 4 (see Section 3.7.2.4). The LCL is considered a conservative estimate of the ambient upper range. As stated in Section 3.7.2, the output may include chemicals that are not attributable to known contaminant sources.

The LCL calculation is distribution dependent. The following subsections detail how the LCL is calculated for normal, lognormal, and nonparametric data sets.

Ambient Limits for Normal Distributions. Evaluation of normally distributed data is a two-step operation. First, the mean and standard deviation, \bar{x} and s_x , are calculated from the data:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad 3.7-1$$

$$s_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} \quad 3.7-2$$

The 80 percent LCL for the 95th percentile of a normal distribution is:

$$LCL_{0.80}(x_{0.95}) = \bar{x} + s_x (2 Z_{0.95} - K_{0.80,0.95}) \quad 3.7-3$$

where:

$Z_{0.95}$ is a table value for the 95th percentile of the standard normal distribution, and

$K_{0.80,0.95}$ is a table value for a specified n , with $1-\alpha = 0.80$ and $p = 0.95$. Z and K can be obtained from Tables A-1 and A-3, respectively, in Gilbert (1987) or from Hahn and Meeker (1991).

Ambient Limits for Lognormal Distributions. Evaluation of lognormally distributed data is a three-step operation. First, the data set is transformed by finding the logarithm of each value, x_i :

$$y_i = \ln x_i \quad 3.7-4$$

Next, the lognormal mean and standard deviation, \bar{y} and s_y , are calculated from the data:

$$\bar{y} = \frac{\sum_{i=1}^n y_i}{n} \quad 3.7-5$$

$$s_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n - 1}} \quad 3.7-6$$

The 80 percent LCL for the 95th percentile of a lognormal distribution is:

$$\text{LCL}_{0.80}(x_{0.95}) = \exp [y + s_x (2 Z_{0.95} - K_{0.80,0.95})] \quad 3.7-7$$

where:

$Z_{0.95}$ is a table value for the 95th percentile of the standard normal distribution, and

$K_{0.80,0.95}$ is a table value for a specified n , with $1-\alpha = 0.80$ and $p = 0.95$.

Z and K can be obtained from Tables A-1 and A-3, respectively, in Gilbert (1987) or from Hahn and Meeker (1991).

Ambient Limits for Nonparametric Distributions. If a normal or lognormal distribution cannot be assumed for a given data set, then distribution-free or nonparametric methods are used to estimate confidence limits and percentiles. The procedure for estimating the 80 percent LCL on the 95th percentile is described as follows:

- 1) The data are ordered from minimum to maximum:

$$x_1 \leq x_2 \dots \leq x_k \dots \leq x_n \quad 3.7-8$$

- 2) Calculate l :

$$l = p(n + 1) - Z_{1-p} \sqrt{np(1-p)} \quad 3.7-9$$

where:

$$p = 0.95$$

n = number of values in the data set

$Z_{1-\alpha} = Z_{0.80}$, as obtained from Table A-1 in Gilbert (1987) or Hahn and Meeker (1991).

The simplified formula is thus:

$$l = 0.95(n + 1) - 0.184\sqrt{n} \qquad 3.7-10$$

- 3) If the calculated l is an integer, the 80 percent LCL on the 95th percentile is the l th largest datum (among the ranked concentrations) in the data set. If l is not an integer, the 80 percent LCL on the 95th percentile is estimated by linear interpolation between the two concentrations closest to l .

3.7.2.4 Step 4 - Determination of Ambient Exceedences by Study Area

As indicated in the previous section, samples with analyte concentrations above ambient values (i.e., 80 percent LCL on the 95th percentile or any detection for inorganics with very low detection frequencies) were assumed to potentially be impacted by site activities.

Potential inorganic contaminants were evaluated for each lithologic group and each analyte by study area. The potential contaminants are summarized by study area on Tables 3.7-8 through 3.7-11. These inorganics are not necessarily COPCs that will be evaluated in the BRA. Comparison of each investigative sample to ambient levels and spatial analyses will be used to identify COPCs in Sections 4.0 through 14.0 as described in the two following sections.

3.7.2.5 Step 5 - Comparisons of Investigative Samples to Ambient Concentrations

In Study Areas Sections 4 through 14, inorganic soil data (or sediment data in some cases) are compared on a sample-by-sample basis to the sample's respective lithologic type ambient concentration. As mentioned above, the ambient concentrations for each analyte and lithologic group are listed in Table 3.7-7. The lithologic assignments for purposes of performing the initial comparison of site data with ambient concentrations is included in the diskette data files in Appendix O.

In Sections 4 through 14, however, it may be noted that although a sample is categorized into a specific lithologic category (Colma, beach/dune, serpentinite, fill), the analytical results

may indicate that it is more similar to another category due to mixing of lithologies. The potential for placement of serpentinite bearing soils into the incorrect lithologic category is perhaps greatest for the fill category. Serpentinite was commonly used as road base material at the PSF and samples from this interval though technically fill, were generally placed into the serpentinite category. This situation also occurs for samples categorized as beach/dune and Colma. For example, a sample originally described as beach/dune because of its physical characteristics may be compared to fill ambient values because it occurred in a fill interval and may be mixed with other lithologies. These additional lithologic interpretations are supported by the spatial analysis, as described below; however, they did not result in changes to the grouping of the ambient data sets as described in step 3 (Section 3.7.2.3).

If there are any concentrations at a site which exceed the ambient value for that inorganic, the results for that chemical are evaluated to judge whether the source of that chemical is the result of U.S. Army activity. This evaluation is described as a spatial analysis, which was conducted at each site for each inorganic detected above ambient concentrations.

3.7.2.6 Step 6 - Spatial Analysis

If an inorganic is present above the ambient concentration in one or more samples (compared to the appropriate lithology as described in step 5 - Section 3.7.2.5), that analyte will be considered in the spatial analysis for that site. The spatial analysis includes evaluation of the following conditions:

- Location of sample with respect to known or suspected source areas
- Patterns in vertical or lateral distribution
- Depth of sample exceeding ambient concentrations
- Association with organic analytes at site
- Lithologic description of sample and other samples at the site
- Physical setting of the site
- Magnitude of ambient exceedence in relation to the range of concentrations at the site
- Range of concentrations in background samples collected from the PSF
- Range of regional ambient concentrations and typical concentrations associated with specific rock composition

- Confidence in reported concentration (i.e., consider data footnotes, accuracy of method, analytical analyte interferences, dilution of sample, or sample collection from water saturated zone).

All of these items are considered in assessing if an inorganic is to be a COPC, meaning that the elevated concentration could be the result of U.S. Army activities. If the inorganic is considered a COPC for a particular site, the inorganic is included in the BRA (Figure 3.7-1). Although only one sample may exceed ambient, all of the site data for that inorganic is included in the risk assessment. In the human health risk assessment, COPCs are screened against PRGs or MCLs to assess if the COPC is a contaminant of concern (COC). The ecological risk assessment evaluates all COPCs.

3.7.3 Chromium Oxidation States

Chromium was evaluated as a chemical of concern in the risk assessment because of its presence at concentrations exceeding the ambient levels for sedimentary units at the PSF. The chromium analysis technique used in the RI provides the value for total chromium in the sample. However, chromium is generally present in nature in two oxidation states: +3 (trivalent) and +6 (hexavalent), and the health risks associated with the two oxidation states differ greatly. Hexavalent chromium (Cr VI) is the more toxic form of chromium. Specific hexavalent chromium analyses were done so that a site-specific average of the hexavalent chromium percentage of total chromium could be used in risk calculations. These analyses were performed for soil samples during the Supplemental RI and for groundwater during the Follow-on RI.

3.7.3.1 Hexavalent Chromium in Soil

The chromium results for soil are presented below and can be found in Appendix O. They indicate that hexavalent chromium is a very small percentage (<0.1 percent) of the total chromium present at the site. These data are collected from a variety of lithologic units at the site as well as from background areas and should be typical of conditions in soils and rock at the site. Chromium VI is generally associated with metal plating operations and because it reduces rapidly to Cr III, is not present to a large degree in naturally occurring surficial deposits. From this evaluation, the amount of hexavalent chromium in relation to trivalent

chromium (0.1 percent) is used in estimating the amount of hexavalent chromium in soil samples analyzed for total chromium and therefore, the risk associated with the total chromium data.

HEXAVALENT CHROMIUM RESULTS FOR SOIL

SAMPLE	DEPTH (ft bgs)	TOTAL Cr ($\mu\text{g/g}$)	Cr VI ($\mu\text{g/g}$)	SAMPLE DESCRIPTION
BKGDSB04	0.0	750	0.24	Serpentinite (surface)
BKGDSB02	2.0	81.1	0.3	Dune Sand
BKGDSB01	2.0	100	<0.06	Colma Fm. (Quarry Road)
BKGDSB01	5.0	90.2	<0.06	Colma Fm. (Quarry Road)
643SB02	2.0	121	<0.06	Behind Building 643, next to serpentinite cliff
643SB01	2.0	92.6	<0.06	East of 643, next to serpentinite cliff

3.7.3.2 Hexavalent Chromium in Water

In the Follow-on sampling, total chromium and hexavalent chromium were analyzed for in ground and surface water samples at sites where chromium was identified in previous sample results and where groundwater was more likely to be considered a resource. The results indicated that hexavalent chromium ranged from less than 1 percent to more than 500 percent of the total chromium concentrations, which is not possible (Table 3.7-12). Review of these results indicate that the reported detections of hexavalent chromium are questionable, and the most reasonable interpretation is that hexavalent chromium does not exist at significant concentrations in any of the sampled media. This interpretation is based on the areas of information discussed below.

- Patterns of Hexavalent Chromium Detections - Locations of ground-water samples with hexavalent chromium detections are not consistent with any definable source of hexavalent chromium. The vast majority of hexavalent chromium detections were reported by one laboratory with many detections exceeding the corresponding total chromium result. This ratio of hexavalent chromium to total chromium exceeds even the ratios found at chrome plating facilities and is not supported by government research

(U.S. Department of the Interior, 1986). Many samples were analyzed for hexavalent chromium at other laboratories with virtually no detections reported.

- There is no historical evidence which suggests that activities involving chemicals associated with hexavalent chromium were ever conducted at the PSF.
- Hexavalent chromium is present in the environment almost exclusively due to industrial processes. In aqueous solution, hexavalent chromium is generally unstable under conditions with neutral pH. Therefore, it is concluded that hexavalent chromium would not persist in ground water at the PSF, and would rapidly reduce to trivalent chromium soon after release to the environment.
- Laboratory Analytical Issues - Problems with the performance of EPA Method 7196, the method used for hexavalent chromium analysis, are common and often are transparent to any kind of validation procedures. Erroneous detections of hexavalent chromium can be caused by interference to the analytical method due to sample turbidity and the presence of naturally occurring reducing agents and/or interfering chemicals in the samples.

A review of the results of the matrix spikes for hexavalent chromium samples indicates:

- The amount of the spike is reasonable for the concentrations reported.
- The percent recoveries of the matrix spikes are nominal (i.e., well within QC acceptance criteria).

Given the arguments previously stated regarding why the hexavalent chromium results are believed to be erroneous, the following explanation of the present observations is offered.

The method employed by the laboratory is known to be subject to a number of interferences. If such an interferant were present, such that the interferant was reported as hexavalent chromium when in fact it was some other analyte or interfering property, then the addition of a matrix spike would simply be additive to the result for the interferant. This would result in apparently acceptable matrix spikes recoveries when, in fact, no hexavalent chromium, or only a small amount, was native to the sample. This effect would be exaggerated at low concentrations.

Since the method itself suggests an operating range of 500 µg/L to 50,000 µg/L, and since most of the native positive detections are significantly lower than 500 µg/L, the data are expected to display less than normal accuracy and greater than normal variability.

It is suspected that the interferant is vanadium. Vanadium interferes strongly with hexavalent chromium detection, particularly at low concentrations. Vanadium is detected in almost all samples with hexavalent chromium detections, often at levels comparable to the hexavalent chromium detections. Although vanadium does not normally present a significant interference at concentrations less than 10 times the hexavalent chromium results, it does produce the same color effect in the sample. At low concentrations such as these an analyst might well interpret a vanadium reaction as hexavalent chromium.

This is not to say that the reported concentrations are of necessity completely false positive. There may conceivably be a hexavalent chromium component to the reported value. However, based on good chemical and engineering judgment and the results from other laboratories, it is a valid conclusion that hexavalent chromium is unlikely to be a significant risk driver at this site.

Subsequent analyses performed by the USEPA National Enforcement Investigations Center under the direction of the NPS indicating the presence of hexavalent chromium in groundwater at the PSF are considered by the U.S. Army to be inconclusive (final USEPA report in progress). The USEPA analyzed groundwater samples from Buildings 215, 231, 937, and Fill Site 1, Landfill 2, Battery Howe/Wagner, and El Polin Spring. The preliminary USEPA report indicates detections of hexavalent chromium at Building 215, Fill Site 1, Battery Howe/Wagner, and El Polin Spring. In contrast, the NPS and USEPA considers that the subsequent data indicate that hexavalent chromium is present in groundwater at the PSF. For conservatism, the BRA will assume that detections of chromium in groundwater and surface water represent hexavalent chromium. However, as discussed above, the risk assessment results for chromium in groundwater should be used with caution, as the presence of hexavalent chromium is questionable. Similarly, no remedial actions should be undertaken on the basis of the hexavalent chromium results unless further research clearly demonstrates that hexavalent chromium is present and, if so demonstrated, that natural attenuation is not occurring (EPA, 1994d). The U.S. Army will consider sampling for

hexavalent chromium in groundwater to further verify its presence in groundwater at the PSF.

3.7.4 Metals Mobility

The mobility of three metals - chromium, nickel and lead - was evaluated using chemical and physical data from PSF samples in conjunction with the geochemical equilibrium model MINTEQA2 (Allison et al., 1991). This work was performed after completion of the Supplemental RI field program. These metals were focused on because they appeared to occur at elevated concentrations and were risk drivers in earlier versions of this report. The potential risk posed by these metals is controlled largely by their aqueous solubility and mobility. The model was used to determine solubility, distribution coefficients, and retardation factors for the metals in 31 soil samples (including Colma Formation, beach/dune sand, serpentinite and fill) from the site. A summary of the mobility evaluation follows and the complete report is presented in Appendix Q. Field programs conducted after the metals mobility study was performed have evaluated the potential for metal migration to deeper soil and groundwater by collecting soil and discrete groundwater samples. This information has been consistent with the model information.

Under oxidizing conditions, metals mobility in soils is typically controlled by adsorption to mineral surfaces and, to a lesser extent, by mineral solubility (Drever, 1982). For example, Cr^{3+} is only sparingly soluble at near-neutral pH, and chromium hydroxide ($\text{Cr}(\text{OH})_3$) precipitation occurs at Cr^{3+} concentrations above 10^{-7} M. In contrast, hydroxides of Pb^{2+} and Ni^{2+} are more soluble than chromium hydroxides at pH values below 9 (Swartzbaugh et al., 1992), but the lower concentrations of these metals may be due to their tendency to sorb strongly to iron oxides and clays (Kabata-Pendias and Pendias, 1984).

Adsorption to oxide and clay surfaces retards metal mobility in soil by binding the metal ions to the soil surfaces, slowing migration. Adsorption is expressed quantitatively as the distribution coefficient, K_d , which is the ratio of adsorbed to dissolved metal concentrations. Metal K_d values are a function of the aqueous metal concentration, the pH, the nature of the adsorbing substrate, and the aqueous composition of the solution. The rate of metals

migration relative to groundwater velocity is expressed by the retardation factor, R (unitless), which is related to K_d by the expression:

$$R = K_d \frac{\rho_b}{\phi} + 1 \quad 3.7-11$$

where ρ_b is the bulk density of the soil, and ϕ is its porosity.

Results of MINTEQA2 calculations suggest that lead and nickel are highly attenuated in PSF soils relative to groundwater. These results also indicate that K_d and retardation values for site soils and fill are log-normally distributed. Calculated retardation factors for nickel center on a geometric mean of 23 for calcium sulfate (CaSO_4) waters and 29 for sodium chloride (NaCl) waters. Lead is much more strongly adsorbed, with geometric means for calculated retention factors of 10,000 in CaSO_4 waters and 15,500 in NaCl waters.

Adsorption constants for chromium are not available in the current MINTEQA2 database (partially because $\text{Cr}(\text{OH})_3$ is so insoluble that adsorption is difficult to measure). However, chromium is highly insoluble, and calculated chromium concentrations in soil solutions never exceeded 6.5 $\mu\text{g}/\text{L}$. Therefore, all three metals will have a high potential for retardation in the soil, and thus a low tendency to migrate away from the site, under the ambient conditions at the PSF.

Geochemical modeling of the PSF soils and fill materials indicates that sorption to the soil matrix will greatly limit metals mobility in groundwater. In water simulations with high total metal concentrations, aqueous concentrations were controlled not by sorption, but by the solubility of hydroxide mineral phases. If mineral phases are limiting metal solubility in the PSF soils, metals will be released at the mineral solubility until the mineral has dissolved completely. Metals will continue to be released at a decreasing rate as they desorb from surfaces. Information on the specific metal-bearing mineral phases in the soil, however, is not available, and additional phases, including clays and ultramafic minerals, may be limiting solubility to levels far below the hydroxide-controlled concentrations. In the absence of identified solubility-controlling phases, it is not been possible to predict the concentration of metals in the groundwater.

3.7.5 Interpretation of Filtered and Unfiltered Water Results

During the Supplemental and Follow-on RI field programs, filtered and unfiltered groundwater samples were collected from most study areas at the Presidio. The purpose of collecting filtered samples was to remove suspended solids from the groundwater sample prior to analysis. During the Initial RI, only filtered groundwater samples were collected. Table 3.7-13 presents a comparison of inorganic concentrations in both filtered and unfiltered groundwater samples. The table includes only RI sampling events for which both a filtered and an unfiltered sample were collected concurrently. For each inorganic, the table shows the total number of samples and detections, as well as, the frequency of detections. The last column of the table presents average concentrations. Average concentrations were calculated using one-half the detection limit for non-detected analytes.

As indicated on Table 3.7-13, the frequency of detections and average concentrations for all inorganics except antimony and copper were lower in the filtered samples. For some analytes, the concentration in the filtered sample was an order of magnitude lower than the unfiltered concentration. The significant difference in concentrations is attributed to the suspended solids present in the unfiltered samples. Since metals generally have higher affinities for soil than water, the suspended solids present in unfiltered samples contribute to the total analyte concentration in the sample. By filtering the suspended solids out of the sample, a result which is more representative of the dissolved concentration can be obtained. This pattern is very evident in discrete groundwater samples collected during the Follow-on RI field program. Because the technique used in this type of sampling results in high levels of suspended solids, the resulting unfiltered samples often contain significantly higher inorganics concentrations than the corresponding filtered samples.

As mentioned above, antimony and copper were detected at higher concentrations and frequencies in the filtered samples than the unfiltered samples. Table 3.7-13 indicates that the concentrations and frequencies of copper are only slightly higher in the filtered sample. Antimony on the other hand, was detected in 66.2% of the filtered samples, but in only 16.2% of the unfiltered samples. The respective average concentrations are 12.45 and 7.90 $\mu\text{g/L}$. A recent study by the USCOE suggests that the brand of filters used during the Follow-on RI field program may contribute antimony to the unfiltered sample (Call, 1994).

In addition, during the Follow-on RI, 16 rinse blanks were analyzed for antimony. Five of the rinse blanks were filtered. Of the five filtered samples, there were four antimony detections ranging from 12.1 to 22.9 µg/L. Of the remaining 11 unfiltered samples, antimony was detected only once at a concentration of 1.79 µg/L. Based on this analysis, the presence of antimony in the filtered samples is believed to be largely due to the filters used during sampling and not representative of actual dissolved antimony concentrations.

3.8 SAMPLING DECISION CRITERIA AND REGULATORY LEVELS

This section describes the criteria used for guiding the Follow-on RI field investigations and for data evaluation in this RI report. The rationale and criteria are provided in detail in the Draft Sampling Design Plan Technical Memorandum, Follow-on RI Report, Presidio Main Installation, Presidio of San Francisco (WJE, 1994a). As described below, several criteria were changed or added during the course of the field program. All changes were approved by regulatory agents prior to implementation. Methodologies for comparing investigative results to the pre-established criteria are also described in this section.

During the Initial and Supplemental RI field investigations, potential contaminant sources were evaluated by analysis of samples for a large suite of compounds. The full suite analyses under these programs included over 140 organic compounds (VOCs, SVOCs, pesticides, herbicides, PCBs, and TPH) and 20 inorganic constituents. At each sample location, commonly only a few organic compounds or inorganic constituents were found at levels of concern.

Sampling Decision Criteria (SDCs) were developed for selected analytes for the Follow-on RI and were used to assess which previously investigated sites to include in the Follow-on RI field program and to assess whether the vertical and lateral extent of chemicals of concern was adequately delineated. During the Follow-on RI, analytical results were compared to the appropriate SDC(s). If a detection in a water or soil sample exceeded the SDC, then additional sampling was considered.

SDC values were based on:

- primary MCLs
- action levels
- USEPA Region IX preliminary remediation goals (EPA, 1994c)
- calculated risk to the environment (based on an ecological risk hazard quotient greater than 10)
- background concentrations (based on the Revised Draft Final RI Report Main Installation, PSF (WJE, 1993a)
- other appropriate values.

Tables 3.8-1 and 3.8-2 summarize the SDCs for soil and water samples, respectively. The SDCs are not necessarily ARARs or clean-up levels, but provided a frame of reference for guiding the Follow-on RI. SDCs developed after submittal of the Draft Sampling Design Plan (WJE, 1994a) are those for chlorinated herbicides in soil and water. Modifications to SDCs include the use of EPA PRGs for pesticides, PAHs, PCBs, and antimony in soils, rather than a calculated human health or ecological risk factor. This change was prompted primarily by regulators' concerns that land use scenarios and assumptions (such as ingestion rates, surface area, duration, frequency etc...) may not be appropriate and that using a criteria of cancer risk of $10E-04$, as identified in the technical memorandum for the Follow-on RI (WJE, 1994a) was too limiting. In addition, the use of PRGs versus calculated risks facilitated the decision making process in the field.

The SDCs are also used in this RI Report to define the vertical and lateral extent of potential chemicals of concerns. However, they were not used to exclude any analytes from evaluation in the BRA.

For some analytes, reporting limits exceeded the SDC value (Tables 3.8-3 and 3.8-4). The three analytical laboratories used for the Follow-on RI provided the lowest reporting limits they could confidently and consistently achieve for each target compound. Reporting limits in excess of SDCs included two PAHs in soil samples analyzed by Superior and QAL. Reporting limits in water samples that were greater than SDCs included three inorganics, four VOCs, nine SVOCS (seven of which were PAHs), two pesticides, and TPH-G.

In evaluating results for analytes with reporting limits in excess of the SDC, the entire sample suite was considered to decide whether additional sampling was warranted. For example, if all results in the PAH sample suite (which includes 15 different PAHs) were below the reporting limit, then additional sampling was generally not conducted. In contrast, if one or more PAHs were detected at concentrations above the SDCs, then additional sampling would be recommended for the entire PAH sample suite, rather than just the specific target analyte with the SDC exceedence.

Soil moisture corrections occasionally resulted in reporting limits that were slightly above SDCs. This was most common for TPH analyses by the immunoassay method because the SDC was set at the reporting limit of 100 µg/g. The samples with the slightly elevated reporting limits were still used to define the limits of the vertical and lateral extent of chemicals.

Reporting limits sometimes exceeded SDCs due to sample dilution by the analytical laboratory. This occurred most commonly with the rapid turnaround PAH analyses in soil samples analyzed by Superior. In these instances, the field chemist provided a qualitative, rather than quantitative evaluation of PAHs by reviewing the raw data packages and chromatograms to assess whether PAHs were present in the sample. However, the elevated reporting limits provided by the laboratory are the values that appear in summary tables and the electronic database in this RI report.

A few changes to PRGs and MCLs have been made since the Follow-on RI was conducted. These are identified in Tables 3.8-1, 3.8-2, and 3.8-5 for perspective.

Concentrations of analytes in the groundwater were compared to primary and secondary California or EPA MCLs (Tables 3.8-2 and 3.8-5) to provide a frame of reference for evaluating the concentrations of inorganics and organics detected in water samples. However, in most PSF study areas and sites, groundwater is not a likely drinking water source because of high salinity or TDS in areas near San Francisco Bay or low water yields in areas such as Battery Howe/Wagner, Nike Facility, and Landfill 2 (Section 2.3.6). In the Crissy Field Groundwater Area, municipal use is considered improbable by the RWQCB; therefore MCLs are not water quality goals (Section 2.3.6). However, MCLs are considered

by the RWQCB to be potentially applicable water quality goals for the Coastal Bluff Groundwater Basin/Area and the West Valley and Northeastern Groundwater Areas, where the beneficial use of groundwater includes potential municipal use, as discussed in Section 2.3.6. This potential use is evaluated site specifically, as groundwater may be excluded for either domestic or municipal supply if TDS levels exceed 3,000 mg/L or wells are incapable of producing an average, sustained yield of 200 gallons per day (gpd), as established in RWQCB Resolution No. 89-39. Therefore, the MCLs may not be directly applicable to study areas or sites at the PSF. In addition, the possible future land use scenarios do not indicate that residential development will occur at the PSF, and the presence of the existing water system, which is connected to the city's water system, makes development of on-site drinking water unlikely.

Groundwater results from study areas adjacent to San Francisco Bay were also compared to EPA National Ambient Water Quality Criteria (AWQC) and California Enclosed Bays and Estuaries Water Quality Objectives (WQO) for Saltwater Aquatic Life Protection (Marshack, 1995) as a frame of reference (Table 3.8-6) in Sections 4 through 14. Final Chronic Values (FCVs), which are higher than the AWQC, are not used in this comparison as they exclude the human fish consumption pathway (EPA, 1996b). The comparison to AWQC and WQO is limited by two major factors. The first is that detection limits below many of the AWQC and WQO are not achievable using EPA certified methods. RI reporting limits for 11 organochlorine pesticides and PCBs were consistently higher than the AWQC and WQO (Table 3.8-6). As a result, comparisons of investigative results to aquatic bay objectives were limited to detected compounds or those with reporting limits lower than the water quality objective or criteria.

The appropriateness of comparing groundwater results to water quality objectives or criteria is also limited by the hydrogeologic features of a coastal aquifer. Concentrations detected in monitoring wells and in discrete groundwater samples are not necessarily indicative of discharge concentrations to San Francisco Bay. Groundwater discharge would be along the seepage face, which is located offshore, and concentrations obtained from inland portions of the aquifer are likely to be higher than at the seepage face. The comparisons are made to

provide a qualitative assessment of the potential impact of groundwater on aquatic life in San Francisco Bay.

3.9 RISK ASSESSMENT

This section describes methods used in the Baseline Risk Assessment (BRA). The BRA was conducted to evaluate potential human health and ecological risks associated with exposure to site-related chemicals in soil, groundwater, sediments, and surface water at the PSF. The full text and data summary tables for the risk assessment are in Section 15 of this RI report.

3.9.1 Human Health Evaluation

Chemicals of potential concern were identified on the basis of a conservative screening method to ascertain data which are appropriate and adequate for use in the BRA. Chemicals retained through the screening process represent the most prevalent, toxic, persistent, or mobile contaminants at each PSF study area.

Two land use scenarios were considered in the risk assessment and sites within each study area were evaluated separately under the following future land use scenarios according to the land use designated in Alternative A in the General Management Plan (GMP) for the Presidio of San Francisco (NPS, 1994).

- Recreational — This scenario was used predominantly for sites along the San Francisco Bay and Pacific shore regions
- Industrial — This scenario was used for sites planned for uses other than recreational.

Where appropriate, the following exposure pathways were considered:

- Ingestion of and dermal contact with soil
- Ingestion of and dermal contact with drinking water
- Ingestion of and dermal contact with groundwater
- Ingestion of and dermal contact with surface water (older child only)
- Ingestion of and dermal contact with sediment (older child only)

Following EPA Region IX guidance, a residential PRG ratio assessment was performed which involves calculating the ratio of the maximum detected site concentration of all

COPCs to the appropriate EPA Region IX residential preliminary remediation goal (PRG). This was applied at all RI sites using data prepared as defined for the industrial scenario (surface and subsurface soil) when available, otherwise using data sets as defined for the recreational scenario (surface soils down to 2 ft only). For each site, the resulting ratio values were then added for all ratios in which the PRG was derived based on cancer risk. This total was multiplied by $1E-06$ to estimate cumulative risk. A separate total was calculated for ratios in which the PRG was derived based on noncarcinogenic hazard to estimate cumulative hazard. If the EPA Region IX PRG was not risk-based (i.e., based on the soil saturation equation ["sat"] or ceiling limit concentration ["max"]) or were California EPA PRGs ("CAL-Modified PRG"), the ratios were calculated but not added to the cumulative risk or hazards.

The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters as was performed in the recreational and industrial risk scenarios assessed in this RI report. The residential PRG ratio assessment is more conservative because it tends to assume larger exposure concentrations, includes all exposure pathways, includes all COPCs, includes all exposure media, and assumes a greater exposure duration and frequency. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented in Appendix U for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

Surface soil samples are those taken from 0 to 0.49 ft bgs and subsurface soil samples are those taken from 0.5 to 14.99 ft bgs. For sites located along the San Francisco Bay for which recreational open space scenarios are proposed, as a conservative assumption of children digging in the sand, surface soil was considered soil samples from surface level to 1.99 ft bgs and subsurface soil was soil samples taken from 2 to 15 ft bgs. Soil samples within parts of the Crissy Field Study Area and EOM designated as within the proposed wetlands footprint might be brought to the surface and spread out along the San Francisco Bay. To conservatively assess the exposure to recreational visitors, the soil from the samples at 0 to

15 ft in the proposed wetlands footprint were separately assessed for incidental ingestion and dermal contact for the recreational visitor.

Upper-bound estimates of lifetime cancer risk were calculated for each of the land use scenarios described above. In the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), USEPA established an acceptable risk range of 1E-04 to 1E-06 for Superfund sites. This risk range was used as a basis for comparison of risk estimates calculated for carcinogens identified at the PSF. Noncancer effects were compared to a hazard index of 1, which indicates that the exposure is below a level that is likely to cause adverse health effects even in the most sensitive members of the population. In addition, maximum soil lead concentrations were compared to a lead soil screening value of 840 mg/kg that is primarily based on the DTSC Pb6 Model results presented in Section 15.1.4.11.

3.9.2 Ecological Evaluation

The objectives of the ecological risk assessment were to identify and quantitate:

- Chemicals related to U.S. Army activities that have the potential to cause adverse effects on ecological receptors. These chemicals are termed chemicals of concern
- Concentrations of the chemicals of concern in surface water, shallow sediments, and soils within 3 feet of the surface
- Risk to ecological receptors
- Sites where chemicals of concern occur at concentrations likely to pose a threat to the environment
- Exposure pathways likely to result in adverse ecological effects.

The ESAP assesses potential impacts of the PSF to aquatic receptors in San Francisco Bay (D&M, 1996a, b). Other receptors are evaluated in this report, as described below.

Ecological receptors are divided into two broad categories based on habitat type. These are receptors that occur in terrestrial environments (e.g., terrestrial plants, soil invertebrates, American robin, mourning dove, peregrine falcon, red-tailed hawk, western harvest mouse, valley pocket gopher, and raccoon), and those that live in aquatic habitats (e.g., benthic

invertebrates, amphibians, fish, mallard duck, and spotted sandpiper). There is some overlap in that some receptors may occur in transitional habitats or in more than one habitat type.

For each of the identified fill sites, landfills, or areas of concern where chemicals occur in soil, exposure by direct contact was evaluated for terrestrial plants and soil invertebrates. In addition, dermal contact with soils was evaluated for mammals and birds. Exposure due to ingestion of soils was evaluated for mammalian and avian wildlife receptors. Uptake of chemicals from soil by biota was modeled with a food web model so that dietary exposure could be quantitatively evaluated.

There are two sites on the PSF where true aquatic habitat occurs (i.e., open water, emergent or riparian vegetation). These sites are Lobos Creek and Mountain Lake. At these locations, ecological risk was evaluated for direct or dermal contact with surface water by aquatic habitat receptors (e.g., benthic invertebrates, amphibians, fish, mallard duck, and spotted sandpiper). Because terrestrial receptors may use surface water as a drinking water source, ingestion of surface water was evaluated for all terrestrial wildlife receptors as well. In addition, El Polin Spring could serve as a source of drinking water for avian and mammalian wildlife, although this surface water source is too small to provide true aquatic habitat of any extent. Therefore, ingestion of chemicals in surface water from El Polin Spring was quantitatively evaluated. Where sediment data were available, exposure to this media by aquatic receptors was evaluated.

Baker Beach is an steeply sloping area that borders the Pacific Ocean along the western side of the PSF. Baker Beach consists of several areas where U.S. Army related contaminants have been detected in soils. In addition, there are some seeps at Baker Beach that could provide drinking water exposure. Because of the size of the seeps, there could be a small subpopulation of amphibians utilizing the area. Therefore, risk at Baker Beach was evaluated for soils and surface water for terrestrial wildlife, and direct contact with surface water by amphibians.

Crissy Field includes several RI sites along the Bay. The proposed future use of part of Crissy Field is redevelopment into a wetland. Therefore, there is the potential for contact with groundwater by aquatic habitat receptors (e.g., benthic invertebrates, fish, mallard

duck, and spotted sandpiper) that may ultimately inhabit the wetland. Because of surface water salinity due to influx from the Bay, the future wetland is not expected to support amphibians, which occur in fresh water. The soils to a maximum depth of 15 feet may be excavated and moved to provide terrestrial habitat; soils below the excavation will then be the sediments in the future wetland. In order to predict future risk, soils within the planned wetlands area (0 to less than 15 ft) were evaluated as if they were sediments and also evaluated as if they were used to make berms or other terrestrial habitat. Although aquatic and terrestrial receptors may not be exposed to all the concentrations represented in this data set, it is the best approximation of the potential exposures with available information.

Determining the nature and extent of exposure is a large component of the ecological risk assessment. However, to predict the actual hazard, toxicological information relative to the various ecological receptors was obtained. For plants and soil invertebrates, a literature review produced estimates of acceptable soil concentrations for most of the contaminants of concern. For birds and mammals, the literature review resulted in daily intake values (mg/kg bw/day) that would not be likely to produce individual or population health effects for each of the contaminants of concern. The Ambient Water Quality Criteria for the Protection of Freshwater Aquatic Organisms and their uses were used to determine adverse effects on populations of aquatic life or amphibians. Sediment Quality Criteria were also used to determine adverse effects on populations of aquatic life or amphibians. Where such toxicity criteria or benchmarks are lacking, ecological risk cannot be quantified.

Risk to ecological receptors is quantified by the Quotient Method, where an exposure estimate is compared to a toxicity criterion and the resulting ratio is called a hazard quotient (HQ), which provides an estimate of potential risk for a specific chemical to a specific receptor. If the HQ is less than 1, it indicates that the chemical presents little or no risk to the receptor. If the HQ exceeds 1, it indicates that the chemical may have a potential for adverse effects on that receptor. However, the relationship between the HQ and the adverse effects is not linear. For example, an HQ of 100 does not mean that the effects are 100 times more severe than an HQ of 1. As the HQ increases in magnitude, it provides an indication that there is more likely to be an adverse effect.

In response to concerns expressed by reviewers of the RI, low and high HQs are calculated for each COPC and each receptor at each assessed site. The HQ low is an estimate of ecological hazard based on toxicity criteria that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. The HQ high is more conservative because it results in larger HQs that are based on even lower toxicity criteria that correspond to levels of exposure that have been shown in published studies to cause no adverse effects. In other words, a larger HQ results when a lower toxicity criterion is used. In this RI report, HQ low values are summed for each receptor at each assessed site to find the total hazard index (HI) based on adverse effects criteria. Likewise, HQ high values are summed to find the HI based on the no adverse effects criteria.

The two HI values represent a range of total estimated ecological risk to a specific ecological receptor from all COPCs at a specific site. This approach is intended to help risk managers make informed decisions on remedial actions at the PSF by using a broad base of scientific information to develop a range of estimated ecological risk. With this information, the risk managers can balance the risk presented by the contaminants with other decision factors such as the destruction of habitat that may be associated with remedial actions.



4. NIKE FACILITY

This section describes the results of investigations conducted at the Nike Facility. The Nike missile facility at the PSF was identified as an area of concern based upon findings reported in the Enhanced PA (ANL, 1989). The following sections describe the study area, present the RI field program results, evaluate the nature, extent, mobility, and migration pathways of potential contaminants found at the facility, and present conclusions.

4.1 AREA DESCRIPTION

The Nike Facility consists of Buildings 1450 and 1451 and three abandoned missile silos (Figure 4.1-1). The facility is located on Battery Caulfield Road approximately 0.4 mi north of the PSF North 15th Avenue entrance and 0.6 mi east of Baker Beach (Figure 1.2-2). The site covers approximately 6 ac of land and is surrounded by a 6-ft chain-link and barbed wire fence. The site is bordered by the 1400s housing area to the north, the former PHS area to the south, the Presidio Golf Course to the east, and the 1500s housing area to the west.

Access to the buildings area is restricted by security fencing and locked gates; the missile silos are accessed from Battery Caulfield Road. The following sections describe the location and physical features of the Nike Facility and its history and land use.

4.1.1 Location and Physical Features

The facility is situated on a terraced, south-facing slope. The elevation of the Nike Facility ranges from approximately 270 ft-PLL in the southeast corner to 330 ft-PLL in the northwest corner, and surface drainage generally flows from the north to the south (Figure 4.1-1). However, approximately 50 percent of the area is covered by pavement, and runoff from the silos area is controlled by a series of swales, boundary drainage ditches, and storm drains located throughout the facility. The locations of the drainage structures are shown on Figure 4.1-2. Large trees are present immediately within the fenced perimeter and along the northern and eastern borders of the facility. Near the south fence line of the Nike Facility, the slope increases steeply to the south. Approximately 135 ft to the downslope from the Nike Facility boundary, and upslope from Landfill 8 (Figure 1.2-1), a densely vegetated area was observed to be wet in the spring of 1996. The occurrence of the wet area is apparently

associated with the unusually wet weather in the winter and spring of 1996 because this area was observed to be dry in the late summer of 1996. In this report, this wet area is referred to as the swale south of the Nike Facility.

Building 1450 is a two-story poured-concrete structure that was used by U.S. Army Explosive Ordnance Demolition (EOD) personnel for administration purposes. The EOD unit did not store explosives at the site. Building 1451 is a single-story, concrete garage that was used for facility maintenance. Each of the three missile silos has similar steel-plated bay doors, currently welded shut, and personnel entry hatches placed in an approximately 50 ft by 70 ft concrete pad. Despite being welded, the bay doors are not watertight and are rusted through in several places. A protective concrete curb surrounds the bay doors of each silo. The remaining area between and around the concrete pads is paved with asphalt.

Visual surveys of the silos were completed during the Initial and Follow-on RI investigations. All three silos were entered during the Follow-on RI, however standing water was present in Silos 1 and 2, and this prevented a walk-through from being performed. All of the silos were initially entered in level B personal protective equipment, and after oxygen levels were found to be 20 percent, the silos were then entered in level C with organic vapor cartridges. The silo configuration and the interior dimensions are illustrated in Figure 4.1-3. The silos are approximately 20 ft deep as is shown on cross sections A-A' and B-B' (Figures 4.1-4 and 4.1-5). Disassembled ventilation duct work and air pumps were present in all three silos. Silo 3, in the southwest part of the Nike Facility, was entered and a walk-through was performed. Electric control boxes are present on the west side of each silo, and the controls for these appear to be very corroded. Two motors are present next to the ladder leading into Silo 3. These motors were probably used to power the hydraulic pumps to lift the silo doors and elevate the missile, and are very corroded. A circular hole in the concrete floor is present in the southeast part of Silo 3. The purpose and depth of this hole is unknown, and water was present in the hole at about 3 ft below the floor. A square hole is present on the west end of the elevator platform. In the southwest part of Silo 3 there is a 20-ft-long hallway that ends in a 5 by 10 ft room. Broken ceiling tiles were observed to be scattered on the hallway floor. An exit door is present in the southwest part of the silo, however it is blocked by construction debris.

4.1.2 History and Land Use

The Nike Facility was constructed in 1955 and became operational during 1956. Nike Ajax operations were conducted at the site for approximately 9 years, after which it was decommissioned having never been converted to accommodate Nike Hercules missiles (ANL, 1989). Nuclear warheads were never located at the site (Defense Nuclear Agency, 1991). The missile system equipment was removed, and the steel bay doors and surface entry hatches to the silos were welded shut. During the time that the site was an active missile operation, Building 1450 was used as the Integrated Fire Control (IFC). The IFC served as the missile-launch control room, the missile-battery maintenance area, administration office, and barracks area. Building 1451 served as the maintenance support building for Nike operations. Operational procedures at the site involved the handling and storage of a variety of materials, including liquid missile fuel, starter fluids, oil, hydraulic fluid, gasoline, solvents, and battery electrolyte. Official records for the disposal of waste materials from the site do not exist. However, the Enhanced PA (ANL, 1989) reported that no fuel, catalysts, acids, or other material associated with Nike installations were disposed of on the PSF. In addition, a reconnaissance of the Buildings 1450 and 1451 showed no evidence of waste storage or surface staining.

The missile silos area has been used as a storage yard for camper trailers and other vehicles, as seen in air photos taken in 1973 and 1988 (Rindgen and Sitton, 1990). During field activities in 1990, the yard was being used as a storage area for telephone poles, steel pipes, and some containerized building refuse. However, all of the stored vehicles that were observed in the 1973 and 1988 aerial photos had been removed from the site. Currently the area is used by the NPS to store trash dumpsters as well as woodchips and gravel for landscaping. Additionally, some ground-level areas of the Nike Facility are being used by the U.S. Army for temporary storage of soil from the Building 637 area for a treatability study of petroleum-contaminated soil. Approximately 500 cubic yards of soil has been placed on plastic material for use in this study, which is expected to end in 1997.

The bay doors are welded shut and access to the site is limited, therefore, the silos do not represent a significant safety hazard. However, the U.S. Army is considering additional measures to improve security to prevent unauthorized entry into the silos. The access doors,

although they are locked, will be welded shut to eliminate any potential safety hazard. The U.S. Army is also considering the possibility of pumping the water out of the Nike silos; however, because the bay doors are not water tight it is likely that surface water will continue to accumulate in the silos.

4.2 SAMPLE LOCATION RATIONALE

Five types of samples were taken at the Nike Facility: wipe, sediment, soil, surface water, and groundwater. The following section explains, in terms of the conceptual model presented in Section 3.1, the rationale for the locations of the various types of samples. Figure 4.1-2 shows the locations of all wipe, sediment, and surface-water samples collected at the Nike facility. Monitoring well and soil boring locations are illustrated on Figure 4.2-1.

A network of concrete troughs containing wiring and covered by 0.25-in-thick steel plates is located in the floor of Building 1450. These troughs, and the concrete utility box to which they lead, are relatively low-lying and would be likely points of accumulation for materials used in the building. The troughs were treated as a primary source within the conceptual model, and five wipe samples were collected and analyzed for SVOCs and inorganic constituents. These samples were generally collected in areas where dirt and dust had accumulated in the troughs.

A former seepage pit is located south of Building 1450. Subsurface soil samples were collected at this location to determine if soils had been impacted by any substances potentially released to the seepage pit. In addition, a monitoring well was installed adjacent to the seepage pit to determine groundwater chemistry and aid in determining the groundwater flow direction in the Nike area.

Building 1451 was the former generator building located in the northwest part of the site. Potential sources near this building include a jet fuel pad, a concrete vault, a concrete fuel pad, and an acid fuel storage shed. These areas of potential concern are illustrated in Figure 4.1-1. One soil boring was drilled at each of these locations to determine if soils had been impacted by contaminants.

One potential contaminant source identified at the facility is materials stored on the paved surfaces of the silo area. The primary release mechanism for this source would be surface-water runoff from the pavement. Surface water in the silos area is channeled into storm drains, which are in turn channeled into drainage ditches along the eastern and western edge of the facility. As indicated in the conceptual model, two potential secondary sources are sediment and soil. The surface water can transport sediment to the storm drains and the outfalls. Water that flows to the outfall will also infiltrate the soil column. Due to the difficulty in sampling the primary source in this case, the secondary sources were targeted. Sediment samples were taken throughout the storm drain system in the silos area, and shallow soil borings were drilled at four of the drain outfalls located beyond the perimeter of the silos area.

The three silos at the facility were identified as potential sources of contaminants of potential concern. All of the silos were examined during the RI field investigation to determine the physical conditions of the subsurface rooms and to identify any remaining equipment. Standing water was present to some extent in all three Nike missile silos. Based on the locations and elevations of the standing water, as well as the design and general condition of the silo doors, it is possible that the water was derived from surface water seepage. However, it is also possible that groundwater could seep into the silos during periods when the groundwater table was high. The water in the silos was sampled for chemical characterization, which could aid in assessing the source of the silo water, as well as potential chemical releases. The primary release mechanism for this water would be leakage from the silos into the soil and infiltration to the groundwater. Five groundwater monitoring wells were installed at the site to investigate groundwater flow and chemistry. The wells were installed upgradient from the Nike Facility, downgradient from Building 1450, and downgradient from each of the missile silos.

4.3 HYDROGEOLOGIC SETTING

This section describes the hydrogeologic setting of the Nike Facility. Five monitoring wells and 30 soil borings were drilled at the Nike facility. Many of the soil borings are only several feet deep, however pilot boreholes for the wells were drilled to the top of bedrock. The lithologic logs from these borings and wells (Appendix B) and several Nike Facility

preconstruction geotechnical borings (COE, 1954) are the basis for the following discussion on the geology at the facility. Three geologic cross sections were constructed for this facility and their locations are presented on Figure 4.1-1.

4.3.1 Soils and Geology

Geologic units in the Nike Facility area include the serpentinite bedrock of the Franciscan Formation, Colma Formation, and dune sand. The bedrock is overlain by Colma Formation deposits, which are overlain by dune sand deposits. In some portions of the site, engineering fill overlies dune sand. The construction of the facility involved grading the area which decreased the depth to bedrock in some areas, while filling in others, thereby increasing the depth to bedrock. The fill material is probably a combination of relocated material from on site, and imported material. There was no indication from observations during drilling that the fill contained any waste material or construction debris.

Surface soils in the unpaved areas of the facility are primarily engineering fill which was used to create stable, level ground surfaces for the construction of the missile silos. The engineering fill consists of alternating layers of sand and clay and extends to a maximum depth of 24.5 ft bgs at Well NKGW01. The amount of engineering fill decreases to the northwest. At Well NKGW05 there is approximately 10 ft of fill material which resembles dune sand. The dune sand in the Nike Facility area is yellowish brown, fine sand, and is poorly graded. The Colma Formation in this area is a yellowish brown, sandy clay. Thin lenses of fine sand may be present in the Colma Formation, and it is usually sandy directly above bedrock.

The bedrock surface is illustrated on geologic cross sections A-A', B-B', and C-C' (Figures 4.1-4, 4.1-5, and 4.3-1, respectively). Bedrock is present at approximately 20 ft bgs in the northern part of the site, and slopes to the southeast where it is present between 32 and 42 ft bgs in the southern part of the site. The upper portion of the serpentinite bedrock is weathered and argillized but hardens with depth.

4.3.2 Hydrology

The Nike Facility is located in the northern portion of the Lobos Creek Groundwater Area. The regional groundwater flow direction in this area is to the south (Figure 2.3-2). Surface water in Lobos Creek that is not diverted for use at PSF eventually flows into the Pacific Ocean.

Groundwater in the northwest portion of the Nike Area occurs approximately 10 ft bgs as a relatively thin (approximately 2 ft thick) layer in dune sand, resting on unsaturated clayey Colma Formation deposits. As such, this thin zone of groundwater appears to be perched. This groundwater is most likely seasonal and a result of the heavy rains which occurred in the winter of 1994-95. Further downgradient, in the southern and eastern portions of the site, groundwater is unconfined within clayey Colma Formation deposits. However, it appears that in the southwestern portion of the site, near Well NKGW05, groundwater in sandy deposits near the bottom of the Colma Formation is confined by overlying clayey deposits. This confined water-bearing zone appears to be approximately 4 ft thick. The thickness of unconfined saturated Colma Formation deposits varies from 10 ft in the central-eastern portion of the site (Well NKGW04) to 17 ft in the southeastern portion of the site (Well NKGW01).

Water levels were measured in April 1995, and a potentiometric surface map was prepared (Figure 4.3-2). The potentiometric contours were drawn utilizing water levels from all the Nike wells including Wells NKGW02 and NKGW03. These two wells monitor a thin layer of groundwater in dune sand that may not be hydraulically connected to groundwater in Colma Formation wells to the south and east. The groundwater flow direction beneath the Nike Facility is to the southeast. Water levels are also plotted on the geologic cross sections (Figures 4.1-4, 4.1-5, and 4.3-1). The potentiometric information is consistent with subsequent data from the quarterly groundwater monitoring program, conducted by Montgomery Watson. However, upgradient Well NKGW03 has been dry for the last three quarters of sampling, from July 1995 through April 1996 (Montgomery Watson, 1996).

The potential interaction between groundwater and water within the silos can be assessed by comparing water levels in the silos to groundwater levels. The water table is approximately 12 ft above the base of Silo 1, where there was approximately 6 ft of water present during

the silo surveys. Based on the available data, groundwater could be present 5 to 11 ft above the base of Silo 2 which contained approximately 2 ft of water at the time of the silo survey. It is unclear if groundwater occurs above the base of Silo 3. Water in the dune sand northwest of Silo 3 at Well NKGW02 does not extend to the dune sand south of the silo at Well NKGW05. Moreover, the confined water-bearing zone encountered at NKGW05 is approximately 8 ft below the base of the silo. Silo 3 contained approximately 1 ft of water in the elevator platform at the bottom of the silo.

The communication between groundwater and water in the silos is unclear. However, groundwater is higher than silo water at Silos 1 and 2. This indicates that there is the potential for groundwater to flow into the silos, particularly during periods when the groundwater table is high. Groundwater occurrence in relation to the water in the bottom of Silo 3 is unclear and therefore, potential flow direction between these two waters is uncertain. It is not clear if the water present in Silos 1, 2, and 3 is a result of groundwater seepage, the collection of rainwater, or a combination of these two mechanisms.

Hydraulic conductivities can be estimated based on the grain size of the materials described in the soil borings. Hydraulic conductivity estimates for the dune sand range from 10^{-4} to 1 cm/sec, and for the Colma Formation range from 10^{-7} to 10^{-3} cm/sec based on grain size (Freeze and Cherry, 1979). Based on the water-level measurements and the potentiometric surface map, the hydraulic gradient of the groundwater is approximately 0.1 ft/ft (Figure 4.3-2). Assuming a porosity of 0.2, the average seepage velocity for the dune sand ranges from $5.0E-5$ to $5.0E-1$ cm/sec. For the Colma Formation, the average seepage velocity ranges from $5.0E-8$ to $5.0E-4$ cm/sec.

The serpentinite bedrock appears to form the lower boundary of the water-bearing zone beneath the Nike Facility Area. Due to its crystalline nature, the hydraulic conductivity of the bedrock probably decreases with depth, and is substantially lower than the overlying unconsolidated material. Groundwater flow within the bedrock is probably controlled by fractures.

Estimation of well yields in the Nike Facility ranged from 20.2 to 392 gpd, as presented in Section 2.3.5.3. An average calculated yield was 127 gpd, below the groundwater resource

requirement of 200 gpd referenced in California Resolution 89-39. The only well with an estimated yield exceeding 200 gpd was Well NKGW05.

4.4 ANALYTICAL RESULTS

The potential contaminant sources considered at the Nike facility include Building 1450 and surrounding structures, materials stored on the paved areas, and the three missile silos. This section presents the results of RI sampling in these areas of concern as well as the results of groundwater sampling. In the course of the three field programs, wipe, sediment, surface-water, soil, and groundwater samples were collected. All sample locations are shown on Figures 4.1-2 and 4.2-1. The data tables referenced in this section show only those chemicals detected at concentrations greater than the CRLs or RIs. A complete list of target analytes is provided in Section 3 tables. The discussion of unknowns is based on criteria in Section 3.5. Unknowns meeting the criteria are discussed at the end of Section 4.4.1.

All of the sediment and soil samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, sodium, and potassium are excluded from the following discussion. All other inorganics detected in soil will be compared to ambient concentrations, as described in Section 3.7. Sediment sample data were not included as part of the PSF data set for evaluating ambient levels, because most sediment data were from storm drains and it is inappropriate to assign lithologic categories to the sediment for use in determining ambient levels. However, sediment data are compared to ambient soil levels as for perspective.

4.4.1 Building 1450 and Surrounding Structures

Five wipe samples were collected from concrete troughs in Building 1450 during the Initial RI field program. Each sample was analyzed for inorganics and SVOCs. Those inorganic

compounds with detections above the CRLs are shown in Table 4.4-1. No SVOCs were detected at concentrations above the CRLs. A sediment sample (NISD09) was collected from an unpaved area near the Building 1450 area at the initiation of the drainage ditch and analyzed for inorganics, VOCs, and SVOCs. Those compounds with detections above the CRLs are shown in Table 4.4-2.

As part of the Follow-on RI field program additional areas surrounding Building 1450 were targeted for investigation. Specific areas targeted were a concrete fuel pad, a jet fuel pad, a seepage pit, an acid fuel shed, and a concrete storage vault (Figure 4.1-1). Soil Boring NKS13, located south (downgradient) of Building 1450, was completed as Well NKGW02. To determine if previous activities in these locations resulted in the release of chemicals to the environment, Borings NKS11 through NKS15 were drilled in each of these areas of concern (Figure 4.2-1). Soil samples were collected from two depths in Boring NKS11 and three depths, approximately 0.0, 5.0, and 10.0 ft bgs, from the other borings and analyzed for inorganics, VOCs, SVOCs, and TPH. Those compounds with detections above the RLs are listed in Table 4.4-3.

Concentrations of inorganics in soil were compared to ambient concentrations in similar types of material. In the Building 1450 and surrounding structures area, most of the soil samples were categorized as beach/dune sediments. The deeper samples from this area were generally similar to Colma Formation lithology. Fill material was present at the surface of NKS13. Inorganic concentrations in the sediment sample were compared to beach/dune concentrations, as surface samples from nearby borings were beach/dune sediments.

All inorganics in the sediment sample were less than the ambient concentrations. No inorganics were detected above ambient concentrations in Boring NKS11 which is adjacent to the concrete fuel pad. With the exception of the deep samples from NKS12 and the surface sample from NKS13, at least one and up to six inorganics were detected above ambient concentrations in all other samples. Zinc was detected above the ambient beach/dune concentration in the 1.0-ft sample from Boring NKS12, which was drilled through the jet fuel pad south of Building 1451. Mercury also was detected above the ambient beach/dune concentration in this sample and above the ambient Colma concentration in the 5.0-ft sample from Boring NKS15, adjacent to the acid fuel shed. Manganese was detected above the

ambient Colma level in the 9.5-ft sample from Boring NKS14, drilled adjacent to the concrete vault. Cyanide was detected above ambient in the two deep samples from NKS13 and all samples from Borings NKS14 and NKS15. Several inorganics, including chromium, copper, cyanide, manganese, nickel, and vanadium, were detected above ambient Colma concentrations in the 9.5-ft sample from Boring NKS15.

No VOCs or SVOCs were detected in sediment sample NISD09. No VOCs were detected in any of the samples from Borings NKS11 through NKS15. The SVOCs phenol and bis(2-ethylhexyl)phthalate were each detected in several of the soil samples. Bis(2-ethylhexyl)phthalate was detected in at least one sample from each of the borings at concentrations ranging from 0.0769 to 0.231 $\mu\text{g/g}$. Phenol was detected in at least one sample from Boring NKS11, NKS12, and NKS13 at concentrations ranging from 0.572 to 1.06 $\mu\text{g/g}$. Except for TPH-D in the 0.0-ft and 5.0-ft samples from Boring NKS13, TPH-D and TPH-G were not detected in any of the samples from Borings NKS11 through NKS15. TPH-D was detected in at concentrations of 22.3 $\mu\text{g/g}$ and 22.2 $\mu\text{g/g}$ in the 0.0-ft and 5.0-ft samples, respectively, from Boring NKS13. This boring is located next to the seepage pit. Total organic carbon was analyzed in three samples from Boring NKS12. Total organic carbon ranged from 3,630 $\mu\text{g/g}$ in the 5.0-ft sample to 1,070 $\mu\text{g/g}$ in the 9.5-ft sample.

4.4.2 Storage Areas and Storm Drain System

Twelve sediment samples (NISD01 through NISD12) were collected during the Initial RI field program. Sediment sample NISD09 is not included in this discussion as it is within the Building 1450 area and was discussed in the preceding section. Six samples were collected from the storm drains (NISD01 through NISD03, NISD05, NISD06, NISD12), one from the drainage ditch surrounding the silo area (NISD04), and four from paved surfaces (NISD07 through NISD08, NISD10 through NISD11). All samples were analyzed for inorganics, VOCs, and SVOCs. Those compounds with detections above the CRLs are shown in Table 4.4-2. Three borings (NKS01, NKS02, NKGW01) were drilled near the southeast corner of the site during the Supplemental RI to further investigate some of the Initial RI detections. The soil samples were analyzed for the same suite of compounds, with the addition of OCPs, PCBs, herbicides, and TPH (Table 4.4-4). During the Follow-on RI, eight additional

sediment samples (NKSE01 through NKSE08; Tables 4.4-5 and 4.4-6) and 16 soil borings (Tables 4.4-7, 4.4-8, and 4.4-9) were drilled to assess the extent of the compounds of concern (lead, zinc, and PAHs) detected in the Initial RI sediment samples and the Supplemental RI soil samples.

Inorganic concentrations in the sediment samples were compared to ambient concentrations in fill materials for perspective as fill covers most of the surface in this area of the Nike Facility. Inorganic concentrations in the sediment samples are discussed below according to the storm drains in which they were detected.

4.4.2.1 Initial RI Results

Inorganics which were detected above ambient fill concentrations in one or more of the five Initial RI sediment samples collected near Silo 1 were arsenic, cadmium, copper, cyanide, lead, mercury, and zinc. Lead was detected above the SDC of 300 $\mu\text{g/g}$ in all five samples with the highest concentration of 2,140 $\mu\text{g/g}$ detected in NISD04, collected from the drainage ditch (Table 4.4-2). The highest concentration of zinc also was detected in this sample (1,660 $\mu\text{g/g}$); zinc was above ambient in all of the sediment samples. Arsenic also was above the ambient fill concentration in all five samples, with the highest concentration of 114 $\mu\text{g/g}$ detected in a sediment sample from the storm drain, Sample NISD05. The highest detection of copper also occurred in this sample; the ambient fill concentration was exceeded in all but one (NISD03) of the Initial RI sediment samples collected near Silo 1. Cadmium exceeded ambient in two of the samples collected from the storm drains (NISD03 and NISD05). Cyanide exceeded ambient in a sediment sample collected from a paved surface (NISD08) and in the sample from the drainage ditch (NISD04). Mercury slightly exceeded ambient in one sample, NISD05, which was collected from the storm drain.

In the sediment samples collected in the storm drains east (NISD02) and west (NISD01, NISD06) of Silo 2 during the Initial RI, only mercury and zinc were detected above ambient concentrations. Mercury was detected above the ambient fill concentration in all three samples; the highest concentration of $> 4.0 \mu\text{g/g}$ was reported in NISD06. Zinc was above the ambient concentration of 280 $\mu\text{g/g}$ in the other two samples. The maximum concentration

of 480 µg/g was detected in Sample NISD02. No inorganics were detected above ambient in the sediment samples collected west of Silo 3.

No VOCs were detected at levels above the CRLs in the Initial RI sediment samples. The SVOCs detected at concentrations above the CRLs are as follows: acenaphthene, acenaphthylene, anthracene, bis(2-ethylhexyl)phthalate, benzo[a]anthracene, benzo[k]fluoranthene, chrysene, fluoranthene, fluorene, 2-methylnaphthalene, pentachlorophenol, phenanthrene, and pyrene. All samples contained at least one detectable SVOC. Bis (2-ethylhexyl) phthalate was detected in two samples. The highest levels of PAHs were detected in samples from the Silo 1 area, with the sum of the PAH detections ranging from 36 to 50 µg/g. Sediment samples near Silo 2 had the lowest total PAH concentrations; they were less than 3 µg/g. West of Silo 3, PAHs were detected in the Samples NISD10 and NISD11, which were collected from paved surfaces (summed detections ranging from 5 to less than 11 µg/g), but not in the storm drain sediment sample (NISD12). Pentachlorophenol was detected in two samples from the storm drains at concentrations of 3 µg/g and > 6.2 µg/g. The highest detection was in sediments collected near Silo 1 (NISD05). The other detection was in the storm drain sediment sample collected east of Silo 2 (NISD02)

Twenty-seven unknown SVOC hydrocarbons were tentatively identified in Sample NISD05, with a total concentration of 150 µg/g, an average concentration of 4 µg/g, and a maximum concentration of 40 µg/g. Twenty-five unknown SVOCs, primarily cyclic hydrocarbons, were tentatively identified in Sample NISD06, with a total concentration of 23 µg/g, an average concentration of 0.5 µg/g, and a maximum concentration of 5 µg/g. Thirty-two unknown SVOC hydrocarbons were tentatively identified in Sample NISD07, with a total concentration of 360 µg/g, an average concentration of approximately 10 µg/g, and a maximum concentration of 30 µg/g.

4.4.2.2 Supplemental and Follow-on RI Results

Based on the results of the sediment samples collected during the Initial RI, additional sediment and soil samples were collected during the Supplemental and Follow-on RIs to further evaluate the extent of potential contaminants, primarily PAHs and inorganics (mainly

lead or zinc), in the storage and storm drain areas surrounding the three silos. The following discussions are ordered according to the silo near where each storm drain originates. That is, the results of samples collected in and around the storm drains which originates north, east and west of Silo 1 are discussed first. The results of samples collected in the storm drains originating near Silos 2 and 3 are discussed second and third, respectively.

4.4.2.2.1 Silo 1 Area

During the Follow-on RI, additional sediment samples (NKSE01 through NKSE03 and NKSE05 through NKSE08) were collected in the drainage ditch to the north and east of Silo 1 (Figure 4.1-2). These samples were collected to further evaluate the extent of PAHs and lead in the drainage ditch. The results of the analyses of these samples are listed in Table 4.4-5. Lead was detected above the SDC of 300 $\mu\text{g/g}$ in two of the seven sediment samples with the highest concentration of 855 $\mu\text{g/g}$ in sample NKSE08, which is the furthest upstream of these samples. Lead was above the ambient fill value of 221 $\mu\text{g/g}$ but below the SDC in Sample NISD02. No PAHs were detected in any of the sediment samples.

To further evaluate the extent of lead in the storm drain system, additional borings were drilled below the stormwater outfall east of Silo 1 during the Follow-on RI. These include Borings NKSB19 through NKSB21 and NKSB25 through NKSB30. PAHs were also analyzed in these samples because they were detected at a total concentration of 50 $\mu\text{g/g}$ in sediment sample NISD03, collected immediately west of the stormwater outfall. Samples were collected from these borings at the surface and between 1.5 and 2.0 ft bgs. The results of lead and PAH analyses of these samples are listed in Table 4.4-7. Lead concentrations in all of the surface samples from the borings are compared to the ambient fill concentration of 221 $\mu\text{g/g}$. Concentrations in deeper samples are compared to the ambient beach/dune concentration of 96 $\mu\text{g/g}$. Lead was detected above both the ambient fill concentration and the SDC of 300 $\mu\text{g/g}$ in the 0.0-ft samples from Borings NKSB19, NKSB20, and NKSB21. Lead was not detected in the 1.7-ft samples from these same borings. Lead was not detected above ambient or the SDC in any of the samples from Borings NKSB25 through NKSB28.

PAHs were detected in two of the surface samples from the borings drilled below the stormwater outfall southeast of Silo 1. Pyrene and fluoranthene were detected in the 0.0-ft

sample from Boring NKSB19 at concentrations of 54.6 $\mu\text{g/g}$ and 56.2 $\mu\text{g/g}$, respectively. The 0.0-ft sample from Boring NKSB27 contained detectable concentrations of eight PAHs: benzo(a)anthracene, benzo(a)pyrene, benzo(b,k)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, phenanthrene, and pyrene. Three of these, benzo(a)anthracene, benzo(a)pyrene, and benzo(b,k)fluoranthene, were detected above their respective SDCs. The sum of the PAH detections in this sample was 19 $\mu\text{g/g}$. Two borings (NKSB29 and NKSB30), spaced at approximately 50 ft intervals, were drilled downstream of Boring NKSB27 to evaluate the distribution of PAHs. No PAHs were detected in any of the samples from these two borings.

4.4.2.2.2 Silo 2 Area

The storm drains around Silo 2 were further evaluated for the presence of contaminants of concern during the Supplemental RI. Two soil samples were collected from each of Borings NKSB01, NKSB02, and the boring for Well NKGW01. The six samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Those compounds with detections above the RLs are shown in Table 4.4-4. All six samples contained several inorganics at concentrations above the CRLs. Inorganic concentrations in these samples were compared to ambient concentrations in fill samples collected across the PSF as discussed in Section 3.7. Only selenium and zinc were detected above ambient fill concentrations. Selenium was detected slightly above ambient in each of the 0.0-ft samples from Borings NKSB01 and NKSB02 and the 1.0-ft sample from Boring NKGW01. Zinc was detected at a concentration of 990 $\mu\text{g/g}$, above the ambient fill concentration of 280 $\mu\text{g/g}$, in the 0.0-ft sample from Boring NKSB01. It was below ambient in the 3.0 ft-bgs sample from this boring.

Neither of the two soil samples collected during drilling of Well NKGW01 contained VOCs, SVOCs, PCBs, or chlorinated herbicides at concentrations above the RLs. Both samples contained TPH-D at concentrations less than 10 $\mu\text{g/g}$. Additionally, a Waste Extraction Test (WET) was conducted on the shallow sample for soluble chromium, lead, and nickel. The soluble concentrations of each of these inorganics were below regulatory STLC values. STLC data from the WET tests are included in Appendix O.1.

The 0.0 ft-bgs sample from Boring NKSB01 contained one VOC, trichlorofluoromethane, at a concentration of 0.006 $\mu\text{g/g}$. In the 3.0 ft-bgs sample, no VOCs were detected. Fourteen SVOCs, which were PAHs with the exception of two phthalates, were detected above CRLs in the shallow sample, and seven were detected in the deep sample. The sum of the PAH detections in the shallow sample was 8.2 $\mu\text{g/g}$ and 1.0 $\mu\text{g/g}$ in the deeper sample, indicating an overall decrease in concentrations with depth. The OCP methoxychlor was detected above the CRL in both samples from Boring NKSB01, with the concentration decreasing from 0.3 $\mu\text{g/g}$ in the shallow sample to 0.010 $\mu\text{g/g}$ in the deep sample. A detection of ppDDD was reported in the shallow sample at a concentration of 0.040 $\mu\text{g/g}$. The sample was diluted by a factor of 10, and the corresponding CRL was 0.060 $\mu\text{g/g}$. A ppDDT detection was reported in the deep sample, but identified at a concentration below the CRL. Aroclor 1260 was detected at a concentration of 0.116 $\mu\text{g/g}$ in the shallow sample from Boring NKSB01. No PCBs were detected above the CRL in the deep sample. The concentration of TPH-D decreased from 1,400 $\mu\text{g/g}$ at 0.0 ft bgs to 50.0 $\mu\text{g/g}$ at 3.0 ft bgs.

Neither of the two samples taken from Boring NKSB02 contained VOCs at concentrations above the CRLs. Four PAHs and two phthalates were detected above the CRLs in the 0.0 ft bgs sample. Of these analytes, only two were detected in the 2.0 ft-bgs sample, both at lower concentrations. The deep sample contained one PAH, benzo[b]fluoranthene, that was not detected above the CRL in the shallow sample. The sum of the PAH detections was 0.80 $\mu\text{g/g}$ in the shallow sample and 0.16 $\mu\text{g/g}$ in the deep sample, indicating an overall decrease in concentration with depth. No OCPs, PCBs, or chlorinated herbicides were detected above the CRLs in either sample. TPH-D was detected at 140 $\mu\text{g/g}$ in the shallow sample, and 9.0 $\mu\text{g/g}$ in the deep sample.

Borings NKSB03, NKSB04, NKSB05 and NKSB06 were drilled surrounding Boring NKSB01 during the Follow-on RI to further delineate the extent of zinc and PAHs detected in Boring NKSB01 (Figure 4.2-1). The soil borings were sampled at two intervals, 0.0 to 0.5 and 2.0 to 2.5 ft bgs, and were analyzed for PAHs and zinc. Analytical results are listed on Table 4.4-8. The deep samples from Borings NKSB05 and NKSB06 and all of the shallow samples were composed of beach/dune sediments. The deep samples from NKSB03 and NKSB04 were collected from the Colma Formation. Zinc concentrations were above ambient

concentrations in both samples from Boring NKSB04 and the 0.0-ft sample from Boring NKSB06. The highest zinc concentration of 180 $\mu\text{g/g}$, which was above the ambient beach/dune concentration of 107 $\mu\text{g/g}$, was detected in the shallow sample from NKSB04.

PAHs were only detected in the 0.0-ft sample from Boring NKSB04. This sample contained fluoranthene, phenanthrene, and pyrene at concentrations ranging from 5.16 to 5.4 $\mu\text{g/g}$. To further evaluate the extent of PAHs near the stormwater outfall east of Silo 2, three soil borings were drilled in the drainage ditch downslope from Boring NKSB04, spaced at 10 ft intervals (Figure 4.2-1). Borings NKSB22 through NKSB24 were sampled at 0.0 to 0.5 and 2.0 to 2.5 ft bgs. The soil samples from these borings were analyzed for PAHs only. No PAHs above the RLs were detected in these soil samples.

4.4.2.2.3 Silo 3 Area

As previously discussed, near Silo 3, Initial RI sediment samples NISD10 and NISD11 were found to contain PAHs, with the summed detections less than 11 $\mu\text{g/g}$ in each sample. To determine the lateral and vertical extent of PAHs present in this area during the Follow-on RI, one sediment sample was collected and two soil borings were drilled. Borings NKSB07 and NKSB09 were drilled on the north and south borders of the potentially impacted area. Soil samples were collected from approximately two depth intervals, 0.0 to 0.5 ft bgs, and 2.0 to 2.5 ft bgs. The sediment sample (NKSE04) was collected from a stormwater catch basin. No PAHs were detected in either the sediment sample (Table 4.4-6) or in the soil samples collected from the two borings (Table 4.4-9).

Also during the Follow-on RI, four soil borings were drilled surrounding the outfall for this storm drain to evaluate the potential for PAH contamination near the downgradient end of the storm drain system (Figure 4.2-1). The 12-in diameter outfall for this drain system is located to the southwest of Silo 3. Two soil samples were collected from Boring NKSB10 at 0.0 and 2.0 ft bgs and one surface soil sample was collected from each of Borings NKSB16, NKSB17, and NKSB18. The samples were analyzed for PAHs. No detections of PAHs above the RLs were reported for any of the soil samples from these four borings (Table 4.4-9).

4.4.3 Silo Water

Surface-water samples, collected from within the silos during the Initial RI, were analyzed for inorganics (unfiltered), VOCs, SVOCs, and PCBs. One sample was collected from each of the three silos. Those compounds with detections above the CRLs are shown in Table 4.4-10. Excluding the analytes that are not typically evaluated as part of risk assessments (calcium, magnesium, potassium, and sodium), six inorganics were detected at concentrations above the CRLs: antimony, arsenic, barium, cyanide, manganese, and selenium. No VOCs or SVOCs were detected at reportable concentrations. Aroclor 1260 was detected above the CRL in the sample from Silo 1 at a concentration of 1 µg/L.

The silos were resampled as part of the Follow-on RI. The results from this sampling are presented in Table 4.4-11. Both filtered and unfiltered samples were analyzed for inorganics. Samples were also analyzed for miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D and TPH-G. Nutrients (calcium, magnesium, potassium, and sodium), data affected by documented blank contamination, and unreliable data are excluded from the following discussion.

Numerous inorganics and miscellaneous parameters were detected in the Follow-on RI water samples from the silos. Concentrations between the two sampling events were generally similar, with an occasional elevated detection, as is typical for groundwater samples. Detections of inorganics in the unfiltered samples from all silos included barium, lead, manganese, and zinc. Detections of inorganics in the filtered samples from all silos included antimony, barium, and copper. The largest decrease in concentrations between the unfiltered and filtered samples were observed for barium, lead, manganese, and zinc. All inorganics were detected in at least two of the silo samples. Concentrations of miscellaneous parameters were generally similar in all silo water samples.

No OCPs or PCBs were detected in this second round of samples from the silos. The VOC 1,2-dichloroethane was detected at 1.2 µg/L in the sample from Silo 2. Bis(2-ethylhexyl) phthalate was also detected in this sample at a concentration of 720 µg/L. TPH-D and TPH-G were detected in the sample from Silo 2 at concentrations of 84,000 and 480 µg/L, respectively.

4.4.4 Groundwater

Before the Follow-on RI was conducted, only one groundwater well was present in the Nike Facility area. Samples from this well, NKGW01, located downgradient of the Nike Facility, were collected during the Supplemental RI and analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Those compounds detected at concentrations above the CRLs/RLs are listed on Table 4.4-12. Both filtered and unfiltered samples were collected for inorganics analyses. As discussed for surface water, nutrients (calcium, magnesium, potassium, and sodium), data affected by documented blank contamination, and unreliable data are excluded from the following discussions. Inorganics detected above the CRLs in the unfiltered sample are: aluminum, arsenic, barium, chromium, cobalt, iron, lead, manganese, nickel, selenium, vanadium, and zinc. The following inorganics were also detected in the filtered sample, in each case at lower concentrations than in the unfiltered sample: arsenic, barium, chromium, manganese, and vanadium. TDS in the sample amounted to 715,000 $\mu\text{g/L}$. No VOCs were detected at concentrations above the CRLs. With the exception of a detection of bis(2-ethylhexyl)phthalate that was documented as associated with blank contamination, no SVOCs were detected. No OCPs, PCBs, chlorinated herbicides, or TPH fractions were detected above the RLs. To more fully characterize groundwater chemistry and flow beneath the site, four additional wells were installed during the Follow-on RI (Wells NKGW02 through NKGW05, Figure 4.2-1). Groundwater samples were collected from each of the five monitoring wells during the Follow-on RI and analyzed for filtered and unfiltered inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. The results are listed on Table 4.4-13.

Numerous inorganics and miscellaneous parameters were detected in the groundwater samples. The highest concentrations of inorganics and miscellaneous parameters did not consistently occur in one or more of the wells. Most of the filtered concentrations of inorganics were lower than concentrations in the unfiltered samples. Exceptions included antimony, arsenic, copper, silver, and zinc. Antimony was not detected in any of the unfiltered samples from the five wells but was detected in all five of the filtered samples. The higher antimony concentrations in the filtered samples, as compared to the unfiltered samples, are attributable to the filter medium (Section 3.7.5). For the other analytes, higher

concentrations in the filtered samples versus the unfiltered samples did not occur consistently. Inorganic and miscellaneous parameter concentrations for Well NKGW01 tended to be lower in the Follow-on RI sample in comparison to the Supplemental RI sample. The exception was mercury, which was detected in the unfiltered sample from Well NKGW01 at 8.60 µg/L but was less than the CRL of 0.500 µg/L during the Supplemental RI.

The VOC chloroform was detected in Well NKGW01 at 1.01 µg/L. The reported detection of bis(2-ethylhexyl) phthalate in Well NKGW01 was affected by blank contamination. No other SVOCs, PCBs, OCPs, or chlorinated herbicides were detected in the samples from the monitoring wells. TPH-G was detected in Well NKGW03 at a concentration of 11 µg/L. No TPH-D was detected in the samples from the five wells.

Subsequent quarterly sampling of the Nike Facility wells has been conducted by Montgomery Watson (four quarters). Samples from the wells have been analyzed for VOCs, TPH, and dissolved and total metals. Numerous inorganics have been detected (Montgomery Watson, 1996). Results for specific analytes will be discussed in the results evaluation section. Chloroform has not been detected again. The only VOC detected has been toluene. Single low detections of toluene in NKGW05 and TPH (diesel range) in NKGW01 were reported.

4.5 RESULTS EVALUATION

This section evaluates the results of the investigations of the Nike Facility with respect to the nature and extent of contaminants of concern as well as contaminant mobility and pathways. Potential contaminant sources at the Nike Facility include Buildings 1450 and 1451 and nearby facilities, the missile silos, and the storage areas around the silos. Most of the area within the Nike Facility is paved, and surface-water runoff is controlled by a series of storm drains that outfall to the ground surface outside the fenced area. The storm drains are considered secondary sources of materials stored around the silos.

The first step in evaluating results involves assessing which analytes are COPCs, as described in Section 3.7. Once COPCs are identified, the nature and extent and fate and

transport of these analytes are evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds are considered COPCs that will be evaluated in the risk assessment. Inorganic analytes are naturally occurring and their presence at a site may or may not be anthropogenic. In determining which inorganic analytes are soil or sediment COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the lithologic composition of the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. The posting maps of inorganic concentrations in soils, included as Figures 4.5-1 through 4.5-8, aid in this evaluation.

The primary organic COPCs detected in sediments and soil in the Nike Facility are PAHs. Posting maps for two of these compounds, benzo(a)pyrene and benzo(a)anthracene, are presented as examples of the distribution of PAHs. These figures, Figures 4.5-9 4.5-10, are used to visualize the extent and aid in identifying potential sources of these analytes. Aroclor 1260 was detected in one soil sample and in one surface water sample; a posting map is included as Figure 4.5-11.

Most inorganic analytes detected in groundwater and surface water are initially considered COPCs and all detected organics, unless of course they are documented as associated with blank contamination or unreliable data, are also considered COPCs. Posting maps for some of these analytes are included as Figures 4.5-12 through 4.5-17 to supplement the nature and extent discussions. Because this site is within the Lobos Creek Groundwater Area, and beneficial uses of the groundwater include municipal and domestic supply (SFRWQCB, 1996), analyte concentrations in groundwater are compared to MCLs. However, as discussed in Section 4.3.2, it is inferred that groundwater could not provide sufficient flow to support an average, sustained yield of 200 gpd, as defined in RWQCB Resolution 89-39 for assessing groundwater as a resource for domestic or municipal water supply. Although the water in the silos will not be used for drinking water, it is also compared to MCLs for a frame of reference.

4.5.1 Nature and Extent

At the Nike Facility, 12 inorganic analytes were detected at concentrations above ambient levels in one or more soil or sediment samples. These include arsenic, cadmium, chromium, copper, cyanide, lead, manganese, mercury, nickel, selenium, vanadium, and zinc. Inorganic posting maps are presented for all of these inorganics, with the exceptions of arsenic, cadmium, selenium, and vanadium. All soil data are posted but only sediment sample data for samples collected from paved surfaces or open ditches are posted (and not sediment from storm drains) as only these data are considered to have an associated exposure pathway. All analytical results for the site, including all soil and sediment samples, were considered in the evaluation of the inorganic results; however, the analysis is presented by potential source area: Building 1450 and surrounding structures, storage areas and storm drain system, and the three missile silos. The following discussions, organized by specific area of the site, first focus on inorganics excluded as site COPCs, then discuss the extent of inorganic COPCs, followed by a discussion of the organics. Assessments of the surface water and groundwater sample data are presented last.

4.5.1.1 Building 1450 and Surrounding Structures

A series of covered utility troughs are located throughout Building 1450. These troughs are low points in which material could be expected to accumulate. Wipe samples were collected from the troughs and analyzed for inorganics and SVOCs. These samples are used only to identify what chemicals are present in the area. The results did not indicate contamination of the concrete-lined troughs, as only low concentrations of several inorganics and no SVOCs were detected above the CRLs.

Areas surrounding Building 1450 that were targeted for investigation include a concrete fuel pad, a jet fuel pad, a seepage pit, an acid fuel shed, and a concrete storage vault (Figure 4.1-1). Soil samples were collected from Borings NKSB11 through NKSB15 and analyzed for inorganics, VOCs, SVOCs, and TPH.

Chromium, copper, cyanide, manganese, mercury, nickel, vanadium and zinc were detected above ambient levels in the area surrounding Building 1450; however, none of these are

thought to be derived from U.S. Army activities at the site, as explained in the following paragraphs.

The chromium, copper, nickel, and vanadium ambient exceedences were in the 9.5-ft sample from NKS15, which is compared to Colma levels; however, these analytes, as well as the manganese, are likely associated with the serpentinite bedrock (Figures 4.5-1, 4.5-2, 4.5-5, 4.5-7). At the same depth in NKS14, manganese also slightly exceeded the ambient Colma level. This detection is also thought to be associated with the naturally elevated levels of manganese in serpentinite bedrock.

Mercury was detected slightly above ambient Colma and beach/dune levels, respectively, in the 5.0 ft bgs sample from NKS15 (0.104 versus 0.0751 $\mu\text{g/g}$) and the 1.0 ft-bgs sample from NKS12 (0.131 versus 0.076 $\mu\text{g/g}$). Zinc was also detected slightly above the ambient concentration of 107 $\mu\text{g/g}$ in the latter sample (110 $\mu\text{g/g}$); however, the amount of naturally occurring zinc in beach/dune materials varies, as zinc was reported at a concentration of 208 $\mu\text{g/g}$ in a background sample of this lithology (Section 3.7). Mercury was not detected in the samples collected above and below the 5.0 ft-bgs sample from NKS15. In noting the variability in the mercury and zinc concentrations across the site and at the PSF and the absence of a concentration-depth pattern that would indicate a source, these analytes are not considered COPCs in this area of the site (Figures 4.5-6 and 4.5-8).

Cyanide was detected above ambient in a majority of the soil samples from the Building 1450 area, at concentrations ranging from 0.321 to 0.597 $\mu\text{g/g}$. Although cyanide was detected in the single background fill sample collected from the PSF at a concentration of 0.392 $\mu\text{g/g}$, any detection of cyanide is initially considered to be above ambient, because of the low frequency of detection and variable detection limits. However, it is unlikely that a source of cyanide would result in the similar concentrations of cyanide found in this area, regardless of sample depth (range of 0.0 to 10.0 ft bgs), location, or lithology (Figure 4.5-3). Furthermore, a source of cyanide associated with U.S. Army activities at the Nike Facility buildings area is unknown. Therefore, cyanide is not considered a COPC.

No VOCs were detected in any of the soil samples collected from the borings drilled in the Building 1450 area. The SVOCs phenol and bis(2-ethylhexyl)phthalate were each detected in

several of the samples. Bis(2-ethylhexyl)phthalate was detected in at least one sample from each of the borings at concentrations ranging from 0.0769 to 0.231 $\mu\text{g/g}$. Phenol was detected in at least one sample from Boring NKS11, NKS12, and NKS13 at concentrations ranging from 0.572 to 1.06 $\mu\text{g/g}$. Both analytes were detected in the deepest samples from the borings, which were collected up to a depth of 10.0 ft-bgs. Neither of these two analytes exhibited any consistent depth-dependent trends. Bis(2-ethylhexyl) phthalate is a ubiquitous indicator compound for common plastics and is not likely to be derived from historical U.S. Army activities at the site. The detections of phenol may also be unrelated to U.S. Army activities; it is unlikely that it would be prevalent at low concentrations vertically and laterally in the soil and also not be detected in groundwater. TPH-D was detected at concentrations of 22.3 $\mu\text{g/g}$ and 22.2 $\mu\text{g/g}$ in the 0.0-ft and 5.0-ft samples, respectively, from Boring NKS13 next to the seepage pit. TPH-D was not detected in the 10.0-ft sample from this same boring.

4.5.1.2 Storage Areas and Storm Drain System

A number of sediment and soil samples were collected to evaluate the nature and extent of contaminants of concern associated with materials stored in the silos area. Sediment and soil samples were collected from and adjacent to the storm drain system which drains the areas around the silos where materials have been stored. The following discussion presents these results according to the storm drains in which they were collected.

4.5.1.2.1 Silo 1 Area

Treated telephone poles were stored near Silo 1. Sediment Samples NISD07 and NISD08 were collected from the asphalt on either side of the poles. A storm drain runs under the storage area; Sample NISD05 was collected from the drain upstream of the poles, and Sample NISD04 was collected downstream, in the perimeter ditch. Also in the perimeter ditch, three sediment samples were collected upstream of the storm drain from Silo 1 (NKSE06 through NKSE08) and three were collected downstream (NKSE01 through NKSE03) from the storm drain. The following inorganics were detected at concentrations above ambient fill concentrations in the sediment samples in the storm drain system near Silo 1: arsenic, cadmium, copper, cyanide, mercury, lead, and zinc. With the exception of cyanide, all of these are believed to be potentially associated with sources in the Nike Facility

and are considered COPCs. Cyanide was detected slightly above the ambient level (reporting limit in this case) in two sediment samples, one collected from the pavement (NISD07) and one from the perimeter drainage ditch (NISD04) but not in either sample collected from the storm drains or in the other sample collected from the pavement. Similar concentrations also were present in other samples at the site. These characteristics indicate cyanide is not likely to be site-derived and is not a COPC.

The concentrations of many of the metals are most likely associated with the chemical used to treat the telephone poles, particularly if it was copper arsenate, as visual inspection would suggest. The lead may be derived from paints or protective coatings, as thought to be often associated with launcher areas of Nike bases (ANL, 1989). Concentrations of most of the metals in the samples collected from the storm drain do not consistently increase or decrease in downstream or surface-to-drain directions. The highest lead (2,140 $\mu\text{g/g}$), zinc (1,660 $\mu\text{g/g}$), and arsenic (114 $\mu\text{g/g}$) concentrations were detected in Sample NISD04 (Figures 4.5-4 and 4.5-8). Lead was not detected in the three Follow-on RI samples collected from the perimeter drainage ditch, upstream from NISD04, suggesting that the source of the lead, and likely the source of the other inorganics, is the Silo 1 area and not the Building 1450 area. The highest concentrations of cadmium, copper, and mercury were associated with sediment collected from within the storm drain closest to Silo 1 (NISD05), also indicating this area as a potential source. Cadmium was detected above the ambient fill level only in sediment collected from the storm drains (NISD03 and NISD05).

Because elevated concentrations of PAHs, lead, and other metals were detected in NISD03 (a sediment sample that was collected from a small storm drain joining the perimeter ditch downstream of the Silo 1 area), downstream samples, including an additional sediment sample (NKSE05) and samples from seven borings (NKSB19 through NKSB21, NKSB25 through NKSB28) were collected during the Follow-on RI. Lead was detected above the SDC of 300 $\mu\text{g/g}$ in the sediment sample and in the 0.0-ft samples from Borings NKSB19, NKSB20, and NKSB21 (Figure 4.5-4). The maximum concentration was 1,200 $\mu\text{g/g}$, detected in NKSB20. Lead was not detected in the 1.7-ft samples from these same borings. Lead was not detected in any of the samples from Borings NKSB25 through NKSB28. These results indicate the lead is limited to soils above 1.7 ft.

Because the elevated concentrations of lead above the SDC of 300 $\mu\text{g/g}$ tend to be associated with the highest levels of other metals, it is inferred that the vertical and lateral distribution of the other metals would generally correspond to the distribution of lead. As shown above, the lead is elevated in sediment samples from the storm drains, paved surfaces, and perimeter drainage ditch. The source of the highest lead concentrations appears to be the Silo 1 area; lead is elevated in sediments downstream of this area, with the highest lead levels concentrated north of Silo 1 at the juncture of the storm drain with the perimeter drainage ditch, and also at the stormwater outfall associated with this drainage ditch. The downstream extent of the lead detections above the SDC of 300 $\mu\text{g/g}$ has been defined at this outfall. The vertical extent appears to be limited to less than 1.7 ft bgs.

PAHs, which can be associated with the telephone poles and the asphalt, were detected in all five of the Initial RI sediment samples near Silo 1. Pentachlorophenol was also detected in one sample collected from the storm drain, NISD05, at a concentration of $>6.2 \mu\text{g/g}$. The sum of the concentrations of detected PAHs in each of these five samples was greater than 30 $\mu\text{g/g}$. During the Follow-on RI, additional sediment and soil samples were collected in the drainage ditch to the north and east of Silo 1 as well as below the stormwater outfall located southeast of Silo 1 to further evaluate the extent of PAHs. No PAHs were detected in the seven sediment samples (NKSE01 through NKSE03, NKSE05 through NKSE08) collected in the northeast corner of the Nike Facility (Figures 4.5-9 and 4.5-10). The absence of PAHs in this area may indicate that the distribution is limited, or that, in the four years in between sampling programs, the PAHs may have been transported downstream or degraded.

Due to the presence of PAHs (summed concentration of 50 $\mu\text{g/g}$) in Initial RI sediment sample NISD03 in a branch of the drain system immediately east of Silo 1 (i.e. above the stormwater outfall), PAHs were also analyzed in samples from Borings NKSB19 through NKSB21 and NKSB25 through NKSB30. These borings were located below the stormwater outfall and outside of the fence. PAHs were detected in two of the samples from the borings drilled below the stormwater outfall southeast of Silo 1. Pyrene and fluoranthene were detected in the 0.0-ft sample from Boring NKSB19 at concentrations of 54.6 $\mu\text{g/g}$ and 56.2 $\mu\text{g/g}$, respectively. The 0.0-ft sample from Boring NKSB27 contained detectable concentrations of eight PAHs: benzo(a)anthracene, benzo(a)pyrene, benzo(b,k)fluoranthene,

benzo(g,h,i)perylene, chrysene, fluoranthene, phenanthrene, and pyrene (Figures 4.5-9 and 4.5-10). The sum of all PAH detections in this sample was 19.2 $\mu\text{g/g}$. No PAHs were detected in any of the 2.0-ft samples from these borings. No PAHs were detected in Borings NKSB29 and NKSB30 located further downslope from the PAH detections in Borings NKSB19 and NKSB27. The data suggest that PAHs are limited to surficial sediments within the Silo 1 storm drains and immediately below the stormwater outfall but that significant lateral or vertical migration has not occurred.

4.5.1.2.2 Silo 2 Area

Inorganics detected above ambient concentrations in the vicinity of Silo 2 include mercury, selenium, lead, and zinc. All of these are considered to be site COPCs. The extent of these inorganics and the organics detected in the soil and sediment east and west of Silo 2 is described in this section.

The storm drain system in the vicinity of Silo 2 was investigated during the Initial RI by sediment Samples NISD01, NISD02, and NISD06 (Figure 4.1-2). All of these were collected from sediment within the storm drains. West of Silo 2, Sample NISD06 was collected from an upstream drain and Sample NISD01 was collected from a drain further downstream. Sample NISD02 was collected from the storm drain east of Silo 2. Only zinc and mercury were detected above ambient fill levels in the sediment samples. Zinc was above the ambient fill level of 280 $\mu\text{g/g}$ in NISD01 and NISD02, at concentrations of 288 and 480 $\mu\text{g/g}$, respectively.

Soil Boring NKSB01, drilled during the Supplemental RI below the outfall of the storm drain associated with NISD02 (east of Silo 2), also had an elevated level of zinc (990 $\mu\text{g/g}$) in the surface sample (0.0 ft bgs), as well as an ambient exceedence of lead (270 $\mu\text{g/g}$) and selenium (1.17 $\mu\text{g/g}$) (Figures 4.5-4 and 4.5-8). Inorganic concentrations in the 3.0 ft-bgs sample from this boring were below ambient fill levels. Follow-on RI borings drilled in this area to investigate the extent of zinc and PAHs in NKSB01 indicated that elevated zinc concentrations were limited to surface samples and confined to a small area surrounding this boring (approximately a 10 ft radius) (Figure 4.5-8). The zinc concentrations in the surface and subsurface samples from Boring NKSB04 are believed to be associated with the natural

zinc concentrations. This is indicated by concentrations reported by XRF of up to 208 $\mu\text{g/g}$ and 224 $\mu\text{g/g}$ in background beach/dune and Colma samples, respectively. Zinc concentrations were not above ambient levels in the Supplemental RI borings drilled near the outlets of the storm drains south and west of Silo 2 area, indicating that elevated levels of zinc are confined to the area east of Silo 2 and to sediments that have accumulated in the storm drains.

As mentioned above, the lead was detected above the ambient fill level but less than the SDC of 300 $\mu\text{g/g}$ in the surface soil sample from Boring NKS01. No other ambient exceedences for lead were noted, either in the sediment from the storm drains or other boring samples, which indicates that the extent of lead above concentrations of concern is minimal.

Mercury was above ambient fill levels in all three sediment samples from the storm drains, ranging from 0.373 $\mu\text{g/g}$ to >4.0 $\mu\text{g/g}$ in NISD06. However, mercury was not detected above ambient in any of the Supplemental RI samples from the Silo 2 area, indicating that the elevated levels have not been transported to soils at the outfalls of the storm drains (Figure 4.5-6).

Selenium was detected above the ambient fill concentration of 0.819 $\mu\text{g/g}$ in all three surface samples from the Supplemental RI borings, ranging from 0.821 to 1.17 $\mu\text{g/g}$. It is uncertain if the selenium is associated with site sources or is present at natural concentrations, since it is within the range of regional ambient concentrations (Table 3.7-1). Because selenium was only detected above ambient levels in surface samples, similar to the other inorganic COPCs, a site source is suggested. However, unlike the other COPCs, selenium was not detected in any sediment samples collected from the storm drain, which may indicate the absence of a site source. For conservatism, selenium is considered a COPC.

To the west side of Silo 2, four PAHs were detected in Sample NISD06 and one PAH was detected in Sample NISD01. East of Silo 2, five PAHs, totaling 2.7 $\mu\text{g/g}$, and pentachlorophenol (3.0 $\mu\text{g/g}$) were detected in Sample NISD02. Additional borings aided in defining the extent of the PAHs west (Supplemental RI) and east (Supplemental and Follow-on RIs) of Silo 2, as described in the following paragraphs.

Supplemental RI Boring NKSB01 was drilled into the engineering fill near the outfall of the drain from which Sample NISD02 was collected. Two samples were collected from the boring, at 0.0 and 3.0 ft bgs, and these samples further define the extent of the contaminants of concern that were detected in Sample NISD02. The 0.0-ft sample contained 13 PAHs above the CRLs, six of which were also detected at lower concentrations in the 3.0-ft sample (Figures 4.5-9 and 4.5-10). The sum of the PAH detections in the surface sample was 8.18 $\mu\text{g/g}$, decreasing to 1.04 $\mu\text{g/g}$ in the deeper sample. In addition to PAHs, the surface soil sample from Boring NKSB01 contained trichlorofluoromethane, two phthalates, methoxychlor, ppDDD, Aroclor 1260 (Figure 4.5-11), and TPH-D. The concentrations of each of these analytes decreased or were not detectable in the 3.0-ft sample from Boring NKSB01. With the exception of the phthalates and TPH-D, there were no other detections of these compounds reported in soil and sediments in the Nike Facility.

Follow-on RI soil borings NKSB03, NKSB04, NKSB05 and NKSB06 were drilled surrounding Boring NKSB01 to further delineate the extent of zinc and PAHs detected in Boring NKSB01. Two soil samples from each boring were analyzed. PAHs were only detected in the 0.0-ft sample from Boring NKSB04. To further evaluate the extent of PAHs near the stormwater outfall east of Silo 2, three more borings were drilled downslope from Boring NKSB04 (Figures 4.5-9 and 4.5-10). No PAHs above the RLs were detected in the soil samples from Borings NKSB22 through NKSB24. The data suggest that potential contaminants of concern are limited to sediments in the storm drains and in surface soil in the immediate vicinity of the stormwater outfall.

West of Silo 2, four PAHs were detected at a summed concentration of less than 1 $\mu\text{g/g}$ in the upstream sediment sample (NISD06). Of these, only pyrene was detected above the CRL in the downstream sample (NISD01), and this detection was at a lower concentration (0.14 $\mu\text{g/g}$). Four PAHs, including benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene, were detected in the 0.0-ft sample from Boring NKSB02 located near the southern terminus of the storm drain south of Silo 2 (Figure 4.5-9). The concentrations of each of these PAHs were lower or not detected in the 2.0-ft sample from the same boring. One PAH, benzo(b)fluoranthene, was detected above the CRL only in the deep sample but not in the shallow sample. Summed concentrations of PAHs were less than 1 $\mu\text{g/g}$ in both samples.

Two phthalates that were detected in the 0.0-ft sample were not detected in the 2.0-ft sample. The concentration of TPH-D decreased from 140 $\mu\text{g/g}$ in the shallow sample to 9.00 $\mu\text{g/g}$ in the deep sample. In general, the data suggest attenuation of chemical concentrations with depth and much lower concentrations than those detected in the storm drains east of Silo 2.

4.5.1.2.3 Silo 3 Area

In an area associated with another portion of the drainage system, treated telephone poles were stored to west of Silo 3. The poles appear to have been treated with creosote. Two sediment samples, NISD10 and NISD11, were collected on the asphalt on either side of the poles, and Sample NISD12 was collected from the nearest storm drain during the Initial RI. No inorganics were detected above ambient concentrations in any of these sediment samples. Five PAHs were detected above the CRLs in the two samples from the asphalt; none of these was detected above the CRLs in the drain, suggesting the asphalt is the source of the PAHs. This was confirmed by the absence of PAHs in sediment sample NKSE04, collected during the Follow-on RI from the storm drain to further assess the extent of PAHs. The distribution appears to be limited to the sediment samples on the asphalt, as none of the samples collected from six borings drilled during the Follow-on RI in this area had any detections of PAHs (Figures 4.5-9 and 4.5-10).

4.5.1.3 Silo Water

The silos were evaluated as potential sources of contaminants of concern. Surface-water samples were collected from each silo to identify any contaminants of potential concern associated with the standing water. Though the water in the silos cannot be considered part of a drinking water supply, the data are compared to drinking water MCLs as a point of reference. Antimony, which is often a result of rusting metal, was detected above the California primary MCL of 6 $\mu\text{g/L}$ in all three silos in both sampling events (Figure 4.5-12). In both sampling events, the highest concentrations were detected in Silos 1 and 2. Both filtered and unfiltered results were above MCLs.

All other detections of inorganics above MCLs in the silo water are attributed to suspended solids present in unfiltered samples. Manganese was detected above the California secondary MCL of 50 $\mu\text{g/L}$ in the Initial RI sample (unfiltered) from Silo 3, but not in the Follow-on RI

mercury are unknown, but may be wood preservatives associated with telephone poles or other materials stored at the site, paint, or agricultural chemicals containing mercury.

The chromium, nickel, and aluminum concentrations are likely due to the fact that the water-bearing zone is situated above weathered serpentinite, and the metals are most likely in colloidal form and not dissolved. This is supported by the variability in the metals concentrations between sampling events, including the four quarters of sampling conducted after the Follow-on RI (Montgomery Watson, 1996), the lower concentrations in the filtered samples, high TDS values in the wells, and absence of elevated levels of these inorganics in soil or sediment (Figures 4.5-13, 4.5-17). The TDS is probably associated with the weathering of the serpentinite bedrock and unconsolidated deposits derived from the bedrock. In support of this inference, there was no significant increase in TDS values between the upgradient and downgradient wells and the highest concentrations were associated with Well NKGW01, which is screened across silt, clay, and weathered bedrock.

Although chloroform was detected in Well NKGW01, it was approximately two orders of magnitude less than the MCL. It has not been detected in subsequent sampling. TPH-D was detected in upgradient Well NKGW03 at 11 µg/L. The only other detection of TPH-D was in NKGW01, at a concentration of 68 µg/L during the summer quarter of 1995 (Montgomery Watson, 1996). Toluene was detected slightly above the detection limit, but well below the MCL, in Well NKGW05 in the spring quarter of 1996 (Montgomery Watson, 1996).

The high TDS values and associated naturally occurring levels of aluminum, chromium, nickel, and manganese, the low saturated thickness, and an estimated insufficient flow to support an average, sustained yield of 200 gpd, combine to minimize the likelihood of the water-bearing zone below the Nike Facility becoming a drinking water source. Antimony, which was originally a cause of concern in the groundwater because it was detected in the silo water, was not detected above the CRL in unfiltered samples, and the low detections in the filtered samples are attributed to the filter medium. This suggests that any connection between water in the silos and groundwater beneath the site is limited. Mercury detected above the MCL in the groundwater from Well NKGW01 may be derived from site sources, as elevated levels of mercury in storm drain sediments were observed.

4.5.2 Contaminant Mobility and Migration Pathways

Migration of contaminants of concern across paved surfaces and in storm drains depends in part on the amount of water and sediment moving into and through the drains. Compounds with high soil affinity, such as PAHs, most inorganics, and OCPs, migrate with soil particles as they are transported through the drain system by the water. Compounds with high solubility migrate through dissolution into the water moving through the drains. This suggests that the compounds detected in the sediment samples at the Nike Facility should be those with high soil affinity and low solubility. Such compounds are less likely to migrate out of the system with water. Inorganics were frequently detected in the sediment samples, which is to be expected because these compounds tend to move with particles rather than dissolving into water. This was demonstrated for chromium, nickel, and lead in the soils at the PSF, as discussed in Section 3.7.4. The same is true of the PAHs, which are the primary representatives of the SVOC suite in the sediment samples. In addition, two pentachlorophenol detections were noted in the sediment samples, both in storm drains. Pentachlorophenol, likely derived from the stored telephone poles, is moderately soluble and would not necessarily appear in all samples. Detections of bis(2-ethylhexyl)phthalate and butylbenzyl phthalate are common regardless of the dominant transport mechanism. Both phthalates and phenol cannot be traced to site-specific sources.

Further evidence of the mobility of the contaminants of concern is achieved through collection of soil samples at downstream locations. Samples were collected at two different depths in borings in the perimeter drainage ditch and the outfalls of the storm drain system. As expected, several inorganics were detected above ambient concentrations in the surface samples, but at lower concentrations in the deeper samples. Trichlorofluoromethane was detected in the shallow sample from Boring NKSB01. The primary transport mechanism for this compound is most likely volatilization, and it was not detected above the CRL at depth. PAHs would also be expected in these soil samples, and several were detected, along with two phthalates. In each case, concentrations decreased with depth, due to strong affinity to soil and low mobility.

The soil samples from two of the borings (NKSB01 and NKSB02) and Well NKGW01, downslope from the Silo 1 and 2 areas, were analyzed for an expanded list of target analytes.

sample (Figure 4.5-15). Manganese was also above the secondary MCL in the unfiltered Follow-on RI sample from Silo 1, but not in the filtered sample or in the Initial RI sample. There were three other metals that were detected at concentrations above MCLs in unfiltered Follow-on RI samples, but not in previous sampling or in filtered samples. These included barium (Silo 2), iron (above secondary MCL in Silo 1), and lead (Silo 1) (Figure 4.5-14).

Aroclor 1260 was detected at a concentration of 1 µg/L in the Initial RI sample from Silo 1, but not in the Follow-on RI sample. The California primary MCL for PCBs is 0.5 µg/L. Aroclor 1260 was detected in only one soil sample in the Nike Facility, near Silo 2, also indicating that the presence of this analyte is very limited. During the Follow-on RI, 1,2-dichloroethane was detected at a concentration of 1.20 µg/L in the sample from Silo 2, in comparison to the MCL of 0.5 µg/L. This VOC was not detected in the previous sample from Silo 2 but was spuriously detected in several water samples across the PSF during the Follow-on RI in areas where it was not expected to be present. It is suspected that its detection may be related to an undocumented laboratory or field contamination. Subsequent quarterly sampling data for the PSF wells have supported this inference. Bis(2-ethylhexyl) phthalate was detected above the MCL of 4 µg/L in the Follow-on RI sample from Silo 2; however, no detections were previously reported in the silo samples or in any of the other Follow-on RI samples. This analyte is a ubiquitous indicator of common plastics and laboratory contamination and is not likely associated with site sources. Elevated levels of TPH-D and TPH-G, 84,000 and 480 µg/L, respectively, were reported in the Follow-on RI samples from Silo 2.

4.5.1.4 Groundwater

Concern over the potential leakage from the silos, and subsequent migration through the soil and into the groundwater, led to the drilling of Wells NKGW01, NKGW04, and NKGW05 downgradient of the silos. Well NKGW02, downgradient of the Building 1450 area, and Well NKGW03, upgradient of the Nike Facility also were drilled to provide information about potential sources. Although the groundwater at the Nike Facility is unlikely to be used as drinking water, the groundwater sampling results have been compared to drinking water MCLs.

In NKGW01, which is downgradient of Silo 2, only aluminum, chromium, nickel, and TDS exceeded MCLs in the Supplemental RI unfiltered samples. The only exceedence of MCLs in filtered samples was chromium, at a concentration of 52.2 $\mu\text{g/L}$, slightly above the MCL of 50 $\mu\text{g/L}$. In the unfiltered Follow-on RI samples, aluminum, chromium, manganese, mercury, and nickel, exceeded the California primary MCL. Antimony exceeded the California primary MCL only in filtered samples, not in any unfiltered samples (Figure 4.5-12). Manganese exceeded the California secondary MCL in unfiltered samples from all wells except NKGW01 and in only one filtered sample, from NKGW05 (Figure 4.5-15). TDS exceeded the California recommended secondary MCL of 500,000 $\mu\text{g/L}$ in both the Follow-on and Supplemental RI samples from NKGW01.

Most of the MCL exceedences for inorganics in the groundwater can be attributed to suspended solids in the unfiltered samples that are associated with naturally occurring inorganics in the serpentinite and serpentinite-derived soils. The exceptions are antimony and mercury. The higher antimony concentrations in the filtered samples, as compared to the unfiltered samples, are attributable to the filter medium, as discussed in Section 3.7.5. Controlled laboratory studies conducted by the USCOE showed that the filters contain antimony that is mobilized by the movement of water through the filter (Call, 1994). Therefore, filtered antimony results are considered to be unreliable and antimony is not considered to be present in detectable concentrations in the groundwater. This is confirmed by subsequent quarterly sampling conducted by Montgomery Watson, in which antimony was not detected above the MCL of 6 $\mu\text{g/L}$ (Montgomery Watson, 1996). Although mercury was detected above the MCL of 2 $\mu\text{g/L}$ in Well NKGW01 during the Follow-on RI, it was not previously detected during the Supplemental RI (Figure 4.5-16). However, during four quarters of sampling conducted by Montgomery Watson for this well, mercury concentrations have ranged from 1.9 to 3.3 $\mu\text{g/L}$ in the unfiltered samples and from <0.20 to 3.1 $\mu\text{g/L}$ in the filtered samples. Mercury has not been detected in any of the other Nike Facility wells. Well NKGW01 is downgradient of Silo 2. Mercury was detected at elevated levels in storm drain sediments in the Silo 1 and Silo 2 areas, but not in any of the silo water samples, indicating that the mercury in the groundwater may be derived from the sediments, or from the source contributing to elevated levels in the sediments. Potential sources of

OCPs are relatively immobile, and those concentrations in the 0.0 ft bgs sample in NKSB01 were not duplicated at 3.0 ft bgs. PCBs increase in their soil affinity with the degree of chlorination. Aroclor 1260, the most chlorinated of the PCB Aroclors, was the only PCB detected. It was detected above the CRL in the 0.0 ft bgs sample from Boring NKSB01 but not in the 3.0 ft bgs sample. TPH-D was also detected in samples from these borings. TPH-D represents the heavier and, therefore, less mobile range of the petroleum hydrocarbon compounds. This limited mobility is demonstrated by the decreased concentrations at depth.

Another potential source of COPCs that was evaluated at the Nike Facility is the standing water in the missile silos. The primary issue of concern that arose from the sampling of the silo water was the potential migration of antimony, which is used in alloys and can be released by rusting metal. In theory, the antimony could migrate with the water leaking from the silos and move through the soil into the groundwater. Therefore, the groundwater downgradient of the silos could potentially be impacted. However, analytical results for downgradient Wells NKGW01, NKGW04, and NKGW05 indicated that groundwater was not impacted by the elevated concentrations of antimony detected in the silo water (Figure 4.5-12). Antimony was not detected above the CRL in the unfiltered groundwater samples, though several other inorganics were, including aluminum, chromium, manganese, mercury, and nickel, at concentrations above California primary MCLs. With the exception of mercury, these concentrations are attributed to the presence of serpentinite bedrock beneath the shallow water-bearing zone rather than surface activity. The mercury detected in NKGW01 may have migrated from sources in the Silo 2 area, as it was elevated in storm drain sediments. There does not appear to be any migration of organics from the site to the groundwater as only sporadic, low detections of organics in the groundwater were reported.

4.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY

This section summarizes the evaluation of results for the Nike Facility, including the risk assessment results, which are presented in detail in Section 15.

4.6.1 Conclusions

The area around the silos at the Nike Facility has been used for storage since the termination of missile activities at the site. Chemical releases from the stored materials to surface sediments on the asphalt have resulted in detectable concentrations of several contaminants of concern, primarily inorganics, TPH, and PAHs. These chemicals have migrated with the sediment into the storm drain system and, in some cases, to the soil below the outfalls outside the perimeter fence. Most of the elevated concentrations are detected in the surface soil and not in subsurface soil.

Rusting metal within the silos has resulted in detectable concentrations of antimony in samples of the standing water in all three silos. The antimony in the silo water does not appear to have been released to the groundwater in the area. The groundwater contained several inorganics, including aluminum, chromium, manganese, mercury, and nickel at concentrations above California primary MCLs. With the exception of mercury, the elevated concentrations are likely due to the presence of serpentinite bedrock and trace amounts of serpentinite in the other geologic units. Mercury was detected above the California primary MCL in Well NKGW01 during the Follow-on RI and in subsequent sampling conducted by Montgomery Watson, indicating a potential site-related source of mercury that has resulted in detections in storm drain sediment and in groundwater near Silo 2.

4.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil and in sediments from open ditches or paved areas were considered in the human health and ecological risk assessments according to the depths in which they occurred and the exposure scenarios that were evaluated. Neither the sediments from storm drains nor the silo water samples were assessed because exposures to these media are unlikely under the future use scenarios for the Nike Facility. Inorganics, miscellaneous parameters, and organics in Nike Facility groundwater are considered in the human health risk assessment. In addition, the PSF water supply (Lobos Creek and Well 13) is evaluated as a drinking water source for the Building 1450 area. The ecological risk assessment evaluated potential transport of contaminants to the swale downslope of the Nike Facility and estimated potential impacts to aquatic receptors.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Nike Facility are summarized in the following sections.

4.6.2.1 Human Health

The Nike Facility was assessed as two areas for the purposes of the human health risk assessment because the GMPA identified institutional (industrial) use around Buildings 1450 and 1451 and open space (recreational) in the other areas of the Nike Facility. Under the industrial scenario evaluated for the area of Buildings 1450 and 1451, exposures to surface (0 to less than 0.5 ft bgs) and subsurface (0.5 to less than 15 ft bgs) soil are possible. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area of the Nike Facility. Under the recreational scenario evaluated for the remainder of the Nike Facility, only exposure to surface soil is assumed.

Two additional assessments of risk were performed for the Nike Facility that are not based on the planned future use of the site. These include assessment of Nike groundwater as drinking water and a residential PRG ratio screening assessment. Groundwater was assessed as drinking water on a site-wide basis at the Nike Facility although the high TDS levels, thin saturated zone, and low expected well yields combine to make groundwater beneath the Nike area an unlikely potable water supply for the industrial worker in the Building 1450 area.

A residential PRG ratio screening assessment for surface and subsurface soil for both areas of the Nike Facility and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on

conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg, used for both industrial and recreational scenarios.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (Federal Register 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ >1E+00, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Nike Facility are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer

risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead soil screening values, are identified.

4.6.2.1.1 Quantification of Carcinogenic Risks

No surface or subsurface soil COCs were determined after COPC screening for the Building 1450 area, and, therefore, no risk was quantitated for soil under the industrial scenario.

Drinking water from the PSF water supply was assessed for Buildings 1450 and 1451. The drinking water COCs, lead, manganese, and nitrate, are not considered carcinogenic so it is unlikely that there is an excess cancer risk for this site. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$.

The groundwater at the Nike Facility was assessed as a drinking water source for institutional workers. After screening against MCLs and PRGs was performed, several inorganics, including aluminum, antimony, arsenic, chromium, cyanide, manganese, mercury, and nickel, chloroform, nitrite/nitrate, and TDS were considered COCs. The total risk is $3E-04$, mostly from ingestion of chromium, which is assumed to be 100% hexavalent chromium for the risk assessment. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

In the Silo/Storage Area, surface soil COCs included arsenic, lead, several PAHs, and Aroclor 1260. Phenanthrene was the only COC in subsurface soil, which is only assessed in the residential PRG ratio screening assessment because subsurface soil is not assessed in the recreational scenario. The future land use recreational scenario was assessed with ingestion of and dermal exposure to surface soil for the Nike silo/storage site. The individual carcinogenic risks were all above $1E-06$ for all COCs except for Aroclor 1260. The total risk for the Nike Silo/Storage Area is $1E-04$. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

4.6.2.1.2 Quantification of Noncarcinogenic Effects

Hazard indices for the COCs in the PSF water supply as drinking water at the Buildings 1450/1451 area were all less than $1E+00$ and therefore, it is unlikely that exposure to COCs at the site will result in noncarcinogenic health effects in the industrial scenario. The total noncarcinogenic index for arsenic, the only noncarcinogenic COC at the Silo/Storage Area,

for the recreational scenario is $1E+00$, mostly from ingestion of surface soil. Manganese in the groundwater as a water source had a noncarcinogenic index of $2E+00$. The residential PRG ratio screening assessment resulted in total hazard indices above $1E+00$ for the Nike Facility Silo/Storage Area and below $1E+00$ for groundwater assessed for Buildings 1450/1451.

The maximum detected value of lead in surface soil at the Nike Facility Silo/Storage Area is 2143 mg/kg, which is greater than the lead soil screening value of 840 mg/kg for recreational use.

4.6.3 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds. In addition, transport of COPCs from soil in the Nike Facility downslope to the swale was estimated and potential impacts to terrestrial and aquatic receptors, including aquatic plants and invertebrates, amphibians, mallard duck, and western sandpiper, were assessed for this swale.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a gray zone where risks are possible but unlikely.

Soil COPCs evaluated in the ecological risk assessment include arsenic, copper, lead, selenium, zinc, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, trichlorofluoromethane,

phenol, several PAHs, ppDDD, methoxychlor, Aroclor 1260, and TPH-D. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, peregrine falcon, western harvest mouse, pocket gopher, and plants and soil fauna exceeded 1 when comparisons were made to the conservative TBV_{Low} .
- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 when comparisons were made to the TBV_{High} .
- Lead is the predominant risk driver, resulting in HQs greater than 1 for the American robin, mourning dove, peregrine falcon, and western harvest mouse when these receptors are exposed through soil or dietary ingestion and risk comparisons are made to the TBV_{Low} .
- Lead is not likely to be of concern to the peregrine falcon or western harvest mouse, although the HQ based on the TBV_{Low} exceeds 1, because the HQ based on the TBV_{High} is well below 1.
- Lead and selenium produce an HQ in excess of 1 for the pocket gopher for soil and dietary exposure; however, when the TBV_{High} is considered, these COPCs do not produce risk.
- Several inorganics (arsenic, copper, lead, and zinc) exceed TBV_{Low} values for the protection of plant and soil fauna. Only lead produced an exceedence of the TBV_{High} .
- Zinc resulted in HQs greater than 1 for American robin and the mourning dove based on the TBV_{Low} and the TBV_{High} for exposure by soil or dietary ingestion.
- Zinc resulted in HQs greater than 1 for western harvest mouse based on the TBV_{Low} and the TBV_{High} when exposed through the diet.

Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS.

Risk estimates for aquatic receptors in the swale downslope of the Nike Facility were obtained from predictions of analyte concentrations in sediment and water that were derived from concentrations of COPCs in soil at the Nike Facility. Risks to the aquatic receptors are minimal and appear primarily for the HQs based on the TBV_{Low} . Except for the aquatic

invertebrates, all HQs and HIs based on the TBV_{High} are less than 1. The highest risks are for aquatic invertebrates based on sediment exposure. There are no HQs that exceed 1 for terrestrial receptors utilizing the swale for drinking water. HI high and low estimates were similar because they were based on chronic AWQC values, which are highly conservative given that the seasonal or temporary nature of this wet area would result in short-term exposures. There is unlikely to be any significant impact on the swale from the Nike Facility.

5. CRISSY FIELD STUDY AREA

This section describes the Crissy Field Study Area and its sample locations, geologic units, hydrogeologic units and processes, analytical results, and an evaluation of the results. The Crissy Field Study Area was selected for further investigation based on agency comments, the *Enhanced Preliminary Assessment Report* (ANL, 1989), and the *Preliminary Assessment for the Supplemental RI* (RLSA, 1992a). The RI's primary objective in the Crissy Field Study Area is to characterize the nature and extent of potential COCs in surface soil, subsurface soil, groundwater, sediments, and on selected building surfaces in five areas: the Consolidated Motor Pool, the POL Area, Fill Site 7 (formerly Landfill 7), Buildings 609, 611, and 633, and the Sewer Lift Stations. Potential contaminant sources investigated at the site include fill material, USTs, buildings, storage areas, and maintenance areas. Release or transport mechanisms evaluated at the Crissy Field Study Area include product releases (spills and leaks), stormwater runoff, physical contact, and infiltration to subsurface soil and groundwater.

5.1 AREA DESCRIPTION

This section describes the physical location, the historical and current uses, and previous environmental investigations of five subsections of the Crissy Field Study Area: the Consolidated Motor Pool; the POL Area; Fill Site 7; Buildings 609, 611, and 633; and the Sewer Lift Stations. This information was used to develop a conceptual model and design a sampling program for the Crissy Field Study Area.

5.1.1 Location and Physical Features

The Crissy Field Study Area is located north of Highway 101 in the north-central portion of the PSF along San Francisco Bay (Figure 5.1-1). The study area encompasses approximately 44 ac and is at an elevation of approximately 10 ft-PLL. There is little topographic relief in the study area.

The Consolidated Motor Pool is located on approximately 5 ac on the south side of the intersection of Mason Street and Old Mason Street and is mostly paved. The four buildings

investigated during the RI in this area are Buildings 634, 640, 642, and 643. The only access to these areas is from Mason Street because a bedrock cliff forms a natural barrier directly behind the buildings to the south. The maintenance area at Building 643 is enclosed by a fence that extends from the east end of Building 643 parallel to Mason Street and south to the northwest corner of Building 640.

The POL Area is the site of a former refueling station located on 0.75 ac southeast of the Consolidated Motor Pool. Building 637 was a former fuel control building linking six ASTs to five pumping islands located near the central portion of the area. The POL Area also contained a vapor-recovery tank, an oil-water separator, and Building 638, which served as a hazardous materials storage area. A bermed storage pad was located adjacent to Building 638. Building 637, the ASTs, fuel islands and other petroleum-related structures were removed in September 1993 (Montgomery Watson, 1995d).

Fill Site 7 encompasses approximately 37 ac and is located north of Old Mason and Mason Streets, west of Mitchell Street and the East-of-Mason Study Area, and east of Livingston and Pennington Streets. The area includes the Crissy Field landing strip and helipad. The helipad is the only area of Fill Site 7 that is fenced and closed to the public. Another fence is parallel to Mason Street and separates the Crissy Field landing strip from the northern section of Crissy Field which is adjacent to the bay. The northern section of Crissy Field and approximately 80 percent of the helipad area are covered with grass; the rest of Fill Site 7 is paved with either concrete or asphalt. There are no buildings in the Fill Site 7 area. Previous reports identified Fill Site 7 as Landfill 7, however it is now identified as a fill site because the supplemental RI data showed that the fill materials consist primarily of locally-derived soil and construction debris.

Building 609, located on the south side of Old Mason Street approximately 800 ft east of the Consolidated Motor Pool, is the PSF commissary. It was built after the 1987 demolition of the original Building 609, which was located on the same site. Building 611 was located on Fill Site 7 and west of Bank Street which is a small north-south street connecting Mason Street and Old Mason Street. A fenced concrete pad is presently located at this site (denoted as Building 611 in Figure 5.1-1). A closed firing range is located southwest of Building 633

and north of the elevated section of Highway 101. It consists of a concrete backstop with sand still in the pit.

Two sewer lift stations, used to convey industrial wastes and sewage, were added to the Follow-on RI sampling program. The first station is located south of Building 644 and southwest of Crissy Field. The second station is located south of Building 606 and southeast of Crissy Field.

5.1.2 History and Land Use

Information concerning the history and use of the Crissy Field Study Area was obtained from aerial photographs (Rindgen and Sitton, 1990), interviews with PSF personnel, the *Building Information Schedule* (Nakata, 1985), and the *Enhanced Preliminary Assessment Report* (ANL, 1989). While some information provided by PSF personnel could not be directly supported by documentation, it is considered reliable and useful for the purpose of the RI. Additional historical information regarding petroleum tanks and underground pipelines in the Crissy Field Study Area was brought to the U.S. Army's attention after the RI field work was completed. Investigation of these features, and resulting corrective action, if any, will be conducted under the U.S. Army's petroleum cleanup program at the PSF.

5.1.1.1 Consolidated Motor Pool Area

Building 634 is a motor pool warehouse built in 1978. It is an 1,800-ft², single-story, brick structure with a continuous concrete footing and an unbermed concrete floor. The building was used to store a variety of materials. Substances most recently stored in the building include motor oil, primers, lubricants, paint thinner, sulfuric acid, chlorine (for pools), hydraulic fluids, insecticides, cleaning compounds, brake fluid, floor waxes, and sodium hydroxide. Hazardous wastes were removed from the building by a commercial contractor. Aerial photographs (Rindgen and Sitton, 1990) show that in October 1959 there was an AST east of the present location of Building 634. April 1973 photographs show that the AST had been removed, and the area had apparently been paved.

Building 640 was built as an airplane maintenance hangar in 1928. It is a two-story, wood-framed, plasterboard structure on a reinforced concrete continuous footing. This 9,540-ft²

building was most recently used for vehicle maintenance. Wastes were removed from the building by a commercial contractor. The building has an unbermed concrete floor, and there have been no reported spills. However, ground staining is visible near the northeast corner of the building in a 1963 aerial photograph, and it is assumed to be the result of spills (Figure 5.1-2). In a 1973 aerial photograph, there is pavement over the stained area.

Building 642 is a 10 ft by 15 ft cinder block structure which contains an emergency generator. In October 1993, fuel oil spilled from a 200-gal AST located adjacent to the southwest corner of the building. The spill resulted in a 10 ft by 10 ft stained area on pavement adjacent to the AST (HLA, 1994).

Building 643 was built in 1923 as an aircraft hangar. This 22,376-ft², single-story, reinforced concrete structure was remodeled with wood frame plasterboard inner walls. Although it is in poor condition, it is considered a historic structure. It was recently used as a maintenance shop for electronic equipment. Although solvents have been routinely used during operations, data gathered as a part of the Enhanced PA indicate responsible operating practices, and no spills have been documented at the site.

5.1.1.2 Petroleum, Oil, and Lubricants Area

Building 637 is a small fuel control building located in the fenced POL Area. A 1946 aerial photograph, which predates construction of the facility, shows one AST on site. By 1959, there were six ASTs and apparent stains on the ground north of the building. The stains, also evident in 1963 and 1973 aerial photographs, suggest leakage or spillage from overfilling. Many of the historically stained areas are now covered by concrete pavement. The six ASTs were connected via underground pipelines to five pumping islands just north of Building 637. The three westernmost diesel fuel ASTs each had a 5,000-gal capacity. The other three ASTs stored gasoline and had capacities of 20,000-gal each. The ASTs, underground piping, fuel islands, and pump control house (Building 637) were removed in September 1993 (Montgomery Watson, 1995d). A 250-gal concrete UST used for gasoline storage was also removed from outside Building 637 in 1993.

Building 638 is a storage building for flammable materials that is also located in the fenced POL area of the Consolidated Motor Pool facility. The building is a single-story, 970-ft²

storage facility of brick, steel, and concrete construction. The specific types of materials stored in the building have not been documented. A waste oil drum storage area was located adjacent to Building 638 with a spill containment system that consisted of an oil/water separator that discharged to the sanitary sewer system. The associated UST, which had a 600-gal capacity was removed in 1993 (Montgomery Watson, 1996a). There is some evidence that spills occurred in the storage area (ECJC, 1990a).

5.1.1.3 Fill Site 7

The landscape at Fill Site 7 has changed dramatically since the late 1800s. A map dated August 2, 1882 (U.S. Surveyor General, 1882) shows a marsh and a tidal inlet and channel located behind a sand spit (Figure 5.1-3). According to an 1851 U.S. Coast Survey map, the marsh and inlet consisted of 97 ac of salt marsh, 10 ac of mudflats and sandflats, and 20 ac of subtidal channels. However, roads may have already started to decrease the size of the wetlands by 1882. By 1894, the road embankments and filled areas had disrupted the wetlands and decreased its area to approximately 80 ac (Dames & Moore, 1995b). There is some uncertainty as to what materials were used to fill the marsh, but the *Enhanced Preliminary Assessment Report* (ANL, 1989) and *Wetland and Riparian Corridor Restoration Feasibility Study* (Dames & Moore, 1995b) reported that the area was filled with bottom muds and sediments dredged from San Francisco Bay in preparation for the 1915 Panama Exhibit, construction debris resulting from the 1906 earthquake, and sand. In 1919, the Crissy Airfield was built on the filled area and was used as an airfield for training and defense through the 1970s (Dames & Moore, 1995b). The complex is now called Crissy Field and includes the helipad, landing strip, and the area between the landing strip and San Francisco Bay. Fill Site 7 extends almost the entire length of Crissy Field.

Aerial photographs from 1946, 1959, and 1963 (Rindgen and Sitton, 1990) show unidentifiable mounded material and debris along the eastern and central coastal portions of Fill Site 7. The photographs corroborate reports by PSF personnel that additional material was disposed of along the shoreline to prevent erosion after the original grading was completed. The 1963 aerial photograph indicates potential staining near a small shed in the eastern section of the study area and near aircraft that were parked on the runway in the central section (Figure 5.1-2). Interviews conducted for the *Enhanced Preliminary*

Assessment Report (ANL, 1989) indicate that waste oils and solvents derived from seaplane and vehicle maintenance activities may have been disposed of along the shoreline. However, documentation of spills, overfills, and disposal practices was not available for these areas. A 1973 photograph (Rindgen and Sitton, 1990) shows a possible outfall at the east end of Crissy Field which may have been related to the storm drain network.

5.1.1.4 Buildings 609, 611, and 633

Building 609 originally served as the PSF Post Exchange until 1987 when it was demolished because of its poor condition. Demolition debris was reportedly disposed of at an off-site landfill. The building, built in 1919, was a 10,502-ft², single-story, wood structure on a reinforced concrete pier foundation. A pesticide spill was reported in the building. The *Enhanced Preliminary Assessment Report* (ANL, 1989) states that the spill involved a small amount of household pesticides which fell off a shelf. A new Building 609 was constructed in 1987 after demolition of the original building. The new building is the PSF commissary.

Building 611, which was located on Bank Street, was a transformer storage vault (ANL, 1989). All that currently remains of Building 611 is a concrete pad, approximately 6 ft by 10 ft, surrounded by a fence. No transformers were present during the RI sampling.

Documentation of previous transformer inventories and potential spill incidents is not available.

Southwest of Building 633 is a small arms firing range. Aerial photographs indicate that sometime between 1963 and 1973, an asphalt parking lot was constructed near the range. The area is currently bounded by a concrete backstop on one side and a chain-link fence and the asphalt parking lot on the other. A concrete floor under the backstop is overlain by sand which ranges from 2.5 ft to 5 ft in depth. The target area is overgrown with vegetation, and there is still sand in the base of the target area.

5.1.1.5 Sewer Lift Stations

Two sewer lift stations located near Crissy Field are used to pump industrial wastes and sewage over the higher elevations of the PSF. The stations have failed during storms due to intermittent power from the emergency generators, and sewage is believed to have overflowed to the storm drain network.

5.1.2 Previous and Ongoing Environmental Investigations

Several previous environmental investigations have been conducted in the Crissy Field Study Area. Most efforts were in response to evidence of petroleum hydrocarbon refueling spills or leaks in the POL Area.

5.1.2.1 Previous Investigations

In August 1990, Globe Engineering of San Francisco, California, prepared a soil and geotechnical report to characterize the extent of hydrocarbons in shallow soil beneath the POL Area (Globe Engineering, 1990). The field investigation included drilling nine 15-ft soil borings and collecting samples at depths of 5, 10, and 15 ft bgs. The analytical data showed that petroleum hydrocarbons were present at all soil sample locations. The highest detections were in samples collected near the fuel supply lines that connected the six vertical ASTs to the pump island (Globe Soil Engineering, 1990).

The ranges of hydrocarbon detections in the soil samples collected by Globe Engineering (1990) follow:

- TPH-G from 9.4 to 6,200 $\mu\text{g/g}$
- TPH-D from 3.6 to 9,400 $\mu\text{g/g}$
- Benzene from 0.06 to 2.5 $\mu\text{g/g}$
- Toluene from 0.07 to 24 $\mu\text{g/g}$
- Xylene from 0.85 to 2,000 $\mu\text{g/g}$
- Ethylbenzene from 0.15 to 150 $\mu\text{g/g}$.

In 1990, ECC of Milpitas, California was contracted to sample the storm drain network in the POL Area for petroleum products, clean out solid and liquid wastes, and resample for petroleum products. A water sample was collected from a storm drain located north of the POL fence (ECC-01 in Figure 5.1-4) and from a storm drain located approximately 500 ft to the north of ECC-01 in the fenced area of the Crissy Field helipad (ECC-02 in Figure 5.1-4). The samples were analyzed for TPH-G, TPH-D, total recoverable oil and grease, and BTEX. Sample ECC-01 contained TPH-D at a concentration of 3,400 $\mu\text{g/L}$ and total recoverable oil and grease at a concentration of 6,600 $\mu\text{g/L}$. TPH-G and BTEX were not

detected. The second storm drain sample had a detection of TPH-D at 180 µg/L. TPH-G, total recoverable oil and grease, and BTEX were not detected in this sample.

After the initial sampling, the main storm drain was steam-cleaned and power-washed using a fire hose. Disposal of hazardous waste liquid was completed by H&H Ship Service. To prevent lateral contamination in the drainage system during cleaning, temporary rubber plugs were installed at all branch pipelines leading to the main storm drain. The plugs were removed from the branch lines after the drainage system was cleaned.

The resampling program was conducted in May 1991 after the storm drain was cleaned. There was insufficient water to obtain a sample from ECC-01, but a sample was obtained from ECC-02. The sample, analyzed for TPH-D and total oil and grease, did not contain detectable concentrations of the target analytes. ECC (1991) concluded that no additional sampling was required.

5.1.2.2 Ongoing Investigations

As described in the following sections of this report, sampling results from the Initial RI in 1990 indicated that refueling activities had affected soil and groundwater within the POL Area. All subsequent investigations at the POL Area were performed under the USCOE tank management program by Montgomery Watson. The USCOE investigations are listed below:

- 1992 - Additional sampling was performed to further evaluate the nature and extent of petroleum hydrocarbons in soil and groundwater in the POL Area.
- 1993 - An Additional Site Investigation was conducted to further characterize the nature and extent of soil and groundwater contamination in the Building 637 area and to collect groundwater quality data for remedial design purposes.
- 1994 - A Source Remediation Measure (SRM) was implemented, consisting of a groundwater extraction and treatment system designed to remove immiscible product and groundwater with relatively high chemical concentrations. The SRM was intended as a first response and was discontinued in May 1995.
- 1995 - An IRA was conducted which involved soil excavation and removal.
- A quarterly groundwater monitoring program is currently in place to continually assess the nature and extent of the identified contaminants.

In February 1995, the NPS completed an FS to determine if the Crissy Field, EOM, and DEH Study Areas could be restored to the pre-1900s land use as a wetlands (Dames & Moore, 1995b). The report covered the effects of a wetlands on current land uses and historic buildings in the area. The potential for re-introducing native vegetation, such as coastal sagewort and evening primrose, and the viability of creating a 30- to 60-acre wetland or freshwater backdune marsh without using an intensive land management approach were also analyzed. Potential water levels were calculated based on stormwater runoff and base flows from the Tennessee Hollow watershed, and the potential sediment loads and effects of tidal fluctuations on groundwater and surface water quality and elevations were determined. The FS concluded that it was feasible to restore wetlands at Crissy Field and riparian areas within Tennessee Hollow. The feasibility of investing the amount of money projected to be needed has not, however, been determined. Additional information required to design and implement the project include an assessment of the Follow-on RI data for impacts to the proposed restoration and an evaluation of additional data needs related to soil and groundwater contamination.

A Machine Gun Butt located southeast of Building 637 is being investigated under a separate program; any additional conclusions or remedial actions will be based upon the information presented in the *Sampling Investigation Report for the Small Arms Firing Ranges* (Montgomery Watson, report in progress).

5.2 SAMPLE LOCATION RATIONALE

This section discusses the locations and types of samples collected during the Initial, Supplemental, and Follow-on RI programs. The sampling programs in each of the five subsections of the Crissy Field Study Area are discussed in the context of the conceptual model presented in Section 3.1 and shown in Figure 3.1-1. The technical approach entailed:

- Locating and characterizing potential sources
- Evaluating potential release mechanisms and determining where released compounds may have accumulated or migrated

- Sampling the appropriate media to assess the extent to which potential contaminants have been released and the importance of each potential release mechanism on the overall distribution of compounds.

The Consolidated Motor Pool and POL areas, Buildings 609, 611, and 633, and the Sewer Lift Stations were assessed in terms of potential contamination sources related to buildings, maintenance areas, and storage areas. The primary release mechanisms associated with these areas are leaks and infiltration from fuel lines and an oil/water separator that are buried at relatively shallow depths; spills and particulate transport from the lift stations and Buildings 609, 611, and 633; and infiltration from the lift stations and Buildings 609 and 633. A review of historical photographs and land uses indicated that surface spills may have occurred in these areas although many of the stained areas have since been paved. Recent investigations identified leaks in underground fuel lines in the POL Area.

Wipe samples were collected from internal building surfaces to determine if chemical residues were present to indicate that a surface spill had occurred. Surface spills and subsurface leaks may initially result in chemical accumulation in surface and subsurface soil. Over time, compounds may infiltrate deeper into the soil, and eventually, to the groundwater or be released into the air through volatilization. To assess the extent of migration, surface and subsurface soil samples were collected in historically stained areas. At the soil boring locations shown in Figure 5.1-2, soil samples were collected to evaluate the effect of infiltration and diffusion on the chemical distribution in soil.

Groundwater samples were collected downgradient of the buildings and leaking fuel lines in the POL Area to assess potential chemical migration to the water table. At Crissy Field, two clay layers separate three water-bearing zones throughout much of the study area. These clay layers appear to be laterally continuous with the clay layers in the 231 Study Area, and it is believed that they are thick enough to inhibit vertical contaminant migration. Samples were collected from wells which were screened across the water table in the upper water-bearing zone in the study area. Some of the wells were screened across the top two water-bearing zones, because the discovery of three water-bearing zones was unexpected in this area, and the upper clay layer was difficult to distinguish in some cases.

Another potential release mechanism associated with surface spills is the movement of contaminated soil by stormwater runoff and particulate transport. Sediment samples from storm drains in the POL Area were collected below grade to evaluate the influence of stormwater runoff on contaminant distribution. As part of the ESAP, stormwater and bay sediment samples also were collected to evaluate this transport mechanism. The chemical concentrations in surface soil were used to evaluate the potential origin of chemicals in the sediments.

The sampling program for Fill Site 7 was designed to determine if either historic activities at the site or the fill material itself had adversely affected subsurface soil or groundwater. The thickness and distribution of the fill varies throughout the site, and initial sample locations were chosen to estimate its areal and vertical extent. In addition, geophysical surveys were conducted to evaluate the depth and boundaries of the fill. To determine the lithologic composition of both the fill and native materials, physical characteristics were documented during the drilling of monitoring wells and soil borings and during test pit excavation. The sample locations are shown on Figure 5.1-2.

Analytical samples were collected to assess the distribution of chemicals in the fill. The potential for contaminant migration from fill material to native sediments was assessed by analyzing soil samples collected in native material and comparing the results to ambient concentrations and to the results from soil samples collected in the fill material. This allowed the determination of a compound's vertical and lateral extent. Subsequent chemical migration from soil to the water table was evaluated through the collection of groundwater samples, which were collected from the upper unconfined water-bearing zone at Fill Site 7. During the Follow-on RI, discrete groundwater samples were collected from all three water-bearing zones to determine the vertical and lateral extent when analyses indicated that California primary MCLs had been exceeded in the upper water-bearing zone. In addition, the soil and groundwater analytical results were evaluated to determine if any patterns existed to indicate the migration of a compound.

Other potential release mechanisms associated with fill material include the movement of contaminated soil by stormwater runoff and/or physical contact. Sediment samples were collected from storm drains to evaluate these transport processes. The significance of

stormwater runoff was evaluated by comparing concentrations in the sediment samples with land uses or detected concentrations in the areas serviced by the drains. Additionally, stormwater and bay sediment data collected under the ESAP are used to evaluate the effects of stormwater runoff on aquatic life in San Francisco Bay. Because much of Fill Site 7 is paved or vegetated, the potential for particulate transport of surface soils is lower than in open spaces.

5.3 GEOLOGIC SETTING

This section describes the geology and the hydrogeologic units and processes in the Crissy Field Study Area. The discussion is based on data compiled during the Initial, Supplemental, and Follow-on RI programs, including lithologic data from 81 soil borings, 15 monitoring wells, and five test pits (Figure 5.1-2). Soil boring depths in the study area ranged from 2 to 83 ft bgs, with the majority of the depths less than 20 ft bgs. The lithologic logs for the wells, soil borings, and test pits are located in Appendix C. Geologic cross sections A-A' and B-B' are presented on Figures 5.3-1 and 5.3-2. The borings and wells used for the cross sections are shown in Figure 5.1-2. Regional investigations with information relevant to the soil and geology of the Crissy Field Study Area include a geologic study of the San Francisco North Quadrangle (Schlocker, 1974) and a regional study of depositional patterns related to eustatic sea level changes (Helley et al., 1979).

5.3.1 Soil and Geology

Surficial geologic units identified and mapped by Schlocker (1974) in the Crissy Field Study Area are artificial fill, beach-dune sand, Colma Formation, and bedrock of the Franciscan Formation. The surficial geology of the Crissy Field Study Area is included on the Geologic Map of the Presidio (Figure 2.3-3). Outcrops of Franciscan Formation bedrock and the Colma Formation on the hillside along the southern edge of the study area are shown on Figure 5.1-1.

The Enhanced Preliminary Assessment Report (ANL, 1989) and Wetland and Riparian Corridor Restoration Feasibility Study (Dames & Moore, 1995b) state that dredged sediments, earthquake debris, and sand were used to fill in the marshlands in the area during

the late 1800s to early 1900s. Filling operations were not documented in detail, but the episodic nature of the fill operations and the shape of the former marsh and tidal channel (Figure 5.1-3) suggest that the thickness of the fill deposits varies throughout the area. Fill thicknesses interpreted from the boring logs ranged from 1 to 9 ft.

The artificial fill encountered during drilling consisted of sand, silt, clay, serpentinite, chert gravel, and road base materials. The composition of the fill indicates that it is locally derived. Boring logs suggest that only a relatively small portion of Fill Site 7 was filled with debris. Debris fill consists of demolition materials including concrete, copper tubing, metal, asphalt blocks, and brick fragments in a silty gravel or sandy gravel matrix. Such debris fill materials appear to be of limited vertical and areal extent, with the greatest volume of debris fill located in the northeastern portion of Fill Site 7. An isopach map of the thickness of debris fill is presented as Figure 5.3-3. As shown on the figure, the thickness of debris fill ranges from 0.7 to 4 ft. Based on the isopach map, the total estimated volume of debris fill in this portion of the Fill Site 7 study area is approximately 3,200 yd³.

Because most of the fill material in the area is comprised of locally-derived sand, silt, and clay, attempts to fully define the extent of the fill using resistivity and electromagnetic (EM) geophysical surveys met with limited success. There was no discernible difference between the EM conductivity of the artificial fill and native material. This prevented the geophysical determination of lateral fill extent. Similarly, fill depth could not be confidently calculated using resistivity data because of insufficient contrast between the artificial fill and natural deposits. Analysis of the resistivity data did, however, show the depth to groundwater. The geophysical data acquired in the approximately 20-ac survey area are contained in Appendix N.

Beneath the artificial fill is a sequence of interbedded, laterally continuous units of sand and silty clays. These units were deposited along the bay margin in salt marsh, beach, and shallow marine environments (Helley et al., 1979). The clays and silts were deposited in salt marsh and shallow marine environments and are locally referred to as bay mud deposits. The sands were generally deposited on beaches along the bay margin. As shown on the cross sections (Figures 5.3-1 and 5.3-2), these depositional facies are generally persistent in a lateral direction both parallel and perpendicular to the shoreline in this area. Continuity in the

direction perpendicular to the shoreline results as the shoreline migrates landward during subsidence and/or sea-level rise or seaward during continental uplift and/or sea-level fall (Helley et al., 1979).

Several layers of beach-dune sand deposits separated by clayey bay mud deposits were encountered during drilling. The sand deposits vary laterally from silty fine- to coarse-grained sand in the southern portion of the study area near the hillside to clean fine- to medium-grained sand in the Fill Site 7 area. In some areas near the hillside, angular gravels are present within the sand layers. Shell fragments are present within the layers in several areas, particularly in the Fill Site 7 area.

Montgomery Watson (1995d) named the beach-dune sand and bay mud layers in the Building 637 area using an A and B designation as shown in the cross sections (Figures 5.3-1 and 5.3-2). The uppermost beach-dune sand layer (Unit A1) directly underlies the artificial fill in most of the study area. The thickness of Unit A1 varies from approximately 10 ft to 0 ft where it is truncated by the artificial and/or debris fill.

The second beach-dune sand layer (Unit A2) is separated from the Unit A1 by a bay mud deposit (Unit A1/A2). The sand varies from clean fine- to medium-grained sand to silty and/or clayey sand in some areas near the hillside. Unit A2 is generally thicker than Unit A1 and appears to be laterally continuous throughout the study area. Unit A2 varies in thickness from approximately 7 ft to over 15 ft and appears to deepen toward the Bay.

The thickest beach-dune sand deposit (Unit B) is separated from Unit A2 by a second bay mud deposit (Unit A2/B). Very few borings penetrated the full thickness of Unit B because of its depth. As shown on cross section A-A', Unit B thickens away from the hillside where it pinches out against the steeply sloping bedrock surface. Montgomery Watson drilled a boring (637SO12) that penetrated 26 ft of the silty sand of Unit B before encountering Franciscan Formation bedrock. Boring LF7SB01 encountered 47 ft of silty to clean fine- to medium-grained sand assigned to Unit B before encountering a stiff greenish-gray clay similar to Units A1/A2 and A2/B.

The bay mud deposits generally consist of organically-rich silty clay and sandy clays with some shell fragments and discontinuous lenses of peat. The sand content of these deposits

tends to decrease with distance from the bedrock hillside, giving way to a more organic composition. Unit A1/A2, which separates Units A1 and A2, varies in thickness from 1.5 to 7 ft and appears to be laterally continuous in the Crissy Field Study Area. It is thickest in the area of Old Mason Street and Mason Street and may coincide with the deepest part of the marsh that existed in this area in 1851 (Figure 5.1-3). The color of Unit A1/A2 ranges from dark green to dark gray and dark brown to dark red.

Unit A2/B separates units A2 and B and appears to be laterally continuous in the study area (Figures 5.3-1 and 5.3-2). This bay mud layer is similar in composition to Unit A1/A2, with the sand content decreasing away from the hillslope. Its thickness varies from about 2 ft to 13 ft in the southwest portion of the study area near Building 640, and it overlies bedrock near the southern portion of the study area.

A third, deeper, bay mud unit was encountered in two deep borings. This layer was designated Unit B/C by Montgomery Watson (1995d) and may correspond with a deep clay layer encountered in Boring 231SB26 in the Building 231 area (see Section 8.2.5). Its maximum documented thickness is 20 ft, and it is composed of dark gray to dark greenish-gray stiff clay to silty clay. The lateral extent of this layer is not known due to the lack of deep boring data.

Underlying Unit B/C, Montgomery Watson (1995d) encountered a deeper sandy deposit which they designated Unit C. The top of this unit was encountered at a depth of 98 ft in Boring 637SO11. Unit C is a dark gray medium dense silty sand with an undocumented thickness and extent.

Exposed in the unpaved regions of the POL Area is a light brown to gray, fine- to medium-grained silty sand that may be part of the Colma Formation. In addition, the area near the sewer lift stations contains fine-grained silty sands, ranging from olive-brown to dark gray, which appear to belong to the Colma Formation.

The bedrock underlying the Crissy Field Study Area is the Jurassic to Upper Cretaceous Franciscan Formation (Schlocker, 1974). It is exposed in the cliff behind Buildings 640 and 643 from approximately 10 to 85 ft-PLL (Figure 5.1-1). The sandstone bedrock unit is described by Schlocker (1974) as thickly bedded massive graywacke, interbedded with thin

layers of shale and fine-grained sandstone, which is intruded by a mostly soft and sheared serpentinite.

None of the borings drilled for the RI in the Crissy Field Study Area penetrated the top of bedrock, but Montgomery Watson, in their investigation of the Building 637 area for the USCOE, drilled several borings to the top of bedrock. The depth to bedrock in these borings confirms that the top of bedrock decreases in elevation to the north, toward the bay and away from the cliff outcrops. Montgomery Watson (1995d) described the bedrock encountered in their borings as soft sheared serpentinite to hard unshaped to moderately sheared serpentinite. Boring 2F-84-105, which was one of several borings drilled by USCOE before the construction of Building 609, was located in what is now the northwest corner of Building 609 and penetrated bedrock at approximately 73 ft bgs. The bedrock at this location is sandstone of the Franciscan Formation.

5.3.2 Hydrogeology

In the Crissy Field Study Area, groundwater occurs within an upper, unconfined, water-bearing zone and several underlying confined water-bearing zones. For the purposes of consistency, the hydrostratigraphic unit designations of Montgomery Watson (1995d) are adopted in the cross section figures and the following discussion. From shallowest to deepest, the main water-bearing zones in the study area are Unit A1, Unit A2, Unit B, and Unit C. These relatively permeable sandy zones are separated from one another by less permeable, clayey, bay mud deposits which have been designated by Montgomery Watson as Unit A1/A2, Unit A2/B, and Unit B/C. Units A1 and A2 appear to be laterally continuous throughout the Crissy Field Study Area. Insufficient deep boring data are available to evaluate whether Units B and C are laterally continuous beneath the study area. The thickness and composition of these units is discussed in Section 5.3.1.

Fifteen groundwater monitoring wells were installed in the Crissy Field Study Area (Figure 5.1-2). All the wells are screened across the water table in Unit A1. Several wells in the study area (LF7GW02, LF7GW03, LF7GW05, LF7GW07, and 637GW05) are screened across Unit A1/A2 where it is thin and difficult to recognize. These wells may be influenced by both Unit A1 and Unit A2.

Groundwater in Unit A1 is unconfined, Unit A2 is semi-confined (Montgomery Watson, 1995d), and Unit B appears to be confined in the Building 637 area. Three monitoring wells, installed by Montgomery Watson and screened in Unit B, become flowing or artesian under high tide conditions (Montgomery Watson, 1995d). The less permeable bay mud units are thought to be responsible for the semi-confined and confined conditions in Units A2 and B, respectively.

The primary groundwater recharge to the Crissy Field Study Area appears to be from a hydraulic connection with upgradient areas such as the Building 231 Site (Figure 2.3-9). Groundwater recharge from infiltration in the Crissy Field Study Area occurs principally in the unpaved portions of the helipad and the area between the landing strip and San Francisco Bay. Smaller unpaved areas around the buildings in the Consolidated Motor Pool and POL Areas, in addition to cracks in the pavement of the remainder of the study area, may also provide lesser avenues for infiltration. Underground storm drains may also be providing some recharge.

Water levels in monitoring wells in the study area were measured during high tide-low tide cycles in both November 1992 and March 1995. Water levels measured in November 1992 ranged from 3.9 to 7.1 ft-PLL during low tide and 5.0 to 7.1 ft-PLL during high tide (Figures 5.3-4 and 5.3-5). Fluctuations in water levels ranged from 0.01 to 2.5 ft between high- and low-tide cycles in the 1992 data. Tidal fluctuations had the greatest effect on water levels in Wells LF7GW04 and LF7GW05, which are located near the shoreline in the north-central portion of the study area. This suggests that the deposits in Unit A1 may be more transmissive than elsewhere in the study area.

The November 1992 data suggest that groundwater discharges into San Francisco Bay regardless of the tidal stage. In the eastern portion of the study area and in the POL and Consolidated Motor Pool Areas, the tidal stage had little effect on the direction and magnitude of the hydraulic gradient. Groundwater flow in the eastern section was toward the north and north-northeast under a hydraulic gradient of approximately 0.003 ft/ft. In the POL and Consolidated Motor Pool Areas, the hydraulic gradient was also 0.003 ft/ft, but groundwater flow was toward the northwest. Tidal influences do appear to affect groundwater flow patterns in the western portion of Fill Site 7, as demonstrated by water

levels in Wells LF7GW04 and LF7GW05. During high-tide cycles in 1992, there was a groundwater mound in this area with flow to the northeast and northwest (Figure 5.3-5). During low tide, groundwater converged in a trough with a hydraulic gradient of 0.02 ft/ft, which was the steepest gradient measured in the study area in 1992.

Water levels measured in March 1995 were generally higher than those measured in 1992, ranging from 5.4 to 8.5 ft-PLL during low tide and from 5.8 to 8.5 ft-PLL during high tide. A comparison of the potentiometric contour maps for high and low tide (Figures 5.3-6 and 5.3-7) suggests that tidal fluctuations did not have an overall notable effect on groundwater flow in the study area during March 1995. Water level fluctuations in individual wells, however, ranged from 0 to 1 ft, with the greatest changes again observed in Wells LF7GW04 and LF7GW05. Wells in the POL and Consolidated Motor Pool Areas exhibited only small variations in water levels due to tidal fluctuations.

The higher water elevations in 1995 slightly changed the groundwater flow direction in the eastern portion of the study area from north to northeast and decreased the hydraulic gradient slightly to 0.002 ft/ft. In the POL and Consolidated Motor Pool Areas, the hydraulic gradient increased slightly to 0.004 ft/ft, but the general flow direction remained to the northwest. A hydrogeologic investigation conducted by Montgomery Watson (JMM, 1992a) in the POL and Consolidated Motor Pool Areas also indicated that groundwater flow in this area was towards the northwest. Data collected by Montgomery Watson in the POL and Consolidated Motor Pool Areas indicated that groundwater could converge around Well 637GW05, but this phenomenon was not observed in the Supplemental and Follow-on RIs.

Data collected by Montgomery Watson (Montgomery Watson, 1995d) suggest that water levels in wells screened in Units A1 and A2 in the southwestern portion of the study area are not tidally influenced. Wells screened in Unit B, however, indicate that the groundwater flow direction in this unit varies from northeast to southwest depending on the tide (Montgomery Watson, 1995d).

5.4 ANALYTICAL RESULTS

This section presents the analytical results for the samples collected during the Initial, Supplemental, and Follow-on RIs in the Consolidated Motor Pool Area, the POL Area, Fill Site 7, the Sewer Lift Stations and Buildings 609, 611, and 633. The results are described in terms of the sampling locations, media sampled, and sampling objectives in each of these areas. The potential contaminant sources evaluated in the Crissy Field Study Area are fill material in Fill Site 7, buildings, storage and maintenance areas, overflow from the sewer lift stations, and leaks from underground fuel lines and an oil/water separator in the Consolidated Motor Pool and POL Areas. Samples were collected from building surfaces, sediment, soil, and groundwater (Figures 5.1-2 and 5.1-4).

The concentrations of inorganic analytes in soil samples are compared to ambient values presented in Section 3.7.2. In general, concentrations are not discussed if they are below ambient values. Most of the soil and groundwater samples and all of the sediment samples contained common elements found in the environment including calcium, potassium, magnesium, and sodium. These compounds are not usually evaluated as part of a risk assessment because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are not discussed in the following sections. Organic compound results are compared to SDCs, as a frame of reference. SDCs are generally risk-based values and were discussed and presented in Section 3.8 of this RI report.

The analytical tables for this section list only the target analytes, presented in Tables 3.3-1 through 3.3-9, that were detected above the CRLs or RLs. They do not include unknown compounds detected during the analyses. Unknown and tentatively identified compounds are discussed only if one or more of the evaluation criteria presented in Section 3.5 were met. A complete chemical database, which includes the VOC and SVOC unknown compounds, is provided in Appendix O.

Samples that were affected by blank contamination are noted in the following discussions with the exception of thallium. Split sample data collected for soil samples at the PSF indicated that the thallium data were not usable for the PSF RI. A more detailed discussion of the data is provided in Section 3.7.

5.4.1 Consolidated Motor Pool Area

This section presents the analytical results for samples collected in the Consolidated Motor Pool Area from building surfaces, sediment, and soil. It also discusses the sediment sample (637SD04) collected in the POL Area because of the small area between it and the sediment samples collected in the Consolidated Motor Pool Area. Sediment sample 637SD05 is indicative of conditions in the helipad portion of Fill Site 7 and is discussed in Section 5.4.3. Because the POL Area affected the groundwater in the Consolidated Motor Pool Area, the groundwater samples collected in the Consolidated Motor Pool Area are included in the POL Area's groundwater results (Section 5.4.2)

5.4.1.1 Wipe and Sediment Samples

Wipe samples were collected at Building 634, 640, and 643 to determine if chemical residues were present in the buildings (Figure 5.1-4). They were analyzed for inorganic analytes and SVOCs, and the results are presented on Table 5.4-1.

Three wipe samples were collected from Building 634 during the Initial RI to evaluate whether chemical residues were present. Sample 634W01 was taken approximately 5 ft inside the south door on a black discolored area on the concrete floor. Sample 634W02 was approximately 6 ft away from the east wall in the middle of the building at a white discolored area on the concrete floor. Sample 634W03 was collected approximately 7 ft away from the west wall of the building on a discolored portion of the concrete floor. Lead, magnesium, and zinc were detected in all three of the wipe samples from Building 634 (Table 5.4-1). No other inorganic analytes were detected in 634W03. Other inorganic analytes detected at least once in Samples 634W01 and 634W02 were chromium, manganese, and nickel. SVOCs were not detected in the wipe samples from Building 634.

Four wipe samples were collected from Building 640 to assess whether compounds were present from spills which may have occurred. Barium, lead, and manganese were detected in all four of these wipe samples (Table 5.4-1). Other metals detected in at least one of the samples include chromium, copper, and zinc. The only SVOCs detected were di-n-butylphthalate and bis(2-ethylhexyl)phthalate in Samples 640W02 and 640W03, respectively.

Three wipe samples (643W01, 643W02, and 643W03) were collected from the interior of Building 643. Barium, chromium, lead, manganese, and zinc were detected in all three of these wipe samples (Table 5.4-1). Other metals detected in at least one of the samples include cadmium, copper, nickel, and mercury. Lead concentrations showed the greatest variance between samples. The concentration of lead in Sample 643W03 was approximately 40 times higher than concentrations detected in other wipe samples. No SVOCs were detected in the samples from Building 643.

Sediment samples were collected from storm drains throughout the area to determine if stormwater runoff was a major transport mechanism in the area. These samples were analyzed for inorganic analytes, VOCs, SVOCs, and TPH, and the results are presented on Table 5.4-2.

Five of the sediment samples collected during the Initial RI reflect conditions in the Consolidated Motor Pool. These are 637SD01 through 637SD04 and 640SD01 (Figure 5.1-4). Because the surface soil samples in the area were classified as fill material, it can be assumed that the sediment samples are composed of the same material. Therefore, sediment sample results are compared to ambient values for fill materials, as a frame of reference. Zinc was detected above the ambient fill concentration in all five samples, at concentrations ranging from 285 to 1,030 $\mu\text{g/g}$. Lead exceeded ambient in three samples, with a maximum detected concentration of 512 $\mu\text{g/g}$. Barium and cadmium each exceeded ambient in one of the five samples. One or more BTEX compounds were detected in samples 637SD02 (benzene and toluene), 637SD03 (ethyl benzene, toluene, and xylene), and 640SD01 (benzene, toluene, ethylbenzene, and xylene). In addition, chlorinated benzenes and ethylenes were detected in 640SD01. SVOCs detected in the sediment samples included PAHs and bis(2-ethylhexyl)phthalate. Between one and three PAHs were detected in each sediment

sample. Bis(2-ethylhexyl)phthalate was detected in 637SD03 and 640SD01. TPH was detected in all six samples, at concentrations ranging from 80 to 100,000 $\mu\text{g/g}$. The highest concentration was in Sample 640SD01.

VOC and SVOC unknowns were identified in the sediment sample from Sample 640SD01 at concentrations of approximately 700 $\mu\text{g/g}$ and 3,300 $\mu\text{g/g}$, respectively. The tentative identifications by the laboratory are benzene compounds for the VOC unknowns and saturated straight-chain hydrocarbons for the SVOC unknowns. The concentrations of SVOC unknowns for Samples 637SD01 and 637SD03 were approximately 190 $\mu\text{g/g}$ and 700 $\mu\text{g/g}$, respectively. These compounds were tentatively identified by the laboratory as saturated straight-chain hydrocarbons and unknown hydrocarbons, respectively.

In March 1992, Montgomery Watson resampled two of the five storm drains, 637SD01 and 637SD03, originally sampled in the area (JMM, 1992b). Three of the sites were not resampled because of a lack of sediment. Stormwater samples were collected from two storm drains that lacked sediments (637SD02 and 637SD04). The sediment and stormwater samples were analyzed for VOCs, SVOCs, and TPH. Sediment samples were also analyzed for OCPs, cadmium, chromium, lead, nickel, and zinc. The Montgomery Watson samples were assigned the same sample numbers as the RI samples with the addition of the letter "A" (i.e. 637SD01A). The sediment results are shown on Table 5.4-3, and the stormwater results are shown on Table 5.4-4. The only inorganic analyte detected above ambient fill levels was zinc, at 670 $\mu\text{g/g}$ in 637SD03A. The organic compounds detected in the sediment samples were benzene in 637SD01A, and toluene, TPH-D, and TPH-G in 637SD03A. BTEX and TPH-G were detected in stormwater from 637SD02A.

5.4.1.2 Surface and Subsurface Soil Samples

Surface and subsurface soil samples were collected in the Consolidated Motor Pool Area in the vicinity of Buildings 640, 642, and 643. Surface soil samples were collected to document spills that may have occurred in the area. Subsurface soil samples were collected and used in conjunction with the surface soil samples to determine if chemicals had migrated deeper into the soil column. Soil sample locations are shown on Figures 5.1-2 and 5.1-4.

One shallow subsurface and one deep subsurface soil sample were collected from each of two borings, 640SO01 and 640SO02, drilled near Building 640. The shallow samples were collected at 2.0 ft bgs, and the deep samples were collected immediately above the saturated zone (4.8 and 4.5 ft bgs). All four samples were analyzed for inorganic analytes, VOCs, SVOCs, and TPH, and the results are presented on Table 5.4-5. All of the samples were collected from native beach-dune sand, and the inorganics results were compared to the appropriate ambient values. No inorganic analytes exceeded ambient values in the samples collected from Boring 640SO01. Chromium, cobalt, and nickel were detected above ambient in both of the samples collected from Boring 640SO02. Trichlorofluoromethane was detected above the CRL in the deep subsurface soil at Boring 640SO01. No SVOCs were detected. TPH was detected in both shallow subsurface soil samples and the deep subsurface soil sample from Boring 640SO01.

In October 1993, a fuel oil spill of unknown proportion occurred from an AST located adjacent to Building 642. The spill resulted in a 10 ft by 10 ft stained area on the pavement near the southwest corner of the building. During the Follow-on RI, a soil boring (642SB01) was drilled through the pavement near the center of the stain. Samples were collected from the surface and subsurface soil and analyzed for TPH. Concentrations decreased from greater than 100 $\mu\text{g/g}$ in the 0.5 ft bgs sample to less than 10 $\mu\text{g/g}$ in the 3.0 ft bgs sample (Table 5.4-6). Three additional samples were collected on 10-ft centers surrounding Boring 642SB01 to the north, south, and west (642SB02 through 642SB04) to define the lateral extent of the impact of the spill. A sample to the east could not be collected due to the presence of Building 642. Surface soil samples were collected from these borings and analyzed for TPH. The detected concentration in each of these samples was less than 100 $\mu\text{g/g}$.

Three surface soil samples (643SS01, 643SS02, and 643SS03) were collected from fill in the unpaved area south of Building 643 during the Initial RI (Figure 5.1-4). All of the samples were analyzed for inorganic analytes, VOCs, SVOCs, and TPH (Table 5.4-7). The inorganics results were compared to ambient fill concentrations. Lead was detected above ambient at all of the sites, and cadmium exceeded ambient in two of the three samples, 643SS02 and 643SS03. Aluminum and iron were detected above ambient values in sample

643SS01, and silver and zinc exceeded ambient in sample 643SS03. PAHs were detected only in sample 643SS03. Bis(2-ethylhexyl)phthalate and TPH were detected at all of the sites. VOCs were not detected.

The concentrations of lead and TPH in the Initial RI samples indicated that additional sampling was necessary to define the vertical distribution of compounds near Building 643. During the Supplemental RI, 2.0 and 5.0 ft bgs soil samples were collected from fill materials in two borings, 643SB01 and 643SB02, located near the southeast corner of Building 643. The 5.0 ft bgs samples were collected from just above the water table (643SB02) and partially within the saturated zone (643SB01). The samples were analyzed for inorganic analytes, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. The results are presented on Table 5.4-8.

Detected inorganics concentrations were compared to ambient fill values. Beryllium was detected above ambient in all four samples. Selenium and vanadium exceeded ambient in the 2.0 ft bgs sample from Boring 643SB02. In addition, a WET performed on soil from Boring 643SB02 yielded chromium, nickel, and lead at concentrations of 0.510, 2.30, and 4.00 mg/L, respectively (Appendix O).

There were no VOC detections in any of the samples from Borings 643SB01 and 643SB02. SVOC detections included butylbenzylphthalate in both 2.0 ft bgs samples and phenanthrene and pyrene in the 2.0 ft bgs sample from Boring 643SB01. The only OCP detection was ppDDT in the 5.0 ft bgs sample from Boring 643SB01. Neither PCBs nor chlorinated herbicides were detected. TPH-D was detected in all four samples at concentrations ranging from 1.0 to 14 $\mu\text{g/g}$, with the maximum concentration detected in the 5.0 ft bgs sample from Boring 643SB01.

Additional sampling was conducted near Building 643 during the FS in 1992. Three surface soil samples, 643SS04 through 643SS06, were collected and analyzed for inorganic analytes and diesel and gasoline fractions of TPH. The results for these samples are shown on Table 5.4-9. The detected inorganics concentrations were compared to ambient fill levels. Lead was detected above ambient at all three sites. Copper and zinc exceeded ambient in sample 643SS04, and barium and mercury were detected above ambient concentrations in Sample

643SS05. TPH-D was detected in all three samples, at concentrations ranging from 5.9 to 91 $\mu\text{g/g}$.

During the Follow-on RI, six surface soil samples (643SB03 through 643SB06, 643SS07 and 643SS08) and four subsurface soil samples (643SB03 through 643SB05) were collected south of Building 643 to define the lateral extent of lead (Table 5.4-10). All of the samples were collected from fill material and analyzed for inorganic lead. Lead was detected above the ambient fill concentration in three of the surface soil samples: 643SB05, 643SS07, and 643SS08. In order to assess whether auto emissions may be a source of lead in the area, the samples from Borings 643SB03 through 643SB06 were also analyzed for organic lead, but it was not detected above the RL. Two of the samples collected from Boring 643SB03 were analyzed for total organic carbon. The detected concentrations were 27,800 $\mu\text{g/g}$ in the surface soil sample and 3,970 $\mu\text{g/g}$ at 2.0 ft bgs.

5.4.2 Petroleum, Oil, and Lubricants Area

This section presents a discussion of the results from soil and groundwater samples collected in the POL Area. Groundwater samples that were collected from the Consolidated Motor Pool Area are discussed in this section because of the effect the POL Area had on surrounding groundwater in the Consolidated Motor Pool Area. Only one sediment sample (637SD04) was collected within the POL Area, and this sample was discussed with the Consolidated Motor Pool Area sediment results in Section 5.4.1. Wipe samples were not collected in the POL Area.

In 1992, Montgomery Watson contracted with the USCOE to evaluate the POL Area under a petroleum program separate from the Presidio Main Installation RI. Therefore, all sampling in this area after the Initial RI was conducted by Montgomery Watson. The results for these samples are, however, discussed in this section of this RI report. This area is included in an ongoing monitoring program which is detailed in quarterly reports. The most recent available report summarizes the sampling conducted during the July 1996 quarter in the Building 637 Area (Montgomery Watson, 1996e). The plume maps from this report for TPH-G and TPH-D in Zone A1 wells are included in Appendix C of this RI report.

5.4.2.1 Surface and Subsurface Soil Samples

Soil samples were collected from four locations in the vicinity of Building 637 during the Initial RI. Samples were collected at 1.8 and 2.8 ft bgs from Boring 637SO01, at 0.0 and 5.0 ft bgs from Boring 637SO02, at 4.2 and 6.0 ft bgs from Boring 637SO03, and at 1.2 and 4.2 ft bgs from Boring 637SO04. In Borings 637SO01 and 637SO04 the shallower sample was collected from fill material, and the deeper sample was collected from native beach/dune sand. In Boring 637SO02 both samples were collected from fill material, and in Boring 637SO03 both samples were collected from native beach/dune sand. All of the lithology logs indicated the presence of weathered serpentinite (Appendix C). All of the samples were taken from the unsaturated zone and analyzed for inorganic analytes, VOCs, SVOCs, and TPH. The results are presented on Table 5.4-11.

The inorganics results for each sample were compared to the appropriate ambient levels with the following results: chromium, cobalt, and nickel exceeded ambient fill concentrations at 1.8 ft bgs in Boring 637SO01, and aluminum was detected above the ambient level for fill at 1.2 ft bgs in Boring 637SO04. Concentrations in the samples collected from the other two borings did not exceed their respective ambient concentrations. The few ambient exceedences noted may be attributable to the presence of the weathered serpentinite in the soil. When compared to ambient serpentinite levels, only the chromium exceedence in the 1.8 ft bgs sample from Boring 637SO01 remains.

There were also several organic compounds detected above CRLs. Ethylbenzene was detected in both samples from Boring 637SO03, and toluene was detected in the shallower sample from Boring 637SO01. Bis(2-ethylhexyl)phthalate and 1,3-dimethylbenzene were also detected at 1.8 ft bgs in Boring 637SO01. PAHs were detected in both samples from Boring 637SO03 and in the deeper sample from Boring 637SO04. The PAH detections at Boring 637SO04 (2-methylnaphthalene and naphthalene) were an order of magnitude higher than in the other samples collected in the area. TPH was detected in all of the samples with the exception of the 2.8 ft bgs sample from Boring 637SO01. The highest concentrations were detected at Borings 637SO03 and 637SO04. The two samples collected from Boring 637SO03 and the deep subsurface sample from Boring 637SO04 contained unknown VOC concentrations of 340, 2,700, and 182,000 $\mu\text{g/g}$, respectively. The tentative identification by

the laboratory for the unknown compounds in both samples from Boring 637SO03 is primarily cyclic hydrocarbons. The VOC unknowns at Boring 637SO04 were tentatively identified as hydrocarbons. Unknown SVOCs were also detected in this sample at approximately 3,500 µg/g. No tentative identification of the SVOCs was provided by the laboratory.

In 1992, Montgomery Watson collected 19 subsurface soil samples from six additional locations near Building 637 (Figure 5.1-5) as part of the USCOE petroleum cleanup program. According to well logs from Montgomery Watson, all of the samples were collected in the unsaturated zone and were comprised of sand, clay, and serpentinite gravel (JMM, 1992b). The samples were analyzed for cadmium, chromium, nickel, lead, zinc, VOCs, TPH-D, and TPH-G. SVOCs and OCPs were analyzed in four samples. The results of this sampling are summarized on Table 5.4-12.

The inorganic detections in these samples were compared to ambient values for fill and serpentinite-derived soils to evaluate whether additional chemicals needed to be addressed in the RI. Inorganic analytes were below ambient values at Boring 637SO05, and nickel was the only inorganic detected above ambient at Boring 637SO09 (Table 5.4-12). Chromium and nickel were both detected above ambient concentrations in the other four borings. In the four borings with chromium and nickel exceedences, the detections of chromium and nickel showed a distinct zone of higher concentrations in the shallow subsurface. These concentrations are most likely attributable to large quantities of serpentinite in the samples, as evidenced by the lithology logs (Appendix C).

BTEX was detected in the surface soil at Boring 637SO05 and the deep subsurface soil at Boring 637SO10. Toluene was detected at Boring 637SO08. No SVOCs or OCPs were detected in the four soil samples that were analyzed for these compounds. TPH-D was detected in the surface and deep subsurface soil at Boring 637SO05 and in the deep subsurface soil at Borings 637SO08 and 637SO10. TPH-G was detected in the surface soil at Boring 637SO05; the shallow subsurface soil at Borings 637SO07, 637SO08, and 637SO10; and the deep subsurface soil at Borings 637SO08 and 637SO10.

During the Initial RI, three surface soil samples and two deep subsurface soil samples were collected near Building 638 and analyzed for inorganic analytes, VOCs, SVOCs, and TPH. The surface soil samples, which consisted of fill material, were collected from stained soil overlying pavement in the vicinity of the waste oil drums north of Building 638. The deep subsurface soil samples were classified as native beach-dune sand.

Lead was detected above the ambient fill concentration in all of the surface soil samples, and mercury and zinc exceeded ambient in samples 638SS02 and 638SS03 (Table 5.4-7). No inorganic analytes were detected above ambient concentrations in the deep subsurface soil samples (Table 5.4-11). VOCs were not detected, and bis(2-ethylhexyl)phthalate in sample 638SS01 was the only SVOC detection. Detected TPH concentrations in the surface soil samples ranged from 80,000 to 100,000 $\mu\text{g/g}$.

Unknown SVOCs were detected at concentrations in excess of the evaluation criteria of 100 $\mu\text{g/g}$ in the three of the surface soil samples. The concentrations were approximately 3,200 $\mu\text{g/g}$, 2,100 $\mu\text{g/g}$, and 2,600 $\mu\text{g/g}$ in samples 638SS01, 638SS02, and 638SS03, respectively. The laboratory tentatively identified the SVOCs as saturated straight-chain hydrocarbons.

5.4.2.2 Groundwater Samples

Groundwater samples were collected from five monitoring wells, 637GW01 through 637GW05 (Figure 5.1-2), during the Initial RI to assess whether potential contaminants in the soil had migrated to the groundwater. The samples were analyzed for inorganic analytes, VOCs, SVOCs, and TPH. The results are presented on Table 5.4-13. Numerous inorganic analytes were detected above the CRLs in all samples. No VOCs or SVOCs were detected above CRLs. TPH was detected at Wells 637GW01, 637GW04 and 637GW05 at concentrations ranging from 100 to 200 $\mu\text{g/L}$.

In 1992, as part of the USCOE program, Montgomery Watson installed and sampled five wells (Wells 637-06 through 637-10) in the POL Area. These wells have all since been replaced, but their former locations are included on the Montgomery Watson plume maps presented in Appendix C. In addition, they resampled Wells 637GW01 through 637GW05 and LF7GW01. All of the samples were analyzed for cadmium, chromium, lead, nickel, zinc,

VOCs, SVOCs, OCPs, and TPH. The results are presented on Table 5.4-14. Filtered and unfiltered samples were collected for the analyses of the inorganic analytes. Chromium, lead, nickel, and zinc were all detected in unfiltered samples from Wells 637GW01, 637GW03, 637-07, and 637-09. At least one of these metals was also detected in the other unfiltered groundwater samples. Cadmium was not detected in any samples. Zinc and lead were the only inorganic analytes detected in the filtered groundwater samples. Zinc was detected in six of the filtered samples, and lead was detected in one sample. One or more of the BTEX compounds were detected in groundwater samples from Wells 637GW01, 637GW03, 637GW04, 637GW05, 637-06, and LF7GW01. Other VOC detections were 1,1,2-trichloroethane in the sample from Well 637-06 and acetone in the sample from Well LF7GW01. The sample from Well 637GW01 contained the only detectable SVOCs: 2,4-dimethylphenol, 2-methylnaphthalene, and naphthalene. There were no OCP detections in the samples. TPH was detected in the wells that had BTEX detections. The highest concentrations of VOCs, SVOCs, and TPH were at Well 637GW01.

The most recent quarterly groundwater results for the Building 637 monitoring wells show that a TPH plume, characterized by elevated concentrations of TPH-G and TPH-D, is present in Units A1 and A2. The Unit A1 plume maps prepared by Montgomery Watson for the July 1996 quarter are presented in Appendix C. The plume extends roughly between Buildings 634, 637, and 640 and the inactive helipad on Fill Site 7. The highest concentrations of TPH-G (1,200 µg/L) and TPH-D (590 µg/L) to date were detected in samples from Well 637-26 during the July 1996 quarter (Montgomery Watson, 1996e). Prior to the July 1996 quarter, the highest TPH concentrations in the Building 637 Area had been consistently detected in Well 637GW04, and, unlike most wells in the area, the concentrations in this well had risen over time. Well 637GW04 has, however, been abandoned. Along with TPH-D and TPH-G, several VOCs, SVOCs and metals were detected in one or more wells (Montgomery Watson, 1996e).

In September 1994, an SRM was initiated to treat contaminated groundwater in the POL Area. The SRM consisted of a product-skimming pump and an extraction pump which removed dissolved and immiscible hydrocarbons from groundwater. Extracted groundwater was treated by dual carbon canisters, and the recovered product was stored in a recovery

tank. Influent and effluent samples were collected and analyzed on a monthly basis. The analytical results of system samples and system performance were presented in monthly reports. The SRM was discontinued in May 1995, and the final data collected on the system are contained in the report for that month (Montgomery Watson, 1995b). Upon termination of the SRM, 992,788 gals of groundwater had been treated, and 25.4 gals of free product and 0.68 gals of dissolved product had been recovered. The influent sample collected for May 1995 contained 31 $\mu\text{g/L}$ of benzene, 0.73 $\mu\text{g/L}$ of toluene, 0.54 $\mu\text{g/L}$ of ethylbenzene, 1.5 $\mu\text{g/L}$ xylene, 430 $\mu\text{g/L}$ of purgeable hydrocarbons, and 91 $\mu\text{g/L}$ of extractable hydrocarbons.

5.4.3 Fill Site 7

This section describes the locations and results of sediment, surface soil, subsurface soil, and groundwater samples collected in the Fill Site 7 area. There are no buildings in Fill Site 7, so wipe samples were not collected in the area. Samples were collected in this area to evaluate fill material as a potential source of contamination to surrounding soil and groundwater. The characterization of the fill material included an assessment of the physical characteristics of the sediment and soil and the collection of sediment, surface soil, subsurface soil, and groundwater samples for chemical analysis. The fill material in the Fill Site 7 area is classified as either debris fill or artificial fill consisting primarily of locally derived beach deposits. Debris fill in the area consists of demolition materials in a silty or sandy gravel matrix, and as discussed in Section 5.3.1 and shown in Figure 5.3-3, is limited in vertical and areal extent.

Sediment samples were collected to determine the effect of stormwater runoff on the transport of potential chemicals. Surface soil samples were collected to assess whether physical contact was likely to be a major transport mechanism. Subsurface soil samples were collected and then used in conjunction with surface soil samples and groundwater samples to assess the effect of infiltration on the distribution of chemicals. The sampling programs during each of the RI field programs are summarized briefly below to provide a framework for better understanding the sampling rationale. Results are then presented by media type in the following subsections.

All of the samples collected during the Initial RI were from the western section of Fill Site 7, which is referred to as the helipad area (Figures 5.1-2 and 5.1-4). One sediment sample (637SD05) was collected and analyzed for inorganic analytes, VOCs, SVOCs, and TPH. A composite surface soil sample (LF7SS01) was collected from four locations and analyzed for inorganic analytes, SVOCs, and pesticides. A discrete surface soil sample (LF7SS02) was analyzed for VOCs. Eight subsurface soil samples were collected from test pits LF7TP01 through LF7TP05 and soil borings LF7SO01 through LF7SO03 and analyzed for inorganic analytes, VOCs, SVOCs, and pesticides. The soil boring samples were collected from the unsaturated zone and the test pit samples were collected from the top of the saturated zone. Groundwater samples were collected from Wells LF7GW01 through LF7GW05 during the Initial RI and analyzed for inorganic analytes, VOCs, SVOCs, and OCPs.

During the Supplemental RI, sediment samples were collected from five storm drain locations (LF7SD01 through LF7SD05) and analyzed for inorganic analytes, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. Surface and subsurface soil samples were collected from 10 soil borings (LF7SB01 through LF7SB10) and during the installation of five monitoring wells (LF7GW06 through LF7GW10). These samples were analyzed for the full suite of Supplemental RI analytes. The soil samples were collected in the unsaturated zone, with the exception of the deepest samples from Boring LF7SB01 and Wells LF7GW08 and LF7GW09 which were partially collected in the saturated zone. Groundwater samples were collected from 10 monitoring wells (LF7GW01 through LF7GW10) and analyzed for inorganic analytes, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, TPH-G, and TDS.

The sampling conducted during the Follow-on RI was designed to determine the vertical and lateral distribution of lead, PAHs, and TPH detected during the earlier phases of the RI. The sampling was focused on three areas within Fill Site 7: the helipad area, Boring LF7SB07, Well LF7GW08, and Well LF7GW09. Surface and subsurface soil samples were collected at 13 locations in the helipad area (LF7SB26 through LF7SB37, and LF7SB41) to delineate the extent of PAHs detected in surface soil samples from the Initial RI. At four locations surrounding Boring LF7SB07, surface and subsurface soil samples were collected and analyzed for TPH-D and TPH-G. Subsurface soil samples were collected and analyzed for

lead from four locations surrounding Well LF7GW08. The collection of subsurface soil samples surrounding Well LF7GW08 was prompted by a groundwater lead detection at this well of 120 µg/L, which exceeds the California primary MCL and Water-Quality Objective for bays and estuaries. Subsurface soil samples were also collected and analyzed for lead from four locations surrounding Well LF7GW09. The samples were collected to further define the extent of lead, which was detected above the SDC of 300 µg/g in a subsurface soil sample from this location.

In addition to the soil sampling, groundwater samples were collected from Wells LF7GW01 through LF7GW10 and analyzed for the full suite of Follow-on RI analytes. Unfiltered discrete groundwater samples were collected from soil borings near Wells LF7GW08 and LF7GW09 to delineate the extent of lead and VOCs detected in monitoring well samples collected during the Supplemental RI. Filtered and unfiltered discrete groundwater samples were collected from Borings LF7SB17, LF7SB42, and LF7SB43 and adjacent to Well LF7GW08. These samples were analyzed for lead to assess whether elevated lead concentrations in discrete groundwater samples were representative of groundwater quality or were an artifact of the sampling and preservation techniques.

5.4.3.1 Sediment Samples

A total of seven sediment samples were collected at Fill Site 7, and the analytical results for these samples are presented on Tables 5.4-2 (637SD05), 5.4-3 (637SD05A), and 5.4-15. Sediment samples collected at Fill Site 7 could not be readily identified with a specific source area or predominant soil type. Therefore, inorganics results for these samples could not be compared to ambient values. Chromium, nickel, lead, and zinc were found in all of the sediment samples collected from Fill Site 7. Sediment in sample LF7SD01 had the highest concentrations of beryllium, cobalt, copper, manganese, and vanadium. Barium and silver concentrations were highest in sample LF7SD04. The highest concentrations of arsenic, cadmium, and mercury were detected in sample LF7SD05. The highest zinc concentration was detected in Sample 637SD05. However, the highest chromium, lead, and nickel concentrations were detected in Sample 637SD05A, which was collected by Montgomery Watson (Figure 5.1-4).

Two of the seven sediment samples contained VOCs at concentrations above the RL. Methylene chloride and trichlorofluoromethane were detected in LF7SD01. Trichlorofluoromethane was also found in LF7SD05 at the detection limit. Unknown VOCs were identified in the sediment sample LF7SD02 at a total concentration of 2,560 µg/g. A tentative identification was not provided by the laboratory.

Numerous PAHs and two phthalate esters were detected among the sediment samples. Fluoranthene and phenanthrene were the only SVOCs detected in Sample 637SD05, but the resampling by Montgomery Watson in the same location (637SD05A) resulted in the additional detection of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-cd)pyrene, and pyrene. In addition, the detected concentrations of fluoranthene and phenanthrene were nearly two orders of magnitude higher than in the previous sample from the same location. Bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene were all detected above RLs in Samples LF7SD01 and LF7SD05. Sample LF7SD01 also contained a detectable concentration of benzo(a)anthracene, and Sample LF7SD05 also contained a detectable concentration of butylbenzylphthalate. Sample LF7SD04 contained detectable concentrations of bis(2-ethylhexyl)phthalate and pyrene, and there were no detectable SVOCs in Samples LF7SD02 and LF7SD03.

The only other detected organic analytes were OCPs and TPH. Sample LF7SD05 contained a detectable concentration of ppDDE (0.30 µg/g), and Sample 637SD05A contained a detectable concentration of toxaphene. The TPH analysis run on Sample 637SD05 provided a result of 1,000 µg/g. The remaining six samples were analyzed for TPH-D and TPH-G. TPH-D was detected in all six samples, at concentrations ranging from 10 to 540 µg/g. The highest concentration was detected in Sample LF7SD01. TPH-G was detected in sample 637SD05A at a concentration of 0.28 µg/g. The SDC for TPH (total) and TPH-D is 100 µg/g. The SDC for TPH was exceeded in sample 637SD05. The SDC for TPH-D was exceeded in samples LF7SD01 and LF7SD04. The single detection of TPH-G was below the SDC of 10 µg/g.

5.4.3.2 Surface Soil Samples

The soil investigation at Fill Site 7 was designed to assess whether the fill material should be considered a potential chemical source. Therefore, in the following summary of results, the chemical distributions in native deposits, locally derived artificial fill, and debris fill samples are presented separately. The vertical and lateral extent of compounds is discussed later, in Section 5.5.3 of this RI report. Sample depths for most of the surface soil samples were between 0.0 and 0.5 ft bgs. A few surface soil samples were assigned deeper sample depths, primarily because of pavement or road base material on the ground surface. The deepest sample considered a surface soil sample in this discussion was collected at 1.1 ft bgs. Analytical results are presented on Tables 5.4-16 and 5.4-17.

Surface soil samples were collected from 15 locations in the Fill Site 7 area and analyzed for the full suite of inorganic constituents. In addition, one composite surface soil sample (LF7SS01) was collected from the helipad area of Fill Site 7. Based on lithology logs, each sample was placed into either the beach/dune or fill soil type for derivation of and comparison to ambient values, as described in Section 3.7 of this RI report. Seven surface soil samples were compared to ambient values for the beach/dune soil type, one of which was comprised of native deposits (LF7SB09), and six of which were comprised of locally derived artificial fill (LF7GW08, LF7GW09, LF7SB07, LF7SB08, LF7SB10, and LF7SS01). The remaining nine surface soil samples (LF7SB01 through LF7SB06, LF7GW06, LF7GW07, and LF7GW10) were compared to ambient values for fill materials. In the following summary, the results from the composite sample are discussed separately from those for the discrete soil samples.

Inorganic Constituents. Of the samples compared to ambient beach/dune sand concentrations, the sample collected from Boring LF7SB09, which consisted of native material, and the samples collected from Borings LF7GW09 and LF7SB10, which consisted of locally derived fill material, were the only three that did not contain ambient exceedences. Mercury, and silver were detected above ambient values in the surface soil samples from Borings LF7GW08, LF7SB07, and LF7SB08. Lead exceeded ambient in the samples collected from Borings LF7GW08 and LF7SB08 and the composite sample LF7SS01. Cobalt was detected above ambient in the samples collected from Borings LF7SB07 and

LF7SB08. The additional inorganics detected above ambient values in the composite surface soil sample (LF7SS01) were aluminum, barium, chromium, manganese, and nickel (Table 5.4-16).

Inorganic exceedences in surface soil samples compared to ambient fill values were limited to four of the nine samples in this category. Barium, beryllium, cobalt, copper, mercury, and manganese were above ambient fill values in the surface soil sample from Well LF7GW06. The antimony, cobalt, chromium, and nickel concentrations in the surface soil sample from Boring LF7SB01 exceeded ambient fill values. The antimony detection in this sample (70.7 $\mu\text{g/g}$) exceeded the ambient value by over two orders of magnitude. The only other detections above ambient in surface soil samples compared to ambient fill values were beryllium in the sample from Well LF7GW07 and cobalt in the sample from Boring LF7SB06.

A WET was conducted on the surface soil samples from Well LF7GW06 and Boring LF7SB01. The detected concentrations of chromium and nickel were, respectively, 0.640 and 3.30 mg/L in Well LF7GW06 and 0.790 and 3.60 mg/L in Boring LF7SB01 (Appendix O). Mercury was detected at a concentration of 0.002 mg/L in the surface soil sample from Well LF7GW06. Lead was not detected in either sample.

Organic Compounds. The only VOC detected in the sixteen surface soil samples was trichlorofluoromethane in the sample from Well LF7GW07 (comprised of fill), at a concentration of 0.006 $\mu\text{g/g}$. The SVOCs detected in surface soil samples collected as part of the Initial and Supplemental RI sampling programs were all PAHs, with the exception of bis(2-ethylhexyl)phthalate in composite sample LF7SS01 (Tables 5.4-16 and 5.4-17). PAHs were detected in 11 surface soil samples, at concentrations ranging from 0.038 to 0.6 $\mu\text{g/g}$ in the discrete samples (Table 5.4-17) and a maximum concentration of greater than 12 $\mu\text{g/g}$ in the composite surface soil sample (LF7SS01).

Thirteen additional surface soil samples were collected in the helipad area during the Follow-on RI (Borings LF7SB26 through LF7SB37 and LF7SB41 in Figure 5.1-2), near the sample locations for composite sample LF7SS01 to further define the extent of PAHs. PAHs were detected in five of these samples, at concentrations ranging from 0.332 to 9.54 $\mu\text{g/g}$ (Table 5.4-18). The maximum detected concentration was at Boring LF7SB41, located near the

northeast corner of the helipad area. The reporting limits for the PAH analyses for Boring LF7SB26 were elevated due to sample dilution, so there were no reported detections. However, a review of the data by the Project Chemist indicated that PAHs were present in this sample, which is also located in the eastern portion of the helipad area.

Organochlorine pesticides were detected in five surface soil samples (LF7SS01, LF7GW06, LF7GW07, LF7SB02, and LF7SB06) at concentrations ranging from 0.002 to 0.110 $\mu\text{g/g}$ in the discrete samples (Table 5.4-17) and at a maximum concentration of 3.2 $\mu\text{g/g}$ in the composite sample (Table 5.4-16). PCBs and chlorinated herbicide concentrations were below reporting limits in all surface soil samples associated with Fill Site 7.

TPH-D was detected in all the surface soil samples collected as part of the Supplemental RI (Table 5.4-17) at concentrations ranging from 1.0 to 380 $\mu\text{g/g}$. The highest concentration, and the only detection to exceed the SDC of 100 $\mu\text{g/g}$, was at Boring LF7SB07. TPH concentrations were below the reporting limit in surrounding surface soil samples (LF7SB12 through LF7SB15) collected during the Follow-on RI (Table 5.4-19 and Figure 5.1-2).

5.4.3.3 Subsurface Soil Samples

Twenty-seven subsurface soil samples were collected from the Fill Site 7 area and analyzed for the full suite of inorganic constituents (Figure 5.1-2). The concentrations of inorganics in five of these samples (Borings LF7GW06, LF7GW07, LF7SB02, LF7SB07 at 2.2 ft bgs, and LF7SB08) were compared to ambient values for fill materials. The remaining 22 samples were compared to ambient values for beach/dune deposits. Four of these (Boring LF7GW08, two samples from Boring LF7GW10, and Test Pit LF7TP01) consisted of locally derived artificial fill, and 18 were native beach/dune deposits (two samples each from Borings LF7GW09 and LF7SB01, and one each from Borings LF7SB03 through LF7SB07 (5.9 ft bgs), LF7SB09, LF7SB10, LF7SO01 through LF7SO03, and Test Pits LF7TP02 through LF7TP05).

Inorganic Constituents. Ambient exceedences in samples compared to fill materials were limited to three samples: Borings LF7GW06, LF7GW07, and LF7SB02 (Table 5.4-17). Beryllium was detected slightly above ambient concentrations in all three samples, with a maximum concentration of 1.410 $\mu\text{g/g}$. The detected barium and mercury concentrations

exceeded the ambient value at 2.0 ft bgs in Boring LF7GW06, and antimony, cobalt, and vanadium were detected above ambient fill values in the 2.0 ft bgs sample from Boring LF7SB02.

Four of the 22 samples compared to ambient values for beach/dune materials had detectable inorganic concentrations above ambient. Exceedences were limited to one inorganic constituent at three locations: arsenic at Well LF7GW08, mercury at Test Pit LF7TP01, and nickel at Test Pit LF7TP04 (Tables 5.4-17 and 5.4-20). The deepest sample from Well LF7GW09 (4.4 ft bgs) was the only subsurface sample with multiple exceedences. In this sample, aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, mercury, manganese, lead, and zinc exceeded ambient beach/dune values (Table 5.4-17).

Additional subsurface soil samples were collected during the Follow-on RI to further define the extent of lead. Lead concentrations in the eight subsurface samples surrounding Well LF7GW09 (Borings LF7SB16 through LF7SB19) were all below the reporting limit or the appropriate ambient concentration (Table 5.4-21), except at 4.0 ft bgs in Boring LF7SB18. Similarly, lead concentrations in the eight subsurface soil samples surrounding Well LF7GW08 (Borings LF7SB21 through LF7SB24) were either below the reporting limit or were detected at concentrations below the appropriate ambient concentration (Table 5.4-22).

The 2.0 and 3.5 ft bgs samples collected from Boring LF7SB19 were analyzed for total organic carbon. The TOC concentration in the 2.0 ft bgs sample, which was comprised of sand, was much lower than in the deeper sample, which contained bay mud and organic material (Table 5.4-21). A WET analysis was conducted on the subsurface soil sample from Well LF7GW09. Chromium, nickel, and lead concentrations were 0.370, 0.800, and 12.0 mg/L, respectively (Appendix O).

Organic Compounds. VOCs were detected in only two of the 27 subsurface soil samples collected from the Fill Site 7 area. Acetone, methyl ethyl ketone, and trichlorofluoromethane were detected in the deepest soil sample from Well LF7GW09 (Table 5.4-17), and 1,1,2,2-tetrachloroethane was detected in the 2.2 ft bgs sample from Boring LF7SB07 (Table 5.4-17). The detected VOC concentrations were low, ranging from 0.005 to 0.076 µg/g.

SVOCs detected in subsurface soil samples were PAHs in five samples (LF7GW06, LF7GW07, LF7GW08, LF7GW09 at 4.4 ft bgs, and LF7SB06), benzyl alcohol in two samples (Borings LF7SB03 and LF7SB05), and di-n-butylphthalate in Boring LF7SB08 (Table 5.4-17). SVOC concentrations were below reporting limits in the remaining 19 subsurface soil samples collected as part of the Supplemental RI (Table 5.4-17), in the eight Initial RI samples (Tables 5.4-20 and 5.4-23), and in the five Follow-on RI samples (Table 5.4-18). Although several PAHs were present in each of the five samples with detections, the particular compounds detected were not consistent between borings. The maximum PAH detection in subsurface soil was 1.100 µg/g of phenanthrene at Boring LF7SB06. PAH concentrations in the other four samples with detections were lower, ranging from 0.047 to 0.530 µg/g. SVOCs identified as UNK633, UNK648 and UNK649 occurred most frequently in the soil boring samples. A tentative identification of these compounds was not provided by the laboratory.

Confirmed detections of organochlorine pesticides occurred in only two of 27 subsurface soil samples. Concentrations were low, with aldrin at 0.002 µg/g (which is below the reporting limit) in a soil sample from Well LF7GW08 (Table 5.4-17) and ppDDE at 0.004 µg/g in the sample from Test Pit LF7TP05 (Table 5.4-20). The only other OCP occurrences were two unconfirmed detections of isodrin, one in Test Pit LF7TP02 and the other in Test Pit LF7TP05 (Table 5.4-20). The isodrin concentrations were low, with a maximum of 0.009 µg/g, and unconfirmed by the laboratory. The only PCB detection in subsurface soil samples from Fill Site 7 was Alocor 1260 in Test Pit LF7TP05 at 0.049 µg/g. Chlorinated herbicides were not detected in subsurface soil samples from Fill Site 7 (Table 5.4-17).

With the exception of the 3.0 ft bgs sample from Boring LF7SB04, TPH-D was detected in all subsurface soil samples collected as part of the Supplemental RI (Table 5.4-17). Concentrations ranged from 1 to 30 µg/g, with the maximum occurring in samples from Borings LF7GW10 and LF7SB02. Four additional subsurface soil samples were collected during the Follow-on RI (Borings LF7SB12 through LF7SB15) to further define the extent of TPH found in the surface soil samples from Boring LF7SB07 (Figure 5.1-2). TPH concentrations in these samples were all below the reporting limit (Table 5.4-19).

5.4.3.4 Groundwater Samples

Groundwater samples were collected for the RI from monitoring wells in the Fill Site 7 area during three sampling events between 1990 and 1995. Wells LF7GW01 through LF7GW05 were sampled during the Initial RI field program (Table 5.4-24), and Wells LF7GW01 through LF7GW10 were sampled during the Supplemental (Table 5.4-25) and Follow-on (Table 5.4-26) RI sampling events. During each sampling event, samples were analyzed for the full suite of inorganic constituents and organic compounds. The major difference between the sampling events relates to the collection of filtered and unfiltered inorganic samples. Only filtered inorganic samples were collected during the Initial RI. During the Supplemental RI, filtered samples were collected from all wells and unfiltered samples from three wells: LF7GW06, LF7GW08, and LF7GW10. The filtered and unfiltered inorganics results for these samples are presented together on Table 5.4-27. Both filtered and unfiltered samples were collected from all wells sampled during the Follow-on RI.

The groundwater sampling program at Fill Site 7 also entailed the collection of discrete groundwater samples during the Follow-on RI. These samples were collected to define the extent of chemicals detected during one of the monitoring well sampling events described above. Details on the analytical suite(s) for the discrete samples will be presented later in this section, and the results are shown on Tables 5.4-28 and 5.4-29.

The monitoring well network in the Fill Site 7 Area is now included in a quarterly sampling program conducted by Montgomery Watson. The most recent available quarterly report details the sampling from the July 1996 quarter (Montgomery Watson, 1996e). These results are incorporated into the discussion of groundwater in the Fill Site 7 Area.

Inorganic Constituents. In the following summary, inorganic constituents are placed into one of two groups. The first consists of unfiltered inorganics that occur in most wells in the Fill Site 7 area. The second group consists of less frequently detected unfiltered inorganics. The grouping is based on the analytical data from the Follow-on RI since this sampling event included the collection of unfiltered samples for all ten of the wells in the area. Filtered and unfiltered results are compared to distinguish between inorganic constituents that are sorbed to particulate matter or colloids, and those that are dissolved. Inorganics that are sorbed are

generally less mobile than inorganics that occur in the dissolved phase. In general, filtering of samples removes colloids and suspended particles from the sample, and therefore reduces analyte concentrations.

Inorganic constituents detected in unfiltered groundwater samples from at least seven of the ten monitoring wells sampled during the Follow-on RI were aluminum, arsenic, barium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc (Table 5.4-26). As noted in Table 5.4-26, the copper and mercury unfiltered results were all affected by method blank contamination and, therefore, may not be indicative of groundwater quality. Copper was, however, detected in most of the filtered groundwater samples, which suggests that it was most likely also present in the unfiltered samples. Of the 15 frequently detected unfiltered inorganics, all but chromium, copper, mercury, nickel, and zinc were also detected in the unfiltered samples collected during the Supplemental RI (Table 5.4-27). Filtering of samples greatly reduced the concentrations of aluminum, chromium, iron, lead, nickel, vanadium, and zinc (Table 5.4-26), indicating that these seven inorganics are primarily absorbed to particulate matter or present in colloidal form, rather than in the more mobile dissolved phase.

Unfiltered inorganics detected less frequently during the Follow-on RI, with number of wells with detections in parentheses, include cadmium (3), selenium (3), silver (2), antimony (1), and cyanide (1). Results affected by blank contamination were not included in this list; beryllium and thallium were each detected once, but both results were affected by blank contamination, as were all mercury detections. Mercury results from previous sampling events were not affected by blank contamination and were all below the reporting limit, indicating that mercury is infrequently, if ever, detected in groundwater from Fill Site 7. Anomalously, antimony detections in filtered samples were higher than in the unfiltered samples. Based on the results of controlled laboratory studies conducted for the Corps of Engineers, this is attributed to the filter medium. The USCOE study showed that the filters contain a significant amount of antimony that is mobilized by the movement of water through the filter (Call, pers comm, 1994).

The extent of lead in groundwater was further characterized during the Follow-on RI by the collection of discrete groundwater samples from 14 locations (Borings LF7GW08, LF7SB17

through LF7SB24, LF7SB38, LF7SB39, LF7SB40, LF7SB42, and LF7SB43). Multi-level samples were centered around Well LF7GW08, where lead was detected at 120 µg/L in a filtered groundwater sample during the Supplemental RI (Table 5.4-25). This groundwater result however, was not confirmed by the Follow-on RI results (Table 5.4-26). Lead concentrations in the discrete groundwater samples exceeded the SDC of 15 µg/L in the shallowest unfiltered samples from Borings LF7SB21 and LF7SB24, with a maximum concentration of 54 µg/L (Table 5.4-28). Lead was either below the reporting limit or the SDC in the remaining 19 multi-level samples surrounding Well LF7GW08.

Shallow discrete groundwater samples were also collected around Well LF7GW09, where a soil sample exceeded the lead SDC of 300 µg/g. In the vicinity of Well LF7GW09, lead was detected in groundwater above the SDC in two unfiltered samples (Borings LF7SB17 and LF7SB19). The maximum concentration was 130 µg/L, in the sample from LF7SB17. To verify this high lead detection, filtered and unfiltered discrete groundwater samples were collected from this same location. Lead concentrations in both of these samples were below the reporting limit of 5 µg/L (Table 5.4-29).

Table 5.4-30 presents a comparison of filtered and unfiltered lead results from discrete groundwater samples collected at Fill Site 7 and the DEH Area. The DEH data were included on this table because the only lead detection in the Fill Site 7 Area occurred in an unfiltered sample without a corresponding filtered sample. These results show that elevated lead in groundwater occurs in the unfiltered samples, which were laden with sediments and had turbidity measurements that often exceeded 200 NTU.

Inorganic analyses were also conducted on the samples collected during the July 1996 quarterly sampling. Samples were analyzed for both filtered and unfiltered metals. The results for this sampling event are contained in the quarterly report for the July 1996 quarter (Montgomery Watson, 1996e) and will be addressed further in Section 5.5 of this RI report.

Organic Compounds. Only three VOCs were detected in groundwater monitoring wells during RI sampling. Chloroform was detected at Well LF7GW10 during the most recent sampling event at a concentration of 2.51 µg/L (Table 5.4-26). During the Supplemental RI, vinyl chloride (3.4 µg/L) and cis-1,2-dichloroethene (5.9 µg/L) were detected in Well

LF7GW09, and Well LF7GW08 contained cis-1,2-dichloroethene at a concentration of 0.360 µg/L. Although these detections were not confirmed by subsequent monitoring well samples collected during the Follow-on RI (Table 5.4-26), discrete groundwater samples were collected around each of these wells to ensure definition of the extent of chlorinated compounds.

Discrete groundwater samples were collected from multiple depths at five locations surrounding Well LF7GW09 (Borings LF7SB16 through LF7SB19 and LF7SB25) and eight locations surrounding Well LF7GW08 (Borings LF7SB20 through LF7SB24, LF7SB38, LF7SB39, and LF7SB40). All samples were analyzed for trichloroethene and its associated breakdown products. There were no detections above the reporting limit in any of the samples associated with Well LF7GW09 (Table 5.4-29). Trichloroethene and vinyl chloride were both detected at low concentrations in samples collected from the upper water-bearing zone (Unit A1) in Borings LF7SB20 and LF7SB23 (Table 5.4-28). Two of the samples collected at Boring LF7SB22 (6.5 ft bgs and 16.5 ft bgs) contained air bubbles. Because of the volatility of chlorinated solvents, the data from these samples are unreliable. However, the non-detects in the remaining 14 discrete samples, in conjunction with the Follow-on monitoring well results, suggest that chlorinated solvents have a very limited extent and are not a major source of contamination at the site.

Unknown VOC compounds were detected at a concentration of 150 µg/L in the Initial RI sample collected from Well LF7GW01. The compounds were tentatively identified by the laboratory as cyclic hydrocarbons. Unknown VOC compounds were detected during the Supplemental RI in samples collected from Wells LF7GW01 and LF7GW04. The concentration in Well LF7GW01 was 130 µg/L. The sample from Well LF7GW04 contained two VOCs at a combined concentration of 460 µg/L. A tentative identification of the compounds was not made by the laboratory for either sample. Analytical results for unknown results are provided in Appendix O.

SVOC detections in groundwater from Fill Site 7 were limited to bis(2-ethylhexyl)phthalate in samples collected during the Supplemental and Follow-on RI, with many results affected by blank contamination (Tables 5.4-25 and 5.4-26). During the Follow-on RI, 10

unidentified SVOCs were detected in the groundwater sample from Well LF7GW07. The total concentration of the unknowns was 126 µg/L.

Organochlorine pesticides and PCBs were not detected in groundwater during any of the three sampling events at Fill Site 7 (Tables 5.4-24 through 5.4-26). One chlorinated herbicide, 2,4-D, was detected during the Supplemental RI at Wells LF7GW05, LF7GW07, and LF7GW09, with the maximum detected concentration equal to 4.90 µg/L (Table 5.4-25). These detections were not confirmed by subsequent sampling during the Follow-on RI.

TPH detections in groundwater samples from the Fill Site 7 area consisted of only a single TPH-G detection in Well LF7GW01 (210 µg/L) in a sample collected during the Supplemental RI (Table 5.4-25). There were no other groundwater detections of TPH-G or TPH-D in the Fill Site 7 area.

The July 1996 quarterly sampling (Montgomery Watson, 1996e) resulted in one detection each of acetone, toluene, vinyl chloride, and TPH-G in Zone A1 wells. Each analyte was detected in a different well. The only organic compound detected in Zone A1/A2 wells was toluene, which was detected twice.

5.4.4 Buildings 609, 611, and 633

This section presents the results from the soil samples collected from Buildings 609, 611, and 633. Potential sources near Buildings 609, 611, and 633 related to pesticide use, transformer storage, and small arms practice, respectively. The samples collected near Building 609 were analyzed for pesticides, the samples collected near Building 611 were analyzed for PCBs, and the samples collected near Building 633 were analyzed for lead. All of the samples from Buildings 609 and 611 were collected from fill. Three of the subsurface soil samples (633SB07, 633SB08, and 633SB10) collected from Building 633 were comprised of locally-derived fill. The remaining surface and subsurface samples were collected from undifferentiated fill and the imported sand still in place at the firing range.

Three surface soil samples were collected near the northeast corner of Building 609. Dieldrin was detected in all three samples, and ppDDT was detected in samples 609SS01 and 609SS03 (Table 5.4-31). Sample 609SS03 also contained ppDDE, which is a degradation

product of ppDDT. The concentrations of dieldrin and ppDDT in the samples did not exceed their respective SDCs of 0.028 and 1.3 $\mu\text{g/g}$.

Three surface soil samples were collected from the former location of Building 611. PCBs were not detected in the samples, and the results are not, therefore, tabulated in this report.

Ten surface soil and 10 subsurface soil samples were collected southwest of Building 633 during the Follow-on RI to determine if lead was present at the closed outdoor firing range. The results for these samples are presented on Table 5.4-32. Five sites were located within the concrete sand pit (Borings 633SB01 through 633SB05) and five sites were located in the asphalt parking lot (633SB06 through 633SB10). The subsurface soil samples from Borings 633SB06, 633SB07, and 633SB09 were collected from the top of the saturated zone. Lead was detected above the ambient fill concentration in four of the five borings drilled within the sand pit, with exceedences at 0.5 ft bgs in Boring 633SB01 and 0.5 and 2.0 ft bgs in Borings 633SB02, 633SB03, and 633SB05. In addition, lead was detected above the ambient beach/dune sand concentration in the 2.5 ft bgs sample from Boring 633SB08.

5.4.5 Sewer Lift Stations

This section discusses the results from surface soil, subsurface soil, and groundwater samples collected at the Sewer Lift Stations. The potential chemical source at these stations is overflow from the stations to the storm drain. The stations pumped industrial wastes and sewage over the higher elevations of the PSF. Two borings were drilled at each of the lift stations during the Follow-on RI (Figure 5.2-1). One surface soil sample was collected from each site and a subsurface sample was collected from Borings CFLSSB01 and CFLSSB02. All of the samples were analyzed for inorganic analytes, VOCs, TPH-D, and TPH-G. The results are presented on Table 5.4-33.

The Colma Formation is present at the ground surface at three of the four borings (CFLSSB01, CFLSSB02, and CFLSSB04). These soil samples were classified as Colma for comparison to ambient concentrations. The sample collected from Boring CFLSSB03 was classified as locally-derived fill and inorganics were compared to ambient values for beach-dune sand deposits. With the exception of cyanide at 3.0 ft bgs in Boring CFLSSB02, all of the detections above ambient values were in surface soil samples. Nickel and lead were

detected above ambient in the surface soil at Boring CFLSSB01. Mercury, lead, and zinc were above ambient values in the surface soil at Boring CFLSSB02. Aluminum, cyanide, and manganese exceeded ambient in the surface soil at Boring CFLSSB03, and copper, mercury, lead, selenium, and zinc were detected above ambient concentrations in the surface soil at Boring CFLSSB04. VOCs and TPH were not detected in any of the samples.

The Sewer Lift Stations are located at the edge of the PSF coastal groundwater zone, which is discussed in Section 2.3, and an unfiltered groundwater sample was collected from two of the four borings, CFLSSB01 and CFLSSB03. The two samples were analyzed for inorganic analytes, TPH-D, and TPH-G, and the results are presented on Table 5.4-34. While numerous inorganics were detected above RLs in both samples, there were not detectable concentrations of TPH-D or TPH-G in either sample.

5.5 RESULTS EVALUATION

The purpose of this section is to determine which among the chemicals detected in the Crissy Field Study Area should be further evaluated in this RI report as COPCs and then describe the nature and extent, and fate and transport of these chemicals. As was the case with the preceding section on Analytical Results, this discussion will be divided into individual sites: the Consolidated Motor Pool, the POL Area, Fill Site 7, Buildings 609, 611, and 633, and the Sewer Lift Stations. In addition, the proposed wetland footprint includes soil samples with the following site IDs: EOMSB01, 04, 05; LF7SB02-19, 21-24; LF7GW06-10; 609SS01-03; and 611SS01-03. Groundwater samples from these locations, when available, and also EOMSB02, EOMSB03, and LF7GW05 were also included. The EOM samples are addressed in Section 14 of this RI report, but sampling in this area did not produce any inorganic COPCs. Therefore, the evaluation of the proposed wetland footprint will be included in the discussion of Fill Site 7. Organic detections in the EOM samples will be included in the Ecological Risk Assessment of the wetland footprint, and also in the terrestrial assessment of the Fill Site 7/EOM shoreline area.

The first step in evaluating the soils results involves the determination of which analytes are COPCs (see Section 3.7), which will be evaluated in the Risk Assessment. Once COPCs are identified, the nature and extent, and fate and transport of these analytes will be discussed.

Analytes that are not considered COPCs will not be discussed further. RI samples were analyzed for inorganic and organic analytes. Inorganic analytes occur naturally, and their presence at a site may or may not be anthropogenic. In determining which inorganic analytes are COPCs, several factors are considered. These include the magnitude and number of detections above ambient values, the spatial distribution of these exceedences, the type of soil in the sample (including the potential presence of serpentinite in samples assigned a different classification based on boring logs), and comparison with concentrations typical of soils in other areas of the region. In addition, the absence or presence of potential sources is assessed. A number of maps presenting posted results for soil samples were used in this evaluation. These maps are presented as Figures 5.5-1 through 5.5-30. The RI assumes that all organic analytes are anthropogenic. Therefore all detected organic compounds are considered COPCs. Posting maps were also prepared for organic analytes in soil (Figures 5.5-31 through 5.5-34).

The fate and potential transport of COPCs is discussed in the context of the physical and chemical properties of the analyte and the sample media, and the relation of the analyte to other detected compounds. The potential contaminant sources away from which the compounds are assumed to be migrating in the Crissy Field Study Area are:

- Fill material
- Buildings and storage and maintenance areas
- Leaks from underground fuel lines and an oil/water separator in the Consolidated Motor Pool and POL Areas
- Overflows from the Sewer Lift Stations.

The compounds detected in wipe samples are also discussed in this section. Because wipe sampling provides qualitative but not quantitative data, risk calculations for dermal exposure were not calculated based on these results. The mobility of analytes detected in wipe samples is limited to direct physical contact because the concrete floors greatly reduce or eliminate downward migration.

In order to provide a frame of reference for discussion, the concentrations of inorganics and organics in groundwater are compared to Primary MCLs and saltwater aquatic standards. The values for each of these criteria are provided in Tables 3.8-2 and 3.8-6. The saltwater

aquatic standards may only be applicable to filtered groundwater within 150 ft of the shoreline, in the area that has been designated a Saltwater Ecological Protection Zone by the SCRs (California Regional Water Quality Control Board, 1996). In addition, comparison to MCLs does not imply that groundwater in the Crissy Field Study Area is suitable for domestic or industrial use. In fact, the GMPA for the PSF prepared by the NPS (1994) does not include development of groundwater in the Crissy Field Study Area for either a drinking water source or industrial use (Section 2.3.6). The groundwater chemistry is used to evaluate whether chemicals in soils are leaching to the groundwater or fluctuations of water-table elevations result in adsorption of dissolved chemicals onto soil particles. This is accomplished by comparing the suites of compounds detected in the soil and in adjacent groundwater. The saltwater aquatic standards are used for comparison because the projected land use for portions of the study area includes restoration of a wetland and because of potential groundwater migration to the San Francisco Bay. Posting maps for inorganic chemical concentrations in groundwater are presented as Figures 5.5-35 through 5.5-41, and vinyl chloride concentrations in groundwater are shown on Figure 5.5-42.

5.5.1 Consolidated Motor Pool Area

The following section discusses the sources, extent, and fate and transport of detected compounds in the Consolidated Motor Pool Area. The area is almost entirely paved and encompasses Buildings 634, 640, 642, and 643 as well as associated parking areas. Samples were collected from artificial fill material, consisting of silty sand with serpentinite gravel, and native beach-dune sand.

Possible sources of compounds in and near Building 634 are leaks and spills. Wipe samples were collected from stained areas on the concrete floor within Building 634 to determine if chemical residues were present. The inorganic analytes detected in the wipe samples from stained areas were chromium, lead manganese, nickel, and zinc. No other compounds were detected.

Possible sources of contamination in and near Building 640 are leaks and spills associated with vehicle and aircraft maintenance as well as from stored materials. Chemical residues detected in at least one of the four wipe samples were barium, chromium, copper, lead,

manganese, zinc, bis(2-ethylhexyl)phthalate, and di-n-butylphthalate. Release mechanisms for outdoor spills occurring after the area was paved are limited to physical contact or stormwater runoff. A sediment sample collected from a storm drain approximately 60 ft north of Building 640 contained detections of BTEX and TPH which may have come from Building 640. The fate and transport of compounds in this sediment sample are discussed with other storm drain samples from the POL area investigation (Section 5.5.2).

Chromium, cobalt, and nickel were detected above ambient levels in subsurface soil from Boring 640SO02. Though the lithologic description suggests that the sample may have consisted of serpentinite-derived sand, a spatial analysis suggests that these detections are higher than those in sand in the rest of the CMP area (see Figures 5.5-6, 5.5-7, and 5.5-13). Because of this, and the boring's proximity to a stained area, these three chemicals will be evaluated as COPCs in subsurface soils in this area. The only organic compounds detected were trichlorofluoromethane in one deep subsurface soil sample and TPH in both shallow samples and in one deep sample. The TPH concentrations decreased with depth.

Trichlorofluoromethane will volatilize in surface soil or migrate into groundwater. The compound was not detected in groundwater, indicating that its distribution is limited.

The concentration of TPH at Building 642 decreased with depth to less than 10 $\mu\text{g/g}$ at 3.5 ft bgs. The lower detection in the deeper sample defines the maximum vertical extent of TPH as 3.5 ft bgs. TPH concentrations in samples located ten ft from the boring do not exceed the SDC of 100 $\mu\text{g/g}$ and, therefore, define the lateral extent. This is approximately the extent of the stained area identified during sampling. Groundwater is present in this area at 9 to 10 ft bgs and does not appear to be affected by the spill.

Solvents were routinely used in Building 643, and although there are no reports of chemical spills at the site, spills associated with electronic maintenance activities were the potential source considered at this site. Wipe samples collected from the interior of the building contained detectable concentrations of barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc. Aluminum, barium, cadmium, iron, lead, mercury, silver, and zinc were detected above ambient concentrations in surface soil samples collected south of Building 643. The maximum vertical extent of elevated levels of these chemicals is

2 ft bgs, as defined by non-exceedences in adjacent subsurface soil samples collected from Borings 643SB01 through 643SB06.

Those inorganics which will not be evaluated as COPCs in surface soils at this site are aluminum, iron, mercury, and silver. Aluminum was reported above the ambient fill concentration in sample 643SS01. When reported to the appropriate number of significant figures, however, the detected concentration is equal to the ambient value of 25,300 $\mu\text{g/g}$. The iron concentration in sample 643SS01 exceeded the ambient fill level. The detected concentration is within the range of iron concentrations in serpentinite background samples and is attributed to sample composition. The detected concentration of mercury in sample 643SS05 (0.37 ng/g) and the detected concentration of silver in sample 643SS03 (3.328 ng/g) slightly exceeded the ambient levels for fill (0.281 and 3.26 ng/g , respectively). Though ambient was exceeded, the detected concentrations reside within the smooth portion of their respective probability plots (Appendix A), and these detections are attributed to sample composition.

Those inorganics which will be evaluated as COPCs in surface soils at this site are barium, cadmium, lead, and zinc. Barium was detected above the ambient fill concentration in one surface soil sample near the southeast corner of Building 643. The exceedence was slight but appears to be anomalously high compared to other samples in the area. Cadmium was detected above the ambient concentration for fill in two surface soil samples south of Building 643. The two exceedences were separated by non-detections. Lead was detected above the ambient fill concentration in nine surface soil samples collected along the south wall of Building 643. The concentrations of the exceedences ranged from 323 to 1430 $\mu\text{g/g}$. Zinc was detected above the ambient fill concentration in two surface soil samples, 643SS03 and 643SS04 collected south of Building 643. Zinc will be evaluated as a COPC at this site, due primarily to the detection in sample 643SS03 (407 $\mu\text{g/g}$).

The inorganics which exceeded ambient values in the subsurface soils were beryllium, selenium and vanadium. The beryllium concentrations exceeded ambient only very slightly in the 2.0 and 5.0 ft bgs samples from both Borings 643SB01 and 643SB02 and may be attributed to silicate minerals in the fill material. In addition, beryllium was not detected in any of the adjacent surface soil samples, suggesting that these detections are not related to

surface activities. Beryllium is not considered a COPC at this site. Selenium and vanadium exceeded ambient only in the 2.0 ft bgs sample from Boring 643SB02. Though ambient was exceeded, the detected concentrations reside within the smooth portion of their respective probability plots (Appendix A), and these detections are attributed to sample composition. Neither selenium nor vanadium will be evaluated as a COPC at this site.

As described above, lead concentrations detected in excess of ambient values were limited to surface soil samples. The lateral extent of lead is defined to the south by a steep cliff of serpentinite bedrock, to the north by Building 643, and to the east and west by detections below ambient at Borings 643SB03 and 643SB06, respectively. This encompasses a rectangular area approximately 400 ft by 35 ft located immediately south of Building 643. The maximum vertical extent, defined by non-exceedences, is 2 ft bgs.

SVOC detections, which included PAHs and phthalate esters, were limited to the surface and shallow subsurface soil samples. One OCP, ppDDT, was detected in one deep soil sample. This compound was not, however, detected in the groundwater, indicating that its distribution is limited. Concentrations of TPH decreased with depth in one boring and increased with depth in the other.

Release mechanisms for compounds detected in the exposed soil south of Building 643 are stormwater runoff, particulate transport, and infiltration to groundwater. PAHs and lead are generally hydrophobic and appear to be adsorbing to the soil. Phthalate esters were detected only in shallow soil and not in groundwater which suggests that they are not migrating. Groundwater flow from the vicinity of Building 643 is toward the helipad area and the absence of PAHs, pesticides, and TPH in downgradient monitoring wells (LF7GW02, LF7GW03, and LF7GW04) indicates that the soil in the vicinity of the building is not a source of groundwater contamination.

5.5.2 Petroleum, Oil, and Lubricants Area

This section discusses the results of samples collected in the POL area in relation to their potential sources and fate and transport within the Crissy Field Study Area. The POL Area is currently being addressed by USCOE under a separate petroleum cleanup program. The results evaluation presented below incorporates data collected during the Initial RI with data

collected during an initial site characterization report performed by Montgomery Watson in 1992. Since the collection of these data, additional site investigations have been performed in the Building 637 Area as part of the USCOE program. In addition, an SRM was temporarily employed to remove and treat contaminated groundwater in this area.

Sediment and stormwater samples were collected from storm drains both within and downstream from the POL area. Because the storm drain system collects stormwater runoff from paved and unpaved areas, numerous chemical sources are potentially represented. These sources include surface spills in the POL Area and at Building 640 that occurred after the area was paved. Samples 637SD01, 637SD03, 637SD04, and 640SD01 are located along the upper branches of the storm drain system in the POL Area (Figure 5.1-4). Similar suites of compounds, including BTEX, PAHs, and TPH, were detected in the sediment samples. The highest concentrations and greatest number of detections were in Sample 640SD01, which was collected from a storm drain that gathers runoff from paved areas between Buildings 639 and 640. Sediment from 637SD03, which is downstream from 640SD01 and along the same branch of the sewer system, had fewer detections and lower concentrations. Concentrations continued to decline in the downstream direction. Chlorinated solvents were detected only in the sediment sample 640SD01. These solvents are soluble in water and have high vapor pressures. They were not detected in a downstream stormwater sample, which suggests that they volatilized and, therefore, are not discharging into San Francisco Bay. The only other detection of a chlorinated solvent in the Consolidated Motor Pool and POL Areas was in a groundwater sample from Well 637GW06, which is near the storm drain with the detection.

After the three upstream branches merge, the storm drain system flows north through the drain from which samples 637SD02 (sediment) and 637SD02A (stormwater) were collected. Chemical concentrations in the sediment sample were lower than the highest concentrations of the same compounds in upstream samples. In addition, there were fewer compounds detected in sample 637SD02. The decrease in concentration of organic compounds in sediments in the downstream direction suggests that migration of compounds through the storm system in the POL Area is limited, with attenuation occurring over a short distance. The stormwater from sample 637SD04 had detectable concentrations of BTEX and TPH-G.

These compounds were not detected in the upstream stormwater sample (637SD04A). A potential source of BTEX and TPH in the stormwater sample is the upstream western branch of the drain system, as BTEX and TPH were detected in sediment samples from that branch (stormwater data were not collected).

Compounds detected in sediment samples within the storm drain system can be transported to the bay through sediment transport or solubilization in stormwater. Compounds that tend to partition to particulate matter (PAHs, pesticides, and many inorganic analytes) will travel with sediments. Compounds with high solubilities (BTEX and chlorinated compounds) may travel to the Bay in the dissolved phase. Concentrations may be reduced to levels below reporting limits prior to discharge to San Francisco Bay because of mixing of the stormwater with other water that is captured by the storm drain system. However, BTEX and chlorinated compounds have high vapor pressures and will more likely volatilize because of the turbulent nature of stormwater.

Stormwater and bay sediment sample data collected under the ESAP provide additional information on the significance of this pathway and the potential effects on aquatic receptors in the bay. The storm drains in the POL area are part of the Outfall 10 drainage system. Both stormwater and bay sediment samples associated with this outfall were collected. Sediment sample locations are shown on the posting maps and are identified by the prefix of "OF10" for Outfall 10, followed by the specific sediment sample number for that outfall (SD01, etc.). The analytes detected in the RI storm drain sediment samples were not present at elevated levels in ESAP stormwater or bay sediment samples collected in 1994 and 1995 from Outfall 10 (Dames & Moore, 1996a, b). Bioassay testing data for these media indicated that there was no significant effect of the toxicity of the stormwater or sediments to the tested species.

A possible explanation of the difference in the analytical results between the earlier RI and the later ESAP sampling is that the high levels are the result of a long period of chemical equilibration under low oxygen conditions during a prolonged drought period (Dames & Moore, 1996a, b). Additionally, because the nearshore area is such a dynamic zone, the potential for accumulation of chemicals in the bay sediment is low. As concluded from the ESAP data, the transport of contaminants in sediment and soil from the POL area to the bay

via the storm drains is not a significant exposure pathway for aquatic receptors in the bay (Dames & Moore, 1996a, b).

Soil and groundwater samples were collected from locations throughout the POL Area during the Initial RI. There appear to be several potential sources, including surface spills that occurred before the area was paved and leaks from underground fuel lines. Compounds most commonly detected were inorganic analytes, BTEX and chlorinated solvents, PAHs, and TPH. Aluminum, cobalt, chromium, and nickel were detected above ambient concentrations at Boring 637SO01 and 637SO04, and chromium and nickel were detected above ambient in several of the soil samples collected by Montgomery Watson. The aluminum exceedence was slight, and along with the cobalt, chromium, and nickel detections, is probably due to weathering of serpentinite, which is common in the soil from these locations. Lead, mercury, and zinc were detected above ambient fill concentrations in surface soil samples collected from the stained area north of Building 638 (638SS01 through 638SS03). These exceedences are likely related to petroleum spills and, therefore, fall under the scope of the USCOE program.

BTEX was detected in numerous subsurface soil samples throughout the POL area. The highest concentrations were detected in the shallow sample from Boring 637SO05, which was located adjacent to the ASTs. BTEX compounds were not detected in the deep sample from this boring. Groundwater samples collected from wells in the POL Area during the Initial RI confirmed the presence of a benzene groundwater plume. Although there were numerous detections of BTEX compounds, only benzene was detected above the California primary MCL in all wells in which it was detected. The only other detection of a BTEX compound above the California primary MCL was ethylbenzene in the sample from Well 637GW01. Detected BTEX concentrations decreased in the direction of groundwater flow to the northwest, with no detections occurring north of Mason Street.

TPH-D and TPH-G were detected in subsurface soil and groundwater throughout the POL Area during the Initial RI. The highest concentrations were in the most upgradient well (637GW01) and subsurface soil samples within 150 ft of the well. Concentrations decreased in the direction of groundwater flow, to the northwest, with no detections occurring north of Mason Street. In general, TPH-D and TPH-G were detected together with isolated detections

of only one fraction occurring in a few samples. The compounds appear to attenuate within 150 to 250 ft in the downgradient direction.

The TPH-G and TPH-D analyses indicate the presence of petroleum hydrocarbons. Both fractions were detected in subsurface soil and groundwater suggesting that at least some of the compounds detected by these methods are soluble. Release mechanisms for these compounds in soil are limited by the pavement in the area. Since the POL Area is included in a quarterly groundwater sampling program, plume maps for TPH-G and TPH-D in Zone A1 wells are available and are included in Appendix C of this RI report.

PAHs were detected in the subsurface soil at two locations (637SO03 and 637SO04). PAHs were not detected in a subsurface soil sample located approximately 20 ft northeast of Boring 637SO04. The only groundwater detection of PAHs was in Well 637GW01. In general, PAHs tend to adsorb to soil. This assumption is strengthened by the lack of detections in most of the groundwater samples. The most likely transport mechanism for these compounds in soil is through movement of particulate matter

5.5.3 Fill Site 7

This section presents a discussion of the sediment, soil, and groundwater results in relation to the potential sources and the fate and transport of detected compounds within Fill Site 7. In addition, the vertical and lateral extent of chemicals identified as COPCs is described.

5.5.3.1 Sediment

Seven sediment samples were collected from Fill Site 7 (LF7SD01 through LF7SD05, 637SD05, and 637SD05A). Sediments and adsorbed compounds in a drain can be derived from local areas serviced by storm drains as well as from upstream catch basins and, if the drains are structurally unsound, potential infiltration from surrounding groundwater. The compounds detected in the sediment samples are discussed in relation to potential sources and likely fate and transport. Areal extent is not summarized in this section because of the uncertainty associated with determining an exact source from a drainage. Instead, the fate and transport of compounds detected in the sediments is discussed in relation to the probability that they will migrate to San Francisco Bay. Under the ESAP, the potential

transport of analytes to the bay was assessed by collecting stormwater samples associated with Outfalls 8, 9, and 10, and bay sediments associated with Outfalls 8 and 10 and between Outfalls 8 and 9. This assessment is incorporated into this section.

Samples LF7SD01 and LF7SD05 are at the beginning of storm drains and collect stormwater runoff from Old Mason Street and Mason Street, respectively (Figure 5.1-4). Sample LF7SD02 is located upstream from Sample LF7SD03 in a storm drain that collects stormwater runoff from the Motor Pool, POL area, and an upstream catch basin. Sample LF7SD04 is located in a storm drain that collects stormwater from Mason Street. Samples 637SD05 and 637SD05A are co-located in a storm drain that collects stormwater from the helipad area in the western section.

The same suite of inorganics was generally detected in all sediment samples collected from Fill Site 7 (Tables 5.4-4 and 5.4-15). The highest concentrations of each inorganic were usually in sample LF7SD01, LF7SD05, or 637SD05. Although LF7SD03 is downstream from LF7SD02, concentrations in sediments were not consistently higher or lower in either of the two samples.

The detected VOCs were methylene chloride and trichlorofluoromethane in the sample from LF7SD01, and only the latter in LF7SD05. Methylene chloride was not detected in any soil or groundwater samples from Fill Site 7. Trichlorofluoromethane was detected in only two soil samples (LF7GW07 and LF7GW09) and in no groundwater samples from Fill Site 7. PAHs were detected in three sediment samples collected for the RI (LF7SD01, LF7SD04, and LF7SD05). A greater variety of PAHs were detected in soil samples from the site. There were no PAH detections in groundwater samples from Fill Site 7, indicating that infiltration of groundwater into the storm drain lines is not a source of PAHs on sediment samples. The concentrations of PAHs in the sediment sample collected by Montgomery Watson (637SD05A), were one to two orders of magnitude higher than the sample collected for the RI approximately 16 months earlier. PAHs are a component of asphalt. In addition, automobiles with leaks and drips are another potential source of PAHs that would be transported to the storm drains. Phthalates (in Samples LF7SD01, LF7SD04, and LF7SD05) were the only other SVOCs detected.

The other analytes detected in samples collected for the RI were ppDDE in Sample LF7SD05, TPH-D in Samples LF7SD01 through LF7SD05, and TPH in Sample 637SD05. The only other OCP detected was toxaphene in the sample collected by Montgomery Watson (637SD05A). The compound ppDDE is a degradation product of ppDDT. Both of these pesticide were found in one surface soil sample (LF7GW07), and ppDDE was also detected in a surface soil sample from LF7SB02. There were no soil detections of toxaphene at Fill Site 7. The low concentrations suggest a source of surface application during routine grounds maintenance at the PSF and transport to the drains as particulate matter suspended in stormwater runoff. TPH-D was detected in most soil samples from Fill Site 7 although runoff from paved areas used by automobiles is probably contributing to the accumulation of TPH-D in sediment samples. There were no detections of OCPs or TPH-D in groundwater samples, indicating that infiltration of groundwater is not a source of chemicals in sediment samples and that compounds absorbed to sediments are not migrating to the groundwater.

Most of the inorganic analytes, PAHs, phthalate esters, and OCPs detected in the storm drains in the Fill Site 7 area exhibit properties of hydrophobic compounds. These compounds will enter the storm drains as suspended particulate matter in stormwater runoff. As the velocity of the stormwater decreases, the particulate matter settles out as sediment in the drains. Depending on the intensity of rainfall events in the area, the compounds may not be flushed from the drains into the bay for long periods of time. As the residence time in the drain increases, the concentrations of the hydrophobic compounds will increase as more of these compounds are deposited in the sediments, but degradation will also be more likely to occur. Regarding VOCs, it is expected that they will volatilize rather than be introduced to the bay as stormwater because the storm drains are either filled with turbulent water or are fairly dry.

Stormwater and bay sediment sample data collected under the ESAP provide additional information on the significance of this pathway and the potential effects on aquatic receptors in the bay. The storm drains in Fill Site 7 are part of the Outfalls 8, 9, and 10 drainage systems. Sediment sample locations are shown on the posting maps and, as an example, are identified by the prefix of "OF08" for Outfall 08, followed by the specific sediment sample number for that outfall (SD01, etc.). ESAP reference samples were collected offshore of the

Crissy Field Study Area, away from the storm drains, to assess analyte concentrations in bay sediment that are representative of ambient conditions. These samples are identified by the prefix of "REF" on the posting maps.

Some of the analytes such as PAHs and pesticides that were detected in the RI storm drain sediment samples were present at lower levels in ESAP Outfall 8 bay sediment samples (Dames & Moore, 1996a, b). Endrin also was detected at a low level (0.00084 $\mu\text{g/g}$) in one of the Outfall 10 bay sediment samples. Detections of organics reported for samples from the reference location at Crissy Field included very low levels of PAHs and single detections of ppDDE and Aroclor 1260. This indicates that these types of analytes may be present at low ambient concentrations at many sites along the bay and are not necessarily derived from soil or storm drain sediments in the Crissy Field Study Area. Metals concentrations in the outfall sediments typically were low with respect to sediment criteria and similar to the concentrations in reference sediments. Bioassay testing data for the sediments indicated that there was no significant toxicity effects to the tested species.

With the exception of TPH-D detected in Outfall 9 stormwater, the stormwater analytical data did not reflect the elevated concentrations detected in the RI storm drain sediment samples. Correspondingly, stormwater bioassay data indicated no toxicity associated with stormwater from Outfalls 8 and 10, but potential low toxicity associated with Outfall 9 stormwater. However, it is inferred that the low levels of toxicity are associated with metals derived primarily from Highway 101 and Lincoln Boulevard (Dames & Moore, 1996a, b). Therefore, as also concluded for the POL area, the ESAP data indicate the transport of contaminants in sediment and soil from the Fill Site 7 area to the bay via the storm drains is not a significant exposure pathway for aquatic receptors in the bay (Dames & Moore, 1996a, b).

5.5.3.2 Soil

The primary purpose of the investigations at Fill Site 7 was to assess whether the fill material is a potential chemical source. To accomplish this, surface and subsurface soil and groundwater samples were collected. The soil results were compared to ambient values previously, in Section 5.4 of this RI report. In this section, only inorganic detections that exceeded ambient values are discussed. Site specific characteristics were assessed and spatial

analyses conducted to identify which of the inorganics with ambient exceedences are due, or possibly due to U.S. Army activities. Inorganics above ambient values are attributed to natural conditions and processes are not considered COPCs and are, therefore, excluded from the risk assessment. All organic detections in soil samples are considered COPCs and are evaluated in the risk assessment. Results are compared to SDCs as a frame of reference and to define the vertical and lateral extent of organic compounds and lead. SDCs for soil are provided in Table 3.8-1 of this RI report.

Inorganic Constituents in Soil. The following inorganics were detected above the appropriate ambient concentrations in soil samples collected at Fill Site 7: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, silver, vanadium, and zinc.

Aluminum was detected above the ambient concentration for beach/dune sand in two samples from the Fill Site 7 area. One of the samples was the composite surface sample from the helipad. In this case, the detected concentration only slightly exceeded the ambient concentration and was well below ambient for fill. Given the area of collection, it is likely that such a composite sample would include some fill material. Aluminum is not considered a COPC in this sample. The second exceedence was at 4.4 ft bgs in Boring LF7GW09. In this case, there were two overlying samples without exceedences, suggesting that the detected concentration in native materials at 4.4 ft bgs is not related to surface activities. Aluminum is not considered a COPC in this sample.

Antimony is considered a COPC at Fill Site 7, including the future wetland footprint, because of ambient exceedences in Borings LF7SB01 (70.7 $\mu\text{g/g}$ at 0.7 ft bgs) and LF7SB02 (55.4 $\mu\text{g/g}$ at 2 ft bgs).

Arsenic was detected above the ambient concentration for beach/dune sand in two samples from the Fill Site 7 area. In each case, the exceedence was overlain by samples which did not exceed ambient concentrations, suggesting that the subsurface detections are not related to surface activities. Arsenic is not considered a COPC in the Fill Site 7 area.

Barium was detected above ambient concentrations in four samples in the Fill Site 7 area. The ambient beach/dune sand concentration was exceeded in the 4.4 ft bgs sample from

Boring LF7GW09. Though the two overlying samples did not contain barium exceedences, the data were affected by blank contamination and cannot be used to assess the likelihood of surface impacts. Detections in Boring LF7GW06 exceeded the ambient level for fill at 0.0 and 2.0 ft bgs. The detected concentration decreased with depth, so a surface source is possible. In addition, the composite surface sample from the helipad (LF7SS01) contained barium at a concentration that exceeded ambient for both beach/dune sand and fill material. Barium is considered a COPC at Fill Site 7, including the future wetland footprint.

Beryllium was detected above ambient levels in six samples from four soil borings in the Fill Site 7 Area. In the two borings with two exceedences (LF7GW06 and LF7GW07), the deeper detection was the lower of the two. This suggests a possible surface source, and beryllium will be evaluated as a COPC at Fill Site 7 and within the future wetland footprint.

Cadmium was detected slightly above the ambient concentration for beach/dune in the 4.4 ft bgs sample from Boring LF7GW09. The two overlying samples from this boring did not contain detectable concentrations of cadmium, suggesting that this detection is not related to surface activities. Cadmium is no considered a COPC at this site.

Chromium was detected above ambient concentrations in two samples, LF7SS01 and the 0.7 ft bgs sample from Boring LF7SB01. The exceedence in LF7SS01 was slight and can most likely be attributed to fill material included in this composite sample. The detected concentration did not exceed the ambient level for fill material. Similarly, the detected concentration in Boring LF7SB01 is also likely a result of sample composition rather than contamination. The lithology log for this boring describes the fill material as containing serpentinite gravel. The detected concentration is well below the ambient value for serpentinite. Chromium is not considered a COPC at this site.

Cobalt was detected above ambient concentrations in one sample from each of six borings within the future wetland footprint. In two of these borings, LF7GW09 and LF7SB02, the exceedence was overlain by a detection below the ambient level. In these cases, it is unlikely that the detection was due to surface influences. Of the remaining four samples, three (LF7GW06, LF7SB06, and LF7SB08) are within four percent of their respective ambient levels. The fourth, LF7SB07, was compared to the ambient concentration for beach/dune

sand, but the lithology log indicates that the sample consisted of fill material. The detected concentration did not exceed the ambient level for fill. A seventh boring (LF7SB01), located outside the future wetland footprint, contained cobalt at a concentration that exceeded the ambient level for fill. The lithology log for this boring describes the fill material as containing serpentinite gravel. The detected concentration is well below the ambient value for serpentinite. Cobalt is not considered a COPC at this site.

Copper was detected above ambient concentrations in two samples in the Fill Site 7 area. The ambient beach/dune sand concentration was exceeded in the 4.4 ft bgs sample from Boring LF7GW09. Though the two overlying samples did not contain copper exceedences, the data were affected by blank contamination and cannot be used to assess the likelihood of surface impacts. The surface sample from Boring LF7GW06 exceeded the ambient level for fill, with a lower detection at 2.0 ft bgs. The concentration decreased with depth, so a surface source is possible. Copper is considered a COPC at Fill Site 7 within the future wetland footprint.

The ambient beach/dune sand level for lead was exceeded in five samples at Fill Site 7. The detected concentration in composite sample LF7SS01 did not exceed the ambient fill level, and this detection is most likely due to sample composition. Though compared to beach/dune sand values, which they only slightly exceed, the 0.5 ft bgs samples from borings LF7GW08 and LF7SB08 consisted of fill materials according to lithology logs. Neither of these samples exceeded the ambient value for fill material. The 4.4 ft bgs sample from Boring LF7GW09 was considerably higher than ambient, but neither of the two overlying samples contained lead at more than 4 µg/g. This suggests that the exceedence is not related to surface activities. Four borings were drilled adjacent to LF7GW09, and from these borings, only the 4.0 ft bgs sample exceeded ambient, and this only slightly. As was the case with LF7GW09, the overlying sample did not exceed ambient. Lead is not considered a COPC at Fill Site 7.

Manganese was detected above ambient concentrations in three samples in the Fill Site 7 area. The ambient beach/dune sand concentration was exceeded in the 4.4 ft bgs sample from Boring LF7GW09. Though the two overlying samples did not contain manganese exceedences, the data were affected by blank contamination and cannot be used to assess the likelihood of surface impacts. The surface detection in Boring LF7GW06 exceeded the

ambient level for fill, with a lower concentration detected at depth. This suggests a surface source is possible. In addition, the composite surface sample from the helipad (LF7SS01) contained manganese at a concentration that slightly exceeded ambient for fill material. Manganese is considered a COPC at Fill Site 7, including the future wetland footprint, primarily due to the surface detection in Boring LF7GW06

Mercury was detected above ambient concentrations in five borings within the future wetland footprint. The ambient beach/dune sand level was exceeded at 4.4 ft bgs in Boring LF7GW09, but the two overlying samples did not contain detectable concentrations of mercury. Near surface samples from Borings LF7GW08, LF7SB07, and LF7SB08 all slightly exceeded the ambient level for beach/dune sand. The detected concentrations in LF7GW06 were more indicative of a potential surface source, with 2.9 µg/g found at the surface, and 1.8 µg/g found at 2 ft bgs. Additionally, the ambient level for beach/dune sand was exceeded in a sample collected at 6 ft bgs from Test Pit LF7TP01. Mercury is considered a COPC in the Fill Site 7 area, including the wetland footprint, due primarily to the detections in Boring LF7GW06.

Nickel was detected above ambient levels in three samples at Fill Site 7, all of which were collected outside the wetland footprint. The ambient concentration for fill was exceeded in the 0.7 ft bgs sample from Boring LF7SB01. The lithology log for this boring indicates the presence of serpentinite gravel, and the detected nickel concentration is considerably lower than the ambient level for serpentinite. The detected concentration in composite sample LF7SS01 exceeded ambient for beach/dune sand, but not for fill material. Given the location and method of collection for this sample, it is likely that the nickel concentration is due to composition rather than contamination. The final nickel exceedence at Fill Site 7 was in the 7.0 ft bgs sample from Test Pit LF7TP04. This sample was collected from the saturated zone, which tends to result in higher detected concentrations of inorganics. The nickel concentration detected in this sample exceeded the ambient beach/dune sand value by only 10%. Nickel is not considered a COPC at this site.

Silver was detected above ambient beach/dune sand concentrations in three Fill Site 7 borings, all of which fall within the future wetland footprint. The maximum exceedence, however, was less than six percent and well below the ambient levels of all other lithology

types at the site. In addition, these values fall within the low end of the range of regional detections presented on Table 3.7-1. Silver is not considered a COPC at Fill Site 7.

Vanadium exceeded the ambient concentration for fill in the 2 ft bgs sample from Boring LF7SB02. The detected concentration exceeded ambient by less than one percent, and the overlying sample contained roughly half as much vanadium. Vanadium is not considered a COPC at this site.

Zinc exceeded the ambient concentration for fill in the 4.4 ft bgs sample from Boring LF7GW09. The detected zinc concentrations in the two overlying samples were each an order of magnitude lower than in the 4.4 ft bgs sample. This suggests that the detected concentration is not related to surface activities. Zinc is not considered a COPC at this site.

Organic Compounds in Soil. The only VOC detected in surface fill materials from Fill Site 7 was trichlorofluoromethane in the boring for Well LF7GW07. The maximum lateral extent is defined by non-detects in surrounding samples from Borings LF7SB03 (east), LF7SB02 (west), LF7SB09 and LF7SB10 (north). The maximum vertical extent is 1.8 ft bgs.

Trichlorofluoromethane was also detected in one deep subsurface soil sample (LF7GW09) but not in groundwater samples, indicating that its distribution is limited. The only other soil VOC detections in the study area were acetone and methyl ethyl ketone, also in subsurface native deposits from Well LF7GW09, and 1,1,2,2-tetrachloroethane in a fill sample from Boring LF7SB07. Trichlorofluoromethane, acetone, methyl ethyl ketone, and 1,1,2,2-tetrachloroethane were not detected in any groundwater samples from Fill Site 7. All of these compounds are volatile and are generally not expected to partition onto soils. Except for 1,1,2,2-tetrachloroethane, these compounds are commonly used in analytical laboratories, although they were not detected in any of the sample blanks associated with the investigative samples. The isolated occurrence, low concentrations (0.005 to 0.076 $\mu\text{g/g}$), and absence in groundwater of VOCs indicates that the soil is locally impacted.

PAHs were the most commonly detected SVOCs in surface fill samples from the study area. Concentrations in surface soils were similar across the site with the exception of samples at Boring LF7SB41 and LF7SS01, which had concentrations an order of magnitude higher than

in other samples. In the eastern portion of Fill Site 7, three areas of PAHs in surface soils were identified and encompass the following adjacent sample locations.

- Borings LF7SB05 and LF7SB06 (southeast corner)
- Borings LF7SB07 and LF7SB08 and Well LF7GW08 (north-central)
- Borings LF7SB01, LF7SB02 and LF7SB10 and Wells LF7GW06 and LF7GW07 (west).

In the helipad area, two areas of PAH detections were identified:

- Borings LF7SB33, LF7SB41 and LF7SS01 (northeast corner)
- Borings LF7SB29, LF7SB35, and LF7SB36, and LF7SS01 (northwest).

At each of the three locations in the eastern portion of Fill Site 7, one to five PAHs were detected, with some overlap in the specific compound detection. The vertical extent of PAHs at each of the locations listed above was defined by non-detects in subsurface samples except in four samples. PAHs were detected in the subsurface samples from Boring LF7SB06 and Wells LF7GW06 and LF7GW08, at concentrations higher than in the associated surface samples, and at Well LF7GW07, at lower concentrations. Although there were some increases in concentrations, all PAH detections were below SDCs except for benzo(a)pyrene at Boring LF7SB06 and Well LF7GW08. The trend in PAH concentrations with depth does not appear to relate to the sample composition; some of the deeper samples were comprised of fill and others of native deposits. PAHs have never been detected in groundwater samples from Fill Site 7, indicating that the compounds in the soil are not migrating, and that the groundwater is not a source for the subsurface PAH detections. This is consistent with the physical properties of PAHs, which have a high affinity for soil.

In the two PAH areas in the helipad area, some but not all of the PAH detections exceeded SDCs. The lateral extent of PAHs is defined by surrounding samples with detections either below RLs or SDCs. The vertical extent of PAHs in the helipad area is defined by non-detects in all subsurface samples and has a maximum extent of 2 ft bgs.

The only other PAH detection in Fill Site 7 was in the deepest native subsurface soil sample from Well LF7GW09. PAH detections in this sample were all below SDCs, except for benzo(a)pyrene. The lateral extent is quite limited and defined by non-detects in all adjacent

subsurface samples (Borings LF7SB04, LF7SB05, LF7SB07, and LF7SB08) with a maximum vertical extent of 5.9 ft bgs. The source of PAHs is uncertain, as there were no PAH detections in the associated surface and shallower (native) sample from this boring. In addition, groundwater from Fill Site 7 does not contain PAHs.

A common source of PAHs in surface soil, in areas subject to high vehicular traffic such as the PSF, is incomplete combustion of fuel. In addition, fluoranthene, fluorene, and acenaphthylene are components of asphalt and fluoranthene and phenanthrene are components of motor oil. PAHs are expected to partition to soil. Particulate transport through stormwater runoff is an important transport process for surface soil. Stormwater runoff may be transporting some PAHs in the northeastern section of the helipad area based on the detections in the sediment sample 637SD05A. The adsorption and biodegradation properties of the compounds, in addition to the lack of groundwater detections, indicate that the compounds are not migrating from soil to groundwater at Fill Site 7.

If a wetland is constructed in portions of Fill Site 7, as planned by the NPS, the majority of the pavement will be removed. If this occurs, infiltration and particulate transport will become more significant transport mechanisms. However, the high affinity of PAHs for soil should continue to prevent the migration of PAHs from soil and sediment to groundwater.

The only other SVOC detections in fill material were phthalate esters and benzyl alcohol. Bis(2-ethylhexyl)phthalate was detected in the surface soil from Sample LF7SS01. The vertical extent is limited as evidenced by concentrations below the reporting limit in all subsurface soil samples from Fill Site 7. Di-n-butylphthalate was the other phthalate detection (in a subsurface fill sample from Boring LF7SB08). There were no other detections of this phthalate in subsurface soil samples from the study area, nor was it detected in groundwater. Sampling at Fill Site 7 indicates that the distribution of phthalates is limited. The source of phthalates is uncertain; they are common laboratory contaminants, but they were not detected in the associated method blank samples. The distribution of benzyl alcohol is also limited and isolated, with two occurrences in subsurface soils, Borings LF7SB03 and LF7SB05, each surrounded by samples with concentrations below the reporting limit. Benzyl alcohol was not detected in groundwater at Fill Site 7, indicating that it is not migrating from the soil.

There are three areas in Fill Site 7 where organochlorine pesticides occur in surface fill materials:

- Boring LF7SB06 (southeast)
- Boring LF7SB02 and Wells LF7GW06 and LF7GW07 (central)
- Composite sample LF7SS01 (helipad).

At all of these locations, concentrations were only slightly above reporting limits, and in some instances they were actually reported at concentrations below the reporting limit. Methoxychlor in composite sample LF7SS01 was the only pesticide detection at the surface that exceeded an SDC (0.033 $\mu\text{g/g}$). The vertical extent of pesticides is defined in the southeast and central areas identified above as 2.9 and 2 ft bgs, respectively, by concentrations below the reporting limit in all associated subsurface soil samples. In subsurface soils from the helipad area, there was one confirmed pesticide detection (ppDDE at Test Pit LF7TP05) at a concentration only slightly above the reporting limit. All other subsurface pesticide detections (two at Test Pit LF7TP05) were below SDCs.

The distribution of pesticides at the site suggests that biodegradation is occurring. Endrin aldehyde and ppDDE were detected with their parent compounds, endrin and ppDDT, in sample LF7SS01 and at Well LF7GW07, respectively. This relationship plus the absence of parent compounds at the other sites, suggests that OCPs are undergoing biodegradation at the site. Because of the low concentrations and adsorptive properties of the compounds, OCPs do not pose a threat to the groundwater at Fill Site 7. This conclusion is supported by the groundwater data for Fill Site 7; pesticide concentrations are consistently below reporting limits.

The only other organic compound detections in soil were Aroclor 1260 in one subsurface sample, Test Pit LF7TP05, and TPH-D in many samples. The concentration of Aroclor 1260 (0.049 $\mu\text{g/g}$) was barely above the reporting limit of 0.048 $\mu\text{g/g}$ and was well below the SDC. The isolated soil occurrence and absence of PCBs in groundwater from Fill Site 7 indicate that the fill material is not a source of PCBs. TPH-D was detected above the SDC of 100 $\mu\text{g/g}$ in one surficial fill sample from Boring LF7SB07. The lateral and vertical extent of TPH-D at concentrations above the SDC is defined by concentrations below the reporting limit in surrounding surface and subsurface samples from Borings LF7SB12

through LF7SB15. All other detections of TPH-D in soil from Fill Site 7 were below the SDC. TPH-D has not been detected in groundwater from Fill Site 7, indicating that compounds are remaining in the soil and do not pose a threat to groundwater quality.

5.5.3.3 Groundwater

This section discusses the overall occurrence of inorganic constituents and organic compounds in groundwater throughout Fill Site 7. In the preceding section, groundwater data were used to evaluate whether chemicals in soil were migrating to the groundwater and also to assess if groundwater was a source of chemicals in soil. In the following section, all groundwater data are considered, and analytical results are compared to two criteria: primary MCLs and saltwater aquatic standards. The values for each of these criteria are provided in Tables 3.8-2 and 3.8-6. Comparisons to primary MCLs provide a frame of reference, as groundwater from Fill Site 7 is not potable due to the natural infiltration of saltwater (Section 2.3.6.4). In addition, current and future land use does not include the use of groundwater at the site for a drinking water supply (Section 2.3.6). The saltwater aquatic standards are used for comparison because the projected land use for portions of Fill Site 7 includes restoration of a wetland. Although these standards were applied to both filtered and unfiltered samples, they may only be applicable to filtered groundwater.

The primary focus of the groundwater investigations at Fill Site 7 was the uppermost unconfined water-bearing zone (Unit A1) because this unit is in direct contact with fill material at the site. For this reason, monitoring wells were installed only in Unit A1, except for Wells LF7GW02, LF7GW03, LF7GW05, and LF7GW07, which are screened across Units A1 and A2 (a semi-confined water-bearing zone). At these wells, the first clay layer (Unit A1/A2) is difficult to recognize. Discrete groundwater samples were collected to characterize groundwater quality in the four water-bearing zones that occur at Fill Site 7 (Units A1, A2, B, and C), which are described in detail in Section 5.3 of this RI report. Locations for the discrete samples were based primarily on the monitoring well and subsurface soil results.

Inorganic Constituents. Frequently occurring inorganics (those detected in at least seven of ten monitoring wells) were identified previously in Section 5.4.3.4 and are aluminum, arsenic, barium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel,

potassium, sodium, vanadium, and zinc. Of these 15 inorganics, only two were detected in groundwater at concentrations above primary MCLs. They are, with the number of exceedences in parentheses:

- aluminum (6)
- chromium (1)

Frequently occurring inorganics exceeding saltwater aquatic standards were also limited and were, with the number of wells with exceedences in parentheses:

- chromium (1)
- copper (8)
- lead (4)
- nickel (9)
- zinc (3)

The detected chromium concentration exceeded the saltwater aquatic standards in Well LF7GW10 during both the Supplemental and Follow-on RI programs. One of the four lead exceedences, Well LF7GW08, was detected during the Supplemental RI program but not repeated during Follow-on RI sampling. The remaining concentrations of frequently detected inorganics exceeding saltwater aquatic standards all occurred only during the Follow-on RI sampling. In addition to these exceedences, copper, lead, and nickel were detected above saltwater aquatic standards in the unfiltered sample collected from Well LF7GW10 during the Supplemental RI program. These analytes did not exceed saltwater aquatic standards in the associated filtered sample (Table 5.4-27).

Less frequently detected inorganics in groundwater (identified in Section 5.4.3.4) are antimony, beryllium, cadmium, cyanide, mercury, selenium, silver, and thallium. Except for cadmium, cyanide, and silver, concentrations of these inorganics were below primary MCLs or saltwater aquatic standards. Cadmium exceeded the primary MCL and the saltwater aquatic standard once during the Supplemental RI program, cyanide exceeded the saltwater aquatic standard once during the Supplemental RI program, and silver exceeded the saltwater aquatic standard once during the Follow-on RI sampling.

One pattern in the distribution of inorganics in groundwater was that the maximum exceedence of MCLs or Water Quality Objectives occurred in either Well LF7GW07, LF7GW09, or LF7GW10, all located in the eastern portion of Fill Site 7. The reason for this is not entirely clear but does not appear to be related to the occurrence of fill material. Soil samples from Well LF7GW07 consisted of fill materials in which beryllium was the only inorganic detected at a concentration above ambient. This suggests that the detections of aluminum, copper, lead, nickel, and zinc detected at this well at concentrations above the primary MCLs or the saltwater aquatic standards are not due to the fill material. In the boring for Well LF7GW09, numerous inorganics were detected at concentrations above ambient values in soils from the deepest subsurface soil sample, comprised partially of clay and collected from within the saturated zone. Fill material is absent from this site, and therefore is an unlikely source of aluminum, copper, and nickel at concentrations above primary MCLs and/or saltwater aquatic standards in the groundwater from this well. At Well LF7GW10, there was a small amount of debris fill (0.7 ft on Figure 5.3-3), and all inorganic detections in the soil samples from the boring for this well were at concentrations below ambient values. This suggests that the groundwater detections of aluminum, cadmium, chromium, copper, nickel, and silver at concentrations above primary MCL and/or saltwater aquatic standards are not due to the fill material.

The potential sources for the detections of inorganics in groundwater that exceeded primary MCLs and/or saltwater aquatic standards are discussed below. The discussion progresses from inorganics that are common in the study area (though the number of exceedences may be few) to those that occur less frequently. Lead results are discussed separately, towards the end of this section, as the monitoring program for lead was more extensive than for other inorganics.

Chromium and nickel are common constituents of serpentinite soils that occur at the PSF. Lithologic descriptions of soils from Fill Site 7 indicate that the beach sand deposits in the area contain grains of serpentinite. Natural weathering of these deposits is thought to be the source of chromium and nickel in groundwater. There is not a known or suspected source of these inorganics that would result in the observed wide areal distribution (detections in most wells). In addition, fill material in the area had chromium and nickel detections below

ambient values for serpentinite derived soils and groundwater concentrations were within the range of concentrations observed elsewhere at the PSF (such as the Building 900s Series Study Area). Other elements common in serpentinite derived soils (iron, manganese, and magnesium) are also ubiquitous in groundwater at Fill Site 7, which further suggests that chromium and nickel in groundwater are due to natural weathering processes.

Similarly, aluminum is a common constituent in all groundwater, due to the weathering of aluminosilicates, and its presence in the Fill Site 7 area does not appear to be related to the fill material. Although the ambient concentration for aluminum was exceeded in one composite surficial soil sample from the helipad area, there is no indication that the aluminum in this sample is due to U.S. Army activities. In addition, concentrations in the subsurface soil from this area are below ambient values. The conclusion that aluminum in groundwater is due to natural weathering is consistent with the observation that groundwater concentrations decrease significantly (in most cases to values below the reporting limit) in filtered samples. This indicates that most of the aluminum occurs absorbed to colloids or particulate matter, which typically occurs in natural water (Hem, 1989).

A source for copper and zinc in groundwater has not been identified. There was only one soil sample in which the ambient values of copper and zinc (as well as several other inorganics) was exceeded: the deepest native sample from Well LF7GW09. However, this single exceedence could not account for the wide distribution of copper and zinc in groundwater. The saltwater aquatic standards for copper are quite low (2.4 µg/L), and detections in Fill Site 7 ranged from 1.57 to 18.4 µg/L, with a mean concentration of approximately 6 µg/L. This value is based on filtered results, because all unfiltered data were affected by blank contamination. The zinc detections in groundwater above the saltwater aquatic standard of 58 µg/L ranged from 69.0 to 222 µg/L. Zinc and copper concentrations in all groundwater samples were below their respective secondary MCLs; primary MCLs have not been established.

Cadmium occurred in Well LF7GW10 at 6 µg/L, as compared to a primary MCL of 5 µg/L. Silver exceeded the Water Quality Objective of 2.3 µg/L in a sample from Well LF7GW10, with a concentration of 7 µg/L. Several other silver results and one other cadmium result exceeded Water Quality Objectives, but all were affected by blank contamination and,

therefore, were not considered representative of groundwater quality. Neither cadmium nor arsenic was detected above ambient values in soil at the wells with groundwater exceedences, suggesting that the soil is not a chemical source and that downward leaching is not an active release mechanism.

Lead detections in unfiltered groundwater exceeded the saltwater aquatic standard of 5.6 $\mu\text{g/L}$ at Wells LF7GW06 and LF7GW07 during the Follow-on RI and at Well LF7GW10 during the Supplemental RI. The maximum detected concentration was 11 $\mu\text{g/L}$ at Well LF7GW07. All unfiltered lead results from groundwater monitoring wells were below the action level of 15 $\mu\text{g/L}$. Lead detections above the action level were, anomalously, in filtered groundwater samples: Well LF7GW08 during the Supplemental RI and Well LF7GW02 during the Follow-on RI. Neither of these elevated detections was confirmed by results from other well sampling events. However, to insure that the extent of lead in groundwater was defined and potential source(s) investigated, discrete groundwater samples were collected during the Follow-on RI. Samples were collected surrounding Well LF7GW08, which had the highest lead groundwater detection (120 $\mu\text{g/L}$ in a filtered sample) and Well LF7GW09, which is upgradient and had lead concentrations in soil above the SDC of 300 $\mu\text{g/g}$.

Five of the unfiltered discrete groundwater samples surrounding Wells LF7GW08 and LF7GW09 had lead detections exceeding the saltwater aquatic standard (Tables 5.4-28 and 5.4-29). The maximum concentration near each well occurred in samples from the uppermost water bearing zone (Unit A1), with concentrations in the deeper water-bearing units all below the action level, and a few above the saltwater aquatic standard.

The discrete groundwater samples for which filtered and unfiltered samples were collected are shown on Table 5.4-30. Because the only lead detection among these samples occurred in an unfiltered sample without a corresponding filtered sample, it is necessary to look elsewhere to find meaningful results. Because the DEH Study Area is nearby and expected to have similar groundwater characteristics, the filtered and unfiltered discrete groundwater results from this area are included on Table 5.4-30. The DEH data indicate that elevated lead in unfiltered discrete groundwater is associated with the suspended sediment in the unfiltered samples, and is not representative of groundwater quality. This was demonstrated at several locations where the concentration of lead in the filtered discrete sample was generally below

the reporting limit while the unfiltered discrete sample had very high lead concentrations. This is attributed to mobilization (dissolution) of lead from the sediments in the discrete groundwater sample into an aqueous phase by the addition of nitric acid, which was used as a preservative in samples. This was particularly noticeable in the discrete groundwater samples because the turbidity in these unfiltered samples was generally quite high, often exceeding 200 NTU.

The variability of unfiltered lead concentrations in co-located discrete groundwater samples at Boring LF7SB17, where lead was detected at 130 $\mu\text{g/L}$ in one unfiltered discrete sample and below the reporting limit in a co-located sample, also demonstrates the impact that sediment has on lead concentrations in groundwater. The differences in lead concentrations are probably due to differences in the geochemical properties of the saturated zone sediments, such as clay or organic matter content, that were included in the groundwater sample.

A source for lead in groundwater at Fill Site 7 has not been identified, but the distribution in soil and groundwater suggests that lead is not leaching from the soil and is not due to U.S. Army activities. All but one of the Follow-on RI soil samples surrounding Wells LF7GW08 and LF7GW09 had lead concentrations below the appropriate ambient value or the reporting limit of 25 $\mu\text{g/g}$. In addition, the subsurface soil in contact with the groundwater at these two locations consisted of native deposits. However, lead will be evaluated in the BRA.

The inorganic analytes detected during the July 1996 quarterly sampling were also compared to primary MCLs and saltwater aquatic standards to assess whether conditions had changed since the RI sampling. The results of this sampling (Montgomery Watson, 1996e) did not show any appreciable difference in the analytes detected above the comparison standards.

Organics. There were few detections of organic compounds in groundwater samples from Fill Site 7 (Tables 5.4-24 through 5.4-26, 5.4-28, and 5.4-29). Cis-1,2-dichloroethene, bis(2-ethylhexyl)phthalate, and 2,4-D were the only organic compounds detected in more than one monitoring well. Other organic detections were vinyl chloride, chloroform, and TPH-G, each of which was detected in only one well, and trichloroethene and vinyl chloride, which were each detected in one discrete groundwater sample. All organic detections were unconfirmed

by results from multiple sampling events. The extent of each of the compounds with detections is discussed below.

During the Supplemental RI, degraded chlorinated solvents cis-1,2-dichloroethene and vinyl chloride were detected in wells in the eastern section of Fill Site 7 (Wells LF7GW08 and LF7GW09). Vinyl chloride exceeded the California primary MCL (0.5 µg/L) at Well LF7GW09 and cis-1,2-dichloroethene was just below the MCL (6 µg/L). The lateral and vertical extent of chlorinated compounds surrounding Well LF7GW09 is very limited, as evidenced by non-detects in all associated discrete groundwater samples (Table 5.4-29). The lateral and vertical extent of chlorinated compounds in groundwater near Well LF7GW08 is defined by non-detects in surrounding discrete groundwater samples from Borings LF7SB21, LF7SB22, LF7SB24, LF7SB38, LF7SB39, and LF7SB40 (Table 5.4-28). Within this area, defined by a circle with a radius of approximately 30 ft centered around Well LF7GW08, trichloroethene, a parent chlorinated solvent, and vinyl chloride were each detected once. Both detections were in the unconfined uppermost water-bearing zone (Unit A1). Only the vinyl chloride detection (0.8 µg/L) exceeded the primary MCL of 0.5 µg/L (Table 5.4-28). The trichloroethene detection was also quite low, 0.7 µg/L. Vinyl chloride has been detected in Well LF7GW08 three times during the quarterly monitoring program (Montgomery Watson, 1996e). Each time the detected concentration exceeded the MCL.

Based on the low concentrations, minimal number of primary MCL exceedences, unconfirmed detections, and limited lateral and vertical distribution, chlorinated compounds do not appear to be a major groundwater contaminant at the site. A specific source for the detections has not been identified. The chlorinated compounds detected in the groundwater were not present in any of the soil samples from Fill Site 7. This suggests that the fill material is not a source of chemicals in groundwater. The chlorinated compounds are degrading as evidenced by the two final degradation products of trichloroethene (cis-1,2-dichloroethene and vinyl chloride). The lack of detections in discrete groundwater samples surrounding Well LF7GW08 and limited extent at Well LF7GW09 indicates that the compounds are not migrating laterally from the site. Vertical migration at the site appears to be limited by the clay layer separating the groundwater in Unit A1 from Unit A2. In addition, natural degradation of the compounds also limits vertical migration.

The possibility of an upgradient source within the Main Post Study Area has been eliminated because chlorinated compounds have not been detected in groundwater from that site. However, a service station, Building 206, and an associated car wash, Building 208, are located upgradient of Fill Site 7, and contamination has been discovered in the area. These buildings were constructed in 1982 and were operated under control of the AAFES by a private contractor until mid-1995. Underground fiberglass storage tanks used at this service station were installed in 1982. All three tanks were leak tested and passed in 1987 and 1994 (Montgomery Watson, 1996b). These USTs and associated piping were removed in July 1996. An investigation of the extent of petroleum contamination in this area being conducted by the Sacramento COE, and currently available data do not include chlorinated solvent analyses.

Most other organics detected in monitoring wells were all at concentrations well below the primary MCLs. Chloroform was detected in one well (LF7GW10) at a concentration over an order of magnitude lower than the primary MCL of 100 µg/L. Similarly, the maximum concentration of 2,4-D, a herbicide, was 4.9 µg/L, as compared to a primary MCL of 70 µg/L. Potential sources for chloroform and 2,4-D have not been identified. The compounds were not detected in any soil samples from Fill Site 7, indicating that the fill material is not a source. These compounds have not been detected in upgradient locations, indicating that the chemicals have not migrated from a distant source outside of Fill Site 7. Saltwater aquatic standards for the organic compounds detected in the Fill Site 7 area have not been established, therefore no comparisons were made. During quarterly monitoring (Montgomery Watson, 1996e), 2,4-D has not been detected, and chloroform has been detected only once, in Well LF7GW11 during the Fall 1995 sampling.

Bis(2-ethylhexyl)phthalate was the only SVOC detected at a concentration above the primary MCL of 4 µg/L. However, this compound was commonly detected in laboratory blanks and is a common plasticizer. Its sole occurrence in Wells LF7GW05, LF7GW06 and LF7GW10 during the most recent sampling event, and the absence of other organic compounds at these wells (except for 2,4-D at Well LF7GW05) suggest that the compound is not of major concern at the site.

TPH-G was detected in Well LF7GW01. This detection is associated with the source in the POL area and will be addressed under a separate program. There were no other detections of TPH-G in groundwater, suggesting that the shallow hydraulic gradients at the site prevent the migration through groundwater of chemicals from the POL Area into Fill Site 7.

The results of sampling by Montgomery Watson for the July 1996 quarter confirmed that the detection of organic compounds is not prevalent in the Fill Site 7 Area.

5.5.4 Buildings 609, 611, and 633

Pesticide and PCB contamination was suspected at Buildings 609 and 611, respectively, because of previous uses. PCBs were not detected in any of the samples at Building 611. OCPs detected at Building 609 did not exceed their respective SDCs.

A closed firing range near Building 633 was investigated to determine if lead had migrated from the site through particulate transport or solubilization. Detections of lead above ambient levels were primarily in the sand used for the firing range. The lateral extent of the detections is defined by the concrete bunker, encompassing an area approximately 160 ft by 15 ft. The maximum vertical extent is defined by the concrete floor, which is approximately 5 ft below the sand.

Although lead was detected above ambient in sand and will be evaluated as a COPC in soils at this site, it is not believed that lead is migrating to the groundwater because the concrete floor should prevent or greatly reduce vertical transport. Data collected from groundwater at downgradient wells in the Consolidated Motor Pool and POL areas by Dames & Moore and Montgomery Watson indicate detections below the action level of 15 µg/L. In addition, groundwater data from downgradient monitoring wells in Montgomery Watson's (1995a) quarterly monitoring report from the 637 Study Area reported median lead concentrations below the action level.

5.5.5 Sewer Lift Stations

The soil and groundwater at the Sewer Lift Stations were analyzed for inorganic analytes and TPH to determine if reported overflows had affected the soil and groundwater surrounding the stations. The soil samples were also analyzed for VOCs. Although inorganic

analytes were detected above ambient concentrations at Borings CFLSSB03 and CFLSSB04, the groundwater at this station did not contain concentrations that exceeded the California primary MCLs. In contrast, the soil from Borings CFLSSB01 and CFLSSB02 had relatively few concentrations that exceeded ambient conditions while the groundwater had several concentrations that exceeded the primary MCLs. Because the stations are located on either side of Crissy Field and should not affect each other, Borings CFLSSB01 and CFLSSB02 (Lift Station 1) are discussed separately from Borings CFLSSB03 and CFLSSB04 (Lift Station 2).

The soil samples at Lift Station 1 were classified as Colma Formation. Nickel and lead exceeded ambient concentrations at the surface in Boring CFLSSB01. Mercury, lead, and zinc were detected above ambient concentrations at the surface in Boring CFLSSB02. The inorganics that will be evaluated as COPCs at Lift Station 1 due to detections in surface soils are lead, mercury, and zinc. Nickel was not included because the detected concentration exceeded the ambient level for the Colma Formation by less than five percent and was considerably lower than the ambient concentration for any other lithology at the site. Cyanide, detected at 3.0 ft bgs, is the only COPC in subsurface soils. Metals concentrations may be associated with historical storage in this area.

Aluminum, arsenic, barium, chromium, lead, and nickel were detected above California primary MCLs in the unfiltered groundwater sample. It is not believed that the surface soil concentrations are affecting groundwater. Aluminum, barium, lead, mercury, nickel, and zinc are expected to partition to soil, but these compounds are soluble in nitric acid which was used to preserve the unfiltered discrete groundwater samples. It is believed that the some of the groundwater concentrations are due to the preservative (nitric acid) disassociating the compounds from the suspended sediment that is abundant in unfiltered discrete samples and are not representative of concentrations in groundwater. As described in Section 5.5.3, lead has been shown to be associated with the suspended sediment in discrete unfiltered groundwater samples (Table 5.4-30). Arsenic and chromium have been detected in filtered groundwater samples from other locations and may be indicative of a dissolved state.

The inorganics that will be evaluated as COPCs at Lift Station 2 due to detections at 0.5 ft bgs are copper, cyanide, mercury, and selenium. Though detected above the ambient levels

for Colma samples, lead and zinc will not be evaluated because the detected concentrations only slightly exceeded ambient and were well below ambient levels for all of the other lithologies at the site. The groundwater at Lift Station 2 did not contain concentrations in excess of the California primary MCLs, so it does not appear that the compounds found above ambient values in the soil are affecting the groundwater.

5.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY

This section summarizes the evaluation of results for the Crissy Field Study Area, including the risk assessment results, as presented in detail in Section 15.

5.6.1 Conclusions

The investigations in the Crissy Field Study Area were designed to assess the chemical impact of U.S. Army activities at the site. Potential sources were identified, and analytical samples were collected from various media. For the purposes of this RI, the area was divided into five subregions: the Consolidated Motor Pool; the POL Area; Fill Site 7; Buildings 609, 611, and 633; and the Sewer Lift Stations. An additional subregion was added for the BRA to allow evaluation of the proposed future wetland.

5.6.1.1 Consolidated Motor Pool

Potential chemical sources evaluated in the Consolidated Motor Pool Area were surface leaks and spills related to vehicle maintenance activities. Both inorganics and organics could have been released by such a source. TPH was the most frequently detected organic compound in soil that will be evaluated in the human health and ecological BRA. The extent of TPH is limited primarily to surface soils located behind Building 643. Two VOCs, several PAHs and phthalates phthalates, and one pesticide were also identified as COPCs for both the human health and ecological risk assessments. The extent of PAHs in soil is limited, with detections occurring in soils from 0 to 2 ft bgs in a small area near the southeast corner of Building 643. A specific source for PAHs, TPH, and inorganic detections in this area is unknown, but it is probably related to accidental surface spill(s).

5.6.1.2 POL Area

Because all COPCs in the POL Area are related to releases of petroleum products, analytical results from this area are not incorporated into the human health or ecological BRA in this RI report. Assessment of this site is being conducted by the Sacramento Corps of Engineers under a separate program.

5.6.1.3 Fill Site 7

The potential chemical sources evaluated in Fill Site 7 are debris and artificial fill materials. The surface soil at Fill Site 7 contained the majority of inorganic analytes detected above ambient concentrations. Although several inorganic analytes were detected above ambient values in subsurface samples, they were generally not the same inorganics that were detected in the surface soils. This indicates that downward migration of inorganics from surface soils to deeper soils is minimal. The fill material has only a local impact, with the areal extent of ambient exceedences generally defined by adjacent samples (within approximately 300 to 500 ft). Inorganics in groundwater reflect natural weathering processes of serpentinite derived soils, with aluminum, iron, nickel, chromium, manganese, and magnesium occurring throughout the site. Inorganics detected above ambient values in soils were generally absent in groundwater, or occurred at concentrations below primary MCLs and/or Water Quality Objectives for saltwater aquatic life protection. The eastern portion of Fill Site 7, at Wells LF7GW07, LF7GW09, and LF7GW10, was the only area where detections in groundwater are generally higher than elsewhere in Fill Site 7. However, these higher groundwater detections do not appear to be derived from leaching of inorganics from fill materials, and may reflect local, natural, hydrogeologic conditions.

Organic compound detections were primarily PAHs in surface soils from the helipad area and TPH-D throughout the site. The helipad area was the only portion of Fill Site 7 with significant exceedences of SDCs for PAHs. The lateral extent of PAHs in the northwestern portion of the helipad is approximately 125 ft by 125 ft, with a maximum vertical extent of 2 ft. The eastern section of the helipad area had a lateral extent of approximately 100 ft by 100 ft, with a maximum vertical extent of 2 ft. PAH concentrations elsewhere in Fill Site 7 were generally below SDCs. Other organics detected in soil were several organochlorine pesticides in surface soils and a single detection of trichlorofluoromethane. Organic compounds

detected in the soil were not detected in groundwater from Fill Site 7, indicating that the fill material and overlying soils are not a chemical source for groundwater contamination, and vice versa. The only organics detected in groundwater in more than one location were two final degradation products of trichloroethene (cis-1,2-dichloroethene and vinyl chloride) and 2,4-D.

5.6.1.4 Buildings 609, 611, and 633

The potential chemical source evaluated at Building 609 was a pesticide spill that reportedly occurred prior to demolition of the building in 1987. Three pesticides were detected in surface soil samples.

PCBs were investigated at Building 611, but there were no detections.

Building 633 was a closed firing range used for small arms and rifle target practice. Lead was the only target analyte at this site, and occurrences at concentrations above ambient were generally limited to the concrete-lined sand pit, which was the receptacle for spent ammunition.

5.6.1.5 Sewer Lift Stations

Surface spills from over-flow at two sewer lift stations were investigated at this site. COPCs were limited to inorganics, as organic compounds were not detected above reporting limits at either of the Sewer Lift Stations.

5.6.1.6 Proposed Wetlands Restoration Area

The proposed wetlands restoration area encompasses samples from both the Crissy Field Study Area and the East-of-Mason site. The sample numbers for soil samples included in this evaluation are as follows: EOMSB01, 04, 05; LF7GW06-10; LF7SB02-19, 21-24; 609SS01-03; and 611SS01-03. Groundwater samples from these same locations, when available, in addition to samples from EOMSB02, EOMSB03, and LF7GW05 were included. The list of COPCs for these samples includes inorganics, VOCs, PAHs and other SVOCs, and pesticides.

5.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

Neither the sediments from storm drains nor the wipe samples were assessed, because exposure to the sediments is unlikely under the future use scenarios for the Crissy Field Study Area, and wipe samples cannot be used quantitatively. The impact of the study area to the ecological receptors in San Francisco Bay was evaluated as part of the ESAP (WJE, 1993b and 1994c), and ESAP data indicate that the transport of contaminants from both the Fill Site 7 and POL Areas is not an exposure pathway that significantly affects the toxicity to aquatic receptors in the bay.

Inorganics, miscellaneous parameters, and organics in groundwater are considered in both the human health and ecological risk assessments. Groundwater data were assessed only for wells and discrete groundwater samples that are located within the proposed wetland area and provide data on the unconfined and semi-confined water-bearing zones (Units A1 and A2, respectively). In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source for the Building 640/643 area.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Crissy Field Study Area are summarized in the following sections.

5.6.2.1 Human Health

The Crissy Field Study Area was assessed as several different areas in the human health risk assessment because the GMPA identified institutional (industrial) use around Buildings 640 and 643, construction (industrial) and open space (recreational) uses within the future wetland footprint, and open space (recreational) in the other areas of the study area. Under the industrial scenario evaluated for the area of Buildings 640 and 643, exposures to surface (0 to less than 0.5 ft bgs) and subsurface (0.5 to less than 15 ft bgs) soil are possible. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area of the Crissy Field Study Area. Under the industrial scenario evaluated for the proposed wetlands restoration area, exposures to groundwater were assessed. Because soil from 0.0 to less than 15.0 ft bgs would be excavated and spread at the surface, soils from this depth range were assessed under the recreational open space scenario. Under the recreational scenario evaluated for the remainder of the Crissy Field Study Area, only exposure to surface soil from 0.0 to less than 2.0 ft bgs is assumed.

Two additional assessments of risk were performed for the Crissy Field Study Area that are not based on the planned future use of the site. These include assessment of groundwater as drinking water and a residential PRG ratio screening assessment. Groundwater was assessed as drinking water within the proposed wetlands restoration area although groundwater beneath the site is an unlikely potable water supply for the industrial worker in the area.

A residential PRG ratio screening assessment for surface and subsurface soil and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Crissy Field Study Area are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

5.6.2.1.1 Quantification of Cancer Risks

Buildings 609, 633, and 642 had all analytes in the surface and subsurface soils screened out during the COPC screening and none remained as COCs. Therefore, these sites within

the Crissy Field Study Area are unlikely to pose potential excess cancer risk to recreational visitors.

Buildings 640 and 643 were assessed together with an institutional worker exposed via ingestion of and dermal contact with COCs in surface and subsurface soil and the PSF water supply. Three inorganics, chromium, lead, and nickel; and one inorganic, phenanthrene were COCs in surface or subsurface soil samples. A total risk of $2E-09$ was determined, which is less than $1E-06$ and, therefore, it is unlikely that exposure to COCs at this site will result in an increased cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Surface soil and subsurface soil COCs at Fill Site 7 included beryllium and several PAHs and pesticides. Ingestion of and dermal contact with surface soil to 2 feet was assessed for recreational visitors at this site. A total carcinogenic risk of $1E-05$ was determined, mostly from incidental ingestion of and dermal contact with benzo(a)pyrene, and ingestion of beryllium in the surface soil. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

In addition to the recreational visitor scenario, a wetlands construction worker scenario was also assessed for the proposed wetlands restoration area. The COCs in groundwater within the proposed wetlands restoration area included several inorganics, VOCs, SVOCs, PAHs, pesticides, and water quality parameters. The total risk is $6E-07$, indicating that it is unlikely that this site will result in an excess cancer risk potential to the wetlands construction worker when exposed to the groundwater via ingestion or dermal contact at the proposed wetlands restoration area.

The COCs in the soil from 0 to 15 ft which may be removed from the proposed wetlands restoration area and distributed elsewhere at the PSF included beryllium, bis(2-ethylhexyl) phthalate, benzo(a)pyrene, phenanthrene, ppDDE, and ppDDT. The total risk is $2E-06$, mostly from ingestion of beryllium in the soil. The residential PRG ratio screening assessment resulted in a total cancer risk for the proposed wetlands restoration area greater than $1E-06$.

Cyanide in surface soil to 2 feet was the only COC for the Sewer Lift Stations on the Crissy Field Study Area. Cyanide is not considered a carcinogen so it is unlikely that there is an excess cancer risk from exposure to this site to the recreational visitor. The COPCs for the Sewer Lift Station are not considered carcinogenic in the residential PRG ratio screening assessment.

5.6.2.1.2 Quantification of Noncarcinogenic Effects

All noncarcinogenic hazard indices are less than 1E+00 and, therefore, it is unlikely that exposure to surface or subsurface soil to recreational visitors, construction workers, or institutional workers at the Crissy Field Study Area will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazards greater than 1E+00 for Buildings 633 and 640/643, Fill Site 7, Crissy Field groundwater, the proposed wetlands restoration area, and the Sewer Lift Station.

The maximum detected value for lead in surface soil at the Building 640/643 area is 1420 mg/kg, which is greater than the lead soil screening value of 840 mg/kg.

5.6.2.2 Ecological

The Crissy Field Study Area was evaluated several ways in the ecological risk assessment because of the difference between the current and projected future land use of the area. Based on the current scenario, separate assessments of exposure of terrestrial receptors to soil at depths less than 3 ft for Buildings 640 and 643, Building 642, Fill Site 7 (including EOM), Building 609, Building 611, Building 633, and each of the Sewer Lift Stations. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Additionally, because a portion of the area is scheduled to be returned to a wetland state, three additional future scenario assessments were performed as described below. Key terrestrial receptors were evaluated for contact with soils in the future wetland footprint because of the possibility of this soil (to a depth of 15 ft) being extracted and spread on the surface. As the current soil/sediments within the wetland footprint would require extraction in order to form the future wetland, these soils/sediments are unlikely to be a source of exposure for future aquatic life. However, all soils within 15 feet of the surface also were

evaluated as if they were sediments under the future wetland scenario. Risks to aquatic plants and invertebrates, fish, sandpipers, mallard ducks, and raccoons were assessed. Aquatic receptors were evaluated for future contact with surface water as estimated by current groundwater data for the future land use conditions in the wetland area.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

5.6.2.2.1 Buildings 640 and 643

Soil COPCs evaluated in the ecological risk assessment were several inorganics, two phthalates, PAHs, and TPH. Results of the risk assessment indicate the following:

- HI values exceeded 1 for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna when comparisons were made between exposure and the conservative TBV_{Low} values.
- HI values exceeded 1 for the American robin, mourning dove, western harvest mouse, and plants and soil fauna when comparisons were made between exposure and the TBV_{High} values.
- Highest risks were predicted for the robin. HQs for barium, cadmium, chromium, lead, TPH, and zinc in soil exceeded 1 for the robin when comparisons were made to the TBV_{Low} values. Cadmium, lead, and zinc in diet also contributed to risk for the robin.

Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS.

5.6.2.2.2 Building 642

The only soil COPC evaluated in the ecological risk assessment was TPH. Results of the risk assessment indicate no potential for adverse ecological effects. Based on the results of the ERA, this site will not be considered for inclusion in the FS.

5.6.2.2.3 Fill Site 7/East of Mason Shoreline Area

Soil COPCs evaluated in the ecological risk assessment included several inorganics, VOCs, PAHs and other SVOCs, pesticides, and TPH. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs for the American robin and plants and soil fauna were greater than 1 when comparisons were made based on the TBV_{High} .
- Levels of barium, copper, manganese, mercury, ppDDE, and ppDDT produced HQs greater than 1 for either the soil or dietary ingestion pathway for the American robin.
- No individual HQs for any pathway, or the total exposure, exceeded 1 for the mourning dove or western harvest mouse. Only the cumulative HI for total exposure (i.e., the sum of all chemicals and all exposure pathways combined) indicated a potential for risk.
- Levels of antimony and manganese in soil were the only COPCs that produced HQs greater than 1 for plants and soil fauna.

It should be noted that the risk drivers for each receptor of concern identified were often infrequently detected. For instance, ppDDT was detected in only 2 of 32 samples collected. This indicates that the occurrence of these risk drivers is not widespread, therefore the likelihood of exposure and risk is minimal. Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS.

5.6.2.2.4 Future Wetland Area

Soil COPCs evaluated in the ecological risk assessment in soil to a depth of 15 ft in the proposed wetland footprint area include several inorganics, VOCs, PAHs and other SVOCs, pesticides, and TPH. Results of the risk assessment for aquatic receptors indicate the following:

- HQs for sediment exposure by aquatic invertebrates based on current soil concentrations of copper, manganese, mercury, ppDDE, ppDDT, and dieldrin exceeded 1 if the soil concentrations do not change in the process of wetland construction.
- Projected HIs for aquatic invertebrates are low, ranging from 4 based on a TBV_{High} to 32 based on a TBV_{Low} .
- The HIs for the sandpiper range from 0.3 based on a TBV_{High} to 2 based on a based on the TBV_{Low} , indicating there is little chance of risk to sandpipers.
- All HQs and HIs for the other receptors were less than 1, indicating no risk.

The exposure pathways evaluated for terrestrial receptors were soil ingestion, dietary exposure, and dermal exposure to the site soils. Risks to avian and mammalian receptors are low. The most significant results are:

- The HI for total exposure for the robin was 40 based on the TBV_{Low} , but only 2 based on the TBV_{High} . The HI assumes that all risks are additive.
- There were HIs in excess of 1 for the mourning dove and western harvest mouse, although all individual HQs were less than 1.
- HQs for barium, copper, mercury, manganese, and ppDDT exceeded 1 for the American robin for either the soil or dietary ingestion pathways when comparisons were made to the conservative TBV_{Low} . No individual HQs for any pathway, or for total exposure, exceeded 1 when comparisons were made to the TBV_{High} .
- HQs for antimony and manganese for plants and soil fauna exceeded 1.
- The dietary ingestion pathway produced the greatest risk for the American robin, where HIs were 30 based on the TBV_{Low} , but only 0.9 based on the TBV_{High} . This indicates that risk to this receptor for the dietary ingestion pathway is in the gray zone, and while effects may be possible in isolated individuals, effects on the population are not expected.

The cumulative HIs for most receptors were low or less than 1. Thus, while several COPCs have been identified as potential risk drivers, the total number of pathways and receptors exhibiting risk is low. Further evaluation of this site is not warranted on the basis of terrestrial ecological risk.

Groundwater COPCs evaluated as potential surface water COPCs in the future wetland area include inorganics considered to be potentially derived from overlying fill materials (antimony, barium, beryllium, copper, manganese, and mercury), 2,4-D, bis(2-ethylhexyl)phthalate, four chlorinated VOCs, and miscellaneous parameters.

The Crissy Field groundwater was evaluated assuming it would be the sole contributor to the future wetland surface water balance (zero dilution), and also assuming it would contribute 50% or 10% of the total water volume in the wetland. This is conservative (i.e., overestimates risk) because influx from the Bay will define the wetland water quality characteristics. In addition, all of the data were unfiltered; this also overestimates aquatic risk because the metals bound to particulates are not readily bioavailable.

There are some potential risks to future aquatic life in the wetland given the current conditions. Furthermore, although inorganic COPCs consisted of antimony, barium, beryllium, copper, manganese, and mercury, these could also be naturally occurring. The risk assessment results indicate that:

- HIs for aquatic life exceed 1, indicating groundwater conditions exceed the minimum chronic AWQC for the 0, 50, or 90% dilution scenarios.
- HIs for aquatic life exceed 1 based on the maximum chronic AWQC for the 0, 50, or 90% dilution scenarios.
- HIs for waterfowl, waders, and raccoons exceed 1 due to predicted dietary ingestion of copper compared to the TBV_{Low} for the zero dilution scenario. There were no exceedences when comparisons were made to the TBV_{High} , however, indicating little potential for adverse population effects.
- HIs for waterfowl and waders exceeded 1 due to predicted dietary ingestion of copper compared to the TBV_{Low} for the 50% dilution scenario. There were no exceedences when comparisons were made to the TBV_{High} , however, indicating little potential for adverse population effects.

- No HIs for avian or mammalian receptors exceeded 1 when exposure was compared to the TBV_{Low} for the 90% dilution scenario.
- Barium, copper, and manganese were the greatest contributors to risk.
- Copper was the only COPC for which HQs exceeded 1 for avian or mammalian receptors.

Because the estimates of risk are so uncertain:

- The ecological risk assessment for Crissy Field will be further evaluated to determine whether this site warrants inclusion into the FS.
- Water and sediments should be sampled after the wetland construction is completed.

5.6.2.2.5 Building 609

The only soil COPCs evaluated in the ecological risk assessment were ppDDE, ppDDT, and dieldrin. Results of the risk assessment indicate the following:

- ppDDT for dietary exposure to the American robin resulted in an HQ of 9 based on the TBV_{Low} and 0.03 based on the TBV_{High} .

The HQs and HIs were less than 1 for each of the other exposure routes and target receptors that were evaluated. Building 609 is an industrial setting and is not likely to contain sufficient habitat to support populations of passerine birds for a prolonged duration. Therefore, the relative risk to ecological receptors attributable to Building 609 is considered minimal. The dietary exposure route assumes that the COPCs will bioaccumulate and transfer through the food chain components of the robin's diet. Given the infrequent detection of ppDDT within the area, the actual likelihood of this occurring is slight. Based on the results of this ERA, this site will not be considered for inclusion in the FS.

5.6.2.2.6 Building 611

There were no detections of PCBs analyzed at this site; therefore, no risk assessment was performed.

5.6.2.2.7 Building 633

The only soil COPC evaluated in the ecological risk assessment was lead. Results of the risk assessment indicate the following:

- Lead in soil resulted in an HQ in excess of 1 for the American robin and the mourning dove for soil ingestion and dietary exposure when comparisons were made to the conservative TBV_{Low} .
- Lead in soil resulted in an HQ in excess of 1 for the American robin and the mourning dove when exposure was compared to the TBV_{High} .
- Lead estimated to occur in diet resulted in an HQ greater than 1 for the western harvest mouse and pocket gopher when exposure was compared to the conservative TBV_{Low} , but no risks were apparent for these receptors when the exposure was compared to the TBV_{High} .
- The HQ for total exposure for the robin was 700 based on the TBV_{Low} , but only 6 based on the TBV_{High} .

The remaining pathways and target receptors evaluated resulted in no risks. However, because risks were observed above the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), the ecological risk assessment for Building 633 will be further evaluated to determine whether this site warrants inclusion into the FS.

5.6.2.2.8 Sewer Lift Stations

Soil COPCs evaluated in the ecological risk assessment for Sewer Lift Station 1 included lead, mercury, and zinc. Results of the risk assessment indicate the following:

- The HI exceeded 1 for the American robin, mourning dove, western harvest mouse, plants and soil fauna when exposure was compared to the conservative TBV_{Low} .
- No HIs exceeded 1 when exposure was compared to the TBV_{High} , indicating that while some isolated individuals may exhibit adverse effects, the population as a whole is unlikely to be affected.
- Lead in soil resulted in an HQ in excess of 1 for the American robin, mourning dove, western harvest mouse, plants and soil fauna when exposure was compared to the conservative TBV_{Low} .
- Zinc resulted in an HQ in excess of 1 for the American robin for exposure through the diet relative to the TBV_{Low} .
- Zinc levels also exceeded TBV_{Low} , but not TBV_{High} values for plants and soil fauna.

The results of the ERA indicate that isolated individuals may be affected, but that populations are not at risk. Given the industrial setting of this site, and the minimal number of TBV exceedences, it is anticipated that this site would not contribute significant risk to ecological receptors. This site is not recommended for further evaluation in the FS.

Soil COPCs evaluated in the ecological risk assessment for Sewer Lift Station 2 included copper, cyanide, mercury, and selenium. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna exceeded 1 when exposure was compared to the conservative TBV_{Low} .
- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 when exposure was compared to the TBV_{High} .
- Copper and selenium were the major contributors to risk for plants and soil fauna.
- Copper, mercury and selenium contributed to risk for avian and mammalian receptors.
- The HQs for the remaining pathways and receptors evaluated were less than 1.

Due to the proximity of buildings there is minimal habitat and little likelihood of extensive use by ecological receptors. Because risks were observed above the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), the ecological risk assessment for Sewer Lift Station 2 will be further evaluated to determine whether this site warrants inclusion into the FS.

6. BUILDING 900s SERIES STUDY AREA

This section presents the area description, sample location rationale, geologic setting, analytical results, results evaluation, and conclusions and recommendations of Building 900s Series Study Area. The Building 900s Series Study Area was selected for further investigation based on the findings reported in the Enhanced PA (ANL, 1989). Most of the buildings in the study area were constructed as maintenance facilities for airplanes. When airfield support activities were reduced, many of the support buildings were converted to vehicle maintenance shops. Potential contaminant sources in the study area include a subsurface release from an UST and/or the associated piping, a surface spill resulting from overfilling a tank, and surface spills and leaks from equipment and storage containers. The primary objectives of the investigation in this study area are to characterize the distribution of chemicals in soil and groundwater and on building surfaces, and to assess the risks to human health and environment that these chemicals may pose.

Release mechanisms characterized include surface-water runoff, particulate transport, and infiltration of chemicals to deeper soil and groundwater. The risk assessment evaluates exposures related to industrial and recreational land use. The groundwater in much of the area exceeds the regulatory standards for potential municipal or domestic water supplies (California Resolution 88-63) and recommended secondary MCLs because of natural intrusion of saltwater into the coastal aquifer (Section 2.3.6.4). It is not practical to utilize this groundwater as a potable water source, and there are no plans to develop water supplies at this study area. The GMPA for the PSF does not include use of groundwater as a drinking water source in the Building 900s Series Study Area (NPS, 1994). For these reasons, the human health risk assessment does not include an evaluation of exposure to groundwater. However, the ecological risk assessment considers the potential impact of groundwater on the Bay.

6.1 AREA DESCRIPTION

The physical characteristics of the Building 900s Series Study Area, including location and physical features, history and land use, are described in this section. Physical features are

critical in assessing the fate of chemicals detected in groundwater, soils, buildings, and sediments. The results of non-RI environmental studies conducted in the study area are also summarized in this section. The rationale for the sampling program in this study area was to fill data gaps that were identified after reviewing data collected during previous investigations. Ongoing investigations are also discussed.

6.1.1 Location and Physical Features

The Building 900s Series Study Area is located on the northern boundary of the PSF, east of the Golden Gate Bridge and adjacent to the FPCGS (Figure 1.2-2). The site covers approximately 15 ac and is bounded by San Francisco Bay to the east and by a bedrock cliff to the west (Figure 6.1-1). North of the study area, the bedrock outcrop extends to the San Francisco Bay shoreline. The southern boundary of the study area is at Building 920. Access to the Building 900s Series Study Area is along Long Avenue near Building 979 or from the south via Mason Street. At the time of the RI field work, the entire building complex was enclosed by fences, which were locked after business hours. The northern part of the study area, north of Building 937, is currently not fenced except for the building 950 area.

There is little topographic relief in the Building 900s Series Study Area. Ground surface elevations range between 10 and 15 ft-PLL, and the beach slopes gradually to San Francisco Bay. Except for the shoreline, which is sand and riprap, most of the ground surface is covered with buildings, concrete, asphalt or very compacted sandy silt. The 17 buildings investigated in the study area are or were located on flat ground along the base of the bedrock cliff. The construction style was mostly slab-on-grade. Figure 6.1-1 shows the location of the buildings and known USTs in the Building 900s Series Study Area. Beneath the study area are water mains, sanitary sewer lines, and terra cotta storm drains with outfalls that drain into San Francisco Bay (Figure 6.1-2).

6.1.2 History and Use

Most of the buildings in the study area were constructed as maintenance facilities for airplanes using Crissy Airfield, which was constructed in 1919. In 1936, airfield support activities were reduced and many of the support buildings were converted to vehicle

maintenance shops. The airfield was then used infrequently until the 1950s, when aviation activities ceased. The U.S. Army's operations in the Building 900s Series Study Area ended with the transfer of the property to the NPS.

The following information on building design and use is from the Enhanced PA (ANL, 1989). Information on the location, contents, and size of USTs was obtained from a preliminary survey conducted by the U.S. Army (WES, 1990) and an UST management plan developed in 1992 (JMM, 1992b). The U.S. Army is currently conducting a comprehensive UST management program to bring all remaining USTs into compliance with federal and local regulations.

On the basis of building history and use, the study area has been divided into three parts:

- the Vehicle Maintenance Area, which contains Buildings 920 and 923 through 937
- the Storage Area, which consists of Buildings 949, 950, 973, and 974
- Building 979, in the northern portion of the study area.

The history and use of each of these sites is presented in the following sections.

6.1.2.1 Vehicle Maintenance Area (Buildings 920 and 923 through 937)

Buildings 920 through 937 are located in the southern portion of the study area and contained most of the PSF vehicle maintenance operations. Building 920 is located along the southern edge of the Building 900s Series Study Area, and was a former motor pool repair shop. During the early 1990s the building was used as a parachute packing, inspection, and repair shop. Since 1993, the building has been used for furniture storage. A 12-in diameter metal cylinder which may have been part of a hydraulic lift system is located within the building, and two independent hydraulic lift cylinders were removed from an area approximately 10 ft southwest of the building in 1993. Some leaking was observed during the removal, but subsequent sampling showed no impact on groundwater, and soil sample detections outside the excavated area were below action levels developed in the FPALDR (Montgomery-Watson, 1995e). Two inactive 50-gal hydraulic oil tanks were believed to be located beneath the concrete slab, however, GPR performed in 1992 failed to locate the tanks (JMM, 1992b).

Building 923 is a small transformer building located near the northwest corner of Building 924. An abandoned solvent dip tank was temporarily stored behind the building (Figure 6.1-3). Building 925, located to the south of Building 923 (Figure 6.1-3), is a fenced transformer pad containing three transformers.

Building 924 is a brick-and-steel structure built in 1958 to support a Nike-missile anti-aircraft defense program. It was most recently used for servicing large vehicles. Aerial photographs, interpreted by Rindgen and Sitton (1990), show that the area immediately west of Building 924 was used for outside storage of various containers beginning some time between 1959 and 1963 and continuing until at least 1988. This likely included waste drums which were stored behind the structure for short periods of time before Safety-Kleen Corporation was contracted for waste removal in the mid-1980s. A target range was also located against the hill behind Building 924. Prior to construction of Building 924, another building was located on the site. An aerial photo from 1946 shows ground staining on the west side of this older building (Figure 6.1-3). Lubricating oils and greases were stored and used in Building 924 prior to transfer of the PSF to the NPS. According to the Enhanced PA (ANL, 1989), two ASTs containing bulk oil and waste oil were once located behind Building 924. The waste oil tank had a 400-gal capacity and was located directly on the soil. Stained soil was observed near this tank at the time of sampling. The capacity of the second tank is unknown, and both tanks have been removed.

Building 926 was constructed on a concrete slab foundation in 1921 as an airplane hangar. The structure was used most recently for automotive body work, painting, and recharging and draining batteries. The aerial photograph taken in 1963 shows ground staining adjacent to the west wall of Building 926 (Rindgen and Sitton, 1990). Outside the north wall of the building are several transformers on metal rails. This area was also used for the storage of paints, waste solvents, and old batteries (Figure 6.1-3). The smaller buildings adjacent to Building 926 (Buildings 929, 930, and 931) were used for storage of materials used in Building 926. Building 927 is adjacent to the northwest corner of Building 926 and was used to store transformers. Materials used in and around this building complex include lead-based paints, waste oils, degreasing solvents, electrolytes, and thinners (including xylene). The area between Buildings 930 and 931 was used for steam cleaning and formerly contained an

underground concrete oil-water separator that was periodically drained. Building 929 also served as a compressed air plant. During a site investigation by RLSA, staining was observed on the back, outside wall of Building 929, beneath a window. The area behind Building 931 was used for vehicle spray painting and temporary drum storage. The Enhanced PA (ANL, 1989) indicates that four USTs, each with a 10,000-gal capacity and unknown contents, were reportedly removed from the vicinity of Building 929 in 1942.

Building 933, built in 1921, was used for aircraft maintenance and as a boiler house. Prior to base closure, the building was used for storage of tires, acetylene and nitrogen tanks, hardware, sandblasting sand, and a variety of new and used machinery parts. Buildings 934 and 935, located just east of Building 933, were both constructed in 1921. Building 934 was used for vehicle maintenance, and Building 935 was a storage area. An inactive UST with a capacity of 500 gal and unknown contents was thought to exist near the southeast corner of Building 934 (WES, 1990). In the Basewide Corrective Action Plan (Montgomery Watson, 1996a), however, it was concluded that this tank did not exist. Aerial photos interpreted by Rindgen and Sitton (1990) do not show any evidence of ground staining or storage in the vicinity of Buildings 933, 934, and 935.

An aerial photograph from 1948 (Pacific Aerial Surveys, 1948) shows what appears to be four aboveground tanks approximately 300 ft east of the center of Building 933. A 1945 map (Post Engineers Office, 1945) shows gasoline pumps in this location. The tanks are not seen in subsequent photographs or a 1949 map showing planned additions to buildings in the study area (Post Engineers Office, 1949).

Building 937 was the main PSF vehicle maintenance shop. The structure was built in 1921 on a concrete slab foundation. Materials used or generated at this building include solvents, waste oils, fuels, paints, and thinners. A 1948 aerial photograph (Pacific Aerial Surveys, 1948) shows what appear to be five outdoor maintenance ramps on the north side of the building. By 1955 some of the ramps had been removed and ground staining is evident (Pacific Aerial Surveys, 1955). Three of the outdoor vehicle maintenance ramps, which were used for changing oil, remain in this area.

When the RI field program began in 1990 there were reportedly two inactive USTs near Building 937. One of the USTs, on the north side of Building 937, was reportedly used for waste oils and/or paint and lacquer thinner, diesel fuel, carburetor cleaners, and degreasing solvents (ANL, 1989 and WES, 1990). The second one, near the northeast corner of Building 937, was reportedly used to store xylene (WES, 1990). During excavations conducted during the IRA, two joined USTs with capacities of 500 and 1,000 gal were found near the north wall of Building 937 (WJE, 1993d). The IRA was initiated in response to RWQCB Order 91-082, issued May 31, 1991. Piping connecting the USTs to the vehicle maintenance ramps was also removed as part of the IRA. Based on a visual inspection, the USTs and piping did not appear to be damaged although the piping joints were loose. The UST reported near the northeast corner of Building 937 was not found.

Building maps from the Post Engineers Office (1945) show that in 1945 there was a building approximately 70 ft east of the northeast corner of Building 937. The building, Building 938, was similar in size and orientation to the buildings in the Storage Area (949, 950, 973, and 974) and was a paint and repair shop (Post Engineer Office, 1945). A photograph from 1948 (Pacific Aerial Surveys, 1948) shows a dark area on a paved wash rack on the bay side of Building 938 (Figure 6.1-3). The photographs also indicate that the area between Buildings 938 and 937 was used for outside storage. In the 1973 photograph there is a dark area outside the east wall of Building 938. Aerial photographs indicate that between 1973 and 1988 the building was demolished; however, the concrete slab foundation remains. The U.S. Army (WES, 1990) located an inactive 50- to 75-gal UST, reportedly used as a hydraulic oil reservoir for a lift rack, near the concrete.

6.1.2.2 Storage Area (Buildings 949, 950, 973, 974)

Buildings 949, 950, 973, and 974 were located in the central portion of the study area. They were demolished by the NPS in 1996. These buildings were open structures that were used for storage of materials, vehicles, and equipment. POL materials used in the maintenance activities of Building 937 were drummed and stored in Building 950. Equipment used for sandblasting was stored in Building 973. The area between Buildings 973 and 974 was used

for sandblasting. The sand and paint chips were periodically removed from the concrete surface in this area (ANL, 1989).

Aerial photos indicate that in 1945 and 1959 the area north of these storage buildings was used for outdoor storage of vehicles and equipment and potentially for the storage of drums. In a 1963 aerial photograph and subsequent aerial photos, the area was no longer being used for storage. A 1988 aerial photo shows that drums were stored outside the southwest corner of Building 950.

6.1.2.3 Building 979

Building 979 was located at the northern end of the study area, approximately 660 ft northwest of Building 937. It was demolished by the NPS in 1996. This building was constructed in the early 1900s as a mine storage facility but was converted to a vehicle maintenance building with a gas station. A 1946 "Printing Plant" plan refers to part of the building as a "Tank House." Building plans prepared in 1956 show an equipment repair room, a floor pit with a drain, a paint shop, hydraulic lifts, repair bays, and lubricating bays. Most recently, the building was used for storage of construction materials and paints. Construction materials and transformers were also stored in front of and beside this building, although transformers were not present during the RI sampling program.

In January 1982, approximately 50 to 100 gal of waste POL were reportedly spilled from a storage tank immediately east of Building 979. The spill was reportedly quickly contained (ANL, 1989). The Enhanced PA Report indicates that there were three abandoned above-ground gasoline tanks located in the vicinity of Building 979. Two inactive USTs, with capacities of 5,000 gal each, were located on the northeast corner of this building. The contents are unknown, but suspected to be diesel fuel (WES, 1990). In addition, a 5,000-gal UST used to store fuel oil was located slightly east of Building 979, adjacent to Building 976. Building 976 was also demolished by the NPS in 1996. The tank was removed in 1993, and confirmation samples from the excavation, as well as subsequent adjacent samples, showed that concentrations in soil were below action levels developed in the FPALDR. USTs have been removed from the Building 979 Area and confirmation soil samples collected as part of the USCOE UST management program.

6.2 SAMPLE LOCATION RATIONALE

Potential contaminant sources evaluated in the Building 900s Series Study Area are USTs, maintenance and storage buildings, and outdoor storage areas. The sampling program for each potential source is discussed in context of the conceptual model presented in Section 3.1 and shown on Figure 3.1-1. Some of the chemical releases in the study area are documented, such as a surface spill from overflowing a tank in the vicinity of Building 979. Other potential contaminant sources in the Vehicle Maintenance and Storage Areas are not as clearly defined. Aerial photographs and information on historical and current activities suggest that there may have been surface spills and/or leaks from equipment in these areas.

The sampling program in the vicinity of Building 937 was designed and conducted before the USTs and associated piping and soil were removed during the IRA. The RI program was conducted to assess the distribution of chemicals associated with this probable source. To characterize the source of the subsurface release, free product samples were collected from wells that had measurable thicknesses of product. Product samples were also collected from accessible USTs near Building 937.

Contamination released by subsurface spills may initially result in the accumulation of contaminants in subsurface soils. Over time, infiltration of water through the contaminated soil may result in the migration of these compounds to deeper soil, and eventually to the groundwater. To evaluate the effect of infiltration on contaminant distribution in the Building 937 area, soil samples were collected from different depths. One soil sample was obtained from immediately above the water table and another from a shallower depth, generally between 3 to 6 ft bgs, or at a different depth if staining was observed.

As discussed in Section 6.1.3, previous investigations in the vicinity of Building 937 documented the presence of organic chemicals in the groundwater. Once chemicals are in the groundwater they can migrate away from the source by advection, dispersion, and diffusion. To evaluate the extent and migration of chemicals dissolved in the groundwater, a more extensive monitoring array was installed in the study area (Figures 6.2-1 and 6.2-2). Deep, intermediate, and shallow wells were installed to assess potential vertical variations in contaminant concentrations in groundwater.

The RI investigation of the surface spill near Building 979 was designed to confirm the effectiveness of remediation already performed at the site. The potential release mechanism considered was the infiltration of chemicals to subsurface soils and the groundwater. During the Initial RI, soil samples were collected from approximately 3 ft bgs and immediately above the water table. In addition, three shallow monitoring wells were installed and sampled. Review of the analytical data from the initial program indicated that chemicals were present in the soil and groundwater. Distinct dissolved phase plumes for chemicals emanating from Buildings 979 and 937 could not be identified. As a result, during the supplemental RI, additional subsurface soil samples were collected, and deep and shallow monitoring wells were installed. During the Follow-on RI field investigation, further assessment of the extent of chemicals was conducted through soil-gas sampling and the collection of discrete groundwater samples from three intervals in the aquifer: first encountered groundwater, an intermediate depth, and above bedrock.

Potential release mechanisms that were investigated in the Vehicle Maintenance and Storage Areas were the movement of contaminated soil particles by surface-water runoff and/or physical contact. Surface soil samples were collected from historically and currently stained areas to evaluate whether chemicals had accumulated in soil. The locations of these stained areas are presented on Figure 6.1-3, and the locations of the surface soil samples are presented in Figure 6.2-3. Wipe samples were collected from interior surfaces of buildings and outdoor paved areas to determine if chemical residues were present. Sediments from storm drains in the Vehicle Maintenance Area were collected to evaluate the influence of surface-water runoff on contaminant distribution. As part of the supplemental RI, subsurface soil samples were collected from areas that had detections of chemicals in surface soils but for which an apparent source had not been identified. In addition, results from a groundwater monitoring program in the Building 900s Series Study Area were used to assess the impact of surface spills.

Other potential sources in the Storage Area are the sand and paint chips created during the sandblasting conducted near Building 973. The primary release mechanism associated with the sandblasting activities is the leaching of chemicals from the paint chips and sand to the

soil. Surface soil samples were collected from beneath the accumulations of blasting sand to evaluate this release mechanism.

6.3 GEOLOGIC SETTING

The following description of the soils and geology, and hydrogeology in the Building 900s Series Study Area is based on the results of soil and well borings that were drilled in 1984 by USAEHA and in 1990 through 1995 as part of the RI and IRA field programs. The locations of all wells and soil borings are shown in Figures 6.2-1, 6.2-2, and 6.1-5. The lithologic logs for all wells and soil borings in the Building 900s Series Study Area are in Appendix D. A table summarizing the dates of well construction and the contractors that performed the installation is also in Appendix D.

6.3.1 Soils and Geology

This section discusses the soils and geologic units found in the Building 900s Series Study Area. The discussion progresses from the surface deposits to unconsolidated subsurface deposits to bedrock.

Most of the surface of the Building 900s Series Study Area is covered with concrete, asphalt, or a compacted sandy-silt fill. Several cross section were completed to illustrate the subsurface geology of the site (Figure 6.3-1). Cross sections A-A', B-B', and C-C' are shown in Figures 6.3-2, 6.3-3, and 6.3-4 respectively. Beneath the surface is artificial fill consisting of sand, silt, clay, and serpentinite and chert gravel. Thickness of the artificial fill material varies from approximately 1.5 to 7 ft. Construction debris consisting of concrete, wood, glass, brick fragments, and wire in a sandy or silty matrix was found in isolated areas with thicknesses ranging from 0.2 to 2.5 ft.

Beneath the artificial fill are sand deposits up to 37 ft thick (Well 979GW06) that end near the serpentinite cliff (Figures 6.3-2 and 6.3-3). The sand grain size and silt content vary laterally and vertically. The sand deposits are grayish brown or olive to dark gray, consist of angular and subangular grains, and are poorly to well sorted. In general, the coarsest grained sands are found in the most poorly sorted deposits. Many of the sand deposits contain shell

fragments that are the size of coarse sand. Layers of peat and other natural organic matter up to 0.9 ft thick were present in sand deposits at Wells 937GW34 and 937GW35. Trace amounts of organic matter are present in sand and clay deposits near Buildings 949, 950, 973, and 974. At Well 937GW01, located adjacent to the serpentinite cliff which borders the site to the southwest, sand deposits are absent and there is a 35-ft thick gray to gray green silty clay with medium to fine sand and traces of gravel. This unit is typical of weathered serpentinite and appears to be limited to the proximity of the cliff (Figure 6.3-3).

Clay and silt materials that vary in thickness from 1-in. lenses to deposits of 2.5 ft are interbedded with sand deposits in portions of the Building 900s Series Study Area such as the area near Building 937 (Figures 6.3-2, 6.3-3, and 6.3-4). The clay deposits in the study area are laterally continuous over only short distances. The most prominent and laterally extensive clay layer in the Building 900s Series Study Area was identified north of Building 937, as seen in Boring 937SO01, where a clay layer approximately 2.5 ft thick was encountered at 6 ft bgs. This clay layer appears to be thinner approximately 100 ft to the east, where it is less than 1 ft thick in Boring 937SO02 (Figure 6.3-4). This clay does not exist 50 ft to the northwest (937GW40) and is only 1 ft thick 75 ft to the southwest (937GW36). The clay texture varies vertically and laterally from predominantly clay to silty and sandy clay.

Schlocker (1974) described the surficial materials in the study area as modern beach sands and artificial fill. Interbedded clays and sands; the discontinuous nature of the materials; the occasional presence of gravel, shell fragments, and organic matter; and the distribution of sands throughout the site suggest that the native sediments were deposited in a beach-intertidal or estuarine environment. The clay units were probably deposited in a low-energy marsh environment. The lack of extensive or continuous clay deposits indicates that this area was dominated by a beach environment.

Bedrock in the Building 900s Series Study Area is predominantly the Franciscan Formation serpentinite and is Jurassic to Late Cretaceous in age (Schlocker, 1974). A sandstone member of the Franciscan Formation was encountered in the northern portion of the study area, in the boring for Well 979GW04. The serpentinite bedrock is exposed in the western

portion of the study area where it forms a cliff approximately 60 ft in height. The top of the bedrock surface is illustrated in the Bedrock Structural Contour Map (Figure 6.3-5). Depth to bedrock under the site generally increases from the cliff to San Francisco Bay, ranging from several ft next to the cliff to approximately 51 ft near the shoreline. In the central part of the study area, north of Building 937, there appears to be a valley in the bedrock surface. This paleovalley is approximately 100 ft wide and 10 ft deep. The axis of the paleovalley trends northeast from Well 937GW01, toward Well 937GW33. The bedrock surface of the paleovalley is steepest close to the cliff and slopes gently toward the bay.

6.3.2 Hydrogeology

This section discusses the hydrogeology of the Building 900s Series Study Area. Topics presented include the occurrence of groundwater, flow directions, the influence of tidal fluctuations in San Francisco Bay on groundwater flow, and the extent of saltwater intrusion into the aquifer.

The hydrogeologic investigation of the Building 900s Series Study Area was designed to assess the groundwater regime in the study area. Groundwater levels and hydraulic gradients were determined, and aquifer properties and tidal influences on groundwater flow were assessed. An array of 53 monitoring wells, shown in Figures 6.2-1 and 6.2-2, was used for the hydrologic investigation. Forty of the monitoring wells are screened in shallow portions of the aquifer, i.e. across the water table. Three of the wells are screened at intermediate depths in the aquifer. The remaining ten wells are screened at the bottom of the aquifer, immediately above the unweathered bedrock surface. Screen lengths range from 4.5 to 19 ft, though most are 10 ft. The construction details and installation dates of all wells in the Building 900s Series Study Area are summarized in Appendices D.2 through D.4. Between 1986 and the beginning of the RI field program in 1990, Well PSF-23 was abandoned. There is no available documentation of when or how this well was abandoned. During a site investigation by RLSA, no evidence of the well was observed. The U.S. Army acknowledges that this "lost well" is a potential conduit for water and, possibly, contaminants if it was not abandoned properly. The impact of this well as a conduit would likely be minimal because of the predominance of sand in this area.

The hydrologic data summarized in this section were compiled from work conducted as part of the RI and IRA. Pertinent portions of the IRA site characterization are included in this report. In the text, only representative examples of the results are presented. A more complete discussion of the IRA investigation is in the SGWPCR (WJE, 1993d) and the Effectiveness Report (WJE, 1993c).

6.3.2.1 Water-Bearing Zone/Aquifer

Groundwater flow in the Building 900s Series Study Area is within an unconfined aquifer consisting primarily of unconsolidated sand, with some clay and artificial fill. The aquifer is underlain by bedrock, primarily serpentinite, and is bounded on the west by a 60-ft cliff of serpentinite (Schlocker, 1974). To the east and northeast lies San Francisco Bay. To the south-southeast, the aquifer extends beyond the limits of the study area, as shown in the coastal zone water table elevation map for the entire PSF (Figure 2.3-6). The aquifer continues into the FPCGS, Crissy Field, and DEH Study Areas, which are all to the south-southeast (Figure 1.2-2). The aquifer pinches out northwest of the study area where the serpentinite bedrock intersects San Francisco Bay. Depth to bedrock data indicate that the aquifer generally thickens toward the bay. The aquifer thickness near the western edge of the study area ranges from 11.7 ft to 39 ft. Near the eastern edge of the study area the aquifer thickness ranges from 44 ft to 51 ft. The maximum thickness encountered was 51 ft in the central portion of the study area.

Recharge occurs from infiltration of precipitation into unpaved portions of the site. Most of the surface area, however, is paved and serviced by storm drains, which limits infiltration. Additional recharge probably originates from the upland area, south of the study area. Because the serpentinite bedrock, which has a relatively low permeability (Schlocker, 1974), probably does not contribute a significant amount of water to the aquifer. Discharge from the serpentinite has been observed at seeps near Baker Beach and Fort Point, and discharge from these seeps is at a very low rate.

6.3.2.2 Flow Directions and Hydraulic Gradients

Groundwater flow throughout the Building 900s Series Study Area is influenced by tidal fluctuations in San Francisco Bay, as demonstrated by the potentiometric surface maps

shown in Figures 6.3-6 through 6.3-13. Separate maps are presented for shallow and deep wells at higher-high and lower-low tides in both November 1992 and March 1995. These selected time periods represent relatively low and high groundwater conditions, respectively. The water levels in the 1995 wells are an average of 1.34 ft higher than the 1992 water levels. The maximum increase in water level between 1992 and 1995 was in Well 937GW01, which exhibited a difference of 6.77 ft. Only two wells, both in the northern part of the study area, had lower water levels in 1995 than in 1992. The higher water levels are probably the result of the unusually large amount of rainfall that occurred in the winter of 1994 and 1995. The potentiometric surfaces were contoured from manual water-level measurements of all wells in the study area.

The two primary sources for potential error in the potentiometric surfaces represented on these figures are the time taken between point measurements and variability in groundwater density. The water level data used in each potentiometric surface map were obtained within a period of approximately 30 minutes (exact times are shown on each map). The U.S. Army found that groundwater levels fluctuate up to 1.5 ft between tidal cycles (USAEHA, 1984), and the greatest change measured between higher-high and lower-low tides during RI investigations was 1.6 ft in Well 937GW39. Using 1.6 ft as a worst case fluctuation and assuming a tidal cycle of 6 hours, the maximum error associated with a measurement period of 30 minutes is estimated to be 0.13 ft. However, the average differences in water levels between tidal cycles for the 1995 measurements were 0.37 ft and 0.66 ft for the shallow and deep wells, respectively, suggesting that the actual error associated with each measurement is considerably less than 0.13 ft. In addition, the error in using these data to calculate horizontal gradients will be minimized by the proximity of wells in any given area. The time lapse between measurements at adjacent wells is only a few minutes. Further, the equipotential contour interval on each of the potentiometric surface maps is 0.2 ft, so the errors due to tidal fluctuations are not likely to dramatically affect the locations of individual contours.

Variations in groundwater density, as indicated by TDS and electrical conductivity (EC) values, occur across the site as a result of saltwater intrusion from San Francisco Bay into the aquifer (see Sections 2.3 and 6.3.2.5). Because the potentiometric surface maps are not

adjusted for this variability in groundwater density, there is some inaccuracy in the calculated hydraulic gradients. Groundwater elevations adjusted for a density of fresh water are higher than the unadjusted groundwater elevations. Estimates of the increase in shallow well hydraulic heads associated with density differences were, however, small in comparison to changes in head across the site. For example, the recalculated groundwater elevation based on the highest Follow-on RI TDS result, which was measured at Well 979GW04, is only 0.1 ft higher than that shown on the potentiometric maps. This is relatively small compared to the total change in head of approximately 2.0 ft along a flow path ending at Well 979GW04. This is not, however, the maximum difference at the site; Well 979GW04 is a shallow well, and adjustments in hydraulic heads associated with density differences are greater in deep wells than in shallow wells. The maximum underestimation of hydraulic head, based on the highest Follow-on RI TDS result in the deep zone (Well 979GW10), was approximately 1.12 ft. This larger error has a significant impact on the interpretation of vertical hydraulic gradients. Because of this impact, vertical gradients were only evaluated qualitatively, and the potential for vertical migration of chemicals in groundwater was assessed using chemical data collected over a five year period from multi-level well clusters; it was not predicted based on calculated vertical gradients (see Sections 6.4 and 6.5).

The November 1992 potentiometric surface maps indicate that during periods of relatively low groundwater levels, groundwater flow in shallow portions of the aquifer throughout most of the site is complex and controlled by the development of ridges and troughs that form in response to tidal fluctuations in San Francisco Bay. Figures 6.3-6 and 6.3-7 show that in some portions of the area there was a complete reversal in the direction of groundwater flow between high and low tides. During high tide, flow was inland, toward the south, south-southwest, and south-southeast and away from a groundwater mound near Building 949. During low tide, the direction of groundwater flow reversed and was predominantly to the north and north-northwest, toward San Francisco Bay. In the south-central portion of the site, complete reversals in the direction of groundwater flow appear to be related to tidal magnitudes. In the southernmost portion of the site, near Buildings 924 and 926, groundwater levels and flow directions are not affected by tidal fluctuations in San Francisco Bay. Groundwater flow in this area generally reflects the regional hydraulic gradient (Figure

2.3-2). The regional gradient was not discernible throughout most of the Building 900s Series Study Area in November 1992 because tidal fluctuations tended to dominate the more regular regional flow path.

The March 1995 shallow well potentiometric surface maps for high and low tide (Figures 6.3-8 and 6.3-9) were created for the monitoring well network that was present after the 1995 Follow-on RI field investigation. These data, which represent higher groundwater conditions than the 1992 data, illustrate different groundwater flow directions than the 1992 potentiometric maps. The groundwater flow directions for the March 1995 high and low tidal sequences are essentially the same, generally to the northeast. In the northern part of the site, groundwater flow is to the north-northeast; and in the central and southern parts of the site, groundwater flow is to the northeast. This is consistent with the regional flow direction. Flow directions in the southern portion of the site are similar to those found in 1992. The 1995 potentiometric maps indicate that, unlike 1992, discharge to the bay is occurring during both high and low tides. From this information, it is apparent that tidal influence does not significantly alter shallow groundwater flow directions in the Building 900s Series Study Area during periods of relatively high groundwater levels.

In November 1992, the groundwater flow in deep portions of the aquifer differed from that in the shallow portions. The potentiometric maps in Figures 6.3-10 and 6.3-11 are based on water-level measurements from high and low tides in wells that are screened at the bottom of the aquifer. These are referred to as deep wells. During high tide, groundwater generally flowed inland. During low tide, groundwater flow directions in the vicinity of the storage buildings reversed toward the bay. Due to tidal influence, deep groundwater flow in this area is complex, flowing north, east, and west, depending on the tidal stage. Measured water level fluctuations between high and low tides ranged from 0.5 to 1.6 ft, with the greatest change measured in Well 937GW39, which is the closest well to the shoreline.

During the Follow-on RI field investigation, three additional deep wells were installed in the Building 900s Series Study Area. The potentiometric surface maps for high and low tides using 1995 data are presented in Figures 6.3-12 and 6.3-13. As was the case for the shallow portions of the aquifer, the deep groundwater flow directions at high and low tides were

generally the same. This is likely due to the large amount of recharge overshadowing the tidal affects on the groundwater flow direction. In addition, groundwater flow directions in the deep portion of the aquifer were generally the same as in the shallow portion for both high and low tides in March 1995.

Horizontal hydraulic gradients calculated from the potentiometric surface maps ranged from 0.001 to 0.03 ft/ft in shallow portions of the aquifer and 0.002 to 0.012 ft/ft in deep portions of the aquifer (Table 6.3-1). The potentiometric maps show that the steepest gradients are south of Building 937, in the vicinity of Building 926 and the uplands recharge area.

Qualitative estimates for the vertical gradients were made by comparing the potentiometric surfaces between the shallow and deep wells. This qualitative comparison showed that the 1992 and 1995 vertical gradients were generally the same. The 1995 higher-high tide maps (Figures 6.3-8 and 6.3-12) show an upward vertical gradient between Building 937 and the shoreline and in the very northern portion of the study area, near Building 979. Immediately to the north of Building 937 the vertical gradient is downward. The vertical gradient in the southern portion of the Building 900s Series Study Area could not be assessed because of the lack of deep wells in this area.

6.3.2.3 Tidal Studies

Tidal studies were conducted in selected wells using pressure transducers and specific conductance/temperature probes attached to data loggers. The data were used to further assess the effects of tidal fluctuations in San Francisco Bay on groundwater flow and the movement of inorganic solutes in the Building 900s Series Study Area. The water level data provided information on changes in the potentiometric surface, and the specific conductance data were used to further define the nature of the saltwater/freshwater interface and qualitatively define the flux, or mass transport, of inorganic solutes through the aquifer.

In all, eight tidal studies were conducted to characterize the hydrogeology in the study area. A summary of the wells used and a record of stages in San Francisco Bay during each tidal study are in Appendix P and the SGWPCR (WJE, 1993b). The first three tidal studies (RI Tidal Studies 1, 2, and 3) were conducted in the fall of 1990 as part of the RI. Five

additional tidal studies (IRA Tidal Studies 1 through 5) were conducted in the fall of 1991 as part of the IRA field investigation, and these included monitoring of groundwater specific conductance in addition to water levels and temperature. While this section provides only a summary of the technical approach and the data collected for the IRA tidal studies, the data are presented in detail in the SGWPCR (WJE, 1993d). Bay stage data were measured during the RI and IRA Tidal Studies at the FPCGS by the National Oceanic and Atmospheric Administration, Tidal Datum Section.

As discussed in the preceding section of this RI report, manual water level measurements indicated that wells in the southern portion of the Building 900s Series Study Area were least influenced by tidal fluctuations. Water levels recorded during the tidal studies provide corroborating evidence to support this conclusion. This is illustrated in Figure 6.3-14, which shows average stage ratios (the ratio of change in groundwater elevation to change in bay stage) for shallow wells monitored during RI Tidal Studies 1 through 3. The decrease of stage ratio values in a southern direction and perpendicular to the shoreline indicate a decrease in tidal influence in this direction. The angle of the contours relative to the shoreline suggests that the transmissivity of the aquifer may be heterogeneous since the decreasing stage ratio is evidently not due entirely to increasing distance from shore.

Analysis of data from RI Tidal Study 3 and IRA Tidal Studies 1 and 2 indicates that groundwater fluctuations in deep and shallow portions of the aquifer are different. The amplitude of water-level fluctuations in deep wells was greater than in shallow wells. Figure 6.3-15 shows water-level hydrographs and specific-conductance versus time graphs for two sets of adjacent deep and shallow wells monitored during IRA Tidal Study 1. The hydrographs show that groundwater fluctuations between high tide and low tide cycles in deep wells (937GW32 and 937GW29) were approximately 0.1 to 0.5 ft greater than those in the adjacent shallow wells (937GW06 and 937GW05). Similar patterns were observed during IRA Tidal Study 2 and RI Tidal Study 3.

The different responses of deep and shallow portions of the aquifer result from changes in the nature of the aquifer with depth. Greater response to tidal fluctuations would result from either an increase in hydraulic conductivity or a decrease in aquifer storage. The storage

term associated with an aquifer is a parameter used to indicate the volume of water an aquifer will release, per unit surface area of aquifer, under a unit decline in hydraulic head. In unconfined aquifers, a decline in head results in the dewatering of pore spaces, which is quantified by the specific yield. In a confined aquifer, pore spaces are not dewatered. Rather, head changes are related to changes in fluid pressure and the compressibility of the aquifer material (Erskine, 1991). The storage term used in conjunction with confined aquifers is the storage coefficient or storativity. In general, storativity values are several orders of magnitude smaller than specific yields. In the case of the Building 900s Series Study Area, the deep portions of the aquifer are behaving in a semi-confined fashion. Even though there apparently are no extensive confining or semi-confining layers within the aquifer, the differences are attributed to changes in storage coefficient, rather than changes in hydraulic conductivity, with depth. The impact of this observation on the understanding of groundwater flow and contaminant transport is that the chemical distribution in deep portions of the aquifer may differ from the distribution in shallow portions. This distribution is discussed in detail in Section 6.5.

6.3.2.4 Aquifer Properties

The potentiometric surface maps and tidal study data discussed in Sections 6.3.2.2 and 6.3.2.3 indicate that the influence of tidal fluctuations in San Francisco Bay on groundwater flow varies laterally and vertically. The influence of heterogeneity in the aquifer material on groundwater flow was evaluated by calculating hydraulic conductivity using rising-head slug tests.

The data were evaluated using the Bouwer and Rice (1976) rising-head slug test method. Hydraulic conductivity values calculated with this method provide information only on the materials in the vicinity of the tested well. Results were used to evaluate spatial variability in the aquifer and were not extrapolated to untested portions of the aquifer. The method of analysis and the recovery curves from which hydraulic conductivities were calculated are provided in the SGWPCR (WJE, 1993d).

The hydraulic conductivity values calculated using the rising-head slug test method ranged from 31 to 110 ft/day (Table 6.3-2 and Figure 6.3-16). Two tests were conducted at each

well, and the distribution of average hydraulic conductivities indicates that there is some variability in the aquifer materials. Lithologies include clay and coarse sand, but at the scale of the Building 900s Series Study Area, these variations do not appear to control hydraulic conductivity.

The hydraulic conductivity values calculated during the Stetson Engineers, Inc. (1986) hydrogeologic investigation of the Building 937 Area were generally lower than those found during the IRA, ranging from less than 1 ft/day to 58 ft/day, (Figure 6.3-16). The lower values may be the result of poorly defined recovery curves. The Stetson Engineers, Inc. analyses consisted of two to six water-level measurements as opposed to ten to twenty water-level measurements at each well during the IRA tests.

The heterogeneity of the aquifer is illustrated in Figure 6.3-14, which shows average stage ratios for shallow wells monitored during RI tidal studies. The stage ratio (ratio of change in groundwater elevation to change in bay stage) values show that propagation of a wave front into the aquifer is at an acute angle to the shoreline and decreases in a southern direction. This may be related to varying transmissivity. Aquifer geometry may also be contributing to the complex groundwater flow in the Building 937 Area.

6.3.2.5 Saltwater/Freshwater Interface and Saltwater Intrusion

In a coastal aquifer, such as the one in the Building 900s Series Study Area, both saltwater and freshwater are typically present. Figure 2.3-10 is a schematic illustration of the interface of fresh groundwater and saltwater in the Building 900s Series Study Area. The position and configuration of the saltwater/freshwater interface is governed by the volume of groundwater discharged from the aquifer to the bay. One characteristic feature of coastal aquifers is that saline water, because of its greater density, remains below the freshwater in a wedge shaped intrusion. There is a gradation from fresh to saline water in an area called the zone of diffusion. In this zone, saline and fresh groundwater are mixed. As the amount of mixing increases, the concentration of ions in the groundwater increases to levels similar to that of bay water. To illustrate seawater intrusion and estimate the areal extent of non-potable water beneath the Crissy Field Groundwater Area, maps showing the distribution of TDS and EC in groundwater, are included in Figures 2.3-11 and 2.3-12 respectively.

TDS results for groundwater were compiled, and average values for sampling events were used to create a coastal zone TDS isoconcentration map which includes the Building 900s Series Study Area (Figure 2.3-11 and Appendix R, Table R-4). The distribution of TDS data with depth is important when discussing saltwater intrusion in that TDS values tend to increase with depth as indicated in Figure 2.3-10. The central and northwestern portion of the Building 900s Series Study Area contains wells screened in the shallow, intermediate, and deep portions of the water bearing zone. Data from these wells generally indicate an increase in TDS concentrations with depth, representing significant saltwater intrusion.

TDS results suggest that much of the aquifer below the Building 900s Series Study Area is located within the diffusion zone of the saltwater/freshwater interface. The TDS values were generally between 200 and 21,000 mg/L. Such values indicate brackish water (Drever, 1982). The California Water Resources Control Board (CWRCB) has established a TDS level of less than 3,000 mg/L within an aquifer as suitable for use as a municipal or domestic water source (Resolution No. 88-63). Approximately 30 percent of the Building 900s Series Study Area is underlain by groundwater exceeding this 3,000 mg/L TDS standard. In addition, average TDS concentrations indicate that all of the study area is underlain by groundwater exceeding the California recommended secondary MCL for TDS (500 mg/L). Lines estimating the areal extent of groundwater exceeding these two standards are shown on Figure 2.3-11.

Figure 2.3-12 shows the EC distribution in groundwater below the Crissy Field Groundwater Area. The distribution of EC data with depth is important when discussing saltwater intrusion in that EC values tend to increase with depth as indicated in Figure 2.3-10. Data from the Building 900s Series Study Area clearly indicate a wedge shaped saltwater intrusion and a corresponding overall increase of EC with depth.

EC data indicate that a large percentage of the Building 900s Series Study Area is underlain by groundwater exceeding the regulatory EC standard of 5,000 $\mu\text{S}/\text{cm}$ for potential municipal or domestic water supplies (California State Water Resources Control Board Resolution No. 88-63). Most of the Building 900s Study Area is underlain by groundwater

exceeding the recommended secondary MCL of 900 $\mu\text{S}/\text{cm}$. Lines estimating the areal extent of groundwater exceeding these two standards are shown on Figure 2.3-12.

In the Building 900s Series Study Area, where there were multi-level data available for both TDS and EC, there is a striking similarity between areas with TDS and EC values exceeding regulatory standards for potential municipal or domestic water supplies (Figures 2.3-11 and 2.3-12). This similarity indicates that the EC and TDS data correlate well in this area.

Vertical variations in electrical conductivity documented during the Follow-on sampling were used to illustrate saltwater intrusion in the Building 900s Series Study Area. In addition, the extent of saltwater intrusion was evaluated by examining lateral and vertical variations of specific conductance measured during groundwater sampling (Figure 2.3-9).

The groundwater of the Building 900s Series Study Area has high TDS and specific conductivity due to naturally occurring ions. The distribution of the major cations in the groundwater indicates that both weathering and saltwater intrusion have contributed ions to the groundwater in the Building 900s Series Study Area. Major ions released by weathering are calcium, magnesium, potassium, and bicarbonate while saltwater intrusion adds sodium and chloride.

Three major water types have been identified in the Building 900s Series Study Area based on the distribution of major ions throughout the study area (WJE, 1993d). The character of the groundwater is determined by considering the relative concentration of ions in water rather than the sum of the concentrations of these ions measured by TDS or, indirectly, by specific conductance. In the Building 900s Series Study Area, saltwater-impacted groundwater has a sodium/chloride character, and groundwater impacted by weathering of native materials has a magnesium/bicarbonate character. Sodium/chloride groundwater is found in wells along the coast, while magnesium/bicarbonate groundwater is found in wells placed along the serpentinite outcrop or screened in the bedrock.

Sodium/magnesium/chloride groundwater is found between the two. The observed distribution of major ions in the groundwater reflects the hydrology and geology of the area rather than U.S. Army activities.

6.4 ANALYTICAL RESULTS

This section presents the analytical results for each potential contaminant source evaluated during the Initial, Supplemental, and Follow-on RI field programs at the Vehicle Maintenance, Storage, and Building 979 areas. Storage areas, surface spills, and USTs are the potential contaminant sources investigated in the Building 900s Series Study Area. The suspected source USTs at Building 937 were removed in 1992 under the IRA field program. The assessment of chemical compounds in the Building 900s Series Study Area was based on collecting wipe, sediment, soil, groundwater, and product samples. Sample locations are shown in Figures 6.1-2, 6.1-5, 6.2-1, 6.2-2, and 6.2-3.

The detection tables presented in this section show only chemicals that were detected above the CRL and/or RL. A full listing of the target analytes can be found in tables in Section 3.3 of this RI report. The complete chemical database is provided on computer diskette in Appendix O. All the sediment, soil, and groundwater samples contained common elements found in the environment, including calcium, potassium, magnesium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under most circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussion. All other inorganics detected in soil will be compared to ambient concentrations, as described in Section 3.7. Wipe samples were collected to determine the nature of chemicals on interior building and exterior paved surfaces. The data are qualitative and therefore were not used in the risk assessment. The identification of unknown compounds are discussed only if one or more of the evaluation criteria presented in Section 3.5 are met. Tentatively identified compounds are listed in the chemical database in Appendix O. Results affected by blank contamination are not discussed.

6.4.1 Vehicle Maintenance Area

This section presents the analytical results of each of the buildings (920 and 923 through 937) of the Vehicle Maintenance Area in the Building 900s Series Study Area. Sampling was conducted in the vehicle maintenance area during the Initial, Supplemental, and Follow-on RI field programs and as part of the FS. All sampling events are summarized in this section. Samples collected to evaluate a specific building are discussed first, and samples used to more specifically define the extent of chemicals of concern are discussed at the end of the section.

6.4.1.1 Buildings 920 through 935

Building 920. Building 920 was investigated during the Follow-on RI to determine if soils beneath the building had been impacted by potential leaks from a hydraulic lift located inside the northeast corner of the building. One soil boring (920SB01) was drilled inside the building, approximately 9 ft south of the lift. Samples were collected at 0.5, 5.0, and 7.5 ft bgs and analyzed for inorganics, TPH-D, and TPH-G. The soil boring location is shown on Figure 6.1-5, and all detections above the RL are presented in Table 6.4-1.

Inorganic concentrations in the shallowest sample (collected from beneath concrete) were compared to ambient values for fill materials. The two deeper samples were comprised of native deposits and were compared to ambient values for the beach/dune lithology type. The only inorganics detected above ambient levels were cobalt, chromium, and nickel, all in the shallow soil sample. There were no detections of TPH-D or TPH-G in any of the samples.

Building 924. Building 924 was used for servicing large vehicles and temporarily storing drums and waste products (ANL, 1989). During the Initial RI, five wipe samples (900W01, 900W02, 900W18, 900W19, and 900W20) were collected in and near Building 924 and analyzed for SVOCs. Target compounds were detected above the CRL only in samples collected inside Building 924 (900W01 and 900W02) (Table 6.4-2). Bis(2-ethylhexyl) phthalate was detected in both 900W01 and 900W02, and di-n-butylphthalate was detected in sample 900W01.

A sediment sample was collected near the northwest corner of Building 924 (900SD02) during the initial RI (Figure 6.1-2). The sample was analyzed for inorganics, VOCs, SVOCs, and TPH. Numerous inorganics were detected. VOCs and SVOCs were not detected. TPH was detected at a concentration of 3,000 $\mu\text{g/g}$ (Table 6.4-3).

Three surface soil samples (900SS02, 900SS04, and 900SS05) were collected in artificial fill behind Building 924 during the Initial RI. The samples were analyzed for inorganics, VOCs, and SVOCs. Three additional surface soil samples were collected in support of the FS from this same area (900SS11, 900SS12, and 900SS13) and two subsurface soil samples (0.7 and 2.5 ft bgs at Boring 925SB01). These samples were analyzed for inorganics, TPH-G, and TPH-D. Sample locations are shown of Figures 6.1-5 and 6.2-3 and analytical results are summarized on Tables 6.4-4, 6.4-5, and 6.4-6. Additional soil samples were collected as part of the Initial RI and analyzed for lead and VOCs. These results (Table 6.4-7) are discussed later in this section.

Inorganic concentrations in the three Initial RI samples and in sample 900SS13 were compared to ambient concentrations for fill materials. Detections in samples 900SS11 and 925SB01 were compared to ambient values for beach/dune deposits. Results from sample 900SS12 were compared to ambient values for serpentinite derived soils. Inorganics detected above ambient fill values were aluminum, cadmium, copper, lead, and zinc in sample 900SS02, copper, lead, and zinc in sample 900SS04, chromium, lead, and nickel in sample 900SS05, and arsenic and lead in sample 900SS13. A larger suite of inorganics was detected above ambient values in sample 900SS11, which was compared to beach/dune ambient values. Inorganics above ambient were aluminum, barium, chromium, copper, mercury, manganese, lead, nickel, and zinc. Chromium and nickel were also above ambient values in both samples from Boring 925SB01 and cobalt was above ambient in the shallower sample from this boring. Arsenic, lead, and zinc were above ambient values for serpentinite derived soils in sample 900SS12.

Trichlorofluoromethane, methylene chloride, and bis(2-ethylhexyl)phthalate were the only organic compounds detected in sample 900SS04. Methylene chloride and several PAHs were detected at concentrations above the CRL in sample 900SS05 (Table 6.4-4). SVOC

unknowns were identified in surface soils samples 900SS02 and 900SS04 at concentrations of 500 and 1,200 $\mu\text{g/g}$, respectively. The compounds were tentatively identified by the laboratory as unknown hydrocarbons. TPH-D was detected in all samples collected for the FS, at a maximum concentration of 21 $\mu\text{g/g}$.

Building 926. Three wipe samples (926W01, 926W02, and 900W03) were collected inside Building 926 (Figure 6.1-2). Two of the samples (926W01 and 926W02) were collected near battery storage shelves in Building 926 and analyzed for inorganics. The concrete surface wiped for 926W01 was corroded, wet and stained. The concentrations of inorganics detected in this sample were greater than in 926W02 (Table 6.4-8). The third wipe sample (900W03) was collected next to a floor drain in the building and analyzed for SVOCs. Bis(2-ethylhexyl)phthalate was the only compound detected in this sample.

Two surface soil samples (900SS14 and 900SS15) were collected in support of the FS and were analyzed for inorganics, TPH-D, and TPH-G (Table 6.4-5). The inorganics detections were compared to ambient fill levels. Chromium, lead, and zinc were found to exceed ambient in 900SS14, and lead exceeded ambient in 900SS15. TPH-D was detected at 37 $\mu\text{g/g}$ in 900SS14, and TPH-G was not detected in either sample.

Building 927. Two wipe samples were collected near the transformers inside Building 927 in 1990 as part of the Initial RI (Figure 6.1-2). Both samples were supposed to be analyzed for PCBs, however, the analysis was not performed because the laboratory hold time was exceeded. The transformers were sampled as part of an ongoing survey conducted by RLSA in 1992. The transformers contained less than 5 ppm PCB and therefore, are classified as non-PCB contaminated transformers. Follow-on soil samples were collected to evaluate any potential impacts to soil outside the building due to the transformers (Figure 6.1-5). Samples were collected at 0.5 and 2.0 ft bgs in each of two borings, 927SB01 and 927SB02, and analyzed for PCBs. As shown on Table 6.4-9 there were no detections of PCBs. The sum of the RLs for the various PCBs is well below the SDC of 1 $\mu\text{g/g}$ for total PCBs.

Building 929. Wipe and surface soil samples were collected in and near Building 929, respectively (Figures 6.1-2 and 6.2-3). No target analytes were detected in the wipe sample (900W04), which was analyzed for SVOCs (Table 6.4-2). The surface soil sample (900SS07) was collected behind Building 929 in artificial fill and was analyzed for inorganics, VOCs, and SVOCs during the Initial RI. Additional surface soil samples (900SS16 and 900SS17) were collected in support of the FS and were analyzed for inorganics, TPH-D, and TPH-G. Inorganic concentrations in all soil samples associated with Building 929 were compared to ambient values for fill materials.

Chromium, lead, nickel, and zinc concentrations exceeded ambient fill values in samples 900SS07 and 900SS16. In sample 900SS17, barium, chromium, lead, cadmium, copper, and zinc concentrations exceeded ambient values. All other inorganics were below ambient concentrations. Methylisobutyl ketone, methylene chloride, and 1,3-dimethylbenzene were the only VOCs detected in sample 900SS07. Bis(2-ethylhexyl)phthalate, phenanthrene and one PCB (at 0.422 $\mu\text{g/g}$) were also detected in the sample. TPH-D was detected in surface soil samples 900SS16 and 900SS17, at a maximum concentration of 130 $\mu\text{g/g}$. There were no detections of TPH-G.

Buildings 930 and 931. Wipe samples were collected inside Buildings 930 and 931 and analyzed for SVOCs (Figure 6.1-2). The sample from Building 930 (900W06) was collected near a wash rack and that from Building 931 (900W07), near a shelf holding solvents and paints. Target analytes were not detected in the sample from Building 931. Bis(2-ethylhexyl)phthalate was the only SVOC detected in the other interior wipe sample (Table 6.4-2). A total of 40 SVOC unknowns were detected in sample 900W06 at average concentrations of approximately 0.2 $\mu\text{g/cm}^2$. The unknowns were tentatively identified by the laboratory as unknown hydrocarbons.

The area between Buildings 930 and 931 was previously used for steam cleaning. A wipe sample (900W05) was collected near a storm drain in this area and a sediment sample (900SD03) was collected from the storm drain (Figure 6.1-2). In addition, two surface soil samples were collected near Building 931 (900SS01 and 900SS06) during the Initial RI (Figure 6.2-3). The sediment and soil samples were analyzed for inorganics, VOCs, and

SVOCs. An additional surface sample (900SS18) was collected in support of the FS and analyzed for inorganics, TPH-D, and TPH-G. The three surface soil samples from this area are comprised of artificial fill and inorganic concentrations therefore are compared to ambient values for fill materials. During the Supplemental RI, a subsurface soil sample was collected near the surface soil samples to assess the vertical distribution of lead (Figure 6.1-5). The sample, 931SB01, was collected from 2 to 2.5 ft bgs in weathered serpentinite and analyzed for the full suite of Supplemental RI analytes.

Numerous inorganics were detected in the sediment sample and both Initial RI surface soil samples (Tables 6.4-3 and 6.4-10). With the exception of mercury, vanadium, and zinc, the concentration of inorganics in both Initial RI soil samples was greater than in the adjacent storm drain sample (900SD03).

Inorganics detected above ambient values in surface soil samples were chromium and lead in all three samples; barium, cadmium, copper, and zinc in sample 900SS01; cadmium, copper, mercury, and zinc in sample 900SS06; and nickel in sample 900SS18. Only barium was detected above ambient concentrations in the subsurface soil sample from this area (Boring 931SB01).

VOCs and SVOCs were detected in two surface soil samples (900SS01 and 900SS06) and the sediment sample (900SD03) near Building 931. Tetrachloroethene was detected in both surface soil samples (Table 6.4-10). Methylene chloride, trichlorofluoromethane, bis(2-ethylhexyl)phthalate, and one PCB (at 0.355 $\mu\text{g/g}$) were detected only in sample 900SS06 and 1,4-dichlorobenzene detected only in sample 900SS01. The concentration of bis(2-ethylhexyl)phthalate in the sediment sample adjacent to sample 900SS06 was greater by several orders of magnitude (Table 6.4-3). 1,3-Dimethylbenzene, toluene, and TPH were also detected in the sediment sample. None of these VOCs and SVOCs were detected in the subsurface sample from Boring 931SB01. Organics detected in 931SB01 were di-n-butylphthalate, OCPs and TPH-D (Table 6.4-11). TPH-D was also detected in surface soil sample 900SS18. The maximum concentration of TPH-D in the vicinity of Buildings 930 and 931 was 90 $\mu\text{g/g}$. SVOC unknowns were identified at concentrations of 1,600 and 800

$\mu\text{g/g}$ in 900SS01 and the sediment sample from 900SD03, respectively. The unknowns were tentatively identified by the laboratory as unknown hydrocarbons.

Building 933. Two wipe samples (900W08 and 900W09) were collected from stained areas inside Building 933, which is used for storage (Figure 6.1-2). The samples were analyzed for SVOCs. Bis(2-ethylhexyl)phthalate was the only compound detected in 900W09. Target analytes were not detected in the other wipe sample (Table 6.4-2). A surface soil sample (900SS08) was collected behind Building 933 in artificial fill and analyzed for inorganics, VOCs, and SVOCs during the Initial RI (Figure 6.2-3). An additional surface soil sample, 900SS19, was collected in support of the FS. Inorganic concentrations in both samples were compared to ambient values for fill materials. Chromium, lead, nickel, and zinc were detected above ambient concentrations in both samples. Mercury exceeded ambient in sample 900SS08. Methylene chloride, bis(2-ethylhexyl)phthalate, and one PCB (at $3.53 \mu\text{g/g}$) were the only organic compounds detected in the sample 900SS08 (Table 6.4-10). TPH-D was detected at $11 \mu\text{g/g}$ in surface soil sample 900SS19 (Table 6.4-5).

Three surface soil samples (900SS09, 900SS20, and 900SS21) were collected north of Building 933, along the base of the cliff behind the vehicle maintenance area (Figure 6.2-3). All samples were analyzed for inorganics, two samples for TPH-D and TPH-G, and one sample (900SS09) was also analyzed for VOCs and SVOCs. Results are presented in Tables 6.4-5 and 6.4-12. Inorganics in each sample were compared to ambient values for fill materials. Lead was detected above ambient in all three samples, with a maximum concentration of $730 \mu\text{g/g}$. Barium, chromium, cyanide, mercury, nickel, and zinc exceeded ambient in sample 900SS09; barium and zinc exceeded ambient in 900SS20; and arsenic, barium, mercury, and zinc in exceeded ambient in sample 900SS21. Detected TPH-D concentrations were below $100 \mu\text{g/g}$ and TPH-G was not detected in any of the samples.

Buildings 934 and 935. One interior wipe sample was collected in Buildings 934 and 935 and analyzed for SVOCs (900W16 and 900W17) (Figure 6.1-2). Phthalates were the only compounds detected above the CRL in these samples (Table 6.4-2). Sediment sample 900SD01 was collected from a storm drain approximately 75 ft east of the

southeast corner of Building 934 and analyzed for inorganics, VOCs, SVOCs, and TPH (Figure 6.1-2). Approximately 2 ft of water was in the storm drain during sampling. Numerous inorganics, bis(2-ethylhexyl)phthalate, two PAHs, and TPH were detected in the sample (Table 6.4-3). A surface soil sample (900SS10) and two subsurface soils samples (0.9 and 2.5 ft bgs at Boring 937SB17) were collected in artificial fill near Building 935 (Figures 6.1-5 and 6.2-3). Cadmium, copper, lead, and zinc were detected at concentrations above ambient values for fill materials in the surface sample (Table 6.4-10). However the cadmium concentration exceeded the ambient value by only 0.03 $\mu\text{g/g}$. Chromium and nickel concentrations in the 2.5 ft bgs sample from Boring 937SB17 exceeded ambient values (Table 6.4-6). Methylene chloride, and four PAHs were detected above CRLs. TPH-D was detected in both subsurface soil samples from Boring 937SB17, at a maximum concentration of 12 $\mu\text{g/g}$.

Subsurface soil samples were collected east of Building 935 during the installation of Well 937GW38 and analyzed for inorganics, VOC, TPH-D, and TPH-G (Figure 6.2-2). Inorganic detections in these samples were compared to ambient values for beach/dune deposits. With the exception of antimony, which was detected at 3.0 and 6.5 ft bgs, no inorganic concentrations exceeded ambient values (Table 6.1-2). VOCs and TPH were not detected in either of these samples.

Area Behind Buildings 924 through 933. Follow-on RI work was deemed necessary along the base of the cliff behind Buildings 924 through 933 because of detected lead concentrations ranging from 339 to 4,700 $\mu\text{g/g}$, and the detection of methylene chloride in several surface soil samples. Two samples were collected from each of eight borings (92431SB01 through 92431SB08) along the edge of the pavement west of the buildings (Figure 6.1-5). Boring locations were evenly spaced from the southern edge of Building 924 to approximately the center of Building 933. Samples were collected at 0.5 and 2.0 ft bgs and analyzed for VOCs and lead; result are shown on Table 6.4-7. No VOCs were detected above the RL, and lead concentrations were detectable in only two samples: 34 $\mu\text{g/g}$ in Boring 92431SB03 at 0.5 ft bgs and 57 $\mu\text{g/g}$ in 92431SB05 at 2.0 ft bgs. These lead detections were below the ambient concentrations for fill and serpentinite, respectively.

6.4.1.2 Building 937

The area in and around Building 937 was the subject of the most extensive sampling program in the Building 900s Series Study Area. The primary focus of the investigation was to assess the nature and extent of contamination suspected to be emanating from the USTs and/or piping near Building 937. To accomplish this, surface and subsurface soil, groundwater, and product samples were collected during the Initial RI field program. Wipe and sediment samples were collected to evaluate whether surface spills had occurred. Additional soil and groundwater samples were collected near Building 937 and two USTs were removed as part of the IRA. This section describes the sampling programs and results for each of these sample types.

The target analyte list for the IRA investigation is in Table 6.1-3. Soil results were presented previously in Section 6.1.3. The inorganic soil, groundwater, and product analytical results from the IRA are discussed in this section. The analytical data for soil samples analyzed during the UST removal are provided in Appendix R. Chemical sources in the soil that were removed as part of the IRA include:

- floating product from beneath Building 937, adjacent to a previously undocumented UST cradle
- tanks and associated piping for two connected USTs containing BTEX compounds and solvents
- two wells that contained product comprised primarily of BTEX compounds
- approximately 1,000 yd³ of soil contaminated with VOCs, TPH-D and TPH-G. Details on the IRA are provided in the SGWPCR (WJE, 1993d).

6.4.1.2.1 Wipe, Sediment, and Surface Soil Sampling Program and Results

Wipe samples were collected from stained areas inside Building 937 and near the covered vehicle ramp on the north side of the building (Figure 6.1-2). Phthalates were the only compounds detected in the six samples (900W10 through 900W15) analyzed for SVOCs (Table 6.4-2). A surface soil sample (900SS03) was collected from between the two outdoor vehicle maintenance ramps and analyzed for inorganics, VOCs, and SVOCs (Figure 6.2-3). The sample was collected in stained artificial fill and all inorganic detections were below

ambient values for fill materials (Table 6.4-12). VOCs and known SVOCs were not detected. The total concentration of unknown SVOCs was approximately 500 $\mu\text{g/g}$ in sample 900SS03. The compounds were tentatively identified by the laboratory as unknown hydrocarbons.

Sediment and surface soil samples (900SD04 and 900SS09, respectively) were collected near the southwest corner of Building 937 (Figures 6.1-2 and 6.2-3). Both samples were analyzed for inorganics, VOCs, and SVOCs. In addition, the sediment sample was also analyzed for TPH. Inorganics detected in the soil sample were also detected in the sediment samples (Tables 6.4-3 and 6.4-12). The concentrations of chromium, cobalt, mercury, nickel, vanadium, and cyanide were greater in the surface soil sample than in the sediment sample. The sediment sample had higher concentrations of barium, lead, manganese, and zinc. Arsenic, beryllium, and cadmium were detected only in the sediment sample. The inorganic concentrations in the surface soil sample were compared to ambient values previously, in Section 6.4.1.1 in the summary of results near Building 933. Only one organic compound, methylene chloride, was detected in the soil sample (Table 6.4-12). Organics detected in the sediment sample include nine PAHs and TPH.

Surface soil sampling was conducted at the northwest corner of Building 937 during the initial RI (900SS03) and during the FS sampling of November 1992 (900SS22). The locations of these samples are shown on Figure 6.2-3. Sample 900SS03 was analyzed for inorganics, VOCs, and SVOCs (Table 6.4-12). The inorganics results were compared to ambient fill concentrations, and there were no exceedences. Sample 900SS03 did not contain detectable VOC or SVOC concentrations. Sample 900SS22 was analyzed for inorganics TPH-D and TPH-G (Table 6.4-5). The sample was composed of fill material. The sample contained lead at a concentration of 370 $\mu\text{g/g}$, which exceeds the ambient fill concentration. The soil also contained TPH-D at 970 $\mu\text{g/g}$ exceeding the SDC of 100 $\mu\text{g/g}$.

6.4.1.2.2 Subsurface Soil Sampling Program and Results

Subsurface soil samples were collected outside the north and east walls of Building 937 and analyzed for VOCs and SVOCs (Figure 6.1-5). The samples were taken to assess the distribution of floating product and the extent of migration of chemicals from the suspected

source. At each location, samples were taken from two depths: approximately 2 to 5 ft bgs within the unsaturated zone; and from immediately above, or partially or entirely within, the saturated zone. The deep samples from sites 937SO01 and 937SO06 were taken above the water table. Samples from sites 937SO03, 937SO04, and 937SO07 were within the saturated zone. At the remaining two locations, the deep samples straddled the saturated and unsaturated zones. Additional subsurface soil samples were collected in support of the IRA and analyzed for inorganics, VOCs, and SVOCs. Results for these samples were presented previously in Section 6.1.3 (Table 6.1-2) and the distribution of VOCs and TPH were also discussed. In this section, inorganic results for samples from Borings 937SB14, 937SB15, and 937SB16 and Wells 937GW36 and 937GW37 are summarized. All the data are integrated in Section 6.5 of this RI report.

Inorganic concentrations in the soil samples collected in Fall of 1992 for the IRA were compared to ambient values for beach/dune deposits, except for the samples from the boring for Well 937GW36, which was compared to ambient values for fill. Antimony was detected above the ambient value of 0.1 $\mu\text{g/g}$ in all samples, at concentrations ranging from 7 to 14 $\mu\text{g/g}$. Arsenic was detected above the ambient value in the saturated zone sample from Well 937GW37, at 5.6 $\mu\text{g/g}$.

VOCs were not detected in shallow or deep soil samples collected along the east wall of Building 937 (937SO03, 937SO05, and 937SO06), except for chlorobenzene in the deep (saturated zone) sample from Boring 937SO03. PAHs were detected in all shallow samples and in only one deep sample, 937SO03B, from this area (Table 6.4-12). The highest PAH concentrations in the shallow zone were in sample 937SO03A. With the exception of phenanthrene, different PAHs were detected in the shallow and deep sample from sample 937SO03. The closest groundwater sample is from Well 937GW03. SVOCs detected in this groundwater sample were naphthalene and 2-methylnaphthalene, both of which were detected in the deep soil sample, and 1,2-dichlorobenzene, which was detected only in the shallow sample from sample 937SO03. VOCs were also detected in the groundwater sample from Well 937GW03.

North of Building 937, acetone and bis(2-ethylhexyl)phthalate were the only organic compounds detected in shallow soil samples, 937SO07A and 937SO01A, respectively. Organic compounds were not detected in the deep sample from 937SO01. Acetone and methylene chloride were detected in deep soil samples from 937SO02 and 937SO07 and bis(2-ethylhexyl)phthalate in sample 937SO04B. The closest shallow groundwater sample collected near the north wall of Building 937 is from Well 937GW11, from which a product sample was also collected. The suites of VOCs and SVOCs detected in the groundwater and product samples were different than those in the soil from the north side of Building 937. Unknown VOCs and SVOCs were identified in soil samples 937SO03B and 937SO01A, respectively. The total unknown VOC concentration was 5,000 $\mu\text{g/g}$. The sum of SVOC unknowns was 250 $\mu\text{g/g}$. The VOC and SVOC compounds were tentatively identified by the laboratory as unknown hydrocarbons.

6.4.1.2.3 Groundwater Sampling Program and Results

Groundwater samples were collected in the Building 937 Area during 13 sampling events between October 1990 and January 1995. The first sampling event included 23 wells and was conducted in Fall of 1990 as part of the Initial RI. Samples were analyzed for the full suite of compounds: inorganics, VOCs, SVOCs, and TPH. Analytical results for these samples are shown in Table 6.4-13. A full listing of Initial RI results is in Appendix O. The remaining sampling events were conducted as part of the IRA quarterly monitoring program. Fifteen wells were sampled in October 1991, December 1991, and March 1992 (sampling events 2, 3, and 4, respectively). Samples were analyzed for major cations and anions, VOCs, and TPH. Subsequent sampling events (sampling events 5 through 13, respectively) included all accessible wells in the Building 937 Area and chemical analyses for the full inorganics suite, in addition to VOCs, TPH-D, and TPH-G. These sampling events were conducted at the following times:

- October 1992
- April, July, and October 1993
- January, April, July, and October 1994
- January 1995.

Table 6.4-14 summarizes the results of the 13 sampling events, showing the frequency and range of detections for each well. Data affected by laboratory blank contamination are not included in this summary table. The table includes summary statistics only for detected compounds. A full listing of results for the IRA sampling events is provided in Appendix O.

In the following presentation of groundwater results, the data from the Initial, Supplemental, and Follow-on RI and IRA sampling programs are integrated to provide an overall assessment of the distribution of inorganics and organic compounds in the area. Trends in chemical distribution over time are discussed in Section 6.5.

Inorganics. Full suite inorganic groundwater analyses were conducted on samples collected during sampling event 1 and sampling events 5 through 13. Both filtered and unfiltered samples were collected during each of these events with exception of sampling event 1, which included only filtered samples. Inorganic analyses during sampling events 3, 4, and 5 were limited to the major ions.

The distribution of major ions and TDS are not addressed in this section, although analytical results are summarized in Tables 6.4-13 and 6.4-14. The common ions (calcium, magnesium, potassium, sodium, chloride, sulfate, and alkalinity) are indicative of natural groundwater chemistry and are not the result of U.S. Army activities. The distribution of major ions was discussed previously in Sections 2 and 6.3, and are also presented in detail in the SGWPCR (WJE, 1993d).

In this summary of inorganics, results are divided into three groups based on the frequency and spatial distribution of unfiltered detections. The first group includes ubiquitous constituents, i.e., those that occurred in nearly every well during each sampling event. The second group includes constituents that occur less frequently but in at least 50 percent of the wells, and the last group includes inorganics that are rarely, if ever, detected at concentrations above the reporting limit. Within each group, the filtered results are also presented. Comparison of filtered and unfiltered results is useful in distinguishing between inorganic constituents that are sorbed to particulate or colloids and those that are truly dissolved. Inorganics that are sorbed are generally less mobile than inorganics that occur in a dissolved phase. In general, filtering of groundwater samples removes colloids and

suspended particles from the sample and therefor reduces analyte concentrations. Results for Wells 937GW02 and 937GW11 are excluded from the following summary of results because unfiltered samples were not collected from these wells. In addition, both wells were removed as part of the IRA at Building 937. As shown in Table 6.4-14, the concentration of filtered inorganics in these wells were higher than in other wells due to the presence of free product. For each inorganic constituent discussed in this section, the ranges of concentrations within the Building 937 Area are based on the maximum concentration at each well, regardless of sampling event. Where the range in maximum concentrations across the site is large, an average of maximum values is also provided.

Frequently Detected Inorganics. Inorganic constituents that were consistently detected during each sampling event are aluminum, barium, chromium, iron, manganese, and nickel. The maximum concentration of aluminum ranged from 330 to 26,100 $\mu\text{g/L}$, with the highest detection occurring in a sample from Well 937GW01. Minimum and maximum unfiltered aluminum concentrations at each well varied by over an order of magnitude in approximately half of the wells sampled. Filtering of groundwater samples significantly reduced the concentration and frequency of aluminum detections. Of the 36 wells with filtered sample results (excluding Wells 937GW02 and 937GW11), filtered aluminum was never detected at 16 wells and had a frequency of occurrence of 25 percent or lower in 18 wells. Excluding the two existing wells that have historically contained product (937GW03 and 937GW36), the maximum concentration of filtered aluminum ranged from 100 to 1,200 $\mu\text{g/L}$, with an average maximum concentration of 345 $\mu\text{g/L}$. Filtered aluminum concentrations in the existing wells that contain product were higher, with a maximum concentration of 15,000 $\mu\text{g/L}$. The absence of filtered aluminum is due to complexing of the ion to form aluminum hydroxide colloids, which occurs naturally in groundwater (Hem, 1989).

Unfiltered barium concentrations were less variable than for aluminum, with minimum and maximum concentrations varying by less than an order of magnitude in all but a few wells. Maximum concentrations ranged from 19 to 820 $\mu\text{g/L}$, with the maximum occurring at Well 937GW21. Filtering of groundwater samples had a minimal effect on the frequency and

concentration of barium detections. Maximum concentrations in filtered samples ranged from 50 to 330 $\mu\text{g/L}$, with the maximum still occurring at Well 937GW21.

Chromium concentrations ranged from 1.2 to 34,000 $\mu\text{g/L}$, with the maximum concentration in a sample from Well 937GW37. The mean concentration of chromium at this well, 4,910 $\mu\text{g/L}$, was considerably lower than the maximum value. Minimum and maximum concentrations of chromium varied by less than an order in magnitude in approximately 60 percent of the wells. Filtered chromium was detected at least once in each well, but filtering of samples reduced the frequency of detection at each well by approximately 10 to 20 percent. The effect of filtering on chromium concentrations was most pronounced in wells that had concentrations in excess of 200 $\mu\text{g/L}$. Maximum chromium concentrations at these wells (937GW01, 937GW07, 937GW19, 937GW22, 937GW36, and 937GW37) were between one to three orders of magnitude lower than in the unfiltered samples. The maximum filtered chromium concentrations, exclusive of wells that were removed as part of the IRA, ranged from 5.7 to 63 $\mu\text{g/L}$.

With one exception, unfiltered iron was detected in all wells during each sampling event. Maximum iron concentrations varied from 470 to 88,800 $\mu\text{g/L}$, with the highest detection occurring at Well 937GW21. At approximately 70 percent of the wells, the minimum and maximum iron concentrations varied by less than an order of magnitude. The impact of filtering on the frequency of iron occurrence varied considerably, resulting in all non-detects at two wells to no impact at 11 wells (i.e., detections during every event); the frequency of occurrences at the remaining 24 wells ranged between these two extremes. Maximum filtered iron concentrations were generally lower than unfiltered iron concentrations, ranging from 240 to 48,000 $\mu\text{g/L}$. Decrease in maximum iron concentration as a result of filtering ranged from small to up to an order of magnitude, though at most wells, concentrations decreased by a factor of 2 or 3.

Unfiltered manganese was detected during each sampling event at all but four wells. The maximum unfiltered manganese concentrations ranged from 55 to 3,400 $\mu\text{g/L}$, with the highest detection occurring at Well 937GW22. Minimum and maximum values of manganese varied by less than an order of magnitude at almost 90 percent of the wells.

Filtering had a minimal impact on the maximum concentration of manganese at each well, with maximum concentrations in filtered samples ranging from 42.3 to 3,000 $\mu\text{g/L}$. In addition, the frequency of occurrence was reduced only slightly in the filtered samples as compared to the unfiltered samples, with no detections occurring at only one well (937GW15).

Unfiltered nickel detections occurred at a frequency of greater than 75 percent in all but six wells. Nickel concentrations ranged from maximum values of 6 to 630 $\mu\text{g/L}$ (Wells 937GW42 and 937GW01, respectively). Minimum and maximum values of unfiltered nickel varied by less than an order of magnitude at almost 90 percent of the wells. Nickel concentrations in filtered groundwater samples were generally lower than in the unfiltered samples, with the maximum concentrations ranging from 6.3 to 190 $\mu\text{g/L}$. The greatest decreases in maximum concentrations as a result of filtering were in wells where the unfiltered nickel concentration exceeded 300 $\mu\text{g/L}$ (Wells 937GW01, 937GW07, 937GW19, and 937GW22). Maximum filtered nickel concentrations at these four wells were over an order of magnitude lower than the unfiltered concentrations.

Moderately Detected Inorganics. Inorganic constituents that were detected less frequently than those discussed as frequently detected inorganics but were detected in at least 50 percent of the wells were arsenic, cadmium, cobalt, copper, lead, vanadium, and zinc. Maximum unfiltered arsenic concentrations ranged from 5 to 87 $\mu\text{g/L}$, with the maximum concentration during each sampling event usually occurring at Well 937GW21. At Wells 937GW01, 937GW21, and 937GW38, unfiltered arsenic was detected during each of the sampling events. Unfiltered arsenic was consistently below the reporting limit at six wells (937GW07, 937GW23, 937GW27, 937GW33, 937GW41, and 937GW43). At most of the remaining wells, unfiltered arsenic was detected at a frequency less than 50 percent, with detections occurring during non-consecutive sampling events. The frequency of arsenic detections was greatly reduced by sample filtering. Ten wells had no detections of filtered arsenic, 17 wells had a frequency of detection less than 25 percent, and three wells had detections during each sampling event (the same three wells with consistent unfiltered detections). Although filtering of samples had a significant influence on the occurrence of arsenic, concentrations at wells where it

was detected were reduced by fairly insignificant amounts, with maximum filtered concentrations ranging from 3.7 to 63 $\mu\text{g}/\text{L}$. This is probably due to the relatively low concentrations of unfiltered arsenic throughout the site.

Unfiltered cadmium was detected in 18 of the 36 quarterly monitored wells. The frequency of detection was 50 percent or less at most of these wells. The only wells to have a frequency of detection greater than 75 percent were Wells 937GW07 and 937GW19. Maximum concentrations of unfiltered cadmium ranged from 0.51 to 3.9 $\mu\text{g}/\text{L}$ at all wells except Well 937GW07, where the maximum concentration was 70 $\mu\text{g}/\text{L}$. Filtered cadmium was not detected in 27 wells and occurred with a frequency of 20 percent or less in nine wells. Well 937GW07 was the only well with a higher frequency of detection (75 percent). Filtered cadmium concentrations were below 2.3 $\mu\text{g}/\text{L}$ in all wells except Well 937GW32. There was a one time, unconfirmed, detection of filtered cadmium in this well at 31 $\mu\text{g}/\text{L}$ during sampling event 1.

Unfiltered cobalt was detected in four wells at a frequency greater than 50 percent (937GW01, 937GW07, 937GW19, and 937GW22), 14 wells at a frequency less than 50 percent, and not at all in the remaining 18 wells. Maximum concentrations of unfiltered cobalt ranged from 10 to 74 $\mu\text{g}/\text{L}$. Filtering of groundwater samples resulted in consistent non-detects of filtered cobalt in all but three quarterly monitored wells (937GW22, 937GW37, and 937GW42). Filtered cobalt was detected during only one of the multiple sampling events at each of these wells. The maximum concentration was 14 $\mu\text{g}/\text{L}$.

Unfiltered copper was detected in all quarterly monitored wells, with maximum concentrations ranging from 1.1 to 52 $\mu\text{g}/\text{L}$, except at Well 937GW12, where the maximum unfiltered copper concentration was 440 $\mu\text{g}/\text{L}$. Although this single detection of 440 $\mu\text{g}/\text{L}$ was found to be a statistical outlier in a trend plot analysis of all data from Well 937GW12, this well had the highest unfiltered copper concentration during each sampling event, with a second highest maximum concentration of 150 $\mu\text{g}/\text{L}$. The frequency of unfiltered copper detections varied throughout the site, with slightly more than half of the wells having a detection frequency greater than 50 percent. Most of these detections occurred during consecutive sampling events, beginning with sampling event 7 in the summer 1993.

Unfiltered copper detections were generally non-consecutive at wells with a frequency of detection lower than 50 percent. Filtering of groundwater samples reduced the frequency of detections at most wells, with only a third of the wells having frequencies greater than 50 percent. The wells that showed the greatest decrease in detection frequency as a result of filtering were generally those in the southern portion of the study area (Wells 937GW12 and 937GW16 through 937GW21). Filtered copper concentrations were lower than unfiltered concentrations, with a maximum concentration of 25 $\mu\text{g/L}$, excluding a statistical outlier at Well 937GW12 (86 $\mu\text{g/L}$). There were no other detections of filtered copper at Well 937GW12, indicating that the high unfiltered concentrations observed at this well are due to copper being sorbed to particulates and/or colloids.

Unfiltered lead was detected at all quarterly monitored wells, except Well 937GW23, however only three wells had detections during each sampling event and six wells had a frequency of detection greater than 75 percent. Detections at most of these wells have been consecutive for the past year. The highest lead detections were at Wells 937GW03, 937GW07, and 937GW19, with a maximum concentration of 180 $\mu\text{g/L}$ (trend plot analyses showed that a higher value of 680 $\mu\text{g/L}$ at Well 937GW07 was a statistical outlier). Maximum unfiltered lead concentrations at all other wells was considerably lower, ranging from 1.2 to 36 $\mu\text{g/L}$. Filtering of groundwater samples greatly reduced the frequency of lead detections, with 23 wells having no detection of filtered lead and the other 12 quarterly monitored wells having only one detection out of multiple sampling events (between eight to eleven events). Filtered lead concentrations in the quarterly sampled wells ranged from 1.4 to 19 $\mu\text{g/L}$, with the highest detection occurring in a well that has historically contained free product (937GW03). The second highest filtered lead detection was 8.81 $\mu\text{g/L}$. The great reduction in the frequency and concentration of lead in the filtered samples, as compared to the unfiltered samples, indicates that the mobility of lead in the groundwater is limited. This same pattern was observed at other study areas at the PSF.

Unfiltered vanadium was detected in 21 of the 36 wells in the Building 937 Area. The frequency of detections was greater than 50 percent in only ten of these wells.

Concentrations of unfiltered vanadium ranged from 5 to 110 $\mu\text{g/L}$, with an average maximum value of 37 $\mu\text{g/L}$. The frequency of vanadium detections in filtered samples was

significantly lower than in the unfiltered samples. Filtered vanadium was detected in only 10 wells, out of which only three wells had more than a single detection (Wells 937GW01, 937GW29, and 937GW38). These three wells are all screened immediately above the serpentinite bedrock. Filtered vanadium concentrations in the quarterly monitored wells were slightly lower than unfiltered concentrations, ranging from 5 to 25 $\mu\text{g/L}$.

Unfiltered zinc was detected in all but two wells, with the maximum concentration of 700 $\mu\text{g/L}$ at Well 937GW07 (exclusive of a statistical outlier at this well of 3,500 $\mu\text{g/L}$). Maximum concentrations at other wells were considerably lower, ranging from 6 to 130 $\mu\text{g/L}$ (exclusive of outliers). The frequency of unfiltered zinc detections was relatively low, with only 10 wells having detections during at least 50 percent of the sampling events and two wells (937GW07 and 937GW19) having detections during each sampling event. The frequency of zinc detections was decreased by filtering, with five wells having no filtered zinc detections, two wells having detection frequencies greater than or equal to 50 percent, and the remaining sampled wells having inconsistent detections. Filtering had a minimal effect on the concentration of zinc, with filtered zinc concentrations ranging from 6 to 160 $\mu\text{g/L}$ (exclusive of outliers), at all wells except Well 937GW07. The maximum concentration of filtered zinc at this well was 367 $\mu\text{g/L}$.

Infrequently Detected Inorganics. Inorganic constituents with a high percentage of non-detects are silver, beryllium, mercury, molybdenum, antimony, selenium, and thallium. Unfiltered silver was detected in 15 of 36 wells, with multiple detections occurring in only seven of these wells. Concentrations of unfiltered silver ranged from 0.50 to 19 $\mu\text{g/L}$, except at Well 937GW20, where there was a detection of 150 $\mu\text{g/L}$ that has not been confirmed by subsequent sample results. Concentrations in filtered samples were considerably lower, with a maximum concentration of 2.2 $\mu\text{g/L}$. In addition, only eight wells had detections of filtered silver; three with multiple detections and the remaining five with single detections.

There were only two beryllium detections in the Building 937 Area. Unfiltered beryllium was detected once at Well 937GW08 and filtered beryllium was detected at Well 937GW02. Molybdenum was detected in unfiltered samples from Well 937GW37 at a maximum

concentration of 44 $\mu\text{g/L}$. There were no other detections of molybdenum, in either filtered or unfiltered samples. Antimony was detected in unfiltered samples during two non-consecutive sampling events at Well 937GW15 at a maximum concentration of 15 $\mu\text{g/L}$. Anomalously, the frequency and concentration of antimony detections in the filtered samples were considerably higher than in the unfiltered, with 29 wells having filtered antimony detections. These detections, which range in concentration from 5.0 to 91 $\mu\text{g/L}$, are attributed to the filter medium. This conclusion is supported by the results of controlled laboratory studies conducted for the Corps of Engineers. Their study showed that the filters contain a significant amount of antimony that is mobilized by the movement of water through the filter (Call, personal communication, 1994).

Unfiltered mercury was detected at seven wells, two of which had multiple detections. Concentrations were relatively low, ranging from 0.11 to 0.38 $\mu\text{g/L}$. Filtered mercury detections were limited to samples collected during sampling event 6. The one exception was at Well 937GW39, where filtered mercury was also detected during sampling event 8. Concentrations of filtered mercury ranged from 0.19 to 0.9 $\mu\text{g/L}$. There were six wells with detections of unfiltered selenium; concentrations ranged from 5 to 44 $\mu\text{g/L}$. All of these detections were one time events that were not confirmed by subsequent sampling events. All but one of the detections occurred during sampling event 11. The five wells that had unfiltered selenium detections during sampling event 11 also had detections of filtered selenium at very similar concentrations during the same event. The filtered results were not confirmed by subsequent sampling, suggesting that the detections may be due to laboratory procedures, although selenium was not detected in the associated blank samples. There were only two filtered selenium detections associated with other sampling events; the maximum filtered selenium concentration was 14.9 $\mu\text{g/L}$. Thallium was detected in only one sample during the 13 sampling events, at a concentration of 1 $\mu\text{g/L}$ in Well 937GW17.

Organic Groundwater Sample Results. Two major types of VOCs have been consistently detected in the Building 937 Area, BTEX compounds and chlorinated compounds. As described in this section, the distribution of each of these compound groups indicate a source area near Building 937. The source was two USTs, associated soil, and product that were removed in 1992 as part of the IRA.

BTEX Compounds. BTEX compounds were consistently detected in four wells; 937GW02, 937GW03, 937GW11, and 937GW36. These wells are located within or adjacent to Building 937 and have historically contained either a measurable thickness or sheen of free product. Some emulsification of product in groundwater may have occurred during sampling of Wells 937GW02 and 937GW11, resulting in concentrations that are not indicative of filtered BTEX in groundwater. Although Wells 937GW03 and 937GW36 contained some amounts of product, it was removed while purging the well and probably did not affect the samples.

Prior to the IRA source removal at Building 937, the highest concentrations of BTEX compounds were detected in samples from Wells 937GW02 and 937GW11. Groundwater samples were collected from these wells during sampling events 1 through 4. Both wells were removed as part of the IRA source removal action in 1992. Well 937GW02 contained concentrations of benzene ranging from 300 to 1,000 $\mu\text{g/L}$, toluene from > 750 to 10,000 $\mu\text{g/L}$, ethylbenzene from 400 to 900 $\mu\text{g/L}$ and xylenes from > 1,500 to 5,000 $\mu\text{g/L}$. The range of detections in Well 937GW11 are: benzene 77.4 to 140 $\mu\text{g/L}$, toluene 7 to 26 $\mu\text{g/L}$, ethylbenzene 6 to 16 $\mu\text{g/L}$, and xylenes 302 to 1,000 $\mu\text{g/L}$.

Well 937GW03 has been sampled during all 13 sampling events and has contained BTEX compounds at maximum concentrations of 72 $\mu\text{g/L}$ (benzene), 42 $\mu\text{g/L}$ (toluene), 64 $\mu\text{g/L}$ (ethylbenzene), and 170 $\mu\text{g/L}$ xylenes. Well 937GW36 was installed in 1992 as a replacement for Well 937GW11, after the source removal at Building 937. BTEX compounds have been consistently detected at this well during each of the nine sampling events (events 5 through 13), with maximum concentrations of benzene, toluene, ethylbenzene, and xylenes of 1,000, 220, 83, and 870 $\mu\text{g/L}$, respectively.

Benzene, toluene, and/or xylenes were detected sporadically in 11 other wells in the Building 937 Area (Wells 937GW01, 937GW10, 937GW12, 937GW15, 937GW17, 937GW21, 937GW23, 937GW28, 937GW31, 937GW41, and 937GW42). The frequency of BTEX compound detections at these eleven wells was low and concentrations were much lower than in the source area, as described below. In the remaining 23 wells in the area, there were no detections of BTEX compounds.

Benzene, toluene, or xylene was detected during only one of nine to 13 sampling events at Wells 937GW10, 937GW12, 937GW15, 937GW21, 937GW28, and 937GW42. Benzene and/or toluene were detected in two out of 10 or 13 sampling events at Wells 937GW01, 937GW23 and 937GW17. At deep Well 937GW31, benzene was detected during three of 13 sampling events and toluene during one of the 13 events. There were no other BTEX compound detections in wells screened at the bottom of the water-bearing zone. Well 937GW41, an intermediate depth well located in the source area, was the only other well with multiple detections; benzene was detected during three of four sampling events.

BTEX compound concentrations were generally an order of magnitude lower in the eleven wells without product than in those containing product. The highest benzene detection was 22 µg/L in an intermediate well (937GW41) located adjacent to Building 937, within the source area. All other benzene detections were limited to wells regionally downgradient of the source area (937GW23, 937GW28, 937GW31, and 937GW42), with a maximum concentration of 3.5 µg/L at Well 937GW31. The one exception was at regionally upgradient Well 937GW21, where benzene was detected at 0.57 µg/L.

Toluene detections in wells not associated with product occurred at Wells 937GW01, 937GW10, 937GW23, and 937GW31, with a maximum concentration of 4.6 µg/L. These wells are regionally downgradient, or cross gradient, from the source area. Detections of toluene upgradient of the source area were at Wells 937GW12, 937GW15, and 937GW17, with a maximum toluene concentration of 2.8 µg/L. The only xylene detection outside of the source area was at Well 937GW12, where the compound was detected once, at a concentration of 1.5 µg/L.

Chlorinated Compounds. Chlorinated compounds were in numerous wells in the Building 937 Area, with the highest concentration near the northeast corner of Building 937. A total of 10 different chlorinated compounds were detected in the Building 937 Area. In the following discussion, these compounds are divided into three groups: parent chlorinated compounds (tetrachloroethene and 1,1,1-trichloroethane), compounds that could be either parents or degradation products (trichloroethene and 1,1-

dichloroethane), and degradation products (1,1-dichloroethene, cis- and trans-1,2-dichloroethene, 1,2-dichloroethane, chloroethane, and vinyl chloride).

Parent solvents were detected in two shallow monitoring wells, 937GW02 and 937GW03, and one deep well, 937GW32. Tetrachloroethene detections all occurred during or prior to sampling event 5. The compound was detected during three of the four sampling events at Well 937GW02, and during one of the 13 events at Wells 937GW03 and 937GW32. The maximum tetrachloroethene concentration was 14 µg/L at Well 937GW02, located inside Building 937. The only other parent chlorinated solvent detected in the Building 937 Area was 1,1,1-trichloroethane in deep Well 937GW32 during sampling events 2 and 3, at concentrations of 400 and 1,000 µg/L, respectively.

Chlorinated compounds that could be either parent or degraded solvents were detected in 10 wells: seven shallow (937GW02, 937GW03, 937GW04, 937GW08, 937GW11, 937GW34, and 937GW35) and three deep (937GW31, 937GW32, 937GW40). Trichloroethene was detected in eight of these wells (all but Wells 937GW04 and 937GW11) at concentrations ranging from 0.5 to 45 µg/L in shallow wells and 1.4 to 820 µg/L in deep wells. 1,1-Dichloroethane was detected in four shallow wells and in one deep monitoring well. Detections were in Wells 937GW02, 937GW04, 937GW11, 937GW31, and 937GW34 and ranged from 0.5 to 20 µg/L.

Degradation products of chlorinated solvents were detected in 26 of the 38 quarterly monitored wells in the Building 937 Area. Consecutive detections of degraded chlorinated solvents occurred in more than half of these wells. Degraded solvents in the Building 937 Area, in order of increasing number of wells with detections are chloroethane (1 well) 1,1-dichloroethene and 1,2-dichloroethane (each in 2 wells), vinyl chloride (18 wells), and 1,2-dichloroethene (25 wells). The distribution of each of these degraded compounds is presented below and generally progresses from the least degraded chlorinated compounds (1,1-dichloroethene and 1,2-dichloroethene) to intermediary compounds (1,2-dichloroethane), and to the final degradation products (vinyl chloride and chloroethane). The actual degradation pathway for a particular parent compound does not necessarily include all the degradation compounds listed above.

Detections of 1,1-dichloroethene are limited to wells that have historically contained free product or are located adjacent to the northeast corner of Building 937. 1,1-Dichloroethene was detected twice in Well 937GW36 at a maximum concentration of 3.5 µg/L (sampling events 6 and 7) and once during sampling event 1 at deep Well 937GW31, at a concentration greater than 150 µg/L.

The frequency, concentration, and distribution of detections of 1,2-dichloroethene was greater than for any of the other chlorinated solvents detected in the Building 937 Area. In the following text, a distinction between results for cis-1,2-dichloroethene, trans-1,2-dichloroethene, and total-1,2-dichloroethenes is not made because during some sampling events the isomers were analyzed separately, and during others only a concentration for total-1,2-dichloroethene was derived. However, Table 6.4-14 summarizes the results for each of the isomers.

1,2-Dichloroethene was detected in three shallow wells that historically contain free product (937GW02, 937GW03, and 937GW36), 15 additional shallow wells, each of the three intermediate monitoring wells, and in four wells screened at the base of the aquifer. In the shallow wells with product, maximum 1,2-dichloroethene concentrations ranged from 41.2 to 600 µg/L. In comparison, the maximum detection in the other shallow wells was 54 µg/L (Well 937GW23). Maximum detections of 1,2-dichloroethene in the 14 remaining shallow wells (937GW04, 937GW05, 937GW06, 937GW12, 937GW15, 937GW20, 937GW22, 937GW26, 937GW27, 937GW28, 937GW33, 937GW34, 937GW35, and 937GW37) ranged from 0.5 to 9.7 µg/L.

Within the intermediate portions of the aquifer, 1,2-dichloroethene was detected in each well (937GW41, 937GW42, and 937GW43) during each of the four sampling events, at concentrations ranging from 4 to 800 µg/L. The maximum concentration was in a sample from Well 937GW41, which is located near the north exterior wall of Building 937. The maximum 1,2-dichloroethene detection within the Building 937 Area (2,400 µg/L) was in deep monitoring well (937GW40). Other deep wells with detections of 1,2-dichloroethene were north of Building 937: Maximum concentrations in samples from Wells 937GW31, 937GW32, and 937GW39 were 1,800 µg/L, 7.2 µg/L, and 3.4 µg/L, respectively.

Detections of 1,2-dichloroethane are limited to wells that have historically contained free product and are located within or immediately adjacent to the northeast corner of Building 937. Wells 937GW02 and 937GW03 contained detectable concentrations of 1,2-dichloroethane ranging from 1 to 170 $\mu\text{g/L}$. The highest detections were consistently in Well 937GW02, located inside Building 937. This well, and surrounding contaminated soil, were removed as part of the IRA (WJE, 1993d).

Chloroethane was detected only once in a sample from Well 937GW42. The concentration was very low, 0.52 $\mu\text{g/L}$, and has not been confirmed by results from other sampling events.

Vinyl chloride, the final degradation compound of chlorinated compounds, was detected in 14 shallow wells, three intermediate wells, and in one deep monitoring well. Consistent (i.e. multiple and consecutive) detections within the shallow aquifer were limited to wells north of or within Building 937, occurring at Wells 937GW02, 937GW03, 937GW22, 937GW23, 937GW28, and 937GW35). Consecutive detections of vinyl chloride south of Building 937 occurred only at Wells 937GW12 and 937GW20. Other detections south of Building 937 were isolated or non-consecutive, and occurred once at Well 937GW26 and twice (but during non-consecutive events) at Wells 937GW21 and 937GW27. The maximum concentration of vinyl chloride in the southern wells (4.1 $\mu\text{g/L}$) was over an order of magnitude lower than the maximum concentration in wells north of Building 937 (110 $\mu\text{g/L}$).

Vinyl chloride was detected in each of the three monitoring wells screened across the middle of the aquifer (Wells 937GW41, 937GW42, and 937GW42) at maximum concentrations ranging from 1.3 to 43 $\mu\text{g/L}$. Well 937GW31 was the only deep well in the quarterly monitoring program in which vinyl chloride was detected. The concentration ranged from 2.9 to 80 $\mu\text{g/L}$.

Other VOCs. There were few detections of VOCs other than the BTEX and chlorinated compounds discussed above. Acetone was detected during one of multiple sampling events at Wells 937GW04, 937GW18, 937GW35, during two sampling events at Wells 937GW02 and 937GW11, and during three sampling events at Well 937GW22. The maximum concentration was 91 $\mu\text{g/L}$ at Well 937GW22. There were one-time detections (out of multiple sampling events) of several other VOCs, which are shown on Table 6.4-

14. Wells with the greatest variety of VOC detections were those that have historically contained product: Wells 937GW02, 937GW03, 937GW11, and 937GW36. At all other wells, detections of VOCs other than BTEX, chlorinated solvents, and acetone are one time occurrences that are unconfirmed by subsequent sampling events. Wells with these isolated, single occurrence detections, are Wells 937GW10, 937GW16, 937GW17, 937GW19, 937GW21, 937GW24, 937GW29, 937GW31, 937GW32, 937GW33, 937GW35, and 937GW37.

SVOCs. Samples collected during the initial RI (sampling event 1) were the only groundwater samples analyzed for SVOCs. Eight wells contained SVOCs: three of which historically contained product (Wells 937GW02, 937GW03, and 937GW11); four additional shallow wells (937GW17, 937GW26, 937GW27, and 937GW28); and one deep well (937GW31).

Five different SVOCs were detected in the Building 937 Area. Naphthalene and 2-methylnaphthalene were both detected in samples from three shallow wells (937GW02, 937GW03, and 937GW11) and only the former in deep Well 937GW31. The maximum concentration of these compounds was 200 $\mu\text{g/L}$ at Well 937GW02. The only other SVOC detection adjacent to Building 937 was 1,2-dichlorobenzene in Well 937GW03. Bis(2-ethylhexyl)phthalate was detected in one well (937GW17) at a concentration of 79.2 $\mu\text{g/L}$ and 4-methylphenol was in three wells (937GW26 through 937GW28) at a maximum concentration of 42.1 $\mu\text{g/L}$. These four wells are all located south of Building 937 and the source area.

Unknown Compounds. The sum of unknown VOCs and/or SVOCs exceeded the evaluation criterion of 100 $\mu\text{g/L}$ in groundwater samples from Wells 937GW02, 937GW03, 937GW11, and 937GW31. Measurable thicknesses of floating product were present in Wells 937GW02 and 937GW11 and an oily sheen was observed on the surface of Well 937GW11 during sampling. The sum of VOC unknowns from Well 937GW02 was 5,500 $\mu\text{g/L}$. The highest identification was 3,000 $\mu\text{g/L}$ of an aromatic hydrocarbon. The SVOC unknowns totaled 19,000 $\mu\text{g/L}$ and were tentatively identified by the laboratory as saturated and aromatic hydrocarbons. The VOC and SVOC unknowns in

the sample from Well 937GW03 totaled 770 and 400 $\mu\text{g/L}$, respectively. The compounds were tentatively identified by the laboratory as unknown hydrocarbons. The unknown VOCs from Well 937GW11 totaled 2,300 $\mu\text{g/L}$ and were tentatively identified by the laboratory primarily as unknown hydrocarbons. The highest identification was 1,000 $\mu\text{g/L}$ of an aromatic hydrocarbon. The SVOC unknowns, which totaled 6,400 $\mu\text{g/L}$, were tentatively identified by the laboratory as mainly saturated and aromatic hydrocarbons. The concentration of unknown VOCs in the groundwater sample from Well 937GW31 totaled 200 $\mu\text{g/L}$. The compounds were tentatively identified by the laboratory as unknown hydrocarbons.

TPH. TPH concentrations in groundwater were measured during the 13 sampling events using two methods of analyses. During the first four sampling events, TPH samples were analyzed for TRPH. This method measures hydrocarbons with chain lengths greater than C_{10} , which includes naturally occurring hydrocarbons associated with organic matter (such as plants). TPH concentrations for samples collected during sampling events 5 through 13 were measured for TPH-G and TPH-D. These methods measure for hydrocarbons with chain lengths of C_2 to C_{12} and C_8 to C_{32} , respectively. TPH-G analysis detects the range of hydrocarbons found in gasoline and TPH-D analysis detects the range of hydrocarbons found in diesel fuel. Chromatograms generated during these analyses can be compared to standards for gasoline and diesel for quantification and to determine if the hydrocarbons detected are similar. The TPH-G and TPH-D analyses are more specific and are therefore more useful in assessing the distribution of anthropogenic hydrocarbons in groundwater. In this summary of results, the TPH-G and TPH-D results are discussed separately from the TRPH results.

Compounds within the TPH-G range were consistently detected in two shallow wells (937GW03 and 937GW36). These wells are located near the source area and have historically contained free product. The maximum concentration was 4,600 $\mu\text{g/L}$ at Well 937GW03 during sampling event 8. Other detections of compounds within the TPH-G range were considerably lower and intermittent. Multiple, but non-consecutive, TPH-G detections occurred at deep Well 937GW31, with a maximum concentration of 270 $\mu\text{g/L}$. TPH-G was detected during two of four sampling events in intermediate Well 937GW41. The only other

TPH-G detections occurred during sampling event 6. There were one time detections of TPH-G (out of nine sampling events) at shallow Wells 937GW34 and 937GW35, with a maximum concentration of 80 µg/L.

Detections of compounds within the TPH-D range were more frequent than TPH-G detections. However, the highest and consistent detections were still limited to wells located within the source area and those that have historically contained product. TPH-D was detected during each of the nine sampling event at Wells 937GW03 and 937GW36 at a maximum concentration of 150,000 µg/L. Other detections of compounds within the TPH-D range in the Building 937 Area were orders of magnitude smaller, with a maximum concentration of 350 µg/L. Well 937GW22, located outside of the source area was the only other well in which TPH-D was detected during each of the nine sampling events. However, the maximum concentration, 310 µg/L, was considerably lower than in the wells located near Building 937.

TPH-D detections in the remaining wells can be divided into three categories: those with a one time detection, those in which TPH-D was detected at least twice, but during non-consecutive events, and those wells in which TPH-D was detected multiple times with at least two detections occurring during consecutive sampling events. TPH-D was detected only once in samples from seven wells (937GW16, 937GW23, 937GW24, 937GW26, 937GW35, 937GW38, and 937GW43), at a maximum concentration of 100 µg/L and an average concentration of approximately 66 µg/L. Twelve wells had multiple, but non-consecutive detections of compounds within the TPH-D range. Concentrations ranged from 50 to 350 µg/L, with the an average maximum concentration of 145 µg/L. Thirteen wells fall into the third category (a minimum of two consecutive detections). Concentrations in these wells ranged from 50 to 230 µg/L with an average maximum concentration of 142 µg/L. The majority of the wells with the one time or multiple/non-consecutive detections of TPH-D are located along the coast, although this is not always the case.

TRPH analyses were conducted during the first four sampling events and prior to the source removal action at Building 937, and the removal of Wells 937GW02 and 937GW11. The concentration of compounds detected by the TRPH analyses was highest in the source area,

at Wells 937GW02, 937GW03, 937GW11, where the maximum concentration was 1,060,000 $\mu\text{g/L}$ at Well 937GW02. Only two other wells, 937GW28 and 937GW31 located regionally downgradient of the source area, had consistent detections of TRPH, with maximum concentrations of 783 $\mu\text{g/L}$ and 23,000 $\mu\text{g/L}$, respectively. Although these detections were confirmed by TPH-D/TPH-G analyses, the summed maximum concentration of TPH-D plus TPH-G were considerably lower, 130 $\mu\text{g/L}$ and 355 $\mu\text{g/L}$ at Wells 937GW28 and 937GW31, respectively. TRPH was detected during two of the three sampling events at Wells 937GW34 and 937GW35, at maximum concentrations of 3,070 $\mu\text{g/L}$ and 102,000 $\mu\text{g/L}$, respectively. Confirmation sampling at these wells using TPH-D and TPH-G analyses resulted in inconsistent detections, with a maximum concentration of only 100 $\mu\text{g/L}$ TPH-D. At the remaining six wells with multiple sampling events, the frequency of occurrence of TRPH detections was 50 percent or lower, with maximum concentrations ranging from 214 $\mu\text{g/L}$ to 860 $\mu\text{g/L}$. These TRPH results were consistently confirmed by TPH-D analyses at only one well, 937GW22. The maximum TPH-D concentration in this well (310 $\mu\text{g/L}$) was about half that of the TRPH detection.

6.4.1.2.4 Product Sampling Program and Results

Product samples were obtained from Wells 937GW02 and 937GW11 and the one accessible UST on the north side of Building 937 (937FP01 in Figure 6.2-1). These wells were removed along with two USTs, product, and soil during the IRA. Results from product sampling are presented in Tables 6.4-15 and 6.4-16. Since the removal of soil, groundwater, and free product, only Wells 937GW03 and 937GW36 have been found to contain free product, but it is only an oily sheen in a layer too thin to allow for sampling. Free product results will not be discussed further since product no longer exists in measurable quantities in the Building 937 Area. Constituent chemicals previously found in free product were either removed during the IRA or are discussed as components of soil or groundwater.

6.4.2 Storage Area

This section presents the analytical results of three of the buildings (949, 950, and 973), of the Storage Area site in the Building 900s Series Study Area. Soil samples near Building

974 were collected as part of investigation of the Building 979 area, and are discussed in Section 6.4.3.

6.4.2.1 Building 949

Building 949 was most recently used for chemical product storage. Due to observed surface staining, four soil borings were drilled inside the building during the Follow-on RI to determine the nature and extent of potential chemicals of concern (Figure 6.1-5). Each soil boring was sampled at 0.5, 3.0, and 5.0 ft bgs, and samples were analyzed for inorganics, VOCs, TPH-D, and TPH-G (Table 6.4-17). Inorganic results were compared to ambient values based on lithology logs. Lithology types, starting with the surface soil sample and progressing to deeper samples are as follows:

- Boring 949SB01 (serpentinite, fill, and beach/dune)
- Boring 949SB02 (fill, fill, beach/dune)
- Boring 949SB03 (fill, serpentinite, beach/dune)
- Boring 949SB04 (fill, beach/dune, beach/dune).

Two subsurface soil samples located slightly east of Building 949 were collected as part of the IRA during the installation of Well 937GW39. The samples were analyzed for inorganics, VOCs, and TPH. Both samples are compared to ambient values for beach/dune lithology.

Copper was the only inorganic detected above ambient concentrations in all four surface soil samples collected from Building 949. The surface soil sample from 949SB03 also contained barium and manganese above the ambient fill concentrations. At a depth of 3 ft bgs, the ambient exceedences were silver and copper at Boring 949SB01, chromium and nickel at Boring 949SB02, copper at Boring 949SB03, and chromium, cobalt, copper, and nickel at Boring 949SB04. Copper was the only inorganic detected above ambient concentrations at a depth of 5 ft bgs (Borings 949SB02 and 949SB03). In the samples collected east of Building 949 (Well 937GW39), chromium and nickel were detected above ambient levels at 3.0 ft bgs, and antimony was detected above ambient at 6.5 ft bgs.

VOCs were not detected in any of the soil samples collected inside Building 949 (Table 6.4-17) or in the shallow subsurface soil sample from Well 937GW39 (Table 6.1-2). Methylene chloride, a common laboratory contaminant, was detected slightly above the reporting limit in the saturated zone sample from Well 937GW39 (though not in groundwater from this area). TPH-D was detected in both soil samples from Well 937GW39, at a maximum concentration of 2.1 µg/g.

6.4.2.2 Buildings 950 and 973

Three surface soil samples (950SS01, 950SS02, and 950SS03) were collected in fill material near Building 950 and analyzed for inorganics, VOCs, SVOCs, and TPH during the Initial RI (Figure 6.2-3). An additional surface soil sample, 950SS04, was collected in support of the FS and analyzed for inorganics and TPH. Two of the samples, 950SS01 and 950SS02, were collected from stained areas inside the building. Sample 950SS02 was comprised of soils that had accumulated on top of compacted road base material. The third sample, 950SS03, was collected outside the building, adjacent to the southwest corner. Sample 950SS04 was collected outside of the building, near the serpentinite cliff. Inorganic concentrations were compared to ambient concentrations for fill materials.

Lead and cadmium concentrations exceeded ambient values in the three samples collected within and adjacent to Building 950 (Table 6.4-18). Other inorganics detected above ambient concentrations in one of the two the interior samples were barium, cyanide, mercury, silver, and zinc. Cobalt, chromium, mercury, nickel, and thallium were detected above ambient fill concentrations in the sample collected adjacent to the serpentinite cliff (950SS04 in Table 6.4-4).

VOCs were not detected in any of the soil samples associated with Building 950 and bis(2-ethylhexyl)phthalate and pyrene were the only SVOCs detected (950SS02). TPH was detected in all three samples. The TPH concentration in each soil sample was several orders of magnitude greater than the sum of the SVOC detections. The concentration of unknown SVOCs in samples 950SS02 and 950SS03 totaled 180 and 1,000 µg/g, respectively. The compounds from sample 900SS02 were tentatively identified by the laboratory as unknown

hydrocarbons. Those from sample 950SS03 were tentatively identified as saturated straight-chain hydrocarbons.

To define the vertical distribution of chemicals, two subsurface soil samples were collected adjacent to sample 950SS02 as part of the supplemental RI (950SB01 in Figure 6.1-5) and analyzed for inorganics, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH. The samples were collected from beneath road base material. Inorganic detections in the 2 ft bgs sample are compared to ambient values for fill materials; detections in the deeper sample are compared to ambient values for beach/dune deposits. Inorganics detected above ambient concentrations in both samples were cobalt, chromium, iron, lead, and nickel. In the deeper sample aluminum, mercury, manganese, and zinc were also above ambient (Table 6.4-11). All other inorganics were below ambient values. VOCs were not detected in the shallow sample and trichlorofluoromethane was the only VOC detected in the deeper sample. Six PAHs, ppDDE, and TPH-D were detected in the shallow sample. The SVOC concentrations in the shallow soil cannot be compared to the deeper sample because the extraction bottle for the deeper sample was broken during the chemical analysis. The concentration of TPH-D was approximately two orders of magnitude less than the total TPH detection in the initial RI surface soil sample. TPH-D was not detected in the deeper sample. Four unknown VOCs were identified in the shallow soil sample from 950SB01 at a total concentration of approximately 330 $\mu\text{g/g}$. Tentative identifications were not provided by the laboratory.

A number of surface sediment, subsurface soil, and wood chip samples were collected in March 1995 by Montgomery Watson in and around Building 950. A summary of this sampling program is contained in a letter report which is included in this RI in Appendix D.6. The four surface sediment samples were analyzed for metals, VOCs, SVOCs, organophosphorus pesticides, PCBs, OCPs, and TPH. Each sample contained detectable concentrations of several inorganics, including lead ranging from 1,030 to 1,240 $\mu\text{g/g}$. Organic detections were limited to one detection of ppDDT, one detection of bis(2-ethylhexyl)phthalate, and four detections of TPH-D, ranging from 940 to 3,900 $\mu\text{g/g}$. Subsurface soil samples ranged in depth from 0.5 to 3.5 ft bgs and were analyzed for the same target analytes as the surface sediment samples. Each sample contained detectable concentrations of several inorganics, but the only significant lead detection was 2,640 $\mu\text{g/g}$.

at 3.5 ft bgs; the greatest lead detection among the remaining five samples was 63 $\mu\text{g/g}$. The only subsurface organic detections were TPH-D at concentrations between 23 and 210 $\mu\text{g/g}$. Wood chip samples were collected from the building's support posts and analyzed for the same analyte suite as the subsurface soil samples. The results for these samples are included in the RCRA Closure Plan.

Three surface soil samples were collected during the Supplemental RI in the vicinity of Building 973 and analyzed for inorganics. Surface soil samples were collected from sand piles outside and inside Building 973. The bottom of each sand pile was not found during sampling. As a result, whether the sample was collected from a paved or unpaved surface is uncertain. The samples were analyzed for inorganics because the sand piles were created while sandblasting paint from vehicles. Two of the samples, 973SS01 and 973SS02 were collected outside the building. The third sample, 973SS03, was collected inside the building. Six additional soil samples were collected in support of the FS and analyzed for inorganics and TPH (Figures 6.1-5 and 6.2-3). The FS samples were collected as follows: one surface soil sample from inside Building 973 (973SS04), another adjacent to the serpentinite cliff (973SS05), two between Buildings 973 and 950 (973SS06 and 973SS07), and two subsurface soil samples from inside Building 973 (1 and 2 ft bgs from Boring 973SB01).

Inorganic concentrations in the seven surface soil and two subsurface soil samples associated with Building 973 were compared to ambient concentrations for fill materials. Lead was detected above ambient in all surface soil samples, with a maximum concentration of 4,000 $\mu\text{g/g}$ (Tables 6.4-4 and 6.4-18). Lead concentrations in the subsurface samples were below ambient (Table 6.4-5). Five other inorganics were detected above ambient concentrations at the surface: mercury in sample 973SS03 (the concentration was 0.012 $\mu\text{g/g}$ above the ambient value), manganese in sample 973SS04, arsenic in sample 973SS05, barium in samples 973SS04 and 973SS07, and copper in sample 973SS04. In the subsurface, antimony, barium, and manganese exceeded ambient levels in the 1 ft bgs sample from Boring 973SB01. TPH-D was detectable in all samples, with a concentration range of 43 to 200 $\mu\text{g/g}$ in surface soils and detections of 7.3 and 11 $\mu\text{g/g}$ in the subsurface. The SDC for TPH-D is 100 $\mu\text{g/g}$. There were no TPH-G detections.

Follow-on RI samples were collected to fully define the vertical and lateral extent of lead and TPH concentrations above the respective SDCs, as encountered during previous sampling in the area. In all, 13 new borings were drilled surrounding Buildings 950 and 973 (Figure 6.1-5). In 12 of those borings, 95073SB01 through 95073SB12, samples were collected at 0.0 and 3.0 ft bgs and analyzed for lead and TPH. In the thirteenth boring, samples were also collected at 0.0 and 3.0 ft bgs but only analyzed for lead. An additional sample was collected for lead analysis from Boring 95073SB03, at a depth of 5.0 ft bgs. All results are shown in Table 6.4-19. Lead was detected above the SDC of 300 $\mu\text{g/g}$ in four surface soil samples and one subsurface soil sample. Lead concentrations in the deeper samples at all these locations were below the SDC or the RL of 25 $\mu\text{g/g}$. All detections were compared to the appropriate ambient levels. At the surface, the ambient fill concentration was exceeded in Borings 95073SB02 and 95073SB04 through 95073SB10. At 3 ft bgs, the ambient fill level was exceeded in Boring 95073SB03, the serpentinite ambient level was exceeded in Borings 95073SB04 and 95073SB12, and the beach/dune sand ambient level was exceeded in Boring 95073SB11. TPH was detected above the SDC in one sample, 95073SB11 at 0.0 ft bgs.

6.4.3 Building 979 Area

This section describes sample locations, analytical suites, and results for soil, groundwater, and soil-gas samples collected in the Building 979 area. Subsurface soil and groundwater samples were collected during the Initial, Supplemental, and Follow-RI in the Building 979 area.

6.4.3.1 Sampling Program

Field efforts during the Initial RI included sampling soil from 2 to 3 ft bgs and immediately above the water table from Borings 979SO01, 979SO02, 979SO03, and 979GW01 (Figures 6.1-5 and 6.2-1). The Initial RI evaluated groundwater samples from shallow Wells 979GW01, 979GW02, 979GW03. Shallow Wells 979GW04 and 979GW07, and deep Wells 979GW05 and 979GW06 were installed as part of the Supplemental RI. Soil samples from Wells 979GW05, 979GW07, Boring 979SB01 and groundwater from Wells 979GW01 through 979GW07 were collected during the Supplemental RI (Figures 6.1-5 and 6.2-1). All soil samples were analyzed for the full suite of Supplemental RI analytes.

Additionally, filtered and unfiltered samples were taken for comparison from Wells 979GW01, 979GW04, and 979GW06.

During the Follow-on RI, three soil samples from Boring 979SB04 were collected and analyzed for TOC (Figure 6.2-1). All other Follow-on RI field work focused on groundwater. Seven existing wells and three newly constructed deep wells (979GW08, 979GW09, and 979GW10) were sampled and discrete groundwater samples from Borings 979SB02 through 979SB09, 979SB12, 979SB13, and 979SB16 were collected (Figures 6.2-1 and 6.2-2). Discrete groundwater samples were taken at three depths: first water; an intermediate depth; and immediately above bedrock. Soil-gas samples were collected prior to the Follow-on RI discrete groundwater sampling program throughout the Building 979 area.

Analyses performed on samples varied with the field programs of the RI. The target analytes, analytical methods, and reporting limits included in each of the suites discussed in this section are presented in tables in Section 3.3. During the Initial RI, soil and groundwater samples were analyzed for VOCs, SVOCs, and TRPH. The sample suite was expanded for the Supplemental RI field program and included inorganics, VOCs, SVOCs, OCPs, PCBs, herbicides, TPH-D, and TPH-G for soil and groundwater samples. Groundwater samples collected from monitoring Wells 979GW01 through 979GW07 during the Follow-on RI were also analyzed for a full suite of compounds. The discrete groundwater investigation focused on organic compounds that had previously been detected at concentrations above the primary MCLs, and therefore was limited to trichloroethene and degradation products. Similarly, samples from wells installed during the Follow-on RI (979GW08, 979GW09, and 979GW10) were analyzed for trichloroethene and degradation products. Samples from the three newly installed wells were also analyzed for TDS and major cations and anions. The analytical suite for the soil-gas survey was trichloroethene, toluene, xylenes, and total VOCs.

The lateral and vertical extent of sampling in the Building 979 Area expanded with each successive field program. To provide a comprehensive evaluation of chemical distribution in the Building 979 area, results from the Initial, Supplemental, and Follow-on RI are presented together in this section discussion, rather than in chronological order. The analytical result summary tables that accompany this text (Tables 6.4-20 through 6.4-27) show results for

each field program and sample media separately. The results for the soil-gas survey are provided in Appendix S.

6.4.3.2 Soil Sample Results

Numerous inorganics were detected in the soil sample from Well 979GW05, which was collected at 6 ft bgs (Table 6.4-22). The sample was a mixture of artificial fill and serpentinite-derived sand, and results were compared to ambient concentrations for fill materials. Antimony, chromium, cobalt, selenium, and nickel were the only inorganics detected above ambient concentrations. A WET test was performed for nickel, chromium, and lead. The concentrations of chromium and nickel detected by WET were 2.00 and 12.0 mg/L, respectively, and are probably due to the serpentinite. Lead was not detected in the WET analysis. A full listing of the WET results is provided in Appendix O.

Two subsurface soil samples (979GW07 and 979SB01 collected from boreholes for Wells 979GW07 and 979GW06, respectively) were composed of fill and native beach sand, respectively. The fill consisted primarily of locally derived sand with a small amount of construction debris and some serpentinite pebbles. Therefore, the concentration of inorganics in both samples is compared to the ambient concentration for beach/dune sand deposits. Thallium concentrations in both samples were above the ambient concentration 0.162 µg/g. In Boring 979SB01 (located east of Building 974), arsenic was detected at a concentration slightly above the ambient concentration of 5 µg/g (Table 6.4-22). All other inorganics were below ambient concentrations in this sample. Chromium and nickel concentrations exceeded ambient values in the sample from Boring 979GW07, probably due to the presence of serpentinite in the sample (Appendix D) which has high naturally occurring concentrations of both metals. The chromium and nickel concentrations are well within the ambient values for serpentinite derived soils.

Total organic carbon concentrations ranged from 1,800 to 8,150 µg/g in the three samples from Boring 979SB04 (Table 6.4-23), with the highest value occurring in the deepest sample (33 ft bgs).

VOCs were not detected in Initial or Supplemental RI soil samples (Table 6.4-20 and 6.4-22, respectively). SVOC detections were limited to PAHs in a 3 ft bgs sample from Boring 979SO01A at a maximum concentration of 1.2 $\mu\text{g/g}$ and a phthalate detection in the sample from Boring 979GW07. Endrin aldehyde and endrin are the only pesticides detected in soil samples from the Building 979 Area. The detections were in adjacent samples collected at 6 ft bgs during the Initial RI (Boring 979GW01 shown in Figure 6.2-1) and Supplemental RI (Boring 979GW05 shown in Figure 6.2-2). Endrin aldehyde was detected at 3.2 $\mu\text{g/g}$ in the Initial RI sample and endrin was reported at 0.004 $\mu\text{g/g}$ (a concentration below the method detection limit) in the Supplemental RI sample. There were no PCB or herbicide detections in soil samples from the Building 979 Area. TPH-D was detected in all three Supplemental RI samples at a maximum concentration of 29 $\mu\text{g/g}$.

6.4.3.3 Inorganic Groundwater Sample Results

Unfiltered groundwater samples were collected from three wells during the Supplemental RI (Table 6.4-25) and from all wells during the November 1994 Follow-on RI sampling event (Table 6.4-26). Both field programs included filtered inorganic analyses for the seven wells in the Building 979 Area (three new wells were installed after these sampling events). In the following discussion, inorganic groundwater results are divided into three groups based on the distribution of unfiltered results in the seven wells sampled as part of the Follow-on RI (unfiltered data were available only for three of the wells sampled during the Supplemental RI). The first group includes constituents that were detected in nearly every well in the Building 979 Area. Inorganics detected less frequently, but in more than half the wells are in the moderately detected group and those constituents detected in less than half the wells are in the infrequently detected group. A comparison of Supplemental and Follow-on RI results is also provided in this section.

Frequently Detected Inorganics. Inorganics detected in most unfiltered samples were aluminum, barium, iron, lead, manganese, and nickel. Maximum concentrations of aluminum, barium, and nickel were in unfiltered samples from Well 979GW04 and were 1,220 $\mu\text{g/L}$, 309 $\mu\text{g/L}$, and 192 $\mu\text{g/L}$, respectively. Aluminum, barium, and nickel concentrations were generally an order of magnitude lower in other samples from the

area, with second highest concentrations of 598 $\mu\text{g/L}$, 48 $\mu\text{g/L}$, and 63.3 $\mu\text{g/L}$. Filtering reduced the concentration of aluminum to below the reporting limit in all samples and had a relatively small impact on the concentrations of barium and nickel. The one exception was at Well 979GW04, where filtered nickel concentrations were several times lower than in the unfiltered samples.

Unfiltered iron concentrations varied significantly at the site, ranging from 139 to 5,440 $\mu\text{g/L}$. Filtering lowered iron concentrations to levels below the reporting limit in nearly all wells. The maximum filtered iron concentration was 1,500 $\mu\text{g/L}$. Both unfiltered and filtered lead detections were generally low, with maximum concentrations of 5.99 $\mu\text{g/L}$ and 1.71 $\mu\text{g/L}$, respectively. All unfiltered lead results from the Follow-on RI were affected by laboratory method blank contamination. The maximum lead concentration in the unfiltered lead samples collected as part of the Supplemental RI was similar (3.15 $\mu\text{g/L}$).

Anomalously, lead concentrations in the filtered sample were sometimes slightly higher than in the unfiltered sample (this was observed in the Supplemental and Follow-on RI samples). Manganese concentrations in unfiltered samples ranged from 132 to 5,020 $\mu\text{g/L}$. Filtering lowered manganese concentrations slightly, and to a level below the reporting limit in only once instance.

Moderately Detected Inorganics. Copper and zinc were each detected in unfiltered samples from four wells at maximum concentrations of 3.56 $\mu\text{g/L}$ and 26 $\mu\text{g/L}$, respectively. However all unfiltered copper results were affected by either laboratory method blank or rinse blank contamination (as indicated in Table 6.4-26). Similarly, three of the unfiltered zinc results were affected by laboratory method blank contamination. Filtering increased the concentration and frequency of copper detections, with a maximum of 24.6 $\mu\text{g/L}$, and detections in six wells (filtered sample results were not affected by blank contamination). Zinc concentrations were lower in all filtered samples (which were not affected by blank contamination), as compared to the unfiltered samples, with detections in three wells and a maximum concentration of 7 $\mu\text{g/L}$. Two of the filtered zinc detections were in samples from wells that had non-detects in the unfiltered samples (Wells 979GW04 and 979GW06), however, because of a ten-fold sample dilution by the analytical laboratory, the reporting limit for the non-detects was

40 $\mu\text{g/L}$ (as opposed to 4 $\mu\text{g/L}$). Probably, these two wells do contain detectable concentrations of unfiltered zinc.

Infrequently Detected Inorganics. Antimony, arsenic, cobalt, cyanide, mercury, selenium, silver, thallium, and vanadium were detected in fewer than half unfiltered samples collected during the Follow-on RI. Arsenic and mercury were each detected in three wells, at maximum concentrations of 5.78 $\mu\text{g/L}$ and 0.9 $\mu\text{g/L}$, respectively. Filtered arsenic concentrations were below the reporting limit in one of the three samples and increased slightly in samples from the two other wells. All unfiltered mercury results were affected by laboratory method blank contamination. Filtered mercury samples were not collected. Selenium and vanadium were each detected in unfiltered samples from two wells at maximum concentrations of 27.3 $\mu\text{g/L}$ and 12 $\mu\text{g/L}$, respectively. Both constituents were detected in filtered samples, but at concentrations higher than in the associated unfiltered sample. Thallium was detected in samples from two wells, 979GW01 and 979GW04. The filtered sample from 979GW01 contained thallium at 1.10 $\mu\text{g/L}$, the unfiltered sample from 979GW04 contained thallium at 3.05 $\mu\text{g/L}$, and the filtered sample from 979GW04 contained thallium at 14.0 $\mu\text{g/L}$. The remaining four constituents (antimony, cobalt, cyanide, and silver) were each detected once in an unfiltered sample, though not all in the same well. Antimony was detected in all filtered samples due to the filter material, as discussed previously in Section 6.4.1.2. Cobalt concentrations were below the reporting limit in all filtered samples, filtered cyanide samples were not collected, and filtered silver was detected at six wells.

Beryllium and cadmium are the only inorganics that were below reporting limits in all unfiltered samples but were detected in filtered samples. Each was detected once in the filtered sample from Well 979GW04, at concentrations of 1 $\mu\text{g/L}$ and 7 $\mu\text{g/L}$, respectively. Chromium is the only inorganic constituent that was not detected above the reporting limit in any of the unfiltered or filtered groundwater samples from the Follow-on RI.

Comparison of inorganic data for groundwater samples collected as part of the Supplemental RI (Table 6.4-25) to those from the Follow-on RI shows a general decrease in concentrations over time. This is probably due to the heavy rains and recharge that occurred in 1994, prior

to and during the Follow-on RI groundwater sampling event. Sampling during the Supplemental RI occurred under much drier conditions. The impact of increased precipitation and recharge on inorganic groundwater chemistry was most pronounced at Well 979GW04, where the saturated zone is relatively thin, as compared to other locations in the Building 979 Area. This well is also located near the northern boundary of the water-bearing zone.

6.4.3.4 Organic Groundwater Sample Results

The following summary of organic detections in groundwater includes the results from the Initial, Supplemental, and Follow-on RI sampling events in the Building 979 Area. Results are summarized in Tables 6.4-21, 6.4-24, and 6.4-26.

Volatile organic compounds were detected in seven of the ten wells in the Building 979 Area. Wells in which there were no detections of VOCs are the shallow and deep wells at the northern boundary of the study area (Wells 979GW04 and 979GW09, respectively) and in deep Well 979GW10, located adjacent to San Francisco Bay (Figures 6.2.1 and 6.2-2). VOC detections in groundwater are limited to chlorinated compounds, with one exception. Benzene was detected in one well, 979GW05, during the Supplemental RI at a concentration of 0.070 $\mu\text{g/L}$, only slightly above the reporting limit of 0.060 $\mu\text{g/L}$. The detection was not confirmed by subsequent sampling during the Follow-on RI, however, the reporting limit was higher.

Chlorinated compounds were detected in seven of the ten monitoring wells in the Building 979 Area, with the highest concentration near the southeast corner of Building 979, at shallow Well 979GW01. A total of six different chlorinated compounds were detected in the Building 979 Area. Detections of potential parent chlorinated solvent compounds were limited to trichloroethene. The remaining five compounds, 1,1-dichloroethene, 1,2-dichloroethane, cis- and trans-1,2-dichloroethene, and vinyl chloride, are all degradation products of chlorinated solvents.

Trichloroethene was detected in all seven wells with VOC detections in the Building 979 Area. Maximum concentrations of trichloroethene in the shallow and deep portions of the

water-bearing zone were 200 µg/L and 85 µg/L, respectively. These detections were near the southeast corner of Building 979, at Wells 979GW01 and 979GW05. Trichloroethene concentrations were an order of magnitude lower in other wells in the Building 979 Area, ranging from 2.74 to 10.1 µg/L in shallow wells and 1 to 1.1 µg/L in deep wells.

Cis-and trans-1,2-dichloroethene are the most commonly detected degraded chlorinated compounds in the Building 979 Area, with detections in seven and six wells, respectively. In shallow portions of the aquifer, cis-1,2-dichloroethene concentrations ranged from 1.6 to 60 µg/L, with the highest concentrations occurring in either Well 979GW01 or 979GW03. Concentrations in samples from deep portions of the aquifer were similar, ranging from 0.6 to 60 µg/L, with the highest concentration consistently at Well 979GW06. The concentration of trans-1,2-dichloroethene was considerably lower in the deep portion of the aquifer, ranging from 0.34 to 3 µg/L. In the shallow zone, trans-1,2-dichloroethene concentrations ranged from 1.6 to 81 µg/L.

1,1-Dichloroethene was detected in a shallow well (979GW01) and a deep well (979GW05). Concentrations were low, with a maximum detection of 2.2 µg/L. Detections of 1,2-dichloroethene were limited to two shallow wells (979GW01 and 979GW07), with a maximum concentration of 1.26 µg/L. The final degradation product of chlorinated solvents, vinyl chloride was detected in three shallow and one deep well. Concentrations in the shallow zone ranged from 8.7 to 62 µg/L, with the highest concentration at either Well 979GW01 or Well 979GW07. Vinyl chloride detections in the deep portion of the aquifer were much lower than in shallow portions and less common. It was detected once (in Well 979GW05) at a concentration of 0.37 µg/L.

Comparison of the Initial, Supplemental, and Follow-on RI results for chlorinated compounds shows that concentrations appear to have decreased over time. The one exception is at Well 979GW03, where there has been an overall increase in concentration of trichloroethene and cis-1,2-dichloroethene over time.

As part of the Follow-on RI, discrete groundwater samples were collected from multiple depths at 10 locations in the Building 979 Area (Figures 6.2-1 and 6.2-2). Each sample was analyzed for trichloroethene and degradation products. Results were used to further define

the lateral and vertical extent of chlorinated compounds in the area and to determine where to install additional groundwater monitoring wells. Deep Wells 979GW08, 979GW09, and 979GW10 (results from these wells were discussed above) were installed after evaluating the discrete groundwater data (Table 6.4-27) as well as the Initial and Supplemental RI results. Detections in the discrete groundwater samples were limited primarily to samples from shallow and intermediate depths, with the highest concentrations occurring in samples collected near Building 979. Compounds were not detected in samples from immediately above bedrock, except at Borings 979SB13 and 979SB16.

Two unknown VOCs were identified in the groundwater monitoring well sample from Well 979GW07. The unfiltered concentration was 680 $\mu\text{g/L}$ and a tentative identification was not provided by the laboratory. Chloroform was the only other VOC detected in the Building 979 Area. The concentration was quite low, 0.960 $\mu\text{g/L}$ in deep Well 979GW05. Chloroform was not detected in the Supplemental RI sample from this well.

SVOC detections were limited to bis(2-ethylhexyl)phthalate in samples collected as part of the Supplemental and Follow-on RI. As footnoted in Tables 6.4-24 and 6.4-26, all of these detections are attributed to method blank contamination and therefore will not be considered in the discussion or BRA sections of this RI report. Unknown SVOCs meeting evaluation criteria described in Section 3.6 were found in samples from groundwater monitoring Wells 979GW04 and 979GW07. The total concentration was 303 $\mu\text{g/L}$ and 166 $\mu\text{g/L}$, respectively. These concentrations exceed the sum of known organic detections in each of these wells. Tentative identifications of the unknown SVOCs were not provided by the laboratory. OCPs, PCBs, and herbicides were not detected in any of the groundwater samples from the Building 979 Area. TPH-D was detected in two wells sampled during the Supplemental RI (Wells 979GW05 and 979GW07). Neither of these detections were confirmed by the Follow-on RI samples, which had non-detects of TPH-D in all wells in the Building 979 Area. TPH-G was detected in one well (979GW01) during the Follow-on RI, but not in earlier samples collected during the Initial or Supplemental RI.

6.4.3.5 Soil-Gas Survey Sample Results

The soil-gas survey was conducted by Environmental Support Technologies in late November and early December 1994, prior to the Follow-on RI discrete groundwater sampling. The survey was performed throughout Building 979 Area in an attempt to identify potential "hot spots" and to assist in selecting discrete groundwater sample locations. Twenty soil-gas probes (probes) were placed 3 ft bgs in an approximate grid pattern in the Building 979 Area (Figure 1, Appendix S). Samples were collected and analyzed for trichloroethene, toluene, xylenes, and total VOCs. Toluene was detected in five samples, trichloroethene was detected in three samples, and xylene was detected in one sample at a total of eight of the sample locations. The results of the discrete groundwater sampling do not confirm trichloroethene detections in these locations. Disparity in the results may be due to the collection of soil-gas samples from beneath paved areas which inhibit the migration of gas in the soil. Also, detections in the groundwater are at low enough concentrations that soil-gas in equilibrium with the groundwater water may not contain measurable concentrations of these compounds. The complete soil-gas survey report is contained in Appendix S.

6.5 RESULTS EVALUATION

The following sections present the evaluation of the sampling results for the Building 900s Study Area. RI sampling was conducted in this area to assess the following potential contaminant sources: storage areas, surface spills, and USTs. The impacts of these potential sources were assessed primarily through the collection of soil and groundwater samples, and the following discussion is divided accordingly. The intent of this evaluation is to describe the nature and extent, and fate and transport of contaminants associated with the sources in the area and to determine which data should be entered into the Risk Assessment.

6.5.1 Evaluation of Chemicals in Soil

The first step in evaluating the soils results involves the determination of which analytes are COPCs (see Section 3.7), which will be evaluated in the Risk Assessment. Once COPCs are identified, the nature and extent, and fate and transport of these analytes will be discussed.

Analytes that are not considered COPCs will not be discussed further. The following sections (6.5.1.1, 6.5.1.2, and 6.5.1.3) identify COPCs and discuss their nature and extent in soil in the Vehicle Maintenance, Storage, and Building 979 areas, respectively. Section 6.5.2 provides a discussion on the fate and transport of the identified COPCs in soil for the entire Building 900s site.

RI samples were analyzed for inorganic and organic analytes. Inorganic analytes occur naturally, and their presence at a site may or may not be anthropogenic. In determining which inorganic analytes are COPCs, several factors are considered. These include the magnitude and number of detections above ambient values, the spatial distribution of these exceedences, the type of soil in the sample, and comparison with concentrations typical of soils in other areas of the region. In addition, the absence or presence of potential sources is assessed. A number of maps presenting posted results for soil samples were used in this evaluation. Specific figure numbers for these posting maps are referenced in the relevant discussion. All organic analytes are assumed to be anthropogenic, and all detected organic compounds are, therefore, considered COPCs. Posting maps were also prepared for organic analytes and are identified in the evaluation discussion.

Chromium, cobalt, manganese, and nickel are not considered COPCs in the Building 900s Series Study Area. Rather, detections of these analytes that exceed ambient concentrations for fill material or beach/dune deposits are attributed to weathering of serpentinite within the sample or in the adjacent soils. As described in Section 3.7 of this report, these four elements are found in serpentinite-derived soils at concentrations significantly higher than in other soils or fill material found at the PSF. Serpentinite is abundant in the study area; it outcrops along the western boundary, subcrops beneath the aquifer, and was used extensively as road base material.

Chromium and nickel were detected at concentrations above ambient values for beach/dune deposits and fill material in many of the soil samples in those lithologic categories. Cobalt and manganese were also detected at concentrations above ambient values, though somewhat less frequently. Review of the analytical data and lithology logs (Appendix D) for the Building 900s Series Study Area indicates that many of the samples, though not categorized

in the serpentinite lithology type, do contain weathered serpentinite as sand or gravel, with the larger pieces exhibiting a high degree of weathering.

With a few exceptions, concentrations of chromium, nickel, manganese, and cobalt throughout the study area were below ambient values for serpentinite soils. The exceptions are one chromium detection and three manganese detections which exceeded the calculated serpentinite ambient values. Of these four detections, only one, a manganese detection, exceeded the maximum concentrations detected in background soil samples composed of serpentinite (Section 3.7). Furthermore, the posting maps prepared for these four analytes indicate that there are no areas of relatively elevated concentrations that might suggest some type of source.

6.5.1.1 Vehicle Maintenance Area

The data used to evaluate soil in the Vehicle Maintenance Area were associated with 22 surface soil samples and 20 soil borings. Posting maps were created to show the results from these samples for the following analytes: aluminum, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, zinc, ppDDD, ppDDE, and ppDDT. These maps are presented as Figures 6.5-1 through 6.5-14.

Inorganics. Inorganics (excluding chromium, cobalt, manganese, and nickel) detected above ambient concentrations in these samples, in order of increasing number of exceedences (with the number of exceedences in parentheses), are cyanide (1), aluminum (2), arsenic (4), cadmium (5), mercury (5), antimony (6), copper (7), barium (8), zinc (16), and lead (21). As discussed in 6.5.1, the detections of nickel, chromium, cobalt, and manganese are attributed to weathering of serpentinite and, therefore, will not be addressed further in this section or evaluated in the BRA.

Cyanide was detected at 0.534 mg/g near the southwest corner of Building 937 (sample 900SS09) during the initial RI sampling. This detection was not confirmed during the FS sampling two years later (900SS21). Cyanide is not considered a COPC in the Vehicle Maintenance Area.

Aluminum was detected above ambient concentrations in two surface soil samples, 900SS02 and 900SS11. During the initial RI, Sample 900SS02 was collected from "stained surficial soils...adjacent to a storm drain at (the) southern end of (the) parking lot behind (Building) 924." Sample 900SS11, collected during the FS from the grass covered hill southwest of Building 942, was identified as beach/dune sand. Neither of these samples exceeds its respective ambient concentration by more than twelve percent. Though above the selected ambient value, the concentration in Sample 900SS02 still resides within the smooth portion of the curve on the normal probability plot (Appendix A) and falls within the range of regional ambient soil concentrations presented on Table 3.7-1. Given the location of Sample 900SS11, it may well have included some fill material due to regrading, and its aluminum concentration of 13,000 $\mu\text{g/g}$ is well below the ambient concentration in fill material. Aluminum is not considered a COPC in the Vehicle Maintenance Area.

Arsenic was detected above ambient concentrations in one soil boring, 937GW37 at 6.5 ft bgs, and three surface soil samples: 900SS12, 900SS13, and 900SS21. The detection in Boring 937GW37, east of Building 937, was roughly ten percent greater than ambient. The overlying sample did not contain arsenic above the ambient concentration, suggesting that the arsenic did not leach down from above; this exceedence does not appear to be a result of U.S. Army activities. This is further supported by the lack of groundwater detections above the relevant standards. Samples 900SS12 and 900SS13 were both collected west of Building 924, while sample 900SS13 was collected near the southwest corner of Building 937. The detection in 900SS12 only exceeds the ambient serpentinite concentration by less than one percent, and arsenic is not considered a COPC in this sample. The detections in 900SS13 and 900SS21, however, do appear to be anomalously high and will be considered in the BRA. In each case, the lateral extent of the ambient exceedence was defined by adjacent surface samples (Figure 6.5-2). Arsenic will be evaluated as a COPC because of surface soil detections along the western edge of the site.

Cadmium was detected above ambient levels in five surface soil samples in three locations. There were three detections several times greater than the ambient concentration value developed for fill materials. All of these detections were in the area immediately west of Buildings 930 and 931. Two additional samples, 900SS02 and 900SS10, were slightly

above the ambient fill concentration. Sample 900SS02 was collected west of Building 924, and 900SS10 was north of Building 935. These areas of elevated cadmium are defined by adjacent non-detections, as shown on Figure 6.5-4. Cadmium will be evaluated as a COPC because of detections in surface soils in the area of Buildings 924 through 935.

Mercury was detected above ambient levels in five surface soil samples along the western boundary of the site between Building 924 and Building 935. Significant exceedences were concentrated on the west side of Building 933 and at the southwest corner of Building 937 (Figure 6.5-9). Detections in subsurface samples, where present, were considerably lower. Mercury is considered a COPC at the surface in this area.

Antimony was detected at concentrations one to two orders of magnitude higher than ambient levels (non-detect) in the 3 and 6.5 ft bgs soil samples collected from six borings at this site (937GW36 through 973GW38 and 937SB14 through 937SB16). Each of these borings was drilled to the east or northeast of Building 937. The lack of antimony detections in other sites within the Building 900s Study Area suggests that these detections are sufficient to consider antimony a subsurface COPC in this area.

Detections of copper at concentrations greater than ambient show a similar distribution to those for cadmium and mercury. There are slight exceedences in surface soils west of Building 924, including one that was not confirmed by FS sampling, and north of Building 935. Even higher detections were concentrated in the vicinity of Buildings 930 and 931 (Figure 6.5-6). Samples collected by Montgomery-Watson as part of the basewide firing range evaluation also showed elevated concentrations at the target range behind Building 924. Copper is considered a COPC at the surface in this area.

Barium was detected above ambient levels in seven surface soil samples and one subsurface sample. Barium is not considered a subsurface COPC, because the detected concentration at 2.0 ft bgs in Boring 931SB01 was within 2 percent of the ambient value for serpentinite and below that for fill and dune /beach sand. It is noted, however, that this sample does underlie an area with numerous ambient exceedences at the surface. In surface soils, the ambient barium concentration for fill material is greatly exceeded in six samples, with a spatial analysis suggesting two areas of concentration, one near Buildings 930 and 931 and the

other at the southwest corner of Building 937. The ambient beach/dune concentration was exceeded in one sample at the corner of Building 942, but only by 1 $\mu\text{g/g}$. Samples collected by Montgomery-Watson as part of the basewide firing range evaluation also showed elevated concentrations at the target range behind Building 924. Barium is considered a COPC in surface soils at this site.

Zinc was present above ambient concentrations in the majority of the surface soil samples collected in this area (Figure 6.5-11). In addition, the data show a concentrated area of higher detections to the west of Building 930, which correlates with the high detections of other metals near this building. There were no ambient exceedences in subsurface samples. Samples collected by Montgomery-Watson as part of the basewide firing range evaluation also showed elevated concentrations at the target range behind Building 924. Zinc is considered a COPC in surface soils in this area.

Lead was detected above ambient levels in all of the surface soil samples from the Vehicle Maintenance Area except for sample 900SS03 (Figure 6.5-7). As with many of the other inorganics, the highest concentrations were detected in the area immediately west of Building 930, with a maximum detection of 4700 $\mu\text{g/g}$. The high lead detections in the area near Buildings 926, 929, 930, and 931 are probably associated with painting activities. However, specific U.S. Army activities that could result in pervasive detections in surface soil samples elsewhere in the Vehicle Maintenance Area are unknown. These data indicate that lead is a COPC in surface soils in this area. Subsurface samples did not contain lead at concentrations greater than ambient. Samples collected by Montgomery-Watson as part of the basewide firing range evaluation also showed elevated concentrations at the target range behind Building 924.

Organics. The analytical results for organic compounds in samples from the Vehicle Maintenance Area indicate that impacts to the soil by U.S. Army activities have been minimal. VOCs detected in samples associated with Buildings 924 through 935 are methylisobutyl ketone, methylene chloride, 1,3-dimethylbenzene, tetrachloroethene, and trichlorofluoromethane. Each of these compounds was detected fewer than five times in the area. Samples with VOC detections were spread throughout the area and often had

adjacent samples with no detections. SVOCs detected in soils were phthalates, PAHs, 1,4-dichlorobenzene, Aroclor 1254, and Aroclor 1260. Detections were inconsistent, with the same suite of compounds often not detected in adjacent samples. There was only one pesticide detection in the Vehicle Maintenance Area. Detections of TPH-D above the SDC of 100 $\mu\text{g/g}$ occurred in two surface soil samples near Buildings 929 and 930 (900SS16 and 900SS17), at a maximum concentration of 130 $\mu\text{g/g}$. The maximum lateral extent of detections greater than 100 $\mu\text{g/g}$ is defined by surface soil samples 900SS14 (approximately 75 ft south) and 900SS18 (approximately 75 feet north). TPH-D detections in both these samples were less than 100 $\mu\text{g/g}$. The maximum vertical extent is 2 ft bgs and is defined by TPH-D detection less than the SDC at Boring 931SB01 (located approximately 30 ft north of sample 900SS17). There were not detections of TPH-G in surface or subsurface soil samples associated with Buildings 924 through 935.

The distribution of organics in soil associated with Building 937 was assessed on the basis of samples collected during the Initial RI, the Feasibility Study, and the IRA. Only samples collected entirely within the unsaturated zone (shallow and deep samples from Borings 937SO01, 937SO06 and 937SB13, shallow samples from Borings 937SB08 through 937SB12, 937SO02, 937SO03, 937SO04, 937SO05, 937SO07, 937SB14, 937SB15, 937SB16, 937GW36, and 937GW37) were used in this evaluation. Detections of organics in saturated zone samples are more indicative of groundwater quality, which is discussed in detail in Section 6.5.3.2. A number of confirmation soil samples were collected during the IRA removal of two USTs and associated soil and product. These samples are not included in this discussion, but the results are provided in Appendix R and are discussed in detail in the SGWPCR (WJE, 1993d).

VOCs detected in the soil in the vicinity of Building 937 are primarily BTEX compounds and chlorobenzene. This is consistent with the known source at the site (the USTs which have since been removed). The extent of VOC detections is defined to the west by non-detects at Borings 937SO01 and 937SO04, to the north by Boring 937SO07, and to the east by several borings. SVOC analyses were conducted on samples collected during the Initial RI. PAHs in unsaturated zone soil samples were found only on the east side of Building 937, at relatively low concentrations (the maximum PAH detection was 0.57 $\mu\text{g/g}$). Because of

the low concentrations, additional sampling for SVOCs was not required in this area. TPH detections in soil borings exceeding the SDC of 100 µg/g occurred only in soil borings saturated with product or collected below the water table.

6.5.1.2 Storage Area

The Storage Area within the Building 900s Study Area consists of four buildings: 949, 950, 973, and 974. To assist in the evaluation of chemicals detected in soil in the vicinity of these buildings, posting maps were created for the following analytes: aluminum, antimony, arsenic, cadmium, chromium, copper, cyanide, iron, lead, manganese, mercury, nickel, thallium, and zinc. These maps, which are presented as Figures 6.5-15 through 6.5-28, also include data from the Montgomery-Watson investigation of soils at Building 950.

Building 949. Inorganics detected above ambient values in soil samples from the five borings associated with Building 949 are antimony, barium, chromium, cobalt, copper, manganese, nickel, and silver. As described in the introduction to Section 6.5.1, the chromium, cobalt, nickel, and manganese detections are attributed to serpentinite and are not evaluated further.

Antimony was detected, and therefore above ambient, at 6.5 ft bgs in Boring 937GW39. This detection is not considered attributable to U.S. Army activities. The lack of detection at 3.0 ft bgs in the same boring precludes migration from the surface, and antimony was detected in the groundwater only during the first of nine sampling events. Antimony is not considered a COPC at this site.

Barium was detected above the ambient concentration for fill in the 0.5 ft bgs sample from Boring 949SB03. The detected concentration exceeded the ambient value by less than two percent, and barium is not considered a COPC at this site.

Copper was detected above ambient concentrations in each boring drilled within Building 949 but not in Boring 937GW39. In all but Boring 949SB01, the detected concentration decreased with depth. This suggests that the elevated copper concentrations are related to activities within Building 949. The deepest sample in which the copper concentration exceeded ambient was collected at 5.0 ft bgs. The extent of elevated copper is not defined by

analytical samples. Copper is a COPC in both surface and subsurface soils at this site. A specific source for the copper at Building 949 is unknown.

The extent of elevated silver detections in Building 949 is very limited, with one subsurface exceedence (3 ft bgs at Boring 949SB01) and non-detections in the deeper sample from the boring and in all other samples associated with Building 949. The detection exceeded the ambient value by slightly more than 1 µg/g. Silver is not considered a COPC in Building 949.

VOCs and TPH were not detected in any of the soil samples associated with Building 949.

Buildings 950, 973, and 974. Inorganics detected above ambient concentrations in soil samples in the vicinity of Buildings 950, 973, and 974 are aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, silver, thallium, and zinc. Though the results for Borings 979SB01 and 979GW07 were presented with the Building 979 discussion, their proximity to Building 974 made them more useful in assessing potential impacts in this area, and they were included in this evaluation. As discussed in the introduction to Section 6.5.1, detections of chromium, cobalt, manganese, and nickel are attributed to sample lithology and are not evaluated further.

Of the remaining analytes, aluminum and iron exceeded ambient only in subsurface soils, and antimony, barium, cadmium, copper, silver, and thallium exceedences were limited to surface soils. Arsenic, cyanide, lead, mercury, and zinc were all detected above ambient in both surface and subsurface soils. A specific source of inorganics in these buildings is not known, but activities at the site suggest surface spills as the most likely source. The distribution of inorganics further suggests that sources are small and isolated, only impacting localized areas of soil.

Aluminum was detected slightly (3.4%) above the ambient concentration for beach/dune sand in the 5.0 ft bgs sample from boring 950SB01. This slight elevation is likely due to the high clay content described in the lithology log, and aluminum is not considered a COPC in this area.

Antimony was detected above the ambient fill concentration in one surface soil sample (973SB01) inside Building 973. This was the only detection of antimony in the immediate vicinity. Antimony will be evaluated as a COPC in surface soils at this site.

Arsenic was detected above the ambient fill concentration in one surface soil sample (973SS05). In addition to exceeding the ambient concentration, this detection was one order of magnitude higher than the nearest detection. This information suggests that the detected arsenic may be attributable to U.S. Army activities. Arsenic is considered a COPC in surface soils at this site. Arsenic was also detected above ambient (beach/dune sand) in the 6.7 ft bgs sample from Boring 979SB01. The detection exceeded ambient by less than three percent.

Barium was detected above ambient in Sample 950SS01, which was collected from a stained area within Building 950. A subsequent surface sample collected from the same stained area by Montgomery Watson also contained barium at a concentration above the ambient level for fill material. Barium is considered a surface COPC at this site.

Cadmium was detected above the ambient fill concentration in three surface soil samples, all within Building 950. This concentration of cadmium detections within the building was further supported by surface soil samples collected by Montgomery Watson. Cadmium is considered a surface COPC at this site.

Copper was detected above ambient in a surface soil sample from inside Building 973. The detected concentration was two percent greater than the ambient concentration for fill. Copper is not considered a COPC at this site.

Cyanide was detected above ambient in Sample 950SS02 at the surface. Cyanide was not detected in the underlying samples (Boring 950SB01). An additional exceedence was noted at 2.0 ft bgs in the nearby Montgomery Watson boring. Cyanide will be evaluated as a surface COPC.

Iron was detected above the ambient fill concentration at 2.0 and 5.0 ft bgs in Boring 950SB01. The detected concentration was below the ambient level for serpentinite.

Montgomery Watson later collected a 2.0 ft bgs sample from an adjacent boring that confirmed the detection but also was identified as serpentinite. The iron in the sample from Boring 950SB01 is attributed to lithology and not surface activities. The overlying surface sample did not exceed ambient. Iron is not considered a COPC.

Lead was detected above the ambient fill concentration in all but one of the surface soil samples collected in this area. The surface soils at the location of the one exception were resampled by Montgomery Watson and found to contain elevated lead. A maximum concentration of 4000 µg/g was detected. The lateral extent of these exceedences was defined by samples in Building 949 and surface samples collected from follow-on borings. Lead will be evaluated as a surface COPC at this site. In addition to the surface exceedences, there were five subsurface exceedences in the vicinity of Buildings 950 and 973. The maximum depth with an exceedence was 5.0 ft bgs.

During the initial RI, mercury was detected above the ambient concentration for fill in Sample 973SS03. The exceedence was not confirmed during follow-on sampling. Mercury was also detected above ambient levels in and to the west of Building 950. In this case, the exceedences were confirmed in both surface and subsurface soils by Montgomery Watson samples. The deepest subsurface exceedence was at 2.0 ft bgs in a Montgomery Watson boring. Mercury will be evaluated as a COPC in this area.

Silver was detected slightly (12%) above the ambient fill concentration in one surface soil sample inside Building 950. The fact that this exceedence was slight and not found in adjacent samples is the rationale for not evaluating silver as a COPC.

Thallium was detected above the ambient concentration for fill materials in Sample 950SS04. Due to data limitations, it was not possible to fully assess the nature and extent of thallium concentrations in this area. Thallium is, therefore, evaluated as a COPC.

Zinc was detected at several times the ambient fill concentration in two surface soil samples collected inside Building 950. These exceedences were confirmed by Montgomery Watson sampling, and zinc is considered a surface COPC in this area. Zinc exceeded the ambient

beach/dune sand concentration in the 5.0 ft bgs sample from Boring 950SB01 though ambient was not exceeded in the overlying sample.

TPH concentrations in excess of 100 $\mu\text{g/g}$ that are associated with Buildings 950 and 973 were detected only in surface soil samples. The vertical and lateral extent is defined by non-detections in all surrounding surface and subsurface soil samples (collected during the Follow-on RI). TPH was detected above 100 $\mu\text{g/g}$ in one of the surrounding samples, indicating that the extent of the high TPH concentrations is limited to the interior of the buildings and the immediate vicinity. Although TPH was detected at levels in excess of 100 $\mu\text{g/g}$ inside the buildings, the maximum sum of VOC and SVOC detections was 4.3 $\mu\text{g/g}$.

6.5.1.3 Building 979

Potential sources associated with Building 979 are surface spills and a UST which is no longer present. Only subsurface soil samples were collected in this area. Inorganics detected above the ambient fill concentration in the Building 979 Area (Boring 979GW05) are antimony, chromium, cobalt, nickel, and selenium. As discussed in the introduction to Section 6.5.1, the chromium, cobalt, and nickel concentrations are attributed to serpentinite in the sample.

Antimony and selenium are considered inorganic COPCs in this area. A source for these metals is unknown. VOCs were not detected in soil, and SVOCs have a limited areal extent, with PAHs occurring in one sample near the southeast corner of Building 979. Pesticides (endrin and endrin aldehyde) were detected at very low levels in a sample near the southeast corner of Building 979. The limited areal extent of inorganics and organics at Building 979 suggests that U.S. Army activities have had a minimal impact on soil. Impacts to groundwater are discussed later in this section.

6.5.2 Fate and Transport of Chemicals in Soil

Surface soil samples were collected near many of the buildings in the study area to assess whether chemicals from surface releases had accumulated. The primary release mechanisms associated with the surface soil are surface-water runoff, particulate transport, and leaching

to deeper soil and groundwater. The chemicals detected in adjacent samples varied, suggesting that the chemicals are isolated and may be the result of small spills.

Inorganics detected in surface soil samples at concentrations above ambient values were generally not found in subsurface soil samples. This indicates that infiltration/percolation is not an important primary release mechanism in the Building 900s Series Study Area. This is further supported by groundwater data, which show that areas of high inorganic concentrations in groundwater are due to natural weathering processes and not U.S. Army activities. In addition, metals that were detected in soils at elevated concentrations, such as cadmium and copper in the vicinity of Buildings 929, 930, and 931, were not found to be a problem in groundwater. This will be discussed in detail later in this RI section.

The most commonly detected organic analytes in surface soil samples were methylene chloride, PAHs, and bis(2-ethylhexyl)phthalate. Methylene chloride is highly volatile and soluble in water and its presence in surface soil samples is unusual. The results may not actually represent Methylene chloride concentrations in the samples because is a common laboratory contaminant. It was not detected in sediment or groundwater samples, which indicates that, if it was present in the soil, its distribution was limited and that leaching, particulate transport, and surface-water runoff are not significant release processes. Further, neither methylene chloride nor any other VOC was detected in Follow-on RI soil samples collected to define the possible extent of these chemicals, indicating that there has not been migration as deep as 0.5 ft bgs. PAHs were detected in two of the four sediment samples collected from catch basins in the study area, but were not always detected in the adjacent surface soil samples. Much of the Building 900s Series Study Area is paved and PAHs on sediment samples are possibly derived from the runoff in paved areas, as the compounds are associated with asphalt. PAHs have a strong affinity for soil and will possibly remain adsorbed to sediments. Discharge of the chemicals to San Francisco Bay would probably be by particulate transport of the sediments in storm drains. Comparison of chemical suites in soils and sediments suggests that surface-water runoff and particulate transport are not major release mechanisms for chemicals in surface soils.

The transport of potential contaminants to the Bay and the potential impact on aquatic life within the Bay were investigated as part of the ESAP. Stormwater and bay sediment samples were analyzed to assess the impact of four primary storm drains in the Building 900s Study Area and the potential migration of contaminated groundwater to the Bay. Sediment sample locations are shown on the posting maps and are identified by the prefix of "OF" for outfall, followed by the outfall number (i.e., 12, 13, 15, 16), and the specific sediment sample number from that outfall (i.e., SD01, etc.).

The analytical and bioassay testing data for stormwater indicated potential toxicity at Outfalls 12, 13, and 16, most likely associated with the concentrations of metals in the stormwater. However, only the drainage associated with Outfall 16 is interpreted to be producing higher than expected concentrations of metals for an urban environment (Dames & Moore, 1996a, b). Based on the drain system configuration, the potential source of these metals (arsenic, chromium, and copper) is the Building 979 area, but no confirmation of elevated levels in the soil has been made. Although these concentrations are higher than those reported in the other outfall samples, the calculated annual mass loading of metals to the Bay from this outfall falls at the lower end of the range estimated for each of the other outfalls. This is due to the low amount of flow typically observed at this outfall. This, in combination with potential dilution at the point of discharge, by rainfall and bay water during high tides, and the absence of apparent impacts to biota at the outfall, suggests that toxicity to aquatic life near the Outfall 16 discharge area predicted from these test results is an overestimation.

Chemicals detected in the stormwater do not appear to be incorporated into the sediments adjacent to the outfalls. Analytical and bioassay testing data for sediments indicated that although low levels of PAHs and pesticides were associated with a few samples from Outfalls 12, 13, and 15 (PAHs only), there was no significant effect on the toxicity of the sediments to the tested species. Therefore, it is likely that the toxicity associated with the stormwater is limited to the stormwater and its collection system, with no residual impact on the bay sediments. Furthermore, the PAHs and pesticides detected in the bay sediments may not be associated with the Building 900s Study Area, but derived from ubiquitous urban emissions and routine agricultural applications, respectively, on either the PSF or nearby properties.

6.5.3 Nature and Extent/Fate and Transport of Chemicals in Groundwater

This section discusses the nature and extent and fate and transport of inorganic and organic chemicals in groundwater. In order to provide a frame of reference for the following discussion, the concentrations of inorganics and organics in groundwater are compared to Primary MCLs and saltwater aquatic standards. The saltwater aquatic standards may only be applicable to groundwater within 150 ft of the shoreline, in the area that has been designated a Saltwater Ecological Protection Zone by the SCRs (California Regional Water Quality Control Board, 1996). In addition, comparison to MCLs does not imply that groundwater in the Building 900s Series Study Area is suitable for domestic or industrial use. In fact, the GMPA for the PSF prepared by the NPS (1994) does not include development of groundwater in the Building 900s Series Study Area for either a drinking water source or industrial use. In addition, several of the California secondary MCLs are exceeded in the study area because of saltwater intrusion, as was discussed previously in Sections 2.3 and 6.3 of this RI report. Because of saltwater intrusion, groundwater in the study area does not meet criteria set forth in California Resolution 88-63 for potential municipal or domestic water supplies. The groundwater chemistry is used to evaluate whether chemicals in soils are leaching to the groundwater or fluctuations of water-table elevations result in adsorption of filtered chemicals onto soil particles. This is accomplished by comparing the suites of compounds detected in the soil and in adjacent groundwater. A regional evaluation of chemicals in groundwater is also provided in this section. Analytical data from the entire Building 900s Series Study Area are integrated in this section.

6.5.3.1 Inorganics

A spatial analysis of inorganic concentrations in groundwater was used to identify areas in the Building 900s Series Study Area where U.S. Army activities may have resulted in the release of inorganics to the groundwater. Representative posting maps were generated for the following analytes: aluminum, antimony, cadmium, chromium, copper, lead, manganese, nickel, thallium, and zinc. The maps present data from the three phases of RI sampling and the January 1995 and January 1996 quarterly sampling rounds. Two maps were created for each analyte except thallium; one contains results from shallow wells, and the other contains results from intermediate and deep wells. In the case of thallium, only the shallow well

results were posted. This series of posting maps is presented as Figures 6.5-29 through 6.5-47.

To identify areas of elevated concentrations, the mean concentration of detections (from multiple sampling events) was calculated for each inorganic analyte at each well. The spatial distribution of primary MCL and saltwater aquatic standard exceedences by these mean concentrations was then examined for patterns. This analysis excludes comparisons to secondary MCLs and major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity, and TDS). The distribution of major ions and TDS was discussed previously in Sections 2 and 6.3 of this RI report.

Three regions of high inorganic concentrations were identified from this spatial analysis. These regions are areas where the mean concentrations of several inorganics either exceed primary MCLs and/or saltwater aquatic standards or are higher than in other portions of the study area. These areas are as follows: north of Building 937 (Wells 937GW01, 937GW10, and 937GW22), southeast of Building 937 (Wells 937GW07 and 937GW37), and in the southern-most portion of the study area (in the vicinity of Wells 937GW17, 937GW18, and 937GW19). The inorganics detected above primary MCLs and saltwater aquatic standards (or at higher concentrations as compared to surrounding wells) in one or more of these areas are aluminum, antimony, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, and zinc. As described below, the elevated inorganic concentrations in groundwater samples from these regions are likely to be attributable to natural weathering processes.

The inorganic groundwater chemistry in the Building 900s Series Study Area reflects the composition of the bedrock and the unconsolidated beach deposits that are largely derived from the serpentinite bedrock as well as the composition of San Francisco Bay. Common constituents of serpentinite that are found in soils at the PSF are chromium, iron, magnesium, manganese, nickel, and cobalt (as described in Section 3.7). All of these ions, with the exception of cobalt, were detected in groundwater throughout the Building 900s Series Study Area, and the higher concentrations occur primarily in the three regions identified above. Concentrations of these ions are higher in some portions of the aquifer than in others because of hydrogeologic factors such as groundwater residence time, variability in

soil chemistry and grain size, temperature, pH, and salinity. It is evident that in the areas of higher concentrations of chromium, iron, magnesium, manganese, nickel, and cobalt, either weathering rates or residence times are greater than in areas of lower ion concentrations.

The spatial analysis further suggests that the elevated aluminum, antimony, cadmium, copper, lead, molybdenum, and zinc detections in groundwater are also due to natural processes. The three regions where these inorganics occur at elevated concentrations consistently coincide with the regions of high concentrations of the serpentinite-derived inorganics described in the preceding paragraph (chromium, iron, magnesium, manganese, nickel, and cobalt). Aluminum, antimony, cadmium, copper, lead, molybdenum, and zinc are common constituents of serpentinite-derived soils, even though the concentrations are not statistically higher than in other soil types at the PSF. The co-occurrence of high concentrations of all inorganics in groundwater from the Building 900s Series Study Area, the evidence that vertical migration of inorganics through soils is limited, and the fact that areas of elevated inorganic concentrations do not correlate with areas of organic compounds all suggest that the aluminum, antimony, cadmium, copper, lead, molybdenum, and zinc detections are likely to be attributable to variability in natural chemistry, weathering rates, or residence times within the Building 900s Series Study Area.

The absence of a source for inorganics in groundwater is further supported by the soil investigations in the study area, which show that leaching is not an active process. Inorganic concentrations in soil decrease with depth to levels below ambient values, and most elevated detections were limited to surface soils. Because inorganics in groundwater are thought to be naturally derived, comparison to aquatic standards was not conducted. In concurrence with the RI results, groundwater discharge to the Bay did not appear to impact inorganics concentrations in ESAP bay sediment samples (D&M, 1996a, b).

6.5.3.2 Organics

This section presents a discussion of organic compounds in groundwater focusing on the three major groups of organics detected in the groundwater in the Building 900s Series Study Area: BTEX compounds, chlorinated solvents and their degradation products, and TPH-D. Detections of other VOCs were infrequent and generally occurred in wells that also

contained BTEX and/or chlorinated compounds. Similarly, SVOC detections were infrequent, at low concentrations, and attributed largely to method blank contamination. There were no detections of OCPs, PCBs, or chlorinated herbicides in groundwater from the study area.

Three approaches are used to understand the distribution of each of the selected chemical groups (BTEX, chlorinated compounds, and TPH-D). The first approach examines trends in concentration over time and uses the analytical data from 13 sampling events (1990 through 1995) in the Building 900s Series Study Area. The second approach identifies source areas by examining where the highest concentrations of compounds occur, regardless of sampling event. Lastly, the current distribution of organic compounds is described using the analytical results from the most recent sampling event. In Section 6.4, results from Buildings 937 and 979 were described separately. In this section, results are integrated to provide a comprehensive description of the chemical distribution in groundwater and to identify source areas.

For each approach, concentrations of related compounds were summed. Concentrations of benzene, toluene, ethylbenzene, and xylene were summed because they are typically found together as low molecular weight compounds in fuels. Chlorinated compounds were summed in two groups: parent chlorinated solvent compounds and degraded chlorinated compounds. The former includes tetrachloroethene and 1,1,1-trichloroethane as well as two compounds that can be either parent or degradation products (trichloroethene and 1,1-dichloroethane). The degraded chlorinated compound group includes 1,1-dichloroethene, cis- and trans-1,2-dichloroethene, 1,2-dichloroethane, and vinyl chloride. TPH-D and TPH-G measurements each constitute a summed concentration of numerous compounds within a defined range of molecule size, which is based on the number of carbon atoms. The results of these analyses are not compound specific, so additional summation was unnecessary except in the case of the trend plots, on which a total TPH concentration was plotted (i.e., the sum of TPH-D and TPH-G results).

The first analytical approach centered on the evaluation of trend plots. The trend plots, which are presented as Figures 6.5-48 through 6.5-64, show a value for every sampling

event during which a well was sampled. If there were no detections of related compounds at a particular well during a given sampling event, the sum of the reporting limits is shown on the trend plots. The summed reporting limit is not directly related to the presence or absence of a compound because individual reporting limits are not additive in reality. Reporting limits are sometimes elevated because of sample dilutions in the analytical laboratory. In these instances, the sum of the reporting limits is still shown on the trend plot even though the points do not necessarily indicate the presence or absence of a compound. On each plot, the "U" symbol indicates a sum of non-detects. Several wells are shown on each trend plot. Well clusters, which consist of two or three wells that screen different portions of the aquifer, are generally shown on the same plot. There is also a series of trend plots that include all wells adjacent to San Francisco Bay. Other wells are generally grouped onto the same trend plot if they screen the same portion of the aquifer (i.e. shallow wells or deep wells) or are adjacent to one another. The trend plots are presented in the report according to compound group as follows. BTEX compound trend plots are shown in Figures 6.5-48 and 6.5-49. Parent chlorinated compound trend plots are shown in Figures 6.5-50 and 6.5-51. Degraded chlorinated compound trend plots are in Figure 6.5-52 through 6.5-57, and TPH trend plots are shown in Figures 6.5-58 through 6.5-64.

Concentration maps were created using data from the most recent RI sampling event, which included sampling of groundwater monitoring wells and the collection of discrete groundwater samples. Figures 6.5-65 through 6.5-74 present the maps of summed concentrations that were created for the four most commonly detected groups of compounds: BTEX, parent chlorinated compounds, degraded chlorinated compounds, and TPH-D. To show the vertical distribution of chemicals, separate maps were created for the shallow, intermediate, and deep portions of the aquifer. The shallow zone maps include results for all wells screened across the water table and the shallowest discrete groundwater samples. The intermediate zone maps include results from the three intermediate wells in the study area (Wells 937GW41, 937GW42, and 937GW43) and discrete groundwater samples collected from the middle portions of the aquifer (available only for chlorinated compounds in the Building 979 Area). The deep zone maps include results for wells that are screened at the bottom of the aquifer and the results for discrete groundwater samples collected immediately

above bedrock. Because discrete groundwater samples for BTEX compounds and TPH-D were not collected, concentrations in intermediate and deep wells are shown on the same maps.

In addition to the summed concentration maps, individual posting maps were created for trichloroethene, cis-1,2-dichloroethene, and vinyl chloride. The maps present data from the three phases of RI sampling and the January 1995 and January 1996 quarterly sampling rounds. Two maps were created for each analyte; one contains results from shallow wells, and the other contains results from intermediate and deep wells. This series of posting maps is presented as Figures 6.5-75 through 6.5-80.

The following discussion incorporates the approaches outlined above to provide a detailed assessment of the distribution of the three compound groups. A summary of source areas is also provided within the context of the discussion.

BTEX Compounds. The BTEX detections in soil and product removed as part of the IRA indicated that there was a BTEX source near the northeast corner of Building 937. The highest groundwater detections of BTEX compounds were in wells that contained product: 937GW02, 937GW03, 937GW11 and 937GW36. Wells 937GW02 and 937GW11 were removed as part of the IRA, and Well 937GW36 is a replacement for Well 937GW11. These four wells are (or were) located within 50 ft of the northeast corner of Building 937, and detected concentrations of benzene consistently exceeded the primary MCL of 1 $\mu\text{g/L}$ in each well. The detected BTEX concentrations are partially attributed to emulsification of some of the product during groundwater sampling and are, therefore, higher than in other wells. This is supported by the much lower concentrations of BTEX compounds in the intermediate and deep wells associated with the well cluster at Well 937GW36 (Figure 6.5-48). Maximum BTEX concentrations in the intermediate and deep zone at this well cluster were 44 $\mu\text{g/L}$ and 3.5 $\mu\text{g/L}$, respectively. In comparison, maximum BTEX compound concentrations in the shallow well at this cluster was often between 100 to 1,000 $\mu\text{g/L}$. Concentrations of BTEX compounds in the intermediate and deep portions of the aquifer show an overall decrease in concentration with time.

Detections of BTEX compounds further than 50 ft from the source area are, with a few exceptions, north-northeast of Building 937, in the regionally downgradient direction. Concentrations of BTEX compounds in shallow, intermediate, and deep wells decrease by an order of magnitude with depth and distance from Building 937. Outside of the source area, there were no detections of toluene, ethylbenzene, or xylene in excess of primary MCLs. The maximum detection of benzene outside of the source area was 3.1 $\mu\text{g/L}$. Benzene was detected above the primary MCL of 1 $\mu\text{g/L}$ at Well 937GW23 (during 2 out of 13 sampling events) and Well 937GW28 (during 1 of 13 sampling events).

As shown in Figure 6.5-49, there have been few detections of BTEX compounds in wells near San Francisco Bay, indicating that migration of these compounds to the bay is limited. There were no detections of BTEX compounds in deep monitoring wells located outside of the source area, indicating that downward vertical migration of BTEX compounds is negligible.

The limited areal and vertical distribution of BTEX compounds, as recorded during the most recent sampling events, is further illustrated in Figures 6.5-65 and 6.5-66. The highest concentrations are within the source area.

Parent and Degraded Chlorinated Compounds. Chlorinated compounds had a greater distribution than the BTEX compounds, and there appear to be two source areas within the Building 900s Series Study Area. One is located near the northeast corner of Building 937, and the other is near the southeast corner of Building 979 (Figures 6.5-67 through 6.5-72). All detections of parent chlorinated compounds clearly associated with the source at Building 937 are within 150 ft of the northeast corner of the building. As shown in the trend plots (Figures 6.5-50 and 6.5-51) concentrations in the deep portion of aquifer in this area have been up to two orders of magnitude higher than in shallow portions. The trend plots also show that since sampling began in 1990, the summed concentration of parent chlorinated compounds has decreased, with very few detections occurring near Building 937 during the most recent sampling event (Figures 6.5-67, 6.5-67, and 6.5-69). The absence of parent chlorinated compounds in deep and shallow wells regionally downgradient of the source area at Building 937, in conjunction with the high

concentrations of degraded chlorinated compounds detected near Building 937 in all three portions of the aquifer during the most recent sampling event (Figures 6.5-70, 6.5-71, and 6.5-72), indicates that the parent compounds are degrading rather than migrating from the source area. Apparently, the compounds degrade more quickly than they are transported through advection (groundwater flow).

Parent chlorinated compounds from Building 937 are not migrating to the southern portions of the Building 900s Series Study Area, as evidenced by the consistent non-detects at 12 monitoring wells during multiple sampling events. The southern-most extent of parent chlorinated compounds is defined by consistent non-detects at shallow Wells 937GW07, 937GW12, and 937GW37 and deep Well 937GW38. The extent of parent chlorinated compounds toward the Bay is defined by consistent non-detects at shallow wells 937GW23, 937GW33, 937GW10, 937GW06, 937GW24, and by nine non-detects in ten sampling events in Well 937GW08. Parent chlorinated compound concentrations within the source area frequently exceeded primary MCLs, often by an order of magnitude or more.

The areal extent of degraded chlorinated compounds associated with Building 937 is greater than the distribution of parent compounds (Figures 6.5-70, 6.5-71, and 6.5-72). Migration of degraded chlorinated compounds from the source area at Building 937 is primarily in the direction of the regional gradient (northeast) in the shallow and intermediate portions of the aquifer (Figures 6.5-70 and 6.5-71). Attenuation of degraded chlorinated compounds in the shallow portion of the aquifer occurs within approximately 150 ft northeast and southeast of the source at Building 937. In the deep portion of the aquifer (Figure 6.5-72), degraded chlorinated compounds appear to migrate to the north-northwest and show less attenuation than in shallow and intermediate groundwater. Exceedences of primary MCLs for degraded compounds are common in wells regionally downgradient from Building 937.

Degraded chlorinated compounds have not been detected in the deep monitoring well south of Building 937. There have been detections south of Building 937 in eight of the 12 shallow monitoring wells in this area. However, the detections of degraded chlorinated compounds south of Building 937 were single occurrences or two non-consecutive occurrences at five of the wells (937GW15, 937GW19, 937GW21, 937GW26, and 937GW37). Multiple and

consecutive detections of degraded compounds south of Building 937 were limited to three wells (Wells 937GW12, 937GW20, and 937GW27).

South of Building 937, exceedences of MCLs for chlorinated compounds are infrequent and concentrations are considerably lower than in the source area. Vinyl chloride detections south of the source area at Building 937 were limited to five wells. These detections were inconsistent and were only slightly above the MCL of 0.5 µg/L (with a maximum concentration of 4.1 µg/L). Cis-1,2-dichloroethene detections above the primary MCL (6 µg/L) occurred in one well (937GW20) during two of ten sampling events at a maximum concentration of 9.7 µg/L. All other cis- and trans-1,2-dichloroethene detections south of Building 937 were below primary MCLs. Chloroform was detected during one of thirteen sampling events, but at a concentration two orders of magnitude lower than the MCL. Parent chlorinated compounds and other degradation products were not detected south of Building 937.

The declining concentration of parent chlorinated compounds over time suggests that the removal of the USTs at Building 937 as part of the IRA has successfully removed the source. Although the concentrations of chlorinated parent compounds were at one time greater in deep portions of the aquifer than in shallow portions, there is no indication that the compounds exist as a separate phase at the bottom of the aquifer (i.e. as a dense non-aqueous phase liquid, or DNAPL). USEPA guidance is that DNAPLs may exist in areas where concentrations in groundwater are greater than one percent of the solubility. This is not the case in the Building 937 Area. For example, the highest concentration of a parent chlorinated compound in the Building 937 Area was 1,000 µg/L of 1,1,1-trichloroethane in a sample from deep Well 937GW32. The solubility of this compound is 4,400,000 µg/L (Verschuere, 1983), therefore, one percent of the solubility is 44,000 µg/L. Observed concentrations were over an order of magnitude lower, suggesting that a DNAPL is not present.

The second source of chlorinated compounds in the Building 900s Series Study Area is near Building 979, where trichloroethene has been detected at a maximum concentration of 200 µg/L at Well 979GW01. Parent chlorinated compounds are found in the shallow,

intermediate, and deep portions of the aquifer in the vicinity of Building 979 (Figures 6.5-67, 6.5-68, and 6.5-69). In contrast with the distribution of parent chlorinated solvents in the Building 937 Area, parent chlorinated compounds are consistently detected in the aquifer near Building 979 and concentrations decrease with depth.

Degraded chlorinated compounds are prevalent in the vicinity of Building 979 in shallow and intermediate portions of the aquifer and occur at low concentrations or not at all in deep portions of the aquifer (Figures 6.5-70, 6.5-71, and 6.5-72). Comparison of the parent and degraded chlorinated compound maps also shows the greater areal extent of degraded compounds, as compared to parent compounds, in shallow and intermediate portions of the aquifer. The low concentration or absence of degraded chlorinated compounds in deep portions of the aquifer at Building 979 suggests that vertical or horizontal hydraulic gradients prevent migration of the degraded compounds to deeper portions of the aquifer and/or the degradation products in deep portions of the aquifer have further degraded to constituent components of water, carbon dioxide, and chloride.

Migration from the source area at Building 979 is to the northeast, east, and south. Migration to the north or northwest is limited, as evidenced by the non-detects in monitoring Wells 937GW04 and 937GW09 and in discrete groundwater samples from Borings 979SB09, 979SB11, and 979SB15. Similarly, close to San Francisco Bay (the ultimate discharge point for groundwater in the Building 900s Series Study Area) there have been no detections of chlorinated compounds in deep monitoring wells or deep discrete groundwater samples.

As with the source at Building 937, chlorinated compounds in shallow and intermediate portions of the aquifer appear to attenuate to concentrations below reporting limits within approximately 150 to 200 feet from the southeast corner of Building 979 (Figures 6.5-67, 6.5-68, 6.5-70, and 6.5-71). In the deep portion of the aquifer, parent chlorinated compounds are more dispersed, with detections thought to be associated with Building 979 occurring approximately 450 ft south of Building 979.

The suspected source for the chlorinated compounds at Building 979 is a surface spill of waste POL that reportedly occurred in January 1982. The spill resulted from leaving a

funnel in an uncapped inlet pipe through which rainwater (during a large storm) entered. The waste POL, displaced by the rainwater, was forced up the inlet pipe and spilled onto the ground surface (ANL, 1989). The spill was quickly contained. A surface spill is consistent with the distribution of chlorinated compounds, which shows a decrease in concentration with depth. All USTs in the Building 979 area are thought to have contained either diesel or gasoline and therefore would not be likely sources for chlorinated compounds. In addition, all USTs in the Building 979 Area have been removed as part of the base-wide UST management program. Therefore, it is felt that there is no existing source currently contributing chlorinated compounds to the groundwater in the Building 979 Area.

Between the Building 937 and Building 979 source areas, is a region near the coast where parent chlorinated compounds are occasionally detected and degraded chlorinated compounds are frequently detected, particularly in shallow portions of the aquifer (Table 6.4-14). The approximate location and extent of this area is the non-contoured region in Figure 6.5-70. The concentrations of chlorinated compounds in this area are consistently lower than in either of the identified source areas (Figure 6.5-56). The relatively low concentrations, absence of parent chlorinated compounds, and no historical evidence of a release of chlorinated compounds in this area all suggest that the chlorinated compounds in this area are derived from the Building 937 and/or the Building 979 source areas. This region is referred to as the mixing zone.

The chlorinated compound detections in the mixing zone are not contoured because of the uncertainty of the source area (Building 937 and/or Building 979). The uncertainty is due largely to the complexity of groundwater flow directions in the Building 900s Series Study Area. As discussed in Section 6.3, groundwater often changes flow directions in response to tidal fluctuations in San Francisco Bay. Local groundwater divides and drainages develop and disappear within a matter of hours. As a result, the distribution of chlorinated compounds outside of the source areas at Buildings 937 and 979 is dispersed. In addition, the natural degradation of chlorinated solvents also adds to the complexity of attributing the detections within the mixing zone to Building 937 and/or Building 979 sources. Degradation rates will vary across the site and are controlled by local conditions. The primary migration direction of the chlorinated compounds from the source at Building 937 to the north and

from the source at Building 979 to the southeast, discussed above, is consistent with the conclusion that chlorinated compounds in the mixing zones are derived from either or both of these source areas.

TPH-D. TPH was detected throughout the Building 900s Series Study Area in the shallow portions of the aquifer (Figures 6.5-58 through 6.5-64). The trend plots show that detections did not occur during consecutive sampling events at most wells. The exception is in the vicinity of Building 937, where there was free product and a known BTEX source. TPH-D concentrations near Building 937 have been as high as 150,000 $\mu\text{g/L}$ in wells that contained product. Outside of the source area, TPH-D concentrations are generally below 200 $\mu\text{g/L}$ in the shallow portions of the aquifer (Figure 6.5-73). At well clusters, the TPH concentrations in intermediate and deep wells are generally similar to or lower than in the associated shallow wells, as shown on trend plots and Figure 6.5-74.

Concentrations of TPH-D and TPH-G were compared to water quality goals developed for the FPALDR (Montgomery Watson, 1995e) of 880 $\mu\text{g/L}$ and 770 $\mu\text{g/L}$, respectively. These values are intended to be protective of human health and the environment. The only current or historical exceedence of the water quality goals are in shallow wells that have historically contained product and are located within or adjacent to Building 937 (Wells 937GW02, 937GW03, 937GW11, and 937GW36). During the most recent sampling event, TPH-D concentrations in this area were approximately 5,000 $\mu\text{g/L}$. Attenuation to concentrations an order of magnitude below the water quality goal occurs over a very short distance, as illustrated in Figures 6.5-73 and 6.5-74. These figures show low concentrations of TPH-D in the intermediate and deep wells beneath the source area and in the shallow wells located approximately 100 ft from Building 937.

The source of the TPH detections is the product associated with the USTs that were removed as part of the IRA. Vertical and lateral migration of TPH-D is limited, as evidenced by the rapid attenuation of TPH-D concentrations away from the source area.

Summary. The distributions of organic compounds in groundwater indicate two source areas in the Building 900s Series Study Area. A source of BTEX, chlorinated solvents, and TPH is located near the northeast corner of Building 937. The source area encompasses Wells 937GW02, 937GW03, 937GW11, 937GW04, 937GW31, 937GW32, and 937GW36. The sources at Building 937 were two USTs, product, and soil that were removed as part of the IRA. The second source area in the Building 900s Series Study Area is chlorinated compounds in the vicinity of Building 979. This source area includes Wells 979GW01, 979GW02, 979GW03, and 979GW05. The northern extent of this source is defined by non-detects in deep and shallow wells north of Building 979. A mixing zone, which contains chlorinated compounds derived from Building 937 and/or Building 979 has also been identified.

Primary MCLs for chlorinated compounds are exceeded at most wells within the Building 937 and Building 979 source areas and within the mixing zone. South of Building 937, there are few detections of chlorinated compounds, and very few detections that exceed primary MCLs.

As part of the ESAP, the potential for bay sediment contamination from VOCs in the Building 900s groundwater was investigated. In Phase I of the ESAP, bay sediment samples were collected offshore from the Building 900s Study Area and analyzed for the suite of VOCs detected in groundwater (Samples 900SD05 through 900SD09). None of these VOCs were detected in the sediment, indicating that the potential impact of groundwater discharge to the bay on infaunal populations is minimal.

6.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY

This section summarizes the evaluation of results for the Building 900s Series Study Area and the results of the risk assessment, which are presented in detail in Section 15.

6.6.1 Conclusions

The investigations in the Building 900s Series Study Area were designed to assess the chemical impact of U.S. Army activities at the site. Potential sources were identified, and

analytical samples were collected from various media. For the purposes of this RI, the area was divided into three subregions: the Vehicle Maintenance Area, the Storage Building Area, and Building 979. The evaluation of groundwater included all three areas. Conclusions for the each subregion and for groundwater are presented in the following four sections.

6.6.1.1 Vehicle Maintenance Area

The evaluation of the Vehicle Maintenance Area was subdivided to allow the separate assessment of Building 937, which was treated in greater detail under the IRA.

Potential contaminant sources for Buildings 923 through 935 in the Vehicle Maintenance Area are surface spills or leaks from equipment. The primary source of inorganics in this area was activities such as steam cleaning and the storage of paints and batteries in the vicinity of Buildings 929, 930, and 931. Elevated inorganic detections elsewhere in the Vehicle Maintenance Area suggest other small, isolated sources. The vertical extent of elevated inorganic detections in soil throughout the area is limited, with very few exceedences of ambient values in subsurface samples. In addition, there is no indication that groundwater is impacted by inorganic soil contamination. Several organic compounds were detected in soil from Buildings 923 through 935, but the lateral and vertical extent was limited, indicating that U.S. Army activities have had little impact on the soil.

The potential contaminant sources evaluated at Building 937 are surface spills and USTs. Two USTs, contaminated soil, and petroleum product have been removed from this area as part of the IRA. Though elevated inorganics have been detected at the site and will be evaluated in the Risk Assessment, a specific source of inorganics is unknown.

BTEX compounds are the most commonly detected organics in soils in the Building 937 Area, with the highest concentrations generally occurring where there is product. Soil samples saturated with petroleum product have been collected outside the area of the IRA excavation and a thin sheen of product has been sometimes observed in Wells 937GW03 and 937GW36. BTEX compounds and TPH are present at high concentrations in shallow groundwater where product is observed. Soil near Well 937GW36 was excavated to the extent possible in 1992 as part of the IRA to remove product. The well was installed after

soil removal. The only remaining potential source for product at this well is in soil beneath the footings for Building 937. Further excavation here would undermine the structural integrity of the building and is not recommended. The area continues to be evaluated through quarterly groundwater sampling.

6.6.1.2 Storage Building Area

The Storage Building Area included four buildings: 949, 950, 973, and 974. These pole-construction buildings were used to store a variety of materials over the history of the site, and Building 950 was temporarily used to store hazardous materials. The potential sources evaluated in this area were surface spills and leaks. Numerous inorganics were detected, generally with limited vertical extents. With the exception of lead, elevated detections of inorganics were generally limited to samples collected from building interiors. Organic COPCs identified in this area include several PAHs, phthalates, ppDDE, TPH, and trichlorofluoromethane.

6.6.1.3 Building 979

The potential source evaluated at Building 979 was surface spills. Elevated chemical detections in soil are limited to a few inorganics, pesticides at very low concentrations, SVOCs, and TPH. The areal extent of each of these is limited and chemicals in the soil do not appear to impact groundwater.

6.6.1.4 Groundwater

The total extent of groundwater contaminated by BTEX, chlorinated compounds, and TPH resulting from releases at Building 937 and 979 has been defined by the investigations in the Building 900s Series Study Area. The chemical sources in each of these areas have been removed. The investigation and quarterly monitoring program show that natural attenuation is occurring. For BTEX and TPH compounds, there has been minimal migration away from the source area at Building 937. Trends in the distribution of chlorinated compounds over time show a decrease in parent compounds due to degradation. Migration of parent compounds south of Building 937 has not occurred. A few detections of degraded

chlorinated compounds have occurred south of Building 937; however, these are isolated occurrences and generally do not exceed primary MCLs.

Inorganic source areas in most of the Building 900s Series Study Area have not been identified for groundwater. Most areas where primary MCLs and saltwater aquatic standards are exceeded are associated with natural weathering processes. Wells 937GW03 and 937GW36, located near Building 937 have contained product. The residual product in these wells is the source of high inorganic concentrations at these locations. Migration of the inorganics from this area is not evident.

6.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

Neither the sediments from storm drains nor the wipe samples were assessed, because exposure to the sediments is unlikely under the future use scenarios for the Building 900s Series Study Area, and wipe samples cannot be used quantitatively. The impact of sediments to ecological receptors in San Francisco Bay was evaluated as part of the ESAP (WJE, 1993b and 1994c), and ESAP data indicate that the transport of contaminants in sediment is not an exposure pathway that significantly affects the toxicity to aquatic receptors in the Bay.

Inorganics, miscellaneous parameters, and organics in groundwater are considered in both the human health and ecological risk assessments. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source for Buildings 290, 926 and 927, 923 through 925, and 937.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than

5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated in the PRG ratio screening. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 900s Series Study Area are summarized in the following sections.

6.6.2.1 Human Health

The Building 900s Series Study Area was assessed as several different areas in the human health risk assessment because of the variation in sources and associated COPCs. The GMPA identified institutional (industrial) use in the Vehicle Maintenance Area and open space (recreational) uses within the Storage Building and Building 979 areas. In addition, a construction (industrial) scenario was evaluated for exposure to groundwater across the site. Under the industrial scenario evaluated for the Vehicle Maintenance Area, exposures to surface soil (0 to less than 0.5 ft bgs), subsurface soil (0.5 to less than 15 ft bgs), and the PSF water supply are assumed. Under the recreational scenario evaluated for the Storage Building and Building 979 areas, only exposure to surface soil from 0.0 to less than 2.0 ft bgs is assumed.

Two additional assessments of risk were performed for the Building 900s Series Study Area that are not based on the planned future use of the site. These include assessment of groundwater as drinking water and a residential PRG ratio screening assessment. Groundwater was assessed as drinking water site-wide although groundwater beneath the site is an unlikely potable water supply for the industrial worker in the area.

The residential PRG ratio screening assessment for surface and subsurface soil and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure

parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 900s Series Study Area are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead soil screening values, are identified.

6.6.2.1.1 Quantification of Cancer Risks

Buildings 920 and 926/927 had no analytes which were COCs in the media sampled. Therefore, these sites were assessed for the institutional worker exposed to the PSF water supply only. The COCs in the PSF water supply are not considered carcinogenic and it is unlikely that there is an excess cancer risk from exposure to them.

PCB 1254, PCB 1260, arsenic, cadmium, lead, mercury, methylene chloride, 1,4-dichlorobenzene, and phenanthrene were the COCs in surface soil for the Building 923 Area (Buildings 923 through 935) which also assessed PSF water supply exposure to the institutional workers. The total risk for the industrial/institutional worker exposed via ingestion of and dermal contact with surface soil and PSF water supply is $2E-05$, mostly from PCB 1254 and arsenic. PCB 1254, PCB 1260, and arsenic have total risks by chemical greater than $1E-06$. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Building 937 had methylene chloride, 2-methylnaphthalene, TPH-diesel fraction, TPH-gas fraction, and phenanthrene as the COCs in subsurface soil for assessment of exposure to institutional workers as well as the COCs in PSF water supply. Methylene chloride, the only carcinogenic COC has a total risk of $7E-08$, which is less than $1E-06$ and, therefore, it is unlikely that exposure to these COCs at this site will result in excess cancer risk. The residential PRG ratio screening assessment, however, resulted in a total cancer risk greater than $1E-06$.

Buildings 950 and 973/974 Area had inorganics (arsenic, cadmium, lead, and thallium as the COCs in surface soil samples. A recreational visitor scenario with exposure via incidental ingestion of and dermal contact with surface soil has an excess carcinogenic risk of $5E-06$ from arsenic, the only carcinogenic COC. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

COCs in the Building 900s Series Study Area groundwater included several inorganics, VOCs, SVOCs, and water quality parameters. Construction workers during the remediation of the USTs at the study area have a total cancer risk of $7E-08$, which is less than $1E-06$

and, therefore, they are unlikely to have excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

6.6.2.1.2 Quantification of Noncarcinogenic Effects

All the noncarcinogenic COCs have hazard indices less than $1E+00$ and, therefore, it is unlikely that exposure to the COCs at these sites will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ for Buildings 923 area, 937, 950, and the Building 900s Series Study Area groundwater.

Maximum detected values of lead in surface soil for the Buildings 923 and 950 areas are 4700 and 4000 mg/kg, respectively. These exceed the soil lead screening value of 840 mg/kg considered acceptable for industrial and recreational scenarios.

6.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds. Additionally, because of the proximity of the site to San Francisco Bay and the planned restoration of this area, waterfowl and wading birds were evaluated for soil ingestion and dermal contact but not dietary exposure, since their feeding is expected to be limited to the shoreline area.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been

shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

The identified COPCs for the Building 900s site included VOCs, PAHs, arsenic, barium, cadmium, copper, cyanide, dieldrin, mercury, lead, antimony, thallium, zinc, TPH-diesel, Aroclor 1254 and 1260, ppDDD, ppDDE and ppDDT in soils.

Results of the HQ evaluation indicate the following:

- HIs exceeded 1 for the American robin, mourning dove, peregrine falcon, western harvest mouse, pocket gopher, and western sandpiper, and plants and soil fauna exceeded 1 when exposure was compared to the conservative TBV_{Low} . HI values were above 1000 for the robin, and above 100 for the dove and the sandpiper.
- HIs exceeded 1 for the American robin, mourning dove, western harvest mouse, western sandpiper, and plants and soil fauna when exposure was compared to the TBV_{High} . HIs were above 10 for the robin.
- Lead produced the highest HQ for any exposure pathway for birds, mammals, and plants and soil fauna based on comparison to the TBV_{Low} and TBV_{High} .
- HQs for lead, PCB 1254, and zinc were greater than 1 for the American robin based on comparison to the TBV_{High} for soil or dietary ingestion.
- Other COPCs that produced HQs in excess of 1 for the American robin were barium, cadmium, copper, ppDDT, DNBP, mercury, PCB 1254, PCB 1260, thallium, and zinc when exposure was compared to the TBV_{Low} .
- Only lead produced an HQ greater than 1 for the mourning dove when exposure was compared to the TBV_{High} .
- COPCs that contribute to the potential risk to plants and soil fauna include zinc, thallium, lead, copper, and cadmium based on comparison to the TBV_{Low} .

Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS from the perspective of ecological risk.

7. DIRECTORATE OF ENGINEERING AND HOUSING STUDY AREA

This section of the Presidio Main Installation RI presents the DEH Study Area description, sample location rationale, hydrogeologic setting, analytical results, results evaluation, and conclusions. Areas within the DEH Study Area were selected for evaluation during 1990 RI activities on the basis of observed building uses and findings reported in the *Enhanced Preliminary Assessment Report* (ANL, 1989). During the summer of 1992, supplemental studies were conducted in the DEH Study Area. Further sampling was conducted in 1994 and 1995 during the Follow-on RI based on agency comments and the analytical results from previous field efforts. The existing wells at the site are being sampled on a quarterly basis, and a report presenting the draft Remedial Action Plan for the site is currently being prepared.

7.1 AREA DESCRIPTION

The DEH Study Area was used by U.S. Army personnel to provide administrative, storage, and maintenance support services for the PSF. The following DEH Study Area locations were evaluated along with their immediate surroundings:

- Building 267 (wash rack)
- Building 268 (maintenance garage)
- Building 269 (pesticide storage)
- Building 283 (vehicle maintenance garage)
- Building 285 (paint shop)
- Building 286 (waste storage area)
- Building 287 (grounds maintenance)
- Building 293 (pesticide storage).

The location and physical features, history and land use, and previous investigations in the DEH Study Area are described in the following sections.

7.1.1 Location and Physical Features

The DEH Study Area is located in the northeastern corner of the PSF and covers an area of approximately 4.4 ac (Figure 2.1-1). A fence encloses the area which is bounded by San Francisco Bay to the north, Allen Street to the south, Lyon Street to the east, and the EOM Study Area to the west. Access to the DEH Study Area is provided by Marina Boulevard to the east and Mason Street to the west.

The topography in the DEH Study Area is flat with ground elevations less than 12 ft-PLL. During the course of U.S. Army activities, the majority of the ground surface in the DEH Study Area was covered with concrete or asphalt, and stormwater runoff was collected by a storm drain network that discharged into San Francisco Bay (Figure 7.1-1). Currently, all of the buildings in the area have been demolished by the NPS in accordance with the reuse plan, and surface soils are exposed over the entirety of the site. As part of the building demolition, existing utilities were disconnected and in part removed or abandoned. In addition, the permanent fences which had restricted access to the general DEH Study Area have been replaced with temporary construction fences. Figures prepared for this RI report reflect conditions at the time of RI sampling.

7.1.2 History and Land Use

The DEH Study Area was mapped as sand dunes by the U.S. Coast Survey in 1851 (D&M, 1995b). In 1882, the area was still considered beach-dune sand by the U.S. Surveyor General (Figure 5.1-2), but it is speculated that the current topography was achieved through grading and the use of debris fill from the 1906 earthquake.

Construction of buildings in the DEH Study Area began in the early 1900s with new buildings periodically constructed in subsequent years. The buildings and their uses are described below. Additional historical information regarding petroleum tanks and underground pipelines in the DEH Study Area was brought to the U.S. Army's attention after the RI field work was completed. Investigation of these features, and resulting corrective action, if any, will be conducted under the U.S. Army's petroleum cleanup program at the PSF.

Building 268 was located in the northeast corner of the DEH Study Area (Figure 7.1-1). The 11,500-ft² building was constructed in 1958 as a temporary structure and had a dirt floor with some concrete and asphalt sections. It endured as a single-story building with a reinforced concrete pier foundation and three sides composed of wood, plywood, and corrugated iron. It was used to store maintenance vehicles prior to the transfer of the PSF to the NPS. The paved area north of Building 268 was used to store wastes and material such as paints prior to off-site disposal. The 1988 aerial photos (Rindgen and Sitton, 1990) indicate debris, equipment, and raw materials along the north side of this building. A survey conducted for the *Enhanced Preliminary Assessment Report* (ANL, 1989) found that the floor of the building and areas in the storage yard were stained.

A 200-gal fuel oil AST was located north of Building 268, and a 1,200-gal AST with a concrete barrier was located approximately 200 ft west of the building. The ASTs have been removed from the area. Interviews with PSF personnel indicated that transformers were stored adjacent to Building 268 and may have been filled with fluid containing PCBs (ECJC, 1990b). The transformers were removed prior to the start of the RI.

Building 269, which was located in the eastern section of the DEH Study Area, was constructed in 1971 for storing and mixing pesticides for use at the PSF (Figure 7.1-1). The 824-ft², single-story, wood and plywood structure was built on a concrete pier foundation. Pesticides were mixed in the northeast corner of the building on a concrete pad with raised curbing on two sides and walls on the remaining two sides. Rinsate wastes were collected by a floor drain and routed to a 1,500-gal UST adjacent to the building (ANL, 1989). During the site survey for the *Enhanced Preliminary Assessment Report* (ANL, 1989), the concrete around a drain on the north side of the building appeared to be stained and cracked. The 1,500 gal tank was removed in July 1995 and found to be in good condition. During the removal of this tank, three additional tanks were discovered and removed. These tanks had contained petroleum products, were in poor condition, and were located above a concrete pad. Petroleum contaminated soil and groundwater were removed, along with the concrete pad. An additional area of petroleum hydrocarbon contamination was identified, but not removed, northwest of the pesticide tank. Additional information regarding the tank removal can be found in the *Tank Removal Report, Building 269* (Montgomery Watson, 1996m).

Building 283 was constructed in 1914 in the eastern part of the DEH Study Area (Figure 7.1-1). The 12,184-ft², two-story, wood and metal structure was built on a reinforced concrete, continuous-footing foundation. The building was historically used for removal and repair of aircraft engines. It was recently used for vehicle maintenance and offices before being transferred to the NPS. A 6,000-pound diesel lift, two compressed-air tanks, and a parts washer with an exhaust hood were used in the building. Used automotive batteries were stored temporarily on wooden pallets in a brick enclosure in the shop, and oil stains were present on the shop floor. Waste oil was temporarily stored in drums resting on pallets in a small shed outside the shop. The pallets were surrounded by a 4-in berm to contain spills, but the asphalt area immediately outside of the shed was stained.

Building 285 was located in the western section of the DEH Study Area (Figure 7.1-1) and was used for painting signs, vehicle components, and furniture with enamel and latex paints before being transferred to the NPS. The 5,914-ft², single-story, wood and metal structure was built in 1944 on a concrete, continuous-footing foundation. It contained a spray booth equipped with a dry filter system to control paint emissions, and an exhaust hood was installed in the mid-1980s to vent paint overspray from the building. A large room adjacent to the paint shop was used for applying interior and exterior latex paints on signs. Waste paints and thinners were drummed and sent to the DEH waste storage area prior to disposal off site. Equipment that used latex paint was cleaned in a sink near the southeast corner of the building.

Buildings 292 through 298 comprised a series of similar storage units located in the northeastern section of the DEH Study Area (Figure 7.1-1). The 144-ft², single-story buildings were constructed in 1951 of metal set on concrete slab foundations with corrugated metal roofs. The units were separated by approximately 4 ft. The area in front of the buildings was paved, but the areas between and behind the units were unpaved. Building 293 was identified for evaluation in the RI because it was used for pesticide storage.

A wash rack located near Buildings 267 and 268, in the northeast section of the DEH Study Area, consisted of a concrete pad and an oil/water separator which discharged to a storm drain. The storm drain discharged to San Francisco Bay. Both the wash rack and the oil/water separator have been removed.

South of Building 286, in the northwestern section of the DEH Study Area, was a storage yard with two sheds. Various waste containers were placed either on pavement or in one of the two storage sheds. According to the *Enhanced Preliminary Assessment Report* (ANL, 1989), stains were observed near the containers and in the storage shed. Used lead-acid batteries were stored in the yard in the second shed. Stormwater runoff discharged to a storm drain.

Building 287 was located in the northeastern section of the DEH Study Area. A metal storage locker on the north side of the building contained gasoline containers, and it was believed that some of the containers may have spilled onto the surrounding soil.

7.1.3 Previous Investigations

Several studies of operations, storage, and handling practices in the DEH Study Area have been completed. In February 1983, a hazardous waste management survey was conducted to evaluate the storage, transport, disposal and recycling of hazardous wastes and to assist in the development of an overall PSF management plan for hazardous waste (ANL, 1989). The survey reported that pesticides and herbicides were being stored and mixed in Building 269. The mixing area was ventilated and bermed, and contained personal protective equipment. Rinsates were drained to an outside storage tank for disposal by a commercial contractor. The survey also identified six 55-gal drums, containing mixtures of used oil and cleaning solvent, that were stored outside the bay doors of Building 283. The area was unbermed and oil-stained, and leak troughs were not being used.

In October 1993, USATHAMA conducted an assessment of toxic and hazardous materials that could potentially migrate off the PSF (ANL, 1989). As a result of this assessment, USAEHA recommended that pesticide storage and handling procedures at PSF be reviewed, the use of pesticides in residential areas be minimized, and spills from the storage area be prevented or minimized.

In February 1995, an FS was completed to determine if portions of the Crissy Field, EOM, and DEH Study Areas could be transformed into a wetlands (D&M, 1995b). The report discussed the effects of a wetlands on current land uses and analyzed the potential for re-introducing native vegetation, such as coastal sagewort and evening primrose, to the area. It

included the calculation of potential water levels based on stormwater runoff and base flows from the Tennessee Hollow watershed (Northeastern Groundwater Area) and the determination of the potential effects of tidal fluctuations on groundwater and surface water quality and elevations. Though included in the wetland FS, the DEH Study Area does not lie within the currently proposed wetland footprint.

7.2 SAMPLE LOCATION RATIONALE

The rationale for sample locations in the DEH Study Area was based on the conceptual model presented in Section 3.1. Potential sources of contamination investigated during the RI included fill material, maintenance activities, and storage areas, and the following media were sampled to evaluate the impacts of these sources: building surfaces (wipe samples), storm drain sediments, surface soil, subsurface soil, and groundwater. Sample locations are shown on Figures 7.1-1 and 7.3-1.

Document review and field observations indicated that spills may have occurred in and around some of the buildings in the DEH Study Area (ANL, 1989). Wipe samples were collected from Building 283 to evaluate if chemical residues were present on building surfaces.

Sediment samples were collected at several locations in the DEH Study Area to assess the potential for chemical migration to San Francisco Bay through stormwater runoff. Samples were collected from catch basins in the drain lines running adjacent to Building 283, south of Buildings 268 and 286, and north of Building 267.

Soil sampling was conducted in the DEH Study Area to assess chemical distributions, evaluate the importance of particulate transport to San Francisco Bay, and determine the degree of chemical infiltration. Surface soil samples were collected to assess whether particulate transport by wind, stormwater runoff, or physical contact was a major transport mechanism. Although most of the DEH Study Area was covered with pavement or concrete, infiltration may have occurred through cracks in these surfaces, and subsurface soil samples were collected to assess the effect of infiltration on chemical distribution.

Four monitoring wells were installed during the Supplemental RI to characterize the groundwater quality in the DEH Study Area. An upgradient well was located south of the study area and three wells were located within the boundaries of the study area (Figure 7.3-1). Discrete groundwater samples were collected during the Follow-on RI from borings near Buildings 286, 287, and 293 to evaluate whether chemicals detected in soil had migrated to groundwater.

7.3 HYDROGEOLOGIC SETTING

This section describes the hydrogeologic data obtained from the drilling logs (Appendix E) and from the water levels that were measured during high and low tides in November 1992 and March 1995. Initial data regarding the soil and geology in the DEH Study Area were obtained from 15 shallow soil borings drilled during the fall of 1990, five shallow soil borings drilled in 1992, the geologic map of the area (Schlocker, 1974), and the San Francisco Soil Survey (Kashiwagi and Hokholt, 1985). During the Follow-on RI, additional data were collected from 35 new soil borings located in the northwestern and eastern sections of the study area (Figure 7.3-1). The borings ranged in depth from 2 to 42 feet.

During the Supplemental RI, four monitoring wells were installed along the boundaries of the DEH Study Area to evaluate the hydrogeologic conditions. Groundwater samples were taken from 10-foot screened intervals in the saturated zone.

7.3.1 Geology and Soil

The DEH Study Area was mapped as dune sand by the U.S. Coast Survey in 1851 (D&M, 1995b). In 1882, the area was also mapped as beach-dune sand by the U.S. Surveyor General (Figure 5.1-2). Following the 1906 San Francisco earthquake, it is believed that the area was graded with artificial fill and debris from the earthquake. The soil survey by Kashiwagi and Hokholt (1985) classifies the area soil as Urban Land, which is equivalent to the geologic classification of artificial fill. According to Schlocker (1974), the native material consists of modern beach-dune sand deposits that are composed primarily of well-sorted, medium- to coarse-grained, gray sand with coarse gravel and large cobbles.

The artificial fill is comprised primarily of dredged sediment and road base material. Data from the soil boring logs indicate that various gradations of gravel, sand, silt, and clay were deposited in most of the filled areas (Appendix E). Fill was encountered in a majority of the soil borings, with thicknesses greater than 10 ft in some areas. Debris fill, assumed to be from either the 1906 earthquake or PSF building demolition, is concentrated in the northwest section of the DEH Study Area (Figure 7.3-2). The lithologic information obtained from the soil borings indicates that up to 15.5 ft of debris fill, consisting of concrete, brick, glass, and asphalt blocks and fragments, was deposited in this area. Based on the isopach map, the volume of debris fill in the DEH Study Area is approximately 11,400 yd³.

The native deposits beneath the fill are recent beach-dune sand deposits consisting primarily of unconsolidated sands and silty sands (Figures 7.3-3 and 7.3-4). They are dark grayish-brown to olive brown or olive gray and range from well to poorly sorted. The beach-dune sand deposits are fine- to coarse-grained with minor amounts of fines and gravels. The grains are angular to rounded and contain quartz, chert, serpentinite, and shell fragments. Based on the logs of deeper borings in the area, most of these deposits extend to at least 40 ft bgs.

Little or no bay mud deposits were encountered in the borings drilled in the DEH Study Area. Three feet of a dark gray silt, possibly bay mud, were encountered at the bottom of Boring DEHSB02 (42 ft bgs), in the eastern section of the study area. The lack of shallower bay mud deposits, however, clearly indicate that the bay mud layers that appear to be laterally continuous in the Crissy Field Study Area (Section 5.3) and the Building 231 area (Section 8.2) do not extend northeastward to the DEH Study Area. This is not unexpected, given that the historical salt marsh in the Crissy Field Study Area did not extend to the DEH Study Area. The eastern extent of the bay mud found in the Crissy Field Study Area is currently undefined because of the lack of deep boring data in the EOM Study Area.

Although bedrock was not reached during drilling operations in this area, the depth to bedrock is projected to be on the order of 45 to 90 ft, based on the regional bedrock structure contour map (Figure 2.3-4).

7.3.2 Hydrology

Groundwater was encountered at depths ranging from 6 to 10 ft bgs in soil borings drilled in the DEH Study Area. Groundwater recharge beneath is thought to have been primarily through lateral flow and infiltration from upgradient areas to the south. Storm drains in the area, if structurally unsound, may also have contributed to groundwater recharge.

Groundwater occurs under unconfined conditions in the beach-dune sand deposits and, where fill thicknesses are greatest, in the overlying fill deposits. Due to the lack of bay mud deposits, there appears to be only one shallow water-bearing zone in the DEH Study Area. As shown on the geologic cross-sections (Figures 7.3-3 and 7.3-4), this water-bearing zone extends to at least 40 ft bgs, based on the boring data.

Groundwater levels were measured during high and low tides on March 16, 1995, and the potentiometric surface maps for these measurement periods are shown on Figures 7.3-5 and 7.3-6. Water level elevations ranged from 4.9 to 5.5 ft-PLL during high tide and 4.0 to 5.5 ft-PLL during low tide. The variability in water levels between tides reflects the response of the water-bearing zone to tidal fluctuations in San Francisco Bay. Groundwater flow during high and low tides in March 1995 was north-northeasterly toward San Francisco Bay at a gradient of 0.002 to 0.003 ft/ft. During high tide in 1995, the water levels in Wells DEHGW03 and DEHGW04 rose enough to slightly alter the groundwater gradient more to the northeast in the northeast section of the DEH Study Area (Figure 7.3-5) relative to the direction in this area during low tide.

During previous investigations at the site, water level measurements indicated that tidal fluctuations can have a greater effect on groundwater flow direction in the DEH Study Area. On November 9, 1992 water levels were measured at high and low tides. The groundwater flow direction during low tide was to the north-northeast (Figure 7.3-7), which is very similar to that of March 1995. During high tide in November 1992, however, groundwater flow reversed to the south-southwest in the northern section and created a shallow trough between the converging flow lines (Figure 7.3-7).

A comparison of the November 1992 and March 1995 measurements shows that the water levels at low tide in March 1995 were 0.68 ft higher in the southern section of the site (Well

DEHGW01) and 0.37 ft higher in the northern section (Well DEHGW03). The higher water levels are attributed primarily to heavy rains in the winter of 1994 to 1995. These higher water levels may have decreased the influence that the fluctuating tides had on groundwater flow direction. However, tidal influence was certainly further decreased by the lower elevation of the high tide in March 1995 (5.4 ft-PLL) in comparison with November 1992 (6.1 ft-PLL).

Field measurements of EC taken during groundwater sampling document the presence of a saltwater wedge beneath relatively fresh water in the water-bearing zone at the DEH Study Area (Figure 2.3-12). At most sampling locations, EC was found to increase significantly with depth as a result of the saltwater intrusion. A more detailed discussion of the EC distribution in the PSF coastal groundwater zone is presented in Section 2.3.6.

7.4 ANALYTICAL RESULTS

This section presents the sampling locations (Figures 7.1-1 and 7.3-1), media sampled, sampling objectives, and analytical results for each potential contaminant source evaluated during the Initial, Supplemental, and Follow-on RIs. The evaluation of target analytes in the DEH Study Area was based on samples collected from building surfaces, sediment, soil, and groundwater. Potential sources in the DEH Study Area are fill material (including debris fill), maintenance activities, and storage areas.

The detection tables presented in this section show only chemicals that were detected above the CRL and/or RL. A full listing of the target analytes can be found in tables in Section 3.3 of this RI report. The complete chemical database is provided on computer diskette in Appendix O. All the sediment, soil, and groundwater samples contained common elements found in the environment, including calcium, potassium, magnesium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under most circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussion. All other

inorganics detected in soil will be compared to ambient concentrations, as described in Section 3.7. Wipe samples were collected to determine the nature of chemicals on interior building and exterior paved surfaces. The data are qualitative and therefore were not used in the risk assessment. The identification of unknown compounds are discussed only if one or more of the evaluation criteria presented in Section 3.5 are met. Tentatively identified compounds are listed in the chemical database in Appendix O. Results affected by blank contamination are not discussed.

Split sample data collected for soil samples at the PSF indicated that the thallium data were not usable for the RI. A more detailed discussion of these data is provided in Section 3.7. In addition, blank contamination was noted for one sediment sample, two subsurface soil samples, and eight unfiltered groundwater samples. These data, though included in Appendix O, will not be discussed in the following sections.

7.4.1 Building Wipe Sampling Results

Seven wipe samples were collected at Building 283 (Figure 7.1-1) during the Initial RI to assess the distribution and concentrations of inorganic analytes and SVOCs in the building. The analytical results are presented on Table 7.4-1. Samples 283W01, 283W02, and 283W03 were collected in and around a parts washing area inside the northwest section of the building. During the collection of these samples, field personnel noted the existence of hydraulic oil, a degreasing agent containing sodium metasilicate, a pressure cleaner containing alkaline salts, and tanks of an industrial cleaner containing 2-butoxethanol (a degreasing agent) in the building. Samples 283W04 and 283W05 were collected in the battery storage and hydraulic lift area in the building. Samples 283W06 and 283W07 were located outside of Building 283 near a small shed east of a large north-facing garage door. The shed housed 55-gal drums of antifreeze and hydrocarbon products used in maintenance operations.

Inorganic analytes were detected in all of the samples and concentrations were within 1 to 2 orders of magnitude of each other throughout the building (Table 7.4-1). Eight different SVOCs, including benzyl alcohol, phthalate esters, and phenols, were detected above the CRL in the samples. Additionally, Sample 283W02 had 1,400 $\mu\text{g}/\text{cm}^2$ of unknown

compounds tentatively identified by the laboratory as oxygenated acids. Analytical data for the unidentified compounds are presented in Appendix O.

7.4.2 Sediment Sampling Results

A total of 11 sediment samples were collected from the storm drains in the DEH Study Area (Figure 7.1-1). Ten of the samples were collected during the Initial RI, and these results are presented on Table 7.4-2. The remaining sample, 286SE01, was collected during the Follow-on field program, and the results are shown on Table 7.4-3. All 11 samples were analyzed for inorganics and SVOCs, and 5 of the samples were also analyzed for VOCs and TPH.

Three sediment samples were collected from the storm drain line near Building 267. Sample 268SD03 is located at the beginning of a storm drain that originates in Building 267 and discharges to San Francisco Bay (Figure 7.1-1). Sample 268SD01 is downstream of Sample 268SD03. Sample 268SD02 is located downstream of Sample 268SD01, at the north boundary of the DEH Study Area.

Samples 283SD03 and 285SD01 are located at the beginning of storm drains that collect stormwater runoff near Buildings 283 and 285, respectively. They discharge into a storm drain that contains Samples 286SE01 and 268SD04 through 268SD06. This drain line collects stormwater runoff from the midsection of the DEH Study Area. Sample 268SD04 is located downstream of Sample 286SE01, Sample 268SD06 is located downstream of Sample 286SD04, and Sample 268SD05 is located near the confluence of this storm drain and a storm drain that collects stormwater runoff along Marine Drive.

Samples 283SD01 and 283SD02 are located in a storm drain that collects stormwater runoff along Marine Drive. Sample 283SD01 is downstream of Sample 283SD02, and both locations are upgradient of the storm drain that collects stormwater runoff from the midsection of the DEH Study Area. A secondary drain collects stormwater runoff north of Buildings 280, 282, and south of Building 283. It discharges into the Marine Drive drain upstream of Sample 283SD02.

Because there are no native soils exposed along the drain lines in the DEH Study Area, detected inorganic concentrations were compared to ambient fill concentrations to provide a

frame of reference for discussion. The analytes that were detected above ambient, with the number of exceedences in parentheses, are as follows: barium (1), cadmium (1), copper (4), cyanide (2), lead (4), mercury (2), and zinc (4). Of the 11 samples, only four contained inorganic analytes at concentrations above ambient fill levels. These four samples, with the number of analytes detected above ambient in parentheses, are as follows: 268SD06 (4), 283SD01 (3), 283SD03 (5), and 285SD01 (6).

Samples 283SD01 through 283SD03, 285SD01, and 286SE01 were analyzed for VOCs. The only detections were in Sample 283SD03. The detected target analytes were BTEX, m-xylene, 1,1,1-trichloroethane, and 1,2-dichloroethene (as total 1,2-dichloroethane).

SVOC analyses were performed on all of the sediment samples. Detections were sporadic with the exception of bis(2-ethylhexyl)phthalate which was found in seven of 11 samples (268SD01, 268SD03 through 268SD06, 283SD02, and 285SD01). Only three samples contained more than one detection. PAHs were detected in Samples 268SD01, 268SD02, 268SD04, 283SD01, and 283SD03. Sample 268SD04 contained the widest variety of PAHs (benzo(a)anthracene, chrysene, fluoranthene, phenanthrene, and pyrene). Only two PAHs, 2-methylnaphthalene and phenanthrene, were detected at the other sampling locations.

Samples 283SD01 through 283SD03, and 285SD01 were analyzed for TPH. TPH-D and TPH-G analyses were performed on Sample 286SE01. Concentrations were above the SDC (100 µg/g) in all of the samples but Sample 286SE01. The detected concentration in Sample 283SD03 was an order of magnitude higher than the other detections.

Samples 283SD01 through 283SD03 contained unidentified VOCs (220 µg/g) composed primarily of hydrocarbons. Unknown SVOCs tentatively identified by the laboratory as primarily polycyclic hydrocarbons (690 µg/g) and cyclic hydrocarbons (2,000 µg/g) were also reported in these samples.

7.4.3 Soil Sampling Results

The following section discusses the analytical results from samples collected in surface and subsurface soil at the DEH Study Area. The soil samples were classified as undifferentiated fill, fill that exhibited properties of native beach-dune sand (locally-derived fill), and native

beach-dune sand. Inorganic concentrations detected in soil samples were, therefore, compared to either fill or beach/dune sand ambient concentrations.

During the Initial RI, 10 surface soil samples and 19 subsurface soil samples were collected in the DEH Study Area, and the sample locations are shown on Figures 7.1-1 and 7.3-1. Surface and subsurface soil samples collected near Buildings 268, 283, and 286 were analyzed for inorganic analytes, VOCs, SVOCs, and PCBs. The results for these samples are presented on Tables 7.4-4 and 7.4-5. Subsurface soil samples were collected from four locations near Building 269 and analyzed for VOCs, SVOCs, pesticides, and PCBs (Table 7.4-6). Three surface soil samples were collected near Building 293 and analyzed for pesticides (Table 7.4-7).

In the vicinity of Building 268, cyanide, copper, lead, mercury, silver, and zinc were detected above the appropriate ambient concentrations in surface soil samples. The only inorganics detected above ambient in subsurface soils were chromium, lead, and zinc, all in shallow subsurface soils. VOC detections were limited to a single detection of toluene in Sample 268SS03. SVOCs detected in surface soils were benzo[a]anthracene, bis(2-ethylhexyl)phthalate, chrysene, ppDDD, dieldrin, fluoranthene, and pyrene. The majority of the detectable compounds were found in Sample 268SS02, which was collected near the northeast corner of Building 268. SVOC detections in subsurface soils consisted of pyrene in the 3.0 ft bgs sample from Boring 268SO02 and bis(2-ethylhexyl)phthalate, a common laboratory contaminant, in the 2.5 ft bgs sample from Boring 268SO03 and the 3.5 ft bgs samples from Borings 268SO04, 268SO05, and 268SO07. PCBs were not detected in any of the surface or subsurface samples in this area.

In the vicinity of Building 283, the majority of the ambient exceedences were detected in the two surface soil samples, Sample 283SS01 and the 0.5 ft bgs sample from Boring 283SO02. Aluminum, barium, copper, mercury, and zinc were detected above ambient beach/dune sand concentrations in both samples. Iron, manganese, silver, and vanadium concentrations exceeded ambient in the 0.5 ft bgs sample from Boring 283SO02, and cadmium and cyanide were detected above ambient in Sample 283SS01. Subsurface exceedences were limited to manganese and silver in the 1.0 ft bgs sample from Boring 283SO01 and cadmium in the 5.0 ft bgs sample from Boring 283SO02. None of the samples contained detectable VOC

concentrations. All of the SVOC detections in this area occurred in two samples, the 1.0 ft bgs sample from Boring 283SO01 and Sample 283SS01. The surface soil sample contained detectable concentrations of bis(2-ethylhexyl)phthalate, ppDDD, fluoranthene, and phenanthrene. The subsurface soil sample contained detectable concentrations of acenaphthene, benzo[a]anthracene, chrysene, 1,2-dichlorobenzene, 2,4-dichlorophenol, dimethyl phthalate, fluoranthene, fluorene, 2-methylnaphthalene, phenanthrene, and pyrene. PCBs were not detected in any of the surface or subsurface samples in this area.

Initial RI sampling in the vicinity of Building 286 involved the collection of samples at 6.5 and 9.5 ft bgs from Boring 269SO09. Inorganic concentrations were compared to ambient beach/dune sand concentrations with the following results: aluminum, barium, copper, iron, lead, mercury, and zinc exceeded ambient in both samples, arsenic exceeded ambient in the 6.5 ft bgs sample, and beryllium and chromium were detected above ambient in the 9.5 ft bgs sample. There were no VOC detections in either sample. Each of the two samples contained detectable concentrations of chrysene, fluoranthene, and phenanthrene. PCBs were not detected in either sample.

The sampling at Building 269 yielded detectable concentrations of methylethyl ketone in three samples, the 1.5 ft bgs sample collected from Boring 269SO03 and both samples collected from Boring 269SO04. The detected concentration was the same in both samples from Boring 269SO04. The 1.5 ft bgs sample from Boring 269SO03 also contained 1,1,1-trichloroethane at a concentration of 0.37 $\mu\text{g/g}$. There were no SVOC detections, and the only pesticide detection was a confirmed detection of ppDDT at the detection limit in the 2.0 ft bgs sample from Boring 269SO02.

Each of the three surface soil samples collected at Building 293 contained detectable concentrations of several pesticides. The detected pesticides, with the number of detections in parentheses, are as follows:

- aldrin (3)
- alpha-benzenehexachloride (1)
- delta-benzenehexachloride (1)
- chlordane (3)

- ppDDD (3)
- ppDDT (3)
- dieldrin (3)
- alpha-endosulfan (3)
- endrin (3)
- heptachlor (3)
- heptachlor epoxide (1)
- lindane (3)
- methoxychlor (2).

During the Supplemental RI, soil samples were collected from two depths in each of three borings: DEHGW02, DEHGW04, and DEHSB01. Boring DEHGW02 was drilled near Building 293, Boring DEHGW04 was drilled north of Building 286, and Boring DEHSB01 was drilled adjacent to Building 283 (Figure 7.3-1). The six samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCB, chlorinated herbicides, and diesel and gasoline fractions of TPH (Table 7.4-8). The inorganic concentrations detected in the 2.0 ft bgs sample from Boring DEHGW02 were compared to ambient fill concentrations, and the other five samples were compared to ambient beach/dune sand concentrations. The only ambient exceedences occurred in the samples from Boring DEHGW04. Antimony, cadmium, cobalt, chromium, iron, manganese, nickel, and selenium were detected above ambient in both samples. Arsenic, copper, lead, mercury, and zinc were detected above ambient in only the 4.0 ft bgs sample. No VOCs were detected in any of the six samples. With the exception of pyrene in the 2.0 ft bgs sample from Boring DEHGW02, all SVOC detections occurred in the 2.0 ft bgs sample from Boring DEHGW04, in which di-n-butylphthalate was detected along with the following PAHs: benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and pyrene. No OCPs, PCBs, or chlorinated herbicides were detected. THP-D was detected in all six samples, at concentrations ranging from 1.0 to 25 µg/g.

WETs for soluble chromium, lead, and nickel were completed during the Supplemental RI for subsurface soil samples collected from Well DEHGW04. Soluble chromium was detected at a concentration of 6,700 µg/L at 2 ft bgs and 550 µg/L at 4 ft bgs. Soluble lead was

detected at a concentration of 2,000 $\mu\text{g/L}$ at 2 ft bgs and 7,000 $\mu\text{g/L}$ at 4 ft bgs. Soluble nickel was detected at a concentration of 31,000 $\mu\text{g/L}$ at 2 ft bgs and 3,000 $\mu\text{g/L}$ at 4 ft bgs. The analytical results are presented in Appendix O.

Follow-on soil sampling was designed to further delineate the extent of chemicals detected in earlier sampling rounds and to assess areas that were not previously sampled. Further delineation was performed at Buildings 268, 269, 286, and 293. New sampling was conducted adjacent to Boring DEHW04 and at Buildings 267 and 287.

As a result of the confirmed pesticide detections in Sample 268SS02, additional samples were collected at the northeast corner of Building 268. In all, six borings were drilled, 268SB01 through 268SB06, and 13 samples were collected: four surface soil samples and nine subsurface soil samples. Sample locations are shown on Figure 7.3-1. All samples were analyzed for OCPs, and the results are presented on Table 7.4-9. Those compounds which were detected in at least one sample were aldrin, chlordane, delta-BHC, dieldrin, endrin, heptachlor, heptachlor epoxide, ppDDE, and ppDDT. The only analyte detected in all samples was chlordane.

One boring, 269SB01, was drilled in a stained area along the north wall of Building 269 (Figure 7.3-1). Samples were collected at 0.5 and 2.5 ft bgs and analyzed for inorganics, OCPs, and chlorinated herbicides (Table 7.4-10). The detected inorganic concentrations were compared to ambient beach/dune sand concentrations, and there were only two exceedences: selenium at 0.5 ft bgs and cyanide at 2.5 ft bgs. There were no detections of OCPs or chlorinated herbicides.

Follow-on sampling at Building 286 involved the collection of samples to define the extent of lead in Boring 268SO09 and new sampling from borings drilled within the stained area to the south of the building (Figure 7.3-1). Subsurface soil samples were collected for lead analysis from six borings surrounding 268SO09. Lead was detected above 25 $\mu\text{g/g}$ in three of the samples (Table 7.4-11), and the ambient fill concentration was exceeded by two of the three.

The samples collected from the south side of Building 286 consisted of 0.5 and 5.0 ft bgs samples collected from four borings, 286SB05 through 286SB08. These eight samples were analyzed for inorganics, VOCs, SVOCs, and diesel and gasoline fractions of TPH (Table

7.4-12). For each boring, the surface sample was compared to ambient fill concentrations, and the subsurface sample was compared to ambient beach/dune sand concentrations. Those inorganics detected above ambient in at least one surface soil sample were antimony, barium, beryllium, copper, and manganese. The 5.0 ft bgs sample from Boring 286SB05 contained aluminum, barium, beryllium, copper, and manganese above ambient. The 5.0 ft bgs samples from Borings 286SB06 and 286SB08 each contained one exceedence: cyanide and chromium, respectively. There were no VOC detections. Three SVOCs were detected: 9H-carbazole was detected in the 0.5 ft bgs sample from Boring 286SB05, bis(2-ethylhexyl)phthalate was detected in all eight samples, and di-n-butylphthalate was detected in all but the 5.0 ft bgs sample from Boring 286SB06. TPH-D was detected in the 0.5 ft bgs sample from Boring 286SB07 at a concentration of 23.6 µg/g.

Eight samples were collected from four borings near Building 293 (Figure 7.3-1) and analyzed for antimony, arsenic, and OCPs (Table 7.4-13). Antimony was not detected. Arsenic was detected in all eight samples, but never above the ambient concentration for either fill or beach/dune sand. The only OCP detected was chlordane, at a concentration of 0.105 µg/g in the 2.0 ft bgs sample from Boring 293SB03.

Three subsurface soil samples were collected from Boring DEHSB02 (Figure 7.3-1), adjacent to Boring DEHW02, and analyzed for total organic carbon. The sample depths were 5.5, 21.0, and 32.0 ft bgs, and the detected concentrations ranged from 300 to 5,200 µg/g (Table 7.4-14). The samples were collected from clean sand and it has not been determined why the middle depth contained an elevated organic carbon concentration in relation to the upper and lower samples.

One boring, 267SB01, was drilled adjacent to the DEH fenceline to the north of Building 267 (Figure 7.3-1). Samples were collected at 0.5 and 3.0 ft bgs and analyzed for lead and TPH (Table 7.4-15). There were no detections.

One boring, 287SB01, was drilled immediately north of Building 287 (Figure 7.3-1). Samples were collected at 0.5 and 5.0 ft bgs and analyzed for TPH (Table 7.4-16). There were no detections.

7.4.4 Groundwater Sampling Results

Four monitoring wells were installed during the Supplemental RI to characterize the groundwater quality in the DEH Study Area. An upgradient well was located south of the study area and three wells were located within the boundaries of the study area (Figure 7.3-1). Groundwater samples from each well were analyzed for inorganic analytes, VOCs, SVOCs, OCPs, chlorinated herbicides, TPH-D, and TPH-G. During the Follow-on RI, additional samples were collected from the wells and analyzed for the same analytical suite plus PCBs.

The analytical results for the samples collected from monitoring wells during the Supplemental RI are presented on Table 7.4-17. An additional sample was collected and filtered for the inorganic analysis from Wells DEHGW01 and DEHGW04, and a comparison of the filtered and unfiltered results is shown on Table 7.4-18. The analytical results for the samples collected during the Follow-on RI, including filtered and unfiltered samples, are presented on Table 7.4-19.

Numerous inorganics were detected in all of these samples, and an in-depth analysis of the effect of filtering is presented in Section 3.7.5. Among the samples collected during the Supplemental field program, the detected TDS level ranged from 438,000 $\mu\text{g/L}$ in the upgradient well (DEHGW01) to 2,300,000 $\mu\text{g/L}$ in Well DEHGW02, which was installed adjacent to Building 293. During the Follow-on RI, the TDS results were similar, with the lowest detection in Well DEHGW01 and the highest detection in Well DEHGW02 (2,360,000 $\mu\text{g/L}$).

There were few organic compounds detected in the samples collected during the Supplemental RI (Table 7.4-17). The only VOC detections were cis-1,2-dichloroethene and trichloroethene in the sample from Well DEHGW02. There were no SVOC detections. A dieldrin detection was confirmed below the reporting limit in the sample from Well DEHGW01. There were no detections of chlorinated herbicides, and the only TPH detection was TPH-D at a concentration of 70 $\mu\text{g/L}$ in the sample from Well DEHGW03. The lack of detectable organic compounds continued in the Follow-on program (Table 7.4-19). Trichloroethene was again detected in Well DEHGW02, and 1,2-dichloroethane was

detected in all four wells, at concentrations ranging from 1.20 to 2.35 $\mu\text{g/L}$. The second highest detection occurred in the sample collected from the upgradient well, DEHGW01. There were no detections of SVOCs, OCPs, PCBs, chlorinated herbicides, or TPH.

Discrete groundwater samples were collected during the Follow-on RI from borings near Buildings 286, 287, and 293. Samples were collected south of Building 286 to characterize the groundwater because of a hazardous waste storage area. Additional samples were collected at Building 286 to assess whether arsenic, lead, or zinc in the soil had migrated to the groundwater. Samples were collected near Building 287 to determine if gasoline from a storage locker had migrated to groundwater. Samples were collected near Building 293 to delineate OCP detections in surface soil and chlorinated VOC detections in groundwater.

The two samples from the hazardous waste storage area south of Building 286 were collected at a discrete depth interval of 10.0 ft bgs from Borings 286SB06 and 286SB08 (Figure 7.3-1). The samples were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, and diesel and gasoline fractions of TPH. With the exception of mercury and nickel, which were detected at higher concentrations in Boring 286SB08, all of the inorganic concentrations were of the same order of magnitude in the two samples. The detected TDS concentration was higher in Boring 286SB06 (1,180,000 $\mu\text{g/L}$) than in Boring 286SB08 (604,000 $\mu\text{g/L}$). There were no VOC detections. The SVOC di-n-butylphthalate was detected in both borings at similar concentrations. TPH-G was detected slightly above the reporting limit in the sample from Boring 286SB08.

The analytical results for the samples collected to assess arsenic, lead, and zinc concentrations in groundwater are presented in Table 7.4-21. The locations of the borings from which the samples were collected, Borings 286SB01 through 286SB04 and 286SB09 through 286SB15, are shown of Figure 7.3-1. One sample was collected from Borings 286SB01 through 286SB04, at depths of 9.0 or 9.5 ft bgs, and analyzed for lead. The detected concentrations ranged from 90 to 1100 $\mu\text{g/L}$. Samples were collected at three depths from Boring 286SB09 and analyzed for lead. The detected concentrations decreased from 540 $\mu\text{g/L}$ at 11.5 ft bgs to 10 $\mu\text{g/L}$ at 29.5 ft bgs. Another sample was collected at 11.5 ft bgs from this same location three months later in order to assess the difference in concentrations between filtered and unfiltered groundwater. Lead was not detected in the

filtered sample, and the detected concentration in the unfiltered sample was only 55 µg/L. Samples were also collected from three depths for lead analysis from Borings 286SB10 and 286SB11. As was the case with the sample from Boring 286SB09, the maximum detected concentration was in the shallowest sample.

The analyte list was expanded for Borings 286SB12 through 286SB15, where samples were collected from three depths and analyzed for arsenic, lead, and zinc. An additional, deeper sample was collected for lead analysis from Borings 286SB13 through 286SB15. With the exception of Boring 286SB14, in each boring where lead was detected, the highest detection was in the shallowest sample. In each boring where arsenic was detected, the highest detection was in the deepest sample. Zinc was detected in all of the samples, but the relative depth of the maximum detection varied. Filtered samples were also collected from the two shallowest depths in each of these four borings, but neither arsenic nor lead nor zinc was detected.

The discrete groundwater sampling at Building 287 consisted of collecting one sample at 10.0 ft bgs from Boring 287SB01 (Figure 7.3-1). This sample was analyzed for diesel and gasoline fractions of TPH, but there were no detections (Table 7.4-22).

Discrete groundwater samples were collected in the vicinity of Building 293 because of the VOC detections in the groundwater samples collected from Well DEHGW02. Samples were collected from three depths in each of five borings, DEHSB03 through DEHSB07, and analyzed for trichloroethene and its breakdown products. The only compounds detected were trichloroethene and cis-1,2-dichloroethene. The only cis-1,2-dichloroethene detection occurred in the intermediate sample collected from Boring DEHSB04, which was located immediately northeast of Building 293 (Figure 7.3-1). Trichloroethene was detected in the intermediate sample from Boring DEHSB04, the shallow sample from Boring DEHSB05, and the shallow and intermediate samples from Boring DEHSB07.

7.5 RESULTS EVALUATION

The following sections present the evaluation of the sampling results for the DEH Study Area. RI sampling was conducted in this area to assess the following potential contaminant

sources: maintenance activities, storage areas, and fill material. The impacts of these potential sources were assessed primarily through the collection of sediment, soil, and groundwater samples. The intent of this evaluation is to describe the nature and extent, and fate and transport of contaminants associated with the sources in the area and to determine which data should be entered into the Risk Assessment. Because all sediment samples were collected from the storm drain system and should not be indicative of soil or groundwater conditions, they are discussed separately.

7.5.1 Sediment

Sampling of the storm drain catch basins was conducted to evaluate the likelihood of chemical migration to San Francisco Bay through the drain line system. Sediment in a particular catch basin may be derived from local surface areas serviced by the catch basin or from upstream sections of the line. As described in Section 7.4.2, sediment samples were collected from eleven catch basins in the DEH Study Area.

Sediment samples were compared to ambient fill concentrations in Section 7.4 in order to provide a frame of reference for discussion. This frame of reference will be used to assess the likelihood that inorganic chemicals are migrating through the drain system toward the San Francisco Bay. A similar evaluation will be provided for the migration of organic compounds. As part of the ESAP, stormwater and bay sediment samples also were collected to evaluate the migration of analytes to the bay and the potential effects on aquatic life in the bay. To supplement the fate and transport evaluation of the RI data, a summary of the ESAP assessment for the DEH Study Area is presented in this section. However, it should be noted that in 1996, the COE removed sediments from the storm drains because of the elevated levels found in some of the sediments. Additionally, as part of the work performed to implement the GMPA for this area, the NPS removed most of the storms drains in the DEH Study Area (Draft RAP for the DEH Study Area).

Because there are no native soils exposed along the drain lines in the DEH Study Area, detected inorganic concentrations were compared to ambient fill concentrations to provide a frame of reference for discussion. Of the 11 samples, only four contained inorganic analytes at concentrations above ambient fill levels. With the exception of Sample 283SD01, which

contained the fewest exceedences, all of the samples are upstream of one or more samples that did not contain inorganic analytes above ambient concentrations. In the case of Sample 283SD01, although it was collected in the southern half of the drain line (Figure 7.1-1), there were no samples collected downstream to help identify whether or not the detected chemicals were being transported. However, each of the three analytes detected above ambient in this sample was shown not to be migrating downstream from the other three samples with exceedences.

The only VOC detections were in Sample 283SD03. The detected target analytes were BTEX, m-xylene, 1,1,1-trichloroethane, and 1,2-dichloroethene (as total 1,2-dichloroethane). The samples collected downstream of Sample 283SD03 were not analyzed for VOCs, but transport of these compounds via stormwater and associated sediment is generally unlikely, because of the volatile nature of the chemicals.

Detections of SVOCs were sporadic. Eight of the 11 samples contained one or no detections, and the three samples with more than one detection were all upstream of a sample with only a single detection, suggesting the storm drain system is not an important transport mechanism for SVOCs. Of the detected PAHs, SDCs were established for benzo(a)anthracene (0.6 µg/g) and chrysene (6 µg/g), and these values were not exceeded in any of the sediment samples.

Samples 283SD01 through 283SD03, and 285SD01 were analyzed for TPH. TPH-D and TPH-G analyses were performed on Sample 286SE01. Concentrations were above the SDC (100 µg/g) in all of the samples but Sample 286SE01. The detected concentration in Sample 283SD03 was an order of magnitude higher than the other detections. The absence of downstream samples which were analyzed for TPH makes it difficult to assess the significance of this transport mechanism for TPH.

As part of the ESAP, the potential transport of analytes detected in DEH Study Area was assessed by collecting and analyzing stormwater and bay sediment samples associated with storm drains in the area. Bay sediment samples collected offshore of the DEH Study Area are shown on the posting maps and are identified by the prefix of "OF01" for Outfall 1, followed by the specific sediment sample number from the outfall (i.e., SD01, etc.).

Detections in these bay sediments included bis(2-ethylhexyl) phthalate, a single low detection of heptachlor (0.00025 µg/g), and low levels of metals. Bioassay testing on the sediments indicate a low potential for toxicity.

The ESAP stormwater data indicate that there is the potential for typical urban-related contaminants, such as hydrocarbons and metals, to be transported to the bay via the Outfall 1 storm drains. The analyte concentrations are indicative of runoff in an urban environment and not U.S. Army sources in the DEH Study Area, as shown by stormwater data collected upstream of the DEH RI samples (Dames & Moore, 1996b). Stormwater bioassay results indicated some toxicity to the tested species; however, because of the intermittent nature of the exposures and the limited time stormwater would be discharged without dilution by bay water, it is not likely that the intertidal environment would be affected by exposure to the discharged stormwater (Dames & Moore, 1996a, b).

In summary, ESAP bay sediment and stormwater samples associated with the storm drain system in the DEH Study Area indicate that although the stormwater samples contain the types of analytes detected in the RI storm drain sediment samples, such as PAHs, TPH-D, TPH-G, and metals, they have not been translocated into the nearshore sediments. In addition, the analyte detections in the stormwater are primarily associated with traffic near the Mason Street entrance to the PSF and not sources in the DEH Study Area. Therefore, the ESAP data indicate that migration of analytes detected in the storm drain sediment samples does not result in a significant exposure pathway for aquatic receptors in the bay.

7.5.2 Soil and Groundwater

Soil and groundwater samples were used together to determine if U.S. Army activities had impacted surface soils and then to evaluate whether chemicals had migrated into subsurface soil or infiltrated to groundwater. The first step in evaluating the soils results involves the determination of which analytes are COPCs (see Section 3.7), which will be evaluated in the Risk Assessment. Once COPCs are identified, the nature and extent, and fate and transport of these analytes will be discussed. Analytes that are not considered COPCs will not be discussed further.

RI samples were analyzed for inorganic and organic analytes. Inorganic analytes occur naturally, and their presence at a site may or may not be anthropogenic. In determining which inorganic analytes are COPCs, several factors are considered. These include the magnitude and number of detections above ambient values, the spatial distribution of these exceedences, the type of soil in the sample, and comparison with concentrations typical of soils in other areas of the region. In addition, the absence or presence of potential sources is assessed. A number of maps presenting posted results for soil samples were used in this evaluation. These maps are included with this RI report as Figures 7.5-1 through 7.5-16. All organic analytes are assumed to be anthropogenic, and all detected organic compounds are, therefore, considered COPCs. Posting maps were also prepared for organic analytes in soil (Figures 7.5-17 through 7.5-21).

In order to provide a frame of reference for the discussion of groundwater, the concentrations of inorganics and organics in groundwater are compared to Primary MCLs and saltwater aquatic standards. The saltwater aquatic standards, which were only used to evaluate filtered samples, may only be applicable to groundwater within 150 ft of the shoreline, in the area that has been designated a Saltwater Ecological Protection Zone by the SCRs (California Regional Water Quality Control Board, 1996). In addition, comparison to MCLs does not imply that groundwater in the DEH Study Area is suitable for domestic or industrial use. In fact, the GMPA for the PSF prepared by the NPS (1994) does not include development of groundwater in the DEH Study Area for either a drinking water source or industrial use. In addition, several of the California secondary MCLs are exceeded in the study area because of saltwater intrusion, as was discussed previously in Section 2.3.6 of this RI report. Because of saltwater intrusion, groundwater in the study area does not meet criteria set forth in California Resolution 88-63 for potential municipal or domestic water supplies. The groundwater chemistry is used to evaluate whether chemicals in soils are leaching to the groundwater or fluctuations of water-table elevations result in adsorption of filtered chemicals onto soil particles. This is accomplished by comparing the suites of compounds detected in the soil and in adjacent groundwater.

7.5.2.1 Inorganic Constituents

The groundwater in the DEH Study Area is in a transitional zone between fresh water and saltwater (Figures 2.3-11 and 2.3-12). Based on TDS and electrical conductivity criteria from the California Water Resources Control Board, the groundwater at DEH was classified as nonpotable. TDS concentrations ranged from 400 to 2,400 mg/L. The average electrical conductivity, measured in samples collected during the Follow-on RI, ranged from 1,900 $\mu\text{S}/\text{cm}$ at 10 ft bgs to 14,000 $\mu\text{S}/\text{cm}$ at 30 ft bgs. It was, therefore, to be expected that a number of the Primary MCLs would be exceeded in groundwater samples collected from this area.

The inorganic analytes detected above the appropriate ambient concentrations in soil samples from the DEH Study Area were aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc.

Aluminum was detected above the ambient beach/dune sand concentration in two samples collected near Building 283, one sample collected near Building 268, and three subsurface samples collected near Building 286. The detected concentrations in the near surface samples (Buildings 268 and 283) are attributed to fill material which is most likely included in the samples. The aluminum concentrations detected in surface samples collected near Building 286 suggest that the ambient exceedences are not related to surface activities. Aluminum is not considered a COPC in the DEH area. Aluminum was detected above the MCL in unfiltered groundwater samples from Wells DEHGW03 (Follow-on RI) and DEHGW04 (Supplemental and Follow-on RIs). In each case, the corresponding filtered sample either did not contain detectable aluminum or had a much lower result (117 versus 10400 $\mu\text{g}/\text{L}$ in Well DEHGW03). The highest detections of aluminum in groundwater were in the two discrete groundwater samples collected near Building 286, 286SB06 and 286SB08. Comparisons of filtered and unfiltered data suggest that these concentrations are due to the lack of filtering and well development.

Antimony will be evaluated as a COPC in the Building 286 Area due to detections in surface soil (0.5 ft bgs) at Borings 286SB06 and 286SB07. In addition, the detected concentrations in the two samples collected from Boring DEHGW04 were several orders of magnitude

higher than ambient, indicating a cause for potential concern in subsurface soils as well. Antimony was detected above the Primary MCL in all four of the filtered monitoring well samples collected during the Follow-on RI. Controlled laboratory studies conducted by the USCOE, however, indicate that the detected concentrations in the filtered samples may be attributable to the filter medium (Call, 1994).

Arsenic exceeded the ambient beach/dune sand concentration in the 4.0 ft bgs sample in Boring DEHGW04, though not in the overlying sample, and in the 6.5 ft bgs sample from Boring 268SO09, above which no sample was collected. Both samples were collected from fill material, and the detected concentrations also exceeded the ambient fill value. Arsenic will be evaluated as a COPC. In addition, arsenic was detected at concentrations nearly an order of magnitude higher than the MCL in the two discrete groundwater samples collected near Building 286, 286SB06 and 286SB08. Comparisons of filtered and unfiltered data suggest that these concentrations may be due to the lack of filtering and well development.

Barium was detected slightly above ambient in samples collected near Buildings 268, 283, and 286. All of the exceedences in surface soil samples were within 15 percent of the appropriate ambient concentration, and the only subsurface exceedences that were greater than 1% above ambient were in the samples collected from Boring 268SO09. Barium is not considered a COPC in surface soils at this site, but the detected concentrations in the subsurface samples from Boring 268SO09 will be evaluated as COPCs. The barium concentration detected in the discrete groundwater sample collected from Boring 286SB06 exceeded the Primary MCL by seven percent, but comparisons of filtered and unfiltered data suggest that these concentrations are due to the lack of filtering and well development.

Beryllium was detected slightly (6 percent) above the ambient beach/dune sand value at 9.5 ft bgs in Boring 268SO09. In this sample beryllium is not considered a COPC related to surface activities because of the slight nature of the exceedence and the lower detected concentration in the overlying sample. Beryllium slightly exceeded (3 percent) the ambient fill concentration in the 0.5 ft bgs sample collected from Boring 286SB07. In this sample, beryllium is not considered a COPC because of the slight nature of the exceedence and the lower detected concentrations in three adjacent samples collected at the same depth. Beryllium also slightly exceeded (3 percent) the ambient fill concentration in the 5.0 ft bgs

sample collected from Boring 286SB05. In this sample, beryllium is not considered a COPC because of the slight nature of the exceedence and the lower detected concentrations in the overlying sample collected from the same boring. Beryllium will not be evaluated as a COPC in the DEH area. Detections of beryllium above the Primary MCL were limited to the discrete groundwater samples collected from Borings 286SB06 and 286SB08. Comparisons of filtered and unfiltered data suggest that these concentrations are due to the lack of filtering and well development.

Cadmium was detected above the ambient beach/dune sand concentration in Boring 283SO02 (5.0 ft bgs) and surface soil sample 283SS01. The detection at 5.0 ft bgs is not attributed to surface activities, because the overlying surface soil sample did not contain a detectable concentration of cadmium. Cadmium will, however, be evaluated as a COPC associated with Building 283 because of the detection in sample 283SS01. Cadmium was also detected above the ambient beach/dune sand concentration in the two samples collected from Boring DEHGW04, but these exceedences are attributed to fill material, the ambient value for which the detected concentrations did not exceed. During the Supplemental RI, the cadmium concentration detected in the filtered sample collected from the area's upgradient well, Well DEHGW01, exceeded both the Primary MCL and the standards for the protection of saltwater aquatic life. This detection was not confirmed during the Follow-on RI, during which cadmium was detected above the Primary MCL in the unfiltered sample from Well DEHGW03.

Chromium was detected above the ambient beach/dune sand concentration in each of the four samples collected inside Building 268. The detected concentrations appear relatively high inside this building when compared to samples collected elsewhere at the site, and chromium will, therefore be evaluated as a COPC. This determination was supported by the detection of chromium above the Primary MCL in the unfiltered sample from Well DEHGW03 during the Follow-on RI. In the vicinity of Building 286, chromium was detected above the ambient beach/dune sand concentration in both samples collected from Boring DEHGW04 (2.0 and 4.0 ft bgs) and the deeper of two sample collected from Borings 268SO09 (9.5 ft bgs) and 286SB08 (5.0 ft bgs). Though the lack of exceedences in the shallow samples from Borings 268SO09 and 286SB08 suggests that the deeper detection is not related to surface activities,

chromium will be evaluated as a COPC near Building 286 because of the detections in Boring DEHGW04, one of which exceeded even the serpentinite ambient value. Notably, though the chromium concentrations exceeded the Primary MCL in the discrete groundwater samples from Borings 286SB06 and 286SB08, chromium was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the samples collected from Well DEHGW04.

Cobalt was detected above the ambient beach/dune sand concentration in the 2.0 and 4.0 ft bgs samples collected from Boring DEHGW04. The detected concentrations, however, are attributed to the serpentinite described in the lithology log (Appendix E), and, since the detected concentrations did not exceed the ambient fill value, cobalt is not considered a COPC in the DEH area. Furthermore, cobalt was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the groundwater samples collected from the DEH Study Area.

Copper will be evaluated as a COPC in the vicinity of Buildings 283 and 286, primarily because of ambient exceedences in surface soils. The ambient beach/dune sand concentration was exceeded in two surface soil samples collected near Building 283, and the ambient value for fill materials was exceeded in three surface soil samples collected near Building 286. Ambient exceedences also occurred in subsurface samples collected near Building 286. Copper will also be evaluated as a COPC in the vicinity of Building 267 as a result of an ambient exceedence in surface soil sample 268SS01. Copper was also detected above the standards for the protection of saltwater aquatic life in all four of the filtered groundwater sample collected from monitoring wells during the Follow-on RI and in the discrete groundwater samples from Borings 286SB06 and 286SB08. While the detections in the discrete samples may be, in part, due to the lack of well development, the detections in the filtered samples indicate that dissolved copper is also present.

Cyanide was detected, and therefore exceeded ambient in three samples in the DEH Study Area: 268SS03, 283SS01, and the 2.5 ft bgs sample from Boring 269SB01. Each of the surface soil samples also contained other inorganics at concentrations greater than ambient, and cyanide will be evaluated as a COPC at Buildings 268 and 283. The shallow sample from Boring 269SB01, however, did not contain a detectable quantity of cyanide, suggesting

that the detected concentration was not a result of surface activities. The only detection of cyanide in groundwater was in the sample collected from Well DEHGW02 during the Follow-on RI. The detected concentration of 6.9 µg/L did exceed slightly the standards for the protection of saltwater aquatic life (1.0 and 5.0 µg/L).

Iron was detected above ambient beach/dune sand concentrations in the 0.5 ft bgs sample from Boring 283SO02 and in both samples from Borings 268SO09 and DEHGW04. The detections in Borings 283SO02 and DEHGW04 were below the ambient fill value and are attributed to the fill material described in the lithology logs. Iron will, however, be evaluated as a COPC in the vicinity of Building 286 because of the detections in Boring 268SO09 exceeded even the ambient value for fill material. Iron was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the groundwater samples collected from the DEH Study Area.

Lead exceeded ambient concentrations in subsurface soil samples collected to the north of Building 286. The lateral extent of these exceedences was defined by Lead-XRF samples collected during the Follow-on RI and lower detections in Boring DEHGW04. A single exceedence was detected in the vicinity of Building 283 (1,200 µg/g in sample 283SS01). The ambient beach/dune sand concentration was exceeded in subsurface soils in the western half of Building 268 and in surface soils to the north of the building. Lead will be evaluated as a COPC in the vicinities of these three buildings. During the Supplemental RI, the lead concentration detected in the filtered sample from the upgradient well, DEHGW01, exceeded the standards for the protection of saltwater aquatic life, and the lead concentration detected in the unfiltered sample from Well DEHGW04 exceeded the Primary MCL. During the Follow-on RI, lead exceeded the Primary MCL in unfiltered samples from Wells DEHGW01 and DEHGW03 and in the discrete groundwater samples collected from Borings 286SB06 and 286SB08. Additional discrete groundwater samples were collected to further assess the extent of the elevated lead in groundwater, and the Primary MCL was exceeded in 17 of 28 samples. Despite extensive sampling to depths as great as 40 ft bgs, the extent of the lead in groundwater was not clearly defined. Table 7.5-1 presents a comparison of filtered and unfiltered lead results from these discrete groundwater samples. These results show that

elevated lead in groundwater occurs in the unfiltered samples, which were laden with sediments and had turbidity measurements that often exceeded 200 NTU.

Manganese exceeded ambient concentrations in samples collected near Buildings 283 and 286, and manganese is considered a COPC at these sites. One of the samples near Building 283 was collected from a stained area, and the other was collected from approximately 25 ft away. Four locations were sampled within the stained area immediately south of Building 286, and one sample from each location contained manganese above ambient. The two samples collected from Boring DEHW01 contained manganese above the ambient beach/dune sand concentration, but these levels are attributed to fill materials described in the lithology log (Appendix E). Manganese was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the groundwater samples collected from the DEH Study Area.

Mercury was detected slightly above the ambient beach/dune sand concentration in two samples in the vicinity of Building 268. The detected concentration in sample 268SS02 is probably attributable to fill material in the sample, and the detection at 3.0 ft bgs in Boring 268SO02 was overlain by surface soil that did not contain detectable concentrations of mercury. The mercury detections in the vicinity of Building 283 were more substantial, including a detected concentration of 0.859 in sample 283SS01. The mercury detections above ambient in the vicinity of Building 286 all appear to be limited to subsurface soils and are unrelated to surface activities. Mercury will be evaluated as a COPC in the vicinity of Building 283. The only detections of mercury in groundwater were in the discrete groundwater samples collected from Borings 286SB06 and 286SB08. The detection in the sample from Boring 286SB08 exceeded the Primary MCL.

Nickel exceeded the ambient beach/dune sand concentration in the 2.0 and 4.0 ft bgs samples collected from Boring DEHW04. The detected concentrations, however, are attributed to the serpentinite described in the lithology log (Appendix E), and, since the detected concentrations did not exceed the ambient fill value, nickel is not considered a COPC in the DEH area. During the Supplemental RI, nickel was reported below the RL but above the standards for the protection of saltwater aquatic life in the filtered sample from Well DEHW02. During the Follow-on RI, these standards were again exceeded in the filtered

sample from Well DEHW02 and were exceeded for the first time in the filtered sample from Well DEHW03. These well locations do not correlate with the ambient exceedences in soil. The discrete groundwater samples collected from Borings 286SB06 and 286SB08 did contain nickel at concentrations above the Primary MCL, but these detections are likely due to the lack of well development and the serpentine in the surrounding soil.

Selenium was detected above the ambient beach/dune sand concentration in the two samples from Boring DEHW04 and the 0.5 ft bgs sample from Boring 269SB01, which was drilled within a stained area. Selenium will be evaluated as a COPC in these two locations.

Selenium was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the groundwater samples collected from the DEH Study Area.

Silver will be evaluated as a COPC in the DEH Study Area as a result of the ambient exceedence in sample 268SS01. Silver was also detected above ambient at the northeast corner of Building 268 and in two samples adjacent to Building 283, but these detections were only slightly above ambient and most likely related to sample composition. Silver was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the groundwater samples collected from the DEH Study Area.

Vanadium exceeded the ambient beach/dune sand concentration in the 0.5 ft bgs sample collected from Boring 283SO02. The detected concentration, however, is attributed to fill material which is most likely present in the sample, and vanadium is not considered a COPC in the DEH area. Vanadium was never detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the groundwater samples collected from the DEH Study Area.

Zinc will be evaluated as a COPC in the vicinity of Buildings 268 and 283. The ambient beach/dune sand concentration was exceeded in subsurface soils in the western half of Building 268 and in surface soils to the north of the building. Two exceedences were detected in the vicinity of Building 283, one at a concentration of 1500 $\mu\text{g/g}$ in (sample 283SS01), and the other in a sample collected from a stained area. Zinc exceeded ambient concentrations in subsurface soil samples collected to the north of Building 286, but these concentrations appear limited to the subsurface and unrelated to surface activities. Zinc was

not detected above the Primary MCL or the standards for the protection of saltwater aquatic life in any of the filtered groundwater samples collected from the DEH Study Area, and the Primary MCL was not exceeded by any of the unfiltered samples.

7.5.2.2 Organic Compounds

Because all organic compounds are attributed to anthropogenic sources, this section simply discusses the spatial distribution of organic compounds among the surface soil, subsurface soil, and groundwater to assess if migration is occurring at the DEH Study Area. The discussion is organized into four groups of building(s) according to their uses and proximity:

- Buildings 267, 268, and 287 (vehicle maintenance and waste or material storage)
- Buildings 269 and 293 (herbicide use)
- Building 283 (vehicle maintenance)
- Building 286 (waste storage).

7.5.2.2.1 Buildings 267, 268, and 287

The organic COPCs in soils at Buildings 267, 268, and 287 include OCPs, PAHs, toluene, and bis(2-ethylhexyl)phthalate. OCPs and bis(2-ethylhexyl)phthalate were detected throughout the soil depths in this area. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant but is also an inert ingredient in some OCPs and may be present at the site due to their application. Both compounds tend to adsorb to soil and can slowly biodegrade. The OCPs were concentrated in the debris fill at the northeast corner of Building 268, and the lateral extent is defined by Borings 268SB03 and 268SB04 (45 ft by 25 ft). The sample collected at 3-ft bgs from Boring 268SB05 contained only chlordane above the SDC, indicating that the vertical and lateral extents of this compound have not been fully defined. The vertical extent is expected to be shallow. PAHs were detected inconsistently, and never at concentrations that exceeded SDCs. Toluene was detected only in surface soil sample 268SS03.

Groundwater samples collected from Well DEHGW03 indicate that organic compounds have not infiltrated to the water table in this area. The only detections of organic compounds were a single detection of TPH-D, during the Supplemental program, and a Follow-on detection of 1,2-dichloroethane, which was detected in all four of the samples collected from this area

during the Follow-on RI. There were no detections of organic compounds in this well during any of the quarterly sampling events for which data are currently available (Montgomery Watson, 1996f).

7.5.2.2.2 Buildings 269 and 293

The organic COPCs at Buildings 269 and 293 include OCPs, methyl ethyl ketone, 1,1,1-trichloroethane in soil and trichloroethene in groundwater. Methyl ethyl ketone and 1,1,1-trichloroethane were detected in shallow and deep subsurface soil samples collected near Building 269. Methyl ethyl ketone and 1,1,1-trichloroethane are used in some pesticide formulations. Although the compounds can become mobile, they were not detected in groundwater. Therefore, they are expected to biodegrade or volatilize in the shallow subsurface soil and biodegrade in the deep subsurface soil.

Trichloroethene was detected above the California primary MCL in the uppermost discrete groundwater sample collected from Boring DEHSB07 and in the two groundwater samples collected from Well DEHW02. The well and boring are located next to each other. The compound is soluble in water, but the lack of trichloroethene in discrete groundwater samples from surrounding borings indicates that it is not migrating from the Well DEHW02 area. Trichloroethene will also biodegrade, and this appears to be its fate based on detections of cis-1,2-dichloroethene at these locations. Because of the isolated detections and the low concentrations, it is believed that the source for these compounds is through a localized spill. Quarterly samples from this well continue to show trichloroethene concentrations in excess of the primary MCL (Montgomery Watson, 1996f).

OCPs were detected above their SDCs in the surface soil at near Building 293. They were not detected in deep subsurface soil or groundwater. Chlordane, dieldrin, heptachlor, ppDDD, ppDDT, methoxychlor, aldrin, heptachlor epoxide, and lindane were present above their respective SDCs in surface and shallow subsurface soil samples. The areal extent of OCPs in the Building 293 area is defined by concentrations lower than the SDC at Borings 293SB01 through 293SB04 at 2 ft bgs. The lateral extent of the OCPs is estimated at 30 ft by 30 ft. The compounds are expected to adsorb to the soil with some biodegradation occurring with time for chlordane, heptachlor, ppDDT, and methoxychlor. Heptachlor

epoxide, dieldrin, and ppDDD will not easily biodegrade. Lindane will volatilize and can be soluble in water; it was not, however, detected in groundwater.

7.5.2.2.3 Building 283

The organic COPCs at Building 283 include benzo(a)anthracene, phthalate esters, 1,2-dichlorobenzene, 2,4-dichlorophenol, and ppDDD in soil. These compounds were not detected in either of the nearby wells, DEHGW01 and DEHGW02. Well DEHGW02 was described in the preceding subsection (7.5.2.2.2), and Well DEHGW01, the upgradient well, has historically contained only a single detection of dieldrin, in the Supplemental RI, and a detection of 1,2-dichloroethane, along with all the other three wells during the Follow-on RI. The lack of organic detections has continued through the quarterly sampling (Montgomery Watson, 1996f).

Benzo(a)anthracene was present above its SDC in the shallow subsurface soil at Boring 283SO01. The vertical extent is defined at 5 ft bgs. Bis(2-ethylhexyl)phthalate and dimethylphthalate were present in Sample 283SS01. These compounds are used in plastic products. Bis(2-ethylhexyl)phthalate will adsorb to soil and dimethyl phthalate will tend to biodegrade.

Boring 283SO01 contained concentrations of 1,2-dichlorobenzene and 2,4-dichlorophenol in the shallow subsurface soil. Building 283 was used to repair and maintain engine parts and 1,2-dichlorobenzene may have been used to remove lead and carbon from engine parts. It is also a motor oil additive and a component of asphalt. The compound is expected to either remain adsorbed to the soil or volatilize since it is in the shallow subsurface soil.

The lateral extent of ppDDD in Sample 283SS01 cannot be definitively delineated because of the lack of data in the surrounding area. However, the sample was collected from a concrete-lined ditch adjacent to the building. The vertical extent is estimated at 1 ft.

7.5.2.2.4 Building 286

The organic COPCs identified in the vicinity of Building 286 were SVOCs and TPH. On the north side of the building, three PAHs were detected in both samples collected from Boring 268SO09, but none of the detected concentrations exceeded SDCs. The 2.0 ft bgs sample

collected from Boring DEHGW04 contained PAHs and di-n-butylphthalate, but the only SDC exceedence was for benzo(a)pyrene. There were no SVOC detections in the underlying sample, at 4.0 ft bgs. PAHs are not expected to infiltrate to groundwater, and there have been no detections of any organics, other than 1,2-dichloroethane in the Follow-on sample, in any of the groundwater samples collected from Well DEHGW04. On the south side of the building, di-n-butylphthalate was detected in all but one of the soil samples and in both of the discrete groundwater samples. The only other SVOC detection, other than bis(2-ethylhexyl)phthalate in soils, was a single detection of 9H-carbazole in the 0.5 ft bgs sample from Boring 286SB05.

TPH-D was detected in both soil samples collected from Boring DEHGW04, but the detected concentrations of 8.0 and 3.3 $\mu\text{g/g}$ were well below the SDC of 100 $\mu\text{g/g}$. The only other TPH detections in the area were TPH-G at a concentration of 11 $\mu\text{g/L}$ in the discrete groundwater sample collected from Boring 286SB08, and at a concentration of 23.6 $\mu\text{g/g}$ in the 0.5 ft bgs sample from nearby Boring 286SB07. Groundwater samples from Well DEHGW04 have never contained detectable TPH concentrations.

The quarterly samples collected from Well DEHGW04 have not contained detectable concentrations of organic compounds (Montgomery Watson, 1996f).

7.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY

This section summarizes the evaluation of results for the DEH Study Area, including the risk assessment results, as presented in detail in Section 15.

7.6.1 Conclusions

The investigations in the DEH Study Area were designed to assess the chemical impact of U.S. Army activities at the site. Potential sources were identified, and analytical samples were collected from various media. Concern in the DEH Study Area relates, primarily, to chemical concentrations in soil. In the vicinity of Buildings 267, 268, and 287, the COPCs in soil were chromium, copper, cyanide, lead, silver, zinc, OCPs and related bis(2-ethylhexyl)phthalate, PAHs, phenol, and toluene. Near Buildings 269 and 293, selenium and OCPs and related compounds were identified as COPCs in soil. The COPCs in soil at

Building 283 included cadmium, copper, cyanide, lead, manganese, mercury, zinc, PAHs, phthalate esters, 1,2-dichlorobenzene, 2,4-dichlorophenol, and ppDDD. The COPCs in soil at Building 286 were antimony, copper, manganese, SVOCs, and TPH.

The data from filtered and unfiltered groundwater samples in the DEH Study Area indicate that inorganic analytes are adsorbing to the soil, and concentrations detected in unfiltered samples are associated with suspended sediment. Detections of organic compounds in groundwater samples have generally been limited to chlorinated solvents in the vicinity of Well DEHGW02.

The distribution of target analytes in the sediment samples collected in the DEH Area suggests that chemical transport through the storm drain system is limited. In general, analytes detected in upstream samples are not detected in downstream samples. This conclusion is supported by the sampling conducted in support of the ESAP, which indicated that although the stormwater samples contain the types of analytes detected in the RI storm drain sediment samples, such as PAHs, TPH-D, TPH-G, and metals, they have not been translocated into the nearshore sediments. In addition, the analyte detections in the stormwater are primarily associated with sources other than the DEH Study Area.

7.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

Neither the sediments from storm drains nor the wipe samples were assessed, because exposure to the sediments is unlikely under the future use scenarios for the DEH Study Area, and wipe samples cannot be used quantitatively. The impact of sediments to ecological receptors in San Francisco Bay was evaluated as part of the ESAP (WJE, 1993b and 1994c), and ESAP data indicate that the transport of contaminants to the bay is not an exposure pathway that significantly affects the toxicity to aquatic receptors in the bay.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead

screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the DEH Study Area are summarized in the following sections.

7.6.2.1 Human Health

The DEH Study Area was assessed as four different areas in the human health risk assessment because of the variation in sources and associated COPCs. Buildings 267, 268, and 287 were evaluated together, Buildings 269 and 293 were evaluated together, and Buildings 283 and 286 were each evaluated individually. The GMPA identified open space (recreational) uses for all of these areas, and only exposure to surface soil from 0.0 to less than 2.0 ft bgs is assumed. No exposure to groundwater was assumed, and the PSF drinking water supply was not assessed in this area.

A residential PRG ratio screening assessment for surface soil and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is

identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the DEH Study Area are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

7.6.2.1.1 Quantification of Cancer Risks

Several PAHs and pesticides were determined as COCs in surface soil samples at Buildings 267/268/287. Exposure to recreational visitors via ingestion of or dermal contact with surface soil to 2 feet resulted in a total carcinogenic risk of 5E-05, mostly from exposure to the pesticides chlordane and dieldrin. The residential PRG ratio screening assessment resulted in a total cancer risk greater than 1E-06.

Seven pesticides were determined to be COCs in surface soil for Building 269/293. A total carcinogenic risk of 1E-04 resulted from ingestion of and dermal exposure to surface soil to

2 feet to recreational visitors, mostly from exposure to the pesticides chlordane and dieldrin. All carcinogenic COCs have a total risk by chemical of greater than $1E-06$ with a total cancer risk of $1E-04$ for the site. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Building 283 had lead, several PAHs, and ppDDD determined as COCs in surface soil samples. A total carcinogenic risk of $2E-06$ was calculated for ingestion of and dermal contact with surface soil to 2 feet for the recreational visitor to Building 283. The main contributor to this risk was dermal contact with benzo(a)anthracene. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Only manganese was determined as a COC in surface soil to 2 feet at Building 286 to assess an exposure to the recreational visitor. Manganese is not considered carcinogenic and therefore, exposure to the surface soil at this site is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$.

7.6.2.1.2 Quantification of Noncarcinogenic Effects

No hazard indices are greater than $1E+00$ at Buildings 267/268/287, 283, and 286, and, therefore, exposure to surface soil to the recreational visitor at these sites is unlikely to result in noncarcinogenic adverse health effects. Chlordane in surface soil resulted in a hazard index of $7E+00$ at Building 269/293, with hazard quotients greater than $1E+00$ for both the ingestion and dermal pathways. All the other pesticide COCs in the soil at this site have hazard indices less than $1E+00$. Residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ for Buildings 283, 286, and the DEH groundwater.

The maximum detected lead value in surface soil at DEH Building 283 is 1200 mg/kg, which is greater than the lead soil screening value of 840 mg/kg.

7.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs evaluated in the ecological risk assessment include several inorganics, VOCs, PAHs and other SVOCs, pesticides, and TPH-D. Results of the risk assessment indicate the following:

- The HIs for American robin, mourning dove, peregrine falcon, western harvest mouse, pocket gopher, and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{Low} values.
- The HIs for American robin, mourning dove, western harvest mouse, and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{High} values.
- HQs for cadmium, chlordane, chromium, copper, dieldrin, endrin, lead, manganese, ppDDD, ppDDT, selenium and zinc exceeded 1 for the robin based on comparison of exposure to the TBV_{Low} .
- HQs that exceeded 1 for the morning dove were chlordane, chromium, copper, endrin, lead, ppDDT, selenium, and zinc.
- Chlordane was the only COPC that resulted in an HQ greater than 1 for the peregrine falcon. The only pathway for which a risk is suggested is the dietary ingestion pathway. This receptor is unlikely to be at risk given the low magnitude of the exceedence, and the fact that there were no HIs or HQs greater than 1 based on the TBV_{High} .

- COPCs that resulted in HQs in excess of 1 for the western harvest mouse were antimony, cadmium, copper, dieldrin, lead, and selenium when exposure was compared to the TBV_{Low} .
- The only COPC that resulted in an HQ in excess of 1 for the pocket gopher when exposure was compared to the TBV_{Low} was selenium. The only pathway for which an HQ exceeded 1 was the dietary ingestion pathway.
- Observed concentrations of antimony, chromium, copper, manganese, silver, and zinc occur above TBV levels protective of plants and soil fauna.

Following extensive efforts to review the available data for DEH, and a quantitative, comprehensive uncertainty analysis of lead contamination, the risk managers have compiled a draft decision document, which is now available for public review. This document will address the remediation effort required for this area. The efforts on the behalf of the Federal and State regulators, and the U.S. Army, serve to illustrate the effectiveness of the approach used in the current RI. The current RI uses highly conservative exposure parameters to obtain a highly conservative risk assessment. Any sites that do not present a risk under this approach can be safely assumed to be free of ecological risk. However, risks were identified for DEH on the basis of both the TBV_{Low} and TBV_{High} values. This indicates that the risk assessment can be used as a cost-effective, scientifically defensible, screening tool in the hands of the risk managers.

8. MAIN POST STUDY AREA

This section describes the results of investigations conducted at sites within the Main Post Study Area. The Main Post Study Area is located in the northeastern portion of the PSF. The area is south and west of U.S. Route 101, north of Fill Site 6, and east of the Building 669 site. San Francisco Bay is approximately 1,000 ft north of the Main Post Study Area.

Six sites within the Main Post Study Area have been investigated during the RI: the Building 215 area, the Building 231 area, the Building 1057 area, the Building 1065 area, the Building 1167 area, and the Building 1151 area (Figure 8.0-1). Building 1040 was identified in the Enhanced PA (ANL, 1989) as requiring further study; however, the transformer area associated with Building 1040 was remediated prior to the 1992 Supplemental RI field investigation (A/C Industrial Cleaning Co., 1991). Therefore, Building 1040 was eliminated from the scope of work for the RI.

Two leaking USTs and associated contaminated soil were reportedly removed from the vicinity of Building 215 during construction of a nearby Burger King restaurant. However, no documentation was available regarding tank removal or confirmatory sampling of soils in the tank excavation. Buildings within the Building 215 area include 215, 211, 87, and 36.

Four USTs and associated petroleum hydrocarbon-contaminated soil and groundwater were removed from the Building 231 area in 1988. An unknown amount of contaminated soil and groundwater remained in place following the tank removal. The remaining USTs were removed in 1993 and 1996. The Building 231 area encompasses Buildings 231, 228, 229, 230, 208, 201, 227, and 1029.

Building 1057 was added to the RI as part of the Follow-on field program on the basis of the NPS-directed review of PSF historical and recent activities. Samples were collected to evaluate the potential release of contaminants associated with a vault near the north end of the building.

Building 1065 was added to the RI as part of the Follow-on field program on the basis of the NPS-directed review of the PSF and CERFA research. Building 1065 has been described as part of the motor pool, as a pathological waste incinerator, and a former service station

(HLA, 1994). Samples were collected to evaluate the potential release of contaminants associated with former activities.

Building 1167, a former furniture repair and paint shop, was added to the RI as part of the Follow-on field program on the basis of the NPS-directed review and CERFA research. During the NPS site inspection in January 1994, three former paint spray booths were observed inside the north side of the building. Two of the booths had a 6-in diameter floor drain. The other booth had a 10 ft by 4 ft by 2 ft deep metal trough in the floor, without an apparent outlet. Samples were collected to evaluate the potential release of contaminants associated with former activities in these areas.

The Building 1151 area includes Buildings 1151 and 1152, as well as a concrete pad (referred to as Building 1153) that holds operating transformers. Prior to 1987, Building 1153 was used for transformer storage (ANL, 1989). The building and transformers investigated in 1987 were removed following the investigation. Three shallow soil samples were collected and analyzed for PCBs.

8.1 BUILDING 215

Building 215 is the westernmost of the sites in the Main Post Study Area. Two leaking USTs were removed from the area, but data regarding confirmatory sampling were not available. The Enhanced PA determined further investigation was necessary to evaluate any potential impact on soil or groundwater at the site (ANL, 1989). This section describes the results of investigations conducted to confirm that remediation was complete in the area of the former USTs.

8.1.1 Area Description

Building 215 is in the western portion of the Main Post Study Area (Figure 8.0-1). Topography slopes gently to the north with elevations ranging from 45 to 50 ft-PLL. A lawn surrounds Building 215 and sidewalks, parking lots, and roadways surround the landscaped area (Figure 8.1-1). Surface water at the site drains to San Francisco Bay via overland flow or the storm sewer system. Other buildings in the area include a Burger King restaurant to the north, and a post office to the west.

Building 215 was remodeled and finished with a stucco exterior in 1988; the type of frame construction is unknown. Documentation of historical uses is limited; however, PSF personnel stated the area was formerly occupied by a gas station and vehicle maintenance facilities.

Aerial photos from 1946 to 1988 indicate that six buildings in the vicinity of Building 215 were removed some time between April 22, 1973 and May 4, 1988 (Ringden and Sitton, 1990). The area once occupied by these buildings is now a parking lot.

Two leaking 10,000-gal USTs were discovered during construction of the Burger King restaurant in the Building 215 area. The tanks contained petroleum products. PSF records indicate that the tanks and approximately 360 yd³ of contaminated soil were removed in March 1988. No known verification samples were collected at the time of removal (ANL, 1989).

8.1.2 Sample Location Rationale

The source of contaminants in the Building 215 area is believed to have been two 10,000-gal USTs that contained petroleum products (Figure 8.1-1). These tanks and associated contaminated soil were removed in March 1988. With reference to the conceptual model (Section 3.1), the primary source at the site would have been releases from the tanks before they were removed. Releases from USTs by leaks or spills would potentially impact soils in the area, and could potentially infiltrate through the soil column to groundwater. One boring was drilled through what is thought to be the backfill material in the former tank location. Soil samples from this boring were collected immediately below the fill and near the water table to evaluate whether soils and groundwater were affected by the USTs. Additional subsurface soil samples were collected from borings near to and downgradient of the former UST location. Monitoring wells were installed and groundwater samples collected upgradient and downgradient of the former location of the USTs to evaluate the effects of the USTs on groundwater.

8.1.3 Geologic Setting

The soils at this site were classified as Urban Land by the San Francisco County Soil Survey (Kashiwagi and Hokholt, 1985). Five soil borings were drilled at this site during the RI field program, three of which were completed as monitoring wells. The lithologic logs for these borings are in Appendix F.1.

Two lithologic units were encountered in the Building 215 area. Fill material was found at the surface and to a maximum depth of approximately 15 ft bgs. Sands, silts, and clays of the Colma Formation were found below the fill deposits. This is consistent with mapping of the area by Schlocker (1974). Fill deposits consist of sand, silty sand and clayey sand with varying amounts of gravel, and minor amounts of concrete and peat-like organic material. Fill deposits range in thickness from approximately 4 to 15 ft and are thickest where the former USTs were removed and backfilled (Figure 8.1-1). The Colma Formation consists of reddish-brown to greenish-brown fine sand with varying amounts of silt and clay and occasional silt and/or clay lenses. Borings were drilled to a maximum depth of 46 ft bgs and did not reach the Franciscan Formation. The closest outcrop of the Franciscan Formation is approximately 0.3 mi south of Building 215. Based on the site-wide structural contour map on the bedrock surface, the depth to the top of the Franciscan Formation is estimated to be about 125 to 150 ft bgs.

Groundwater at this site is within the Northeastern Groundwater Area. Three monitoring wells were installed in the vicinity of Building 215. One well was installed upgradient of the USTs and two wells were installed downgradient. Due to the presence of a building immediately downgradient of the former UST location and underground utilities in the area, the downgradient wells were placed as close as possible to the former UST location.

Well-sorted sands and silty, clayey sands of the Colma Formation comprise the aquifer at the site. Depth to groundwater is approximately 32 ft bgs, as measured in March 1995. The water-levels measured at low and high tide were similar, indicating that tidal fluctuations in the bay do not significantly impact water levels in the Building 215 area. The water-level elevations indicate that groundwater flow is to the north-northeast at a gradient of approximately 0.013 ft/ft (Figure 8.1-1). Groundwater recharge is most likely due to infiltration of surface water through the overlying fill and sediments, and from infiltration of

precipitation and surface water (including El Polin Spring) in unpaved areas upgradient of the site.

8.1.4 Analytical Results

The potential contaminant source at the site was two USTs that were removed during renovation of buildings in the area. Soil and groundwater samples were collected during the Initial RI field investigation to evaluate the nature and extent of residual contamination in soils, and to assess whether any contaminants which might be present had migrated to groundwater. The three groundwater monitoring wells were resampled in November 1994 as part of the Follow-on RI sampling program.

Five soil borings were drilled in and around the former tank location at Building 215 (Figure 8.1-1), and 10 samples, two from each boring, were collected for chemical analysis. Shallow sample depths ranged from 5.0 to 13.5 ft bgs. The deep sample depths ranged from 15.5 to 41.5 ft bgs. All samples were analyzed for the VOCs and SVOCs listed in Section 3.3. A table summarizing analytical results was not prepared because no detections above CRLs were reported by the laboratory for any sample.

Monitoring wells were installed in three of the six borings at the site. Well 215GW01 was installed upgradient and Wells 215GW02 and 215GW03 were installed downgradient of the former UST locations. Groundwater samples were collected and analyzed for VOCs and SVOCs to evaluate whether the removed tanks had adversely impacted groundwater. A table summarizing analytical results from the Initial RI is not presented because no detections above the CRL were reported by the laboratory for any sample. All three wells were sampled during the Follow-on RI and analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH, and miscellaneous parameters. Results of the Follow-on RI sampling are presented in Table 8.1-1. Numerous inorganics and miscellaneous parameters were detected. 1,2-Dichloroethane was detected at a concentration of 2.39 $\mu\text{g/L}$ in Well 215GW01. 1,2-Dichloroethane was detected in several other water samples during the Follow-on RI where it had not been detected before and it is suspected that these detections would not be confirmed by additional sampling. As indicated above, this analyte was not detected in any of the Building 215 wells during the Initial RI. Chloroform was detected in

Well 215GW02 at a concentration of 0.630 µg/L. No other VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, or TPH fractions were detected above the RLs.

8.1.5 Results Evaluation

No target analytes were detected above the CRL in any soil samples or groundwater samples collected during the Initial RI. As discussed below, several inorganics, miscellaneous parameter, and two organic compounds were detected in the Follow-on RI groundwater samples. Because this site is in the Northeastern Groundwater Area and beneficial uses of the groundwater include municipal and domestic supply (SFRWQCB, 1996), analyte concentrations in groundwater are compared to MCLs. Although no quantitative evaluation has been made, it is inferred that groundwater could potentially provide sufficient flow to a well to support an average, sustained yield of 200 gpd, as defined in RWQCB Resolution No. 89-39 for assessing groundwater as a resource for domestic or municipal water supply. However, it is unlikely that the groundwater would be used for drinking water, because of the naturally elevated TDS and chloride concentrations associated with saltwater intrusion from the bay. In addition, the GMPA does not indicate that groundwater will be used as a drinking water source.

Two inorganics were detected above Primary MCLs in Building 215 groundwater. Aluminum was detected in the unfiltered sample from upgradient Well 215GW01 at a concentration of 1,070 µg/L which is above the California primary MCL of 1,000 µg/L. However, aluminum was not detected in the filtered sample from this well. Antimony was detected above the California primary MCL of 6.0 µg/L in all three filtered samples from Wells 215GW01, 215GW02, and 215GW03, at a maximum concentration of 12.6 µg/L. Antimony was not detected in any of the three unfiltered samples. The higher antimony concentrations in the filtered samples, as compared to the unfiltered samples, are attributed to the filter medium, as discussed in Section 3.7.5. Therefore, filtered antimony results are considered to be unreliable and antimony is not considered to be present in detectable concentrations in the groundwater.

There were two exceedences of California recommended secondary MCLs. TDS exceeded the California recommended secondary MCL of 500,000 µg/L in Well 215GW03 and

chloride exceeded the California recommended secondary MCL of 250,000 µg/L in Well 215GW01. These elevated levels are attributed to saltwater intrusion from the bay. They do not exceed the regulatory standards for potential municipal or domestic water supplies required by California State Water Resources Control Board Resolution No. 88-63, but it is likely that overpumping in this area could result in increased concentrations.

One organic, 1,2-dichloroethane, was detected at a concentration exceeding the California primary MCL of 0.5 µg/L. It was detected at 2.39 µg/L in Well 215GW01; however, it is suspected that this detection would not be confirmed by additional sampling, as discussed above. This was indicated for other sites where this analyte was detected during the Follow-on RI, but subsequent sampling performed by Montgomery Watson did not confirm its presence. The chloroform concentration reported in Well 215GW02 was well below the California primary MCL of 100 µg/L. It is suspected that the source of the chloroform is overchlorination of the potable water supply, as low, sporadic concentrations of chloroform and other trihalomethanes have been detected in other areas of the Main Post (Montgomery Watson, 1996b). No other VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, or TPH fractions were detected.

8.1.6 Conclusions and Risk Assessment Results

This section summarizes the evaluation of results for the Building 215 area, including the risk assessment results, as presented in detail in Section 15.

8.1.6.1 Conclusions

The investigative results in the Building 215 area demonstrate that contamination associated with USTs formerly located at this site has been remediated. There were no analyte detections in any of the soil samples collected at the site. It is recommended that Well 215GW01 be resampled as part of the site-wide groundwater monitoring program to confirm the presence or absence of 1,2-dichloroethane in the shallow groundwater at this site. All three of the wells have been recommended for a year of quarterly sampling in the Draft Basewide Groundwater Monitoring Plan (Montgomery Watson, 1996b).

Exposure to inorganics, miscellaneous parameters and the two detected organics, 1,2-dichloroethane and chloroform, in groundwater beneath Building 215 is evaluated in the human health risk assessment. Risk to ecological receptors is not addressed because of the unlikely existence of an exposure pathway.

8.1.6.2 Risk Assessment Summary

The GMPA identified institutional (industrial) use around Building 215. Under this scenario exposures to surface (0 to less than 0.5 ft bgs) and subsurface (0.5 to less than 15 ft bgs) soil are possible. Because there were no analytes detected in soil samples in the study area, only the groundwater beneath the site was evaluated in the risk assessment. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source. Because there is not a reasonable groundwater exposure pathway for ecological receptors, an ecological risk assessment was not performed for this site.

Two of the assessments of risk performed for Building 215 are not based on the planned future use of the site. These include the assessment of groundwater as drinking water and a residential PRG ratio screening assessment. Groundwater was assessed as drinking water although it is an unlikely potable water supply for the industrial worker in the area.

The residential PRG ratio screening assessment for groundwater (there were no detected analytes in soil samples) was performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

In the human health risk assessment, concentrations of the COPCs for groundwater are first screened against MCLs. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial

screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A $1E-06$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (Federal Register 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 215 groundwater are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

8.1.6.2.1 Quantification of Cancer Risks

The total cancer risk is $7E-05$ for the institutional worker at Building 215, mostly from ingestion of the inorganics arsenic, beryllium, and chromium from the groundwater. The residential PRG ratio screening assessment of groundwater resulted in a total cancer risk greater than $1E-06$.

8.1.6.2.2 Quantification of Noncarcinogenic Effects

Several inorganics, chloroform, 1,2-dichloroethane, chloride, and TDS were the COCs in groundwater as a water source at Building 215. No hazard indices are greater than 1E+00, indicating that it is unlikely that exposure to the COCs in the media at this site will result in noncarcinogenic adverse health. Residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00 at Buildings 215.

8.2 BUILDING 231 AREA

The Building 231 area is located in the north-central portion of the Main Post Study Area (Figure 8.0-1); a detailed map of the site is shown in Figure 8.2-1. Prior to the RI, four USTs were removed in 1988 by Martech Environmental Systems, along with associated contaminated soil and groundwater. Additional work was done during the RI to determine the extent of soil contamination and more fully characterize the site hydrogeology. An interim remedial action (IRA) was initiated in 1990 which included groundwater and vapor extraction wells and associated treatment equipment. As discussed in Section 8.2.1.3, the system was last operational in 1993. Additional USTs were removed in 1993 and 1996. This site has been removed from the CERCLA process and the site remedial actions will be completed under the UST program. A corrective action plan (CAP) for the site is currently under preparation. The following discussion of the Building 231 area is presented for informational purposes only.

8.2.1 Area Description

The Building 231 area is located in the northeastern portion of the PSF. The area includes Halleck Street west of Building 231, Gorgas Avenue north and east of Building 231, and Buildings 227, 228, and 229 to the south (Figure 8.2-1). The physical setting, history and land use, and previous investigations are described in the following sections.

8.2.1.1 Physical Setting

Surface elevations within the Building 231 area are between 10 and 30 ft-PLL, and the ground surface slopes gently to the north-northeast. Surface-water runoff discharges to San

Francisco Bay via storm drains. Most of the area is covered by buildings or pavement; small areas east and southeast of Building 231 are covered by grass.

8.2.1.2 History and Land Use

Building 231 was built in 1950 as a service station for privately-owned vehicles. It was operated under the control of the Army Air Force Exchange Service (AAFES) by a private contractor until mid-1995. Most recently, Building 231 housed a tire store where automobile repairs including tire mounting, tune-ups, oil changes, and brake work were performed.

Building 228, immediately south of Building 231, was constructed in 1909 as a bakery. Based on building use records, the building was used for dry cleaning operations some time after 1950, and prior to 1973. Dry cleaning equipment in the building has not been in service since 1984.

All USTs in the immediate vicinity of Building 231 are shown in Figure 8.2-1; descriptions of their size and contents are presented in Table 8.2-1. For reference purposes, numbers for each tank listed in Table 8.2-1 correspond to the numbers next to tank locations shown in Figure 8.2-1. Three pump islands were located immediately east of the former UST location north of Building 231. A gravity-fed 4-in steel fuel oil line is located between Buildings 228 and 231, terminating at Building 229. This line was abandoned in place some time prior to November 1975 (Tronoff, 1975). The fuel distribution system and USTs are included in the COE basewide petroleum cleanup program. Numerous underground and aboveground utilities are at the site. These utilities include water, sanitary sewer, storm drains, gas, electric, and telephone lines.

A second service station, Building 206, and an associated car wash, Building 208, are located north of Building 231 and Gorgas Avenue, downgradient of the former location of the Building 231 tanks. These buildings were constructed in 1982 and were operated under control of the AAFES by a private contractor until mid-1995. Underground fiberglass storage tanks used at this service station were installed in 1982. All three tanks were leak tested and passed in 1987 and 1994 (Montgomery Watson, 1996b). These USTs and associated piping were removed in July 1996. An investigation of the extent of petroleum contamination in this area is being conducted by the Sacramento COE.

8.2.1.3 Previous Investigations

Four 10,000-gal USTs at Building 231 were removed in November 1988 after failing integrity tests. These tanks formerly stored leaded and unleaded gasoline. During the removal, the four USTs, their gasoline pumps, approximately 700 yd³ of contaminated soil, and approximately 5,300 gals of groundwater were removed and disposed of off-site (ELM, 1991). In December 1988, eight soil borings were drilled to aid in defining the extent of contamination; three of these borings were completed as monitoring wells (231GW01, 231GW02, and 231GW03). Based on laboratory analysis of samples from the borings, it was estimated that an additional 1,000 yd³ of soil containing petroleum hydrocarbons remained in place (ECJC, 1990b).

In 1990, a soil vapor-groundwater extraction and treatment system was installed near the former site of the underground fuel tanks north of Building 231. The system includes seven shallow extraction wells and 11 injection wells. Each extraction well is equipped with a 2-inch diameter pneumatic pump for groundwater pumping and each well is connected to blower which creates a vacuum to facilitate vapor extraction. Extracted groundwater can be treated by a modified UV peroxidation system and vapors can be treated utilizing a catalytic fume incinerator. A search of BRAC files did not yield any information regarding groundwater pumping rates, treatment system performance or monitoring data. This treatment system was operational in 1992 and 1993. However, the contractor, Martech, went out of business and the system has not been operational since late 1993. Due to the unique design of the system, it was believed that a new contractor could not operate the system effectively.

The depth of burial of the removed USTs north of Building 231 is unclear. However, given the typical depth of burial and typical dimensions of 10,000-gal tanks, the bottom of the tank excavation was probably 14 to 18 ft bgs. Therefore, the tanks and associated backfill material probably spanned across at least the uppermost bay mud unit and perhaps deeper layers of bay mud which act to separate the sandy beach deposits that form the main water-bearing zones in the Building 231 area (see Section 8.2.3). This is important to the distribution of contamination in groundwater as discussed in Section 8.2.5.

Additional investigations were initiated by RLSA in October of 1991 at Building 231. The purposes of these studies were to further characterize the extent of contamination in soil and groundwater, and to conduct quarterly sampling of groundwater. The results of these studies were contained in an IRA report dated February, 1992 (RLSA, 1992b). Additional borings and wells were drilled and sampled during the RI Follow-on sampling program. The results of all of these studies are described in Section 8.2.4.

In 1993, Tanks 6, 7, 8, and 9 were removed from between Buildings 231 and 228. According to Montgomery Watson (1996b), approximately 500 gal of fuel product were removed from Tank 6. Upon removal, obvious corrosion and evidence of product release were noted. This tank reportedly stored gasoline (Table 8.2-1). Analytical results from previous tank sampling confirmed the presence of gasoline (Section 8.2.4.2). Approximately 575 gal of product were removed from two of the other three tanks (Montgomery Watson, 1996b). The third tank was empty. The tanks reportedly held cleaning solvents (Table 8.2-1); product samples indicated the USTs contained mostly light petroleum hydrocarbons, including toluene and xylenes and very low concentrations of chlorinated hydrocarbons believed to be indicative of dry cleaning solvents (Montgomery Watson, 1996b). Analytical results from previous tank sampling of one of these three tanks (Tank 8) confirmed the presence of toluene, xylene, and ethylbenzene (Section 8.2.4.2). The USTs showed no sign of integrity failure but stained soil was noted as contaminated (Environmental Chemical Corporation, 1993). Approximately 57 yd³ of soil were excavated during removal of these three tanks; the depth of the excavation was approximately 10 ft bgs.

8.2.1.4 Ongoing Investigations

Montgomery Watson has been conducting quarterly groundwater monitoring of selected wells at the Building 231 site since July 1993. Groundwater samples have been collected from Wells 231GW01 through 231GW21 and analyzed for VOCs and TPH. Cumulative monitoring results are contained in quarterly and annual summary reports by Montgomery Watson.

The COE is evaluating data collected under three phases of the RI and during quarterly monitoring to assess what measures will be needed to remediate the Building 231 area.

Although highly unlikely, it is possible that the existing soil vapor-groundwater extraction and treatment system could be retrofitted to remediate the site. A CAP is currently in preparation by the COE's contractor.

Additional work is being conducted under the basewide petroleum cleanup program to remove and assess the fuel distribution lines and tanks in this area. The last confirmed tank associated with Building 231 (Tank 5) was removed in late 1996.

8.2.2 Sample Location Rationale

Leaking USTs and some of the associated contaminated soil had been removed from the Building 231 area prior to the RI field activities. However, the Enhanced PA (ANL, 1989) concluded that there was potential for residual contamination at and downgradient of the site, to the north and east.

In the context of the conceptual model (Section 3.1), the primary source at the site would have been leaks or spills from the removed tanks. Releases from USTs by leaks or spills would potentially impact soils in the area, and could infiltrate through the soil column to groundwater. Other potential sources at the site included a waste oil tank located in Building 231, a gasoline tank located south of the southwest corner of Building 231, and former dry cleaning operations conducted in Building 228 (Figure 8.2-1).

During the Initial RI field program, soil borings and hand auger borings were drilled to further characterize the nature and extent of target analytes in subsurface soils at the site from known and potential sources. Four of these borings were completed as monitoring wells; groundwater samples were collected from these four wells and three pre-existing wells and analyzed to assess groundwater quality in the area.

Initial RI data indicated that the hydrogeology and extent of groundwater contamination had not been fully characterized. The site was investigated further as part of the IRA in October 1991. Additional soil borings and monitoring wells were drilled to aid in characterizing the groundwater flow system and to delineate subsurface contamination.

During the RI Follow-on sampling program, it was necessary to drill and sample additional borings and wells in and around the Building 231 area because previous investigations had not fully characterized the extent of contamination. Soil and depth-discrete groundwater samples were collected from soil borings drilled upgradient, downgradient, and crossgradient from suspected contaminant sources. Monitoring wells were installed in the intermediate and deep water-bearing zones adjacent to shallow monitoring wells at three locations. The purpose of these well clusters was to evaluate vertical gradients and the vertical extent of contamination. The three well clusters are 231GW06/20/21, 231GW17/18/19, and 231GW13/15/16 (Figure 8.2-1). Depth-discrete groundwater samples were also collected from some borings to aid in delineating the vertical extent of contamination in groundwater.

During the Follow-on RI, soil samples were collected two hand auger borings drilled immediately north of Building 228. Dry cleaning operations apparently took place in an interior room on the north end of the building. The borings were drilled outside of, but adjacent to the north side of Building 228 next to an air scrubber unit and a cutoff drain pipe leading from inside the building. Two samples from each boring were collected to evaluate the potential for organic contamination related to the dry cleaning operation.

8.2.3 Hydrogeologic Setting

Information pertaining to soils, geology, and hydrogeology is from data obtained during previous investigations, the RI field programs, the IRA field program, and readily available information such as U.S. Geological Survey (USGS) maps and publications. The geology and hydrology of the Building 231 area are described in the following sections.

8.2.3.1 Geology

Soils encountered during drilling in the Buildings 228/231 area represent three distinct units, artificial fill underlain by marine and/or beach sand and bay mud deposits. Field logs and well construction data are presented in Appendices F.2 and F.3.

Fill materials were encountered at land surface in all borings and consisted of sand, silty sand, and sandy silt with varying amounts of gravel, brick, and cinders. The thickness of fill materials ranges from 1.1 to 13.0 ft. Fill thickness is variable across the site due to

construction activities related to urban development including building construction, underground tank and utility placement, construction of elevated sections of U.S. Highway 101, etc. In some areas, the fill deposits extend below the water table and form at least part of the uppermost water-bearing unit. Fill depths were either identified in the field or later interpreted as fill from soil descriptions on boring logs and stratigraphic correlation with other logs.

Directly underlying the fill material in some areas are deposits consisting primarily of organic-rich silty clay and silty clayey sands with discontinuous lenses of peat and stringers of well-sorted fine- to medium-grained sand. These deposits, locally referred to as bay mud, range in thickness from 1.5 to over 12 ft. Several laterally continuous layers of bay mud have been identified in the subsurface in the Building 231 area. The bay mud units are generally more numerous and/or thicker to the north toward the bay as depicted on cross section A-A' (Figure 8.2-2). Bay mud deposits are interpreted to have been deposited either in a tidal flat environment or in brackish or saltwater marshes along the margins of the bay during the Holocene epoch (Helley et. al., 1979).

Bay mud deposits are interlayered with beach or shallow marine deposits of unconsolidated, well-sorted, greenish-gray, fine- to medium-grained sands with varying but generally small amounts of silt and organic material, as well as occasional seashell fragments. The composition of these layers suggests deposition in a shallow marine or beach environment. These layers range in thickness from less than one ft to almost 60 ft in the central portion of the Building 231 area at Boring 231SB26. At this location, marine sands were encountered from a depth of 28 ft to about 86 ft bgs. A deeper bay mud unit at least 35 ft thick was encountered in the deepest portion of the boring. Based on the log of Boring 231SB26, the depth to bedrock is greater than 128 ft in this area. It is believed that a deep channel may have been cut into bedrock in this area in the mid to late Pleistocene when sea level was much lower and that this channel was filled in with bay mud and shallow marine sands as sea level rose in the late Pleistocene and Holocene time. The shape of this channel or valley in the bedrock surface is best illustrated on the bedrock structural contour map on Figure 2.3-4 which suggests a depth to bedrock of approximately 200 ft bgs in the central portion of the Building 231 area.

8.2.3.2 Hydrology

Groundwater below the southern portion of the Building 231 site is considered to be in the Northeastern Groundwater Area; groundwater in the northern area of the site is within the Crissy Field Groundwater Area. Three water-bearing zones, herein referred to as shallow, intermediate, and deep, have been identified in the Building 231 area. The shallow water-bearing zone is primarily composed of artificial fill, beach sand, and, in some areas such as at well cluster 231GW06/20/21, bay mud (Figures 8.2-2 and 8.2-3). The intermediate water-bearing zone consists of beach sand below the base of the uppermost bay mud unit and is typically 15 to 25 ft bgs. The deep water-bearing zone consists of marine and/or beach sand below the second layer of bay mud. Based on data from Boring 231SB26, the deep water-bearing zone is relatively thick, extending from about 25 to 30 ft bgs to 86 ft bgs. Only Boring 231SB26 penetrated the full thickness of the deep water-bearing zone.

The shallow, intermediate, and deep water-bearing zones are separated from one another in most areas near Building 231 by less permeable bay mud units. This stratigraphy is very similar to the sequence of beach sands and bay mud layers observed throughout the Crissy Field Study Area to the northwest. Although very little stratigraphic data are available between Crissy Field and the Building 231 area, it is believed that the unit designations of Montgomery Watson (1995d) in the Building 637 area can be correlated to the stratigraphy in both the Crissy Field Study Area (Section 5.3) and the Building 231 area. The shallow and intermediate water-bearing zones in the Building 231 area may be equivalent to Units A1 and A2 of Montgomery Watson. The deep water-bearing zone in the Building 231 area is believed to be equivalent to Unit B of Montgomery Watson. Based on its stratigraphic position, the deep bay mud encountered in Boring 231SB26 (Figure 8.2-2) may be equivalent to bay mud Unit B/C in the Building 637 area.

Based on the cross sections, the beach sand deposits that comprise the intermediate and deep water-bearing zones are laterally continuous in the Building 231 area. Beach sand deposits in the shallow water-bearing zone are not as continuous laterally, being either truncated by artificial fill or grading laterally into bay mud deposits. In general, the bay mud deposits are thicker and more laterally continuous in the north portion of the site, nearer to the historical

marsh that existed in the Crissy Field Study Area. To the south, such as at Well 231GW09 (Figure 8.2-2), the bay mud units appear to either thin or pinch out.

Table 8.2-2 summarizes the water-bearing zone screened by each well. For clarity, wells are classified into three groups according to water-bearing zone(s) screened. There are three deep zone monitoring wells, four intermediate zone wells, and 12 shallow zone wells. Water level elevation data collected on April 14, 1995 are contoured separately for each of the three water-bearing zones on Figures 8.2-4, 8.2-5, and 8.2-6. The magnitude and direction of the horizontal hydraulic gradient are similar for all three water-bearing zones. The gradient direction varies from north to northwest in the shallow zone to north-northeast in the intermediate and deep zones. The magnitude of the hydraulic gradient varies from almost 0.02 ft/ft in the shallow zone in the northern and southern portions of the Building 231 area to as low as approximately 0.006 ft/ft in the intermediate and deep zones. Water-level data collected by Montgomery Watson indicate similar direction and magnitude of the hydraulic gradients (Montgomery Watson, 1996b).

A comparison of water levels in the three 3-well clusters (231GW13/15/16, 231GW06/20/21, and 231GW17/18/19) provides information on vertical gradients in the Building 231 area (Table 8.2-3). For data collected April 14, 1995, the elevation of the potentiometric surface is highest in the deep zone and lowest in the shallow zone, indicating an upward hydraulic gradient. The difference in potentiometric head between the shallow and the deep zones is about 3 ft at well clusters 231GW17/18/19 and 231GW06/20/21 and is 5.5 ft at downgradient well cluster 231GW13/15/16. It is apparent that the bay mud units act as confining layers which prevent equilibration of head potential across the three water-bearing zones. The intermediate and deep zones are considered to be semiconfined to confined water-bearing zones while the shallow zone is primarily unconfined. At deep Well 231GW13, the potentiometric head level is above the ground surface and the deep zone at this location is artesian.

Review of available groundwater data and distance from the San Francisco Bay suggest that tidal fluctuations have minimal impact on water levels in the Buildings 231 area. Wells in this area are located at least 1,000 ft from San Francisco Bay. Two sets of water levels taken at high and low tides on the same day fluctuated by less than 0.1 ft.

Slug tests were performed on Wells 231GW07, 231GW11, and 231GW12 during the IRA (RLSA, 1992b). Wells were chosen based on the geologic interval screened. Wells 231GW07 and 231GW11 are considered to be shallow zone wells while Well 231GW12 is classified as an intermediate zone well. Two slug tests were performed at each well, and the data were analyzed using AQTESOLV software written by Geraghty & Miller, Inc. Well 231GW07 data were analyzed using both the Bouwer-Rice method for unconfined aquifers and the Cooper-Bredehoeft-Papadopoulos (CBP) method for confined aquifers. Both methods were used because although Well 231GW07 is classified as a shallow well, the screened interval may extend into the underlying intermediate zone which is believed to be confined or semiconfined. Results of both methods indicate a hydraulic conductivity of approximately 0.47 to 0.62 ft/day. Well 231GW11 is screened in the shallow unconfined water-bearing zone, therefore data were analyzed using the Bouwer-Rice method for unconfined aquifers. Results indicate a hydraulic conductivity of 1.1 to 1.4 ft/day. Well 231GW12 is screened in the intermediate confined water-bearing zone; therefore data were analyzed using the CBP method for confined aquifers. Results indicate a hydraulic conductivity of 3.8 ft/day.

8.2.4 Analytical Results

Soil and groundwater samples were collected and analyzed during several investigations conducted between 1990 and 1995 to evaluate the extent of contamination related to potential contaminant sources in the area. Potential sources include USTs formerly located north of Building 231, USTs located between Buildings 231 and 228, and a waste oil UST located in the southeast corner of Building 231. This section summarizes analytical results from soil and groundwater samples collected during the Initial and Follow-on RIs as well as during the IRA.

8.2.4.1 Soil Sample Results

Analytical data from soil samples collected during the Initial RI, IRA, and Follow-on RI are listed in Tables 8.2-4 through 8.2-7. Eight soil samples were collected from borings during the Initial RI. The samples were analyzed for inorganics, VOCs, SVOCs, and TPH (Table 8.2-4). Detections of these analytes in the eight samples are presented in Table 8.2-4.

All of the eight Initial RI samples contained numerous inorganics. As all of these samples were collected from the Building 231 Area, which is being further evaluated by the COE, no analysis of inorganic ambient exceedences is presented in this section. The inorganic concentrations will be evaluated according to protocol established for the basewide petroleum cleanup program.

VOC detections were limited to one detection each of benzene, 1,3-dimethyl-benzene, and tetrachloroethene. Benzene and 1,3-dimethyl-benzene were detected in Sample 231GW06B, and tetrachloroethene was detected in Sample 231SO01A. The highest VOC concentration detected was 0.84 $\mu\text{g/g}$ of tetrachloroethylene in Sample 231SO01A, at a depth of 0.5 ft bgs. This sample is located just south of Building 231.

SVOCs detected in Initial RI soil samples are listed in Table 8.2-4. SVOCs detected were bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, ppDDD, and pyrene. Bis(2-ethylhexyl)phthalate and fluoranthene were detected four times, phenanthrene was detected three times, ppDDD and pyrene were each detected once. With the exception of bis(2-ethylhexyl)phthalate, none of the SVOCs were detected at a concentration $> 0.5 \mu\text{g/g}$. The maximum detected concentration of bis(2-ethylhexyl) phthalate was 5.4 $\mu\text{g/g}$.

TPH was detected in three of the five samples that were analyzed from the Initial RI. The highest concentration (5,000 $\mu\text{g/g}$) was in Sample 231GW04A at a depth of 3.5 ft. This sample was collected in the vicinity of Tanks 6, 7, 8, and 9 between Buildings 231 and 228 (Figure 8.2-1).

Seven soil samples were collected from seven borings during field work for the IRA in the Building 231 area. All samples were analyzed for VOCs and TPH. Detections above the CRL are listed in Table 8.2-5. Six different VOCs were detected in the seven samples, including the four BTEX compounds and acetone and methylethyl ketone/2-butanone. The later two compounds were detected in four of the seven samples while none of the BTEX compounds were detected in more than two samples. None of the VOCs were detected at concentrations $> 0.2 \mu\text{g/g}$. In addition, TPH was detected in four samples at concentrations ranging from 100 to 6,000 $\mu\text{g/g}$. The sample with the highest TPH concentration was collected from Boring 231SB05 which is located adjacent to Tank 6 south of Building 231.

During the Follow-On RI, two borings were drilled adjacent to the north side of Building 228 to evaluate whether soil contamination is present related to former dry cleaning operations at the site. Two samples from each boring were analyzed for VOCs and SVOCs. As shown on Table 8.2-6, the only analyte detected was bis(2-ethylhexyl)phthalate. This compound was detected in three of the four samples collected at concentrations ranging from 0.124 to 0.440 $\mu\text{g/g}$.

Soil samples were collected from seven additional borings in the Building 231 area during the Follow-on RI. Soil samples were collected from two depths in the unsaturated zone from each boring and analyzed for lead and TPH by immunoassay or for TPH-D and TPH-G. Lead was not detected above the SDC in any of the samples (Tables 8.2-7). Four of the seven soil samples analyzed for TPH by immunoassay contained TPH >100 $\mu\text{g/g}$. TPH-D and TPH-G were below their respective SDCs in all samples except the 4 ft-bgs sample from Boring 231SB16 and the 0.5 ft-bgs sample from Boring 231SB28. TPH-D and TPH-G in the sample from Boring 231SB16 were 165 and 88.5 $\mu\text{g/g}$, respectively. TPH-D was detected at 170 $\mu\text{g/g}$ in the sample from Boring 231SB28.

8.2.4.2 Groundwater Sample Results

Groundwater samples were collected from monitoring wells during the Initial RI, IRA, and Follow-on RI. Discrete groundwater samples were collected from multiple depths in several borings during the Follow-on RI. Analytical results of groundwater samples are discussed chronologically starting with the Initial RI.

Groundwater samples were collected from Well 231GW01 through 231GW07 during the Initial RI. Groundwater samples were analyzed for inorganics, VOCs, SVOCs, and TPH. In addition, a sample of product was collected from a UST adjacent to Building 228 and analyzed for VOCs to characterize the product in the tank. Results of these samples are listed in Table 8.2-8. All inorganic elements shown were detected above the CRL in at least one sample. The only organic analyte detected in the water samples was benzene, which was detected once at a concentration of 40 $\mu\text{g/L}$ in Well 231GW01. No SVOCs were detected at levels above the CRL in groundwater samples. TPH was detected in four of the seven wells sampled, at concentrations ranging from 100 to 500 $\mu\text{g/L}$. The free product sample was found to contain ethylbenzene, toluene, and xylene, at 200, 200, and 900 $\mu\text{g/g}$, respectively.

Five monitoring wells were installed as part of the IRA at Building 231 to augment the seven monitoring wells that were installed during and before the Initial RI. Groundwater samples were collected from all twelve monitoring wells and one injection well (from the groundwater treatment system) during quarterly monitoring conducted for the IRA. Three rounds of monitoring were conducted in October 1991, December 1991, and March 1992. All samples were analyzed for a limited list of inorganics (calcium, iron, potassium, magnesium, and sodium), miscellaneous parameters, VOCs, and TPH. The injection well was not in use as part of the groundwater treatment system when it was sampled.

Numerous inorganics and miscellaneous parameters were detected in the groundwater samples (Table 8.2-9). VOCs were detected only in Wells 231GW01, 231GW04, 231GW09, 231GW10, and 231GWIN02. Well 231GWIN02, in close proximity to, and downgradient of the removed USTs, contained the highest number and concentrations of VOCs. All VOCs detected at the site were detected at least once in Well 231GWIN02. These VOCs included BTEX compounds and methylethyl ketone, methyl-n-butyl ketone, and acetone. Benzene, toluene, and xylenes were detected in all three sampling rounds for Well 231GWIN02. Benzene was only detected in monitoring Well 231GW01 (up to 5.4 µg/L) and injection Well 231GWIN01 (up to 300 µg/L). TPH was detected in 24 of 39 investigative samples from the 13 wells, at concentrations ranging from 241 to 7,220 µg/L.

Unfiltered discrete groundwater samples were collected from 11 borings during the Follow-on RI. In some borings, groundwater samples were collected from two or more discrete depths to evaluate the vertical extent of contamination. The discrete groundwater samples were analyzed for lead, VOCs, and TPH-D and TPH-G. The results are listed on Tables 8.2-10 and 8.2-11. Lead was detected in several of the samples. The highest lead concentration was 840 µg/L in the 27 ft-bgs sample from Boring 231SB16 located immediately downgradient of the former location of the USTs (Figure 8.2-1). The high lead results may be due, at least in part, to the turbid nature of the samples. Lead concentrations in filtered samples collected in other study areas, including the Crissy Field and DEH Study Areas, were generally much lower than in unfiltered samples.

Either TPH-D or TPH-G or both were above their respective SDCs in nine of the 11 borings. Borings 231SB18 and 231SB19 were the only sample locations to not have detectable TPH-

G or TPH-D. The only VOCs detected were trichlorofluoromethane and chloroform. However, the two chloroform detections were qualified as unreliable while the detected concentrations of trichlorofluoromethane were less than 2 µg/L. One of the detections of trichlorofluoromethane was considered a non-detect because it was detected in the trip blank at a concentration of 1.1 µg/L.

Seven new groundwater monitoring wells were installed and sampled as part of the Follow-on RI. These wells were installed in the three different water-bearing zones to assist in evaluating the vertical extent of groundwater contamination. Samples were collected from the new wells and analyzed for a limited number of inorganics (calcium, iron, magnesium, potassium, sodium, and lead), miscellaneous parameters, and TPH-D and TPH-G. The results from sampling these new wells are listed in Table 8.2-12. All inorganics and miscellaneous parameters were detected in all samples, with the exception of lead and nitrate. Lead was detected in one sample, from Well 231GW20, at a concentration of 7 µg/L. Nitrate was detected in four samples at concentrations ranging from 357 to 6,910 µg/L. TPH-D and TPH-G were each detected twice. The highest concentrations of both were reported in Well 231GW21. TPH-D was detected at a concentration of 4,700 µg/L, and TPH-G was detected at a concentration of 3,300 µg/L.

Samples were collected from Tank 8 (Sample 228FP02) during the Initial RI (Figure 8.2-1, Table 8.2-8), and Tanks 6 (Sample 231TK01) and 9 (Sample 228TK02) during the IRA (Figure 8.2-1 and Table 8.2-13) to characterize their contents. Sample 231TK01 was obtained from an UST immediately south of Building 231 which is reported to have contained gasoline (Tank 6, Figure 8.2-1). Analytical results confirm the presence of gasoline (Table 8.2-13).

Tanks 7, 8, and 9 were believed to be unrelated to historical fueling operations at Building 231. Sample 228FP02, collected from Tank 8, which was reported to contain dry cleaning solvents, was analyzed for VOCs. VOCs detected were xylene, toluene, and ethylbenzene suggesting that the tank contained fuel hydrocarbons. Sample 228TK02 was obtained from Tank 9 which was reported to have contained dry cleaning solvents (WES, 1990). Analytical results do not confirm the reported contents; rather, examination of the TPH chromatogram shows a pattern more similar to Jet A fuel. It is not believed that Jet A fuel was used at the

site. According to the draft Building 231 Area Corrective Action Plan, as referenced in the Basewide Groundwater Monitoring Plan (Montgomery Watson, 1996b), Tank 9 may have contained Stoddard solvent. When the tanks were removed in 1993, Tanks 7, 8, and 9 were found to be connected to Building 228, and not Building 231. This information suggests that after the tanks were no longer used to support dry cleaning operations (which ended in 1984), they may have been used in support of the automobile maintenance activities at Building 231.

8.2.5 Results Evaluation

The following is a preliminary evaluation of the data collected during the RI. A more detailed analysis will be conducted under the USCOE's CAP. The analytical sampling results are evaluated in this section to assess if the potential sources at this site have resulted in impacts to soil and groundwater. Previous UST removals have indicated that leaks or spills from USTs associated with the former automobile service station have resulted in contaminated soil and groundwater. Residual contamination from the removed tanks, and possibly other USTs in the area, were identified as potential sources of contamination in the Enhanced PA (ANL, 1989).

Because a portion of the site is within the Northeastern Groundwater area and beneficial uses of the groundwater include municipal and domestic supply (SFRWQCB, 1996), analyte concentrations in groundwater are compared to MCLs. However, a portion of the site is within the Crissy Field Groundwater Area, where there is a low probability for future municipal use. As presented in Section 2.3.5.3, it is estimated that groundwater below the site could provide sufficient flow to a well to support an average, sustained yield of 200 gpd, as defined in RWQCB Resolution No. 89-39 for assessing groundwater as a resource for domestic or municipal water supply. However, it is unlikely that the groundwater would be used for drinking water, because of the naturally elevated TDS and chloride concentrations associated with saltwater intrusion from the bay. In addition, the GMPA does not indicate that the groundwater will be used for drinking water.

8.2.5.1 Soil Evaluation

Numerous inorganics were detected in the eight Initial RI samples. Lead was the only inorganic analyzed in Follow-on RI soil samples; it was not detected above the SDC. As all of these samples were collected from the Building 231 Area, which is being further evaluated by the COE, no analysis of inorganic ambient exceedences is presented in this section. The inorganic soil concentrations will be evaluated according to protocol established for the basewide petroleum cleanup program.

VOCs that were detected in the eight Initial RI samples were limited to one detection each of benzene, 1,3-dimethyl-benzene, and tetrachloroethene. A concentration of 0.84 $\mu\text{g/g}$ of tetrachloroethylene was detected in a shallow soil sample collected just south of Building 231. With the exception of bis(2-ethylhexyl)phthalate, none of the SVOCs that were detected were above a concentration of 0.5 $\mu\text{g/g}$. Because bis(2-ethylhexyl)phthalate is a common laboratory contaminant and phthalates tend to be ubiquitous indicators of plastics, it is not likely that the detections are associated with site contamination.

TPH was detected in three of the five samples that were analyzed from the Initial RI. The highest concentration was 5,000 $\mu\text{g/g}$ in Sample 231GW04A at a depth of 3.5 ft. This sample was collected in the vicinity of Tanks 6, 7, 8, and 9 between Buildings 231 and 228 (Figure 8.2-1). The highest TPH concentration detected in seven samples analyzed during the IRA was also from the area of the tanks situated between Buildings 231 and 228. These data indicate a second source of petroleum hydrocarbon contamination in addition to the known hydrocarbon release from tanks formerly located north of Building 231.

The lack of detectable VOCs, particularly organic solvents, in soil samples collected from just north of Building 228 suggests that dry cleaning operations have not impacted soil and groundwater in the area. Concentrations of BTEX compounds in samples collected during the IRA were relatively low, below 0.2 $\mu\text{g/g}$, suggesting that most of these compounds have volatilized since the petroleum fuel leaks occurred.

Additional soil samples were collected during the Follow-on RI to further evaluate the extent of soil contamination in the Building 231 area. Based on soil sample results from all phases of work, the lateral extent of petroleum hydrocarbon contamination in soil has not been fully

defined. TPH-D was detected above the SDC of 100 $\mu\text{g/g}$ in borings located in the vicinity of both suspected source areas, immediately south of Building 231 and in the parking lot north of Building 231. The downgradient extent of TPH in soil appears to be defined by the lack of TPH-D in above SDCs in Borings 231SB30 and 231SB31 and the boring for Well 231GW07 (Figure 8.2-1). The lateral extent of soil contamination to the east has not been fully defined to the east of Building 231. Either TPH or TPH-D was detected at or above the SDC in samples from Borings 231SB04, 231SB15, 231SB07, and 231SB28. The latter boring is located just east of Building 231 (Figure 8.2-1), suggesting that either significant lateral migration has occurred or that another source(s) of petroleum hydrocarbons may be present. The CAP will make the determination whether such sources are present.

8.2.5.2 Groundwater Evaluation

None of the inorganic concentrations in groundwater exceeded California primary MCLs but iron, manganese, and TDS exceeded California secondary or recommended secondary (for TDS) MCLs in several samples. Sulfate and chloride recommended secondary MCLs were exceeded in the first sample from injection Well 231GWIN02, and also in the second sampling event for sulfate (Table 8.2-9). The elevated levels of chloride and TDS are attributed to saltwater intrusion from the bay. They do not exceed the regulatory standards for potential municipal or domestic water supplies required by California State Water Resources Control Board Resolution No. 88-63, but it is likely that groundwater extraction in this area could result in increased salt concentrations.

The action level for lead in groundwater of 15 $\mu\text{g/L}$ was exceeded in more than one half of the discrete, unfiltered groundwater samples collected during the Follow-on RI. The highest concentration of 840 $\mu\text{g/L}$ was detected in the deepest sample (27.0 ft-bgs) from 231SB16. There were no exceedences in the unfiltered groundwater samples from the Follow-on RI or in filtered samples collected during the Initial RI from monitoring wells. Therefore, it is believed that the elevated lead concentrations are caused by the turbid nature of the depth-discrete groundwater samples. Data collected in other study areas, including Crissy Field and DEH, also support this interpretation. Lead is not above the SDC in the soil, also indicating that the elevated detections of lead in the depth-discrete samples are not likely associated with U.S. Army sources.

The groundwater data indicate that the lack of detectable organic solvents in groundwater samples suggests that dry cleaning operations have not impacted groundwater in the area. The VOCs detected, primarily BTEX, are indicative of a source of petroleum hydrocarbons associated with fuels. Benzene was detected above the primary MCL of 1 µg/L in 1990 and 1991 samples from Well 231GW04 and in the 1991 and 1992 samples from Well 231GWIN02. The only other MCL exceedence for organics was in this well; toluene was detected above the California Primary MCL of 150 µg/L (Follow-on SDC was 1,000 µg/L, based on the USEPA MCL).

The results of analysis of groundwater samples indicates that petroleum hydrocarbon contamination is present in all three water-bearing zones beneath the Building 231 area. Evidence of contamination in the deep zone is provided by results of discrete groundwater samples from Boring 231SB26. Samples collected from depths of 46.0, 66.5 and 80.5 ft all had TPH-D concentrations well above the SDC. TPH-G concentrations also exceeded the SDC in the 46.0- and 66.5-ft samples. TPH-D was detected in deep Well 231GW20 at the SDC of 100 µg/L. TPH-D and TPH-G were not detected in downgradient deep Well 231GW13 or in deep Well 231GW17 to the west-northwest of Building 231. Subsequent quarterly monitoring data collected by Montgomery Watson, beginning in the summer of 1995, have indicated a single detection of TPH (fuel oil range) in one of the three deep wells (Montgomery Watson, 1996d). This detection (340 µg/L) was reported in Well 231GW20 for the 1996 winter quarter.

TPH has been detected in intermediate zone Well 231GW06 and in discrete groundwater samples collected from the intermediate zone in Borings 231SB20 and 231SB21. TPH-G was detected above the SDC in the downgradient intermediate Well 231GW15. Wells 231GW03 and 231GW04 which are screened in both the shallow and intermediate zones contained TPH above SDCs during groundwater monitoring for the IRA. These data suggest that petroleum hydrocarbons have migrated into the intermediate and deep zones from the former UST area north of Building 231. This is possibly due to the bottom of the tanks likely having been placed into the intermediate water-bearing zone based on the typical dimensions and depth of placement of 10,000-gal tanks.

The lateral extent of petroleum hydrocarbons in the shallow water-bearing zone appears to have been defined based on groundwater samples from monitoring wells and discrete groundwater samples from borings. Based on quarterly groundwater monitoring results, Montgomery Watson shows the hydrocarbon plume in the shallow zone as extending from the tanks between Buildings 231 and 228 to shallow aquifer to less than 300 ft downgradient to the north (Montgomery Watson, 1996d). This information is consistent with observations at other UST sites that have indicated that hydrocarbon plumes rarely exceeded 200 ft in length due to natural attenuation (Montgomery Watson, 1996b). Discrete groundwater samples from Borings 231SB12 and 231SB13 suggest that the TPH-G plume may extend slightly farther than the TPH-D plume. This is consistent with the fact that lighter weight hydrocarbons tend to be more mobile than heavier weight hydrocarbons such as diesel fuel.

8.2.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 228 and 231 areas, including the risk assessment results for Building 228, as presented in detail in Section 15.

8.2.6.1 Conclusions

The results of field investigations confirm the presence of two primary sources of fuel hydrocarbons in the Building 231 area. Fuel hydrocarbons are known to have leaked from USTs that were removed in 1988 from the parking lot north of Building 231. In addition, soil and groundwater samples indicate a second source of fuel hydrocarbons in the vicinity of the tanks located between Buildings 231 and 228. Leaks and/or spills of fuel hydrocarbons from these sources have resulted in soil and groundwater contamination at the site.

Petroleum hydrocarbon soil contamination extends from south of Building 231 to the north and east of Building 231. The eastern extent of soil contamination has not been fully defined. Fuel hydrocarbons in groundwater extend from the area of the USTs between Buildings 231 and 228 downgradient to Well 231GW15. Groundwater contamination was found in all three water-bearing zones downgradient of Building 231 in the Follow-on RI, but subsequent monitoring results have not shown any consistent detections in the deep aquifer. However, based on the results of discrete groundwater samples collected from Boring 231SB26, the vertical extent of groundwater contamination has not been delineated.

The Building 231 area will not be considered in the BRA. Given that the COPCs are petroleum hydrocarbons and that the suspected sources are USTs formerly located at the site, the assessment of the need for further investigation of the vertical extent and further investigations or remedial actions will be conducted under the COE basewide petroleum cleanup program. A CAP is under preparation. Recommendations for future sampling of the Building 231 wells are presented in the *Basewide Groundwater Monitoring Plan* (Montgomery Watson, 1996b).

In the Building 228 area, the only COPC in soil is bis(2-ethylhexyl) phthalate. It is suspected that this analyte is not site-derived, and other analytical data indicate that the former dry cleaning operations at Building 228 have not impacted soil and groundwater. Subsequent groundwater sampling conducted by Montgomery Watson supports this inference. Bis(2-ethylhexyl)phthalate will, however, be evaluated as a COPC in both the human health (subsurface soil) and ecological risk assessments for the Building 228 site, as all detected organics are considered to be COPCs, unless the data are considered unreliable or affected by blank contamination as discussed in Section 3.6.

8.2.6.2 Risk Assessment Summary

As presented in Section 3.7, the COPCs in soil (only bis(2-ethylhexyl)phthalate at the Building 228 site) were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 228 area are summarized in the following sections.

8.2.6.2.1 Human Health

The GMPA identified commercial/office (industrial) uses for the Building 228 area, and exposures to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are possible. At this site, all soil samples were collected within the subsurface depth interval. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for subsurface soil was also performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A $1E-06$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ $>1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ $<1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 228 area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

8.2.6.2.1.1 *Quantification of Cancer Risks*

Because there were no COCs identified in subsurface soil, Building 228 had the PSF water supply (Lobos Creek and Well 13) only assessed with ingestion and dermal contact to commercial/office workers. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$.

8.2.6.2.1.2 *Quantification of Noncarcinogenic Effects*

COCs in the PSF water supply (lead, manganese, and nitrate) were assessed for ingestion and dermal exposure. No hazard indices are greater than $1E+00$, indicating that it is unlikely that exposure to the COCs in the media at these sites will result in noncarcinogenic adverse health. Residential PRG ratio screening assessment resulted in a total hazard index less than $1E+00$ at Buildings 228.

8.2.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 228 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and

water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

The only soil COPC identified for the Building 228 ecological risk assessment was bis(2-ethylhexyl)phthalate. Comparison of exposure to receptor TBVs indicated no potential risk to terrestrial receptors exposed via ingestion of soil, dietary exposure, or dermal contact. No further evaluation of this site is warranted.

8.3 BUILDING 1057

Building 1057 was added to the RI as part of the Follow-on field program on the basis of the NPS-directed review of PSF historical and recent activities. Samples were collected to evaluate the potential release of contaminants associated with a vault near the north end of the building. The following sections describe the Building 1057 area, the field program, results, and conclusions.

8.3.1 Area Description

Building 1057 is located in the east-central portion of the Main Post Study Area to the southeast of Building 1065 (Figure 8.0-1). Elevations in the area are around 15 ft-PLL and the surface slopes very gently to the northeast toward the San Francisco Bay.

Building 1057 is approximately 20 ft by 30 ft. A small (1.8-ft by 1.9-ft by 1.4-ft deep) metal-covered vault is located outside of and adjacent to the north side of the building (Figure 8.3-1). The bottom of the vault was noted to be concrete, approximately 3/8 in thick. A 4-in steel pipeline, parallel to the building, terminates inside the vault (HLA, 1994). There is no indication that the building is connected to the vault; the pipe may be part of the storm drain system.

Building 1057 was constructed in 1924. It was reportedly used as a former maintenance shop, wood shop, and medical R&D facility (HLA, 1994). Although this building historically contained radioisotope use sites, it was determined that this building met the NRC's criteria for release of facilities for unrestricted use (TETC, 1994).

During the NPS site inspection in January 1994, the building was empty. It was thought that Building 1057 may have been used as a storage shed, but that it was unlikely that this building was used as a shop or R&D facility due to the small size of the building and lack of equipment (HLA, 1994).

8.3.2 Sample Location Rationale

The concrete vault immediately north of Building 1057 was considered to be a potential source of contamination to the underlying soils and shallow groundwater. In order to evaluate whether soils were affected by releases from the vault, two samples were collected. A sediment sample was collected above the concrete in the bottom of the vault and a soil sample was collected from 3 ft bgs (1.6 ft below the bottom of the vault) from a boring drilled through the bottom of the vault. The soil samples were analyzed for TPH-G and TPH-D, inorganics, VOCs, and SVOCs.

8.3.3 Geologic Setting

Very little site-specific information concerning the subsurface geology in the immediate vicinity of Building 1057 is available as the only boring drilled in this area for the RI Follow-on sampling program was terminated at 3.5 ft bgs. Boring 1057SB01 encountered poorly graded loose sand beneath the vault which is either fill or possibly beach sand. Borings drilled in the Building 1167 area to the north encountered bay mud consisting of clay, sandy clay and clayey sand in the upper ten ft of soil. Borings drilled in the Building 1065 area to the west encountered four to six ft of artificial fill underlain by either sandy beach deposits or clayey bay mud deposits. Based on the site-wide bedrock structural contour map (Figure 2.3-4), the depth to bedrock in the Building 1057 area is estimated to be on the order of 70 to 90 ft bgs.

Groundwater was encountered at a depth of 2 ft-bgs in Boring 1057SB01. No wells were installed in the Building 1057 area but information from wells in the Building 231 and DEH areas suggest that the groundwater at Building 1057 is very shallow and the gradient is to the north-northeast.

8.3.4 Analytical Results

Two investigative samples were collected during the Follow-on RI to evaluate whether contaminants are present in or beneath the vault on the north side of Building 1057. Sediment Sample 1057SE01 was collected from just above the concrete floor of the vault. A subsurface soil sample was collected from Boring 1057SB01 about 1.6 ft below the base of the vault. Both samples were analyzed for inorganics, VOCs, SVOCs, and TPH-D and TPH-G. The results of the analyses are listed on Tables 8.3-1 and 8.3-2.

The sediment and soil samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, potassium, magnesium, and sodium are excluded from the following discussion of results. All other inorganics detected in the samples were compared to ambient concentrations, as described in Section 3.7. Detections that were affected by blank contamination are not discussed.

No VOCs were detected above the RLs in the sediment sample collected from the vault. Three phthalates were detected in the sample at concentrations ranging from 12.3 to 28.4 $\mu\text{g/g}$. TPH-D was detected at 12.2 $\mu\text{g/g}$. The sediment is isolated from the underlying soil by the concrete vault, but for perspective, inorganic concentrations in the sediment sample were compared to ambient fill concentrations because fill is the most likely lithology to be present in the area. Antimony, cadmium, lead, mercury, and zinc were detected above ambient fill concentrations.

Antimony was the only compound detected above ambient in the soil sample collected from beneath the vault. Antimony was detected at 0.154 $\mu\text{g/g}$ relative to the ambient fill concentration of 0.1 $\mu\text{g/g}$. All other inorganics that were above ambient in the sediment sample were at least an order of magnitude lower in the soil sample. No VOCs or TPH fractions were detected in the soil sample. Two of the three phthalates that were detected in the sediment sample were present in the soil sample. Bis(2-ethylhexyl) phthalate and di-n-butyl phthalate were detected at concentrations less than 0.2 $\mu\text{g/g}$, approximately two orders of magnitude below their respective concentrations in the sediment sample.

8.3.5 Results Evaluation

The potential source of contamination in the Building 1057 area is the small concrete vault on the north side of the building. Potential inorganic contaminants detected above ambient fill concentrations in the sediment sample that was collected from the bottom of the vault include antimony, cadmium, lead, mercury, and zinc. Organics detected in the sediment sample include TPH-D and three phthalates. With the exception of antimony, all of the inorganics and the phthalates were a minimum of approximately an order of magnitude lower in the subsurface soil sample collected 1.6 ft beneath the concrete bottom of the vault than in the sediment sample from the vault. The antimony in the sediment sample and in the soil sample were detected slightly above ambient. However, they are not considered to be site related, as concentrations in the sediment and soil were similar, unlike the other inorganics detected above ambient in the sediment sample, and within the range of potentially naturally occurring concentrations (Section 3.7). TPH-D was not detected in the soil sample from beneath the vault. The concrete floor of the vault appears to have effectively limited migration of potential contaminants from the vault to the underlying soil. It is not likely that migration of contaminants detected in the sediment in the vault via the groundwater pathway is likely, as the detected inorganics and TPH-D tend to sorb to sediments, which are likely to remain in the vault. Furthermore, the nature of the analytes detected in sediment in the vault indicates that the source of the analytes may be surface water runoff from the surrounding roads.

8.3.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1057 area, including the risk assessment results, as presented in detail in Section 15.

8.3.6.1 Conclusions

COPCs in the vicinity of the vault at Building 1057 appear to be limited to the sediment within the vault itself. Although cadmium, lead, mercury, zinc, and TPH-D were detected at elevated levels in sediment from within the vault, they were not detected at levels of concern in the soil sample collected below the vault. Phthalates, which were detected in the sediment sample at concentrations ranging from 12.3 to 28.4 $\mu\text{g/g}$, were detected at concentrations less than 0.2 $\mu\text{g/g}$ in the soil sample collected 1.6 ft below the vault. The concrete floor of the vault appears to have limited migration of COPCs through the vault to underlying soil. The COPCs detected in the vault may not be related to past activities in Building 1057 but probably resulted from surface water runoff from Birmingham Road north of the vault.

8.3.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health risk assessment according to the depths at which they occurred and the exposure scenarios that were evaluated. The sediment collected from the vault was assessed as surface soil. Cadmium, lead, mercury, zinc, and butylbenzylphthalate are evaluated as surface soil COPCs. Bis(2-ethylhexyl) phthalate and di-n-butyl phthalate are evaluated as both surface and subsurface COPCs. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

No COPCs from the Building 1057 site will be included in the ecological risk assessment of the Main Post Study Area, due to the improbable exposure pathway for ecological receptors to sediment in the metal covered vault or to the soil beneath the concrete vault.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than

5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated.

The GMPA identified institutional (industrial) use around Building 1057. Under the industrial scenario, exposures to surface (0 to less than 0.5 ft bgs) and subsurface (0.5 to less than 15 ft bgs) soil are possible. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for surface and subsurface soil was also performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected

carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ $>1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ $<1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the FPCGS Study Area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

8.3.6.2.1 Quantification of Cancer Risks

Because no COCs were identified in sediment or subsurface soils, Building 1057 had the PSF water supply (Lobos Creek and Well 13) only assessed with ingestion and dermal contact to commercial/office workers. The residential PRG ratio screening assessment resulted in a total cancer risk equal to $1E-06$.

8.3.6.2.2 Quantification of Noncarcinogenic Effects

COCs in the PSF water supply (lead, manganese, and nitrate) were assessed for ingestion and dermal exposure. No hazard indices are greater than $1E+00$, indicating that it is unlikely that exposure to the COCs in the media at these sites will result in noncarcinogenic adverse health. Residential PRG ratio screening assessment resulted in a total hazard index greater than $1E+00$ at Building 1057.

8.4 BUILDING 1065

Building 1065 was added to the RI as part of the Follow-on field program on the basis of the NPS-directed review of the PSF and CERFA research. Samples were collected to evaluate

the potential release of contaminants associated with former activities. The following sections describe the Building 1065 field program and its results. Because potential site sources are associated with petroleum hydrocarbons, the site has been removed from the CERCLA process and any additional work will be conducted under the basewide petroleum cleanup program. The following discussion is presented only for informational purposes.

8.4.1 Area Description

Building 1065 is located in the central portion of the Main Post Study Area (Figure 8.0-1). Topography in the area slopes gently to the north-northeast with elevations ranging from about 13 to 18 ft-PLL. Building 1065 is surrounded by asphalt pavement and other buildings including Buildings 1062, 1063, 1040, 1047, 1087, 1088, and an above ground fuel oil storage tank immediately northwest of Building 1040 (Figure 8.4-1). Numerous underground fuel oil distribution lines are present in the shallow subsurface to the north of the above ground fuel oil tank. The only landscaped areas are west and southwest of Building 1065 between Buildings 1040 and 1029 (Figure 8.0-1). Surface water in the area drains to San Francisco Bay via overland flow or the sewer system.

Building 1065 was constructed in 1919. It has been described as part of the motor pool, as a pathological waste incinerator, and a former service station (HLA, 1994). The Enhanced PA (ANL, 1989) and the CERFA report (TETC, 1994) indicated that a UST, containing oil or various POL products, may have been under or near Building 1065. However, Montgomery Watson's April 7, 1995 Tank Status Map indicates that the existence of this tank is unsubstantiated. Building 1065 was demolished in the summer of 1996 by NPS contractors.

8.4.2 Sample Location Rationale

Potential sources in the Building 1065 area include unsubstantiated UST(s) under or near Building 1065, a sump immediately northeast of Building 1065, stained areas in the pavement to the south of Building 1065, and the above ground fuel oil tank and associated distribution lines northwest of Building 1040. Releases from these potential sources could potentially impact soils and shallow groundwater in the area. To assess the presence, distribution, and concentration of petroleum hydrocarbons and lead in the area, nine borings were drilled and sampled. Soil samples were collected from above the water table and

groundwater samples were collected with a depth-discrete groundwater sampling device. Samples were analyzed for TPH-G and TPH-D, and for lead.

8.4.3 Hydrogeologic Setting

Information pertaining to soils and geology is taken from data obtained during the RI field program and readily available information such as USGS maps and publications. A total of nine borings were drilled in the Building 1065 area during the RI Follow-on investigation. No wells were installed in this area.

Soils encountered during drilling in the Building 1065 area represent three distinct units, artificial fill underlain by bay mud deposits interbedded with marine and/or beach sand. Field logs are presented in Appendix F.6.

Fill materials were encountered immediately below land surface in all borings in the Building 1065 area. Fill materials ranged from 4- to 6-ft thick in all borings and consist of sand, sandy gravel, and sandy silt with small amounts of clay, brick, glass, and concrete. Fill depths were either identified in the field or later interpreted as fill from soil descriptions on boring logs and stratigraphic correlation with other logs.

Directly underlying the fill material are interbedded bay mud deposits and marine or beach sand deposits. Figure 8.4-2 is an interpretive geologic cross section constructed from boring logs in the Building 1065 area. Two layers of bay mud were encountered in some of the deeper borings. The bay mud deposits consist of dark greenish gray clay to sandy clay with trace to some organics including roots and plant material. The upper layer of bay mud is of variable thickness and appears to grade laterally into sandy beach deposits such as between Borings 1065SB07 and 1065SB08 (Figure 8.4-2). The lower bay mud layer appears to pinch out to the east between Borings 1065SB07 and 1065SB06.

The beach deposits consist of poorly graded fine-grained sand with very little clay or silt. These deposits are very similar to the beach or marine sand layers in the subsurface at the Building 231 area. The beach deposits vary in thickness due to lateral facies changes between the beach deposits and the bay mud deposits. The uppermost sand layer appears to be laterally discontinuous as shown on cross section A-A' (Figure 8.4-2). Below a depth of

about 15 ft bgs, the beach deposits are more prevalent than the bay mud deposits. Over 20 ft of beach deposits were encountered in Boring 1065SB08 below 18 ft.

Groundwater at this site is within the Northeastern Groundwater Area. Groundwater was encountered at a depth of about 5 ft in Building 1065 borings. This is consistent with water levels measured in wells in the Building 231 to the west. No wells were installed in the Building 1065 area but data from wells in the Building 231 and DEH areas suggest that the groundwater gradient is nearly flat but to the north-northeast toward the San Francisco Bay. Depth-discrete water samples were generally easier to collect in the sandy beach deposits than in the bay mud deposits. This suggests that the beach deposits are more permeable than the bay mud deposits which appear to form confining units in the Building 231 area. No well data are available to evaluate whether the layers of bay mud in the Building 1065 area are acting as confining layers.

8.4.4 Analytical Results

Potential contaminant sources in the Building 1065 area include unsubstantiated underground tank(s) under or near Building 1065, a sump immediately northeast of Building 1065, stained areas in the pavement to the south of Building 1065, and the above ground fuel oil tank and associated fuel oil distribution lines northwest of Building 1040 and south of Building 1065. Samples were collected from subsurface soils and groundwater. Soil samples were collected from four borings (1065SB01 through 1065SB04) and depth-discrete water samples were collected from eight of the nine borings. Sample locations are shown on Figure 8.4-1.

The results of analyses of soil samples for lead and TPH-D and TPH-G are listed on Table 8.4-1. Lead was detected above the XRF RL of 25 $\mu\text{g/g}$ in three of the 11 soil samples. The maximum concentration detected was 324 $\mu\text{g/g}$, which was detected in the 0.5 ft-bgs sample from 1065SB02. The two other detections of lead were in the 0.5 and 5.0 ft-bgs samples from Boring 1065SB03, at concentrations of 52.5 $\mu\text{g/g}$ and 48 $\mu\text{g/g}$, respectively.

No TPH-G or TPH-D was detected in any of the soil samples; however, TPH was detected by immunoassay in the 5.0 ft bgs sample from Boring 1065SB03 at a concentration of >100 $\mu\text{g/g}$.

Depth-discrete water samples were collected from each of the nine borings with the exception of Boring 1065SB03. Sample results are listed on Table 8.4-2. Lead was detected in 14 out of 22 unfiltered water samples at concentrations ranging from 5 to 12,000 $\mu\text{g/L}$. Two filtered samples were analyzed for lead for comparison to unfiltered samples. Neither of the filtered samples contained detectable lead while the corresponding unfiltered samples contained 5 and 7 $\mu\text{g/L}$ of lead. The high lead results may be due, at least in part, to the turbid nature of the samples. Lead concentrations in filtered samples collected in other study areas, including the Crissy Field and DEH Study Areas, were generally much lower than in unfiltered samples, particularly for groundwater samples collected using a depth-discrete groundwater sampling device.

TPH-D and TPH-G were detected in at least one depth-discrete water sample from six of the eight borings from which water samples were collected. In general, TPH-D concentrations were one to two orders of magnitude greater than TPH-G concentrations in the same samples. TPH-D concentrations ranged from <50 to 3,200 $\mu\text{g/L}$ while TPH-G concentrations ranged from <10 to 34 $\mu\text{g/L}$. Thirteen out of 23 depth-discrete water samples contained detectable TPH-D above the SDC of 50 $\mu\text{g/L}$ with four samples containing greater than 1,000 $\mu\text{g/L}$. In contrast, only 11 out of 22 samples contained detectable TPH-G concentrations above the SDC of 10 $\mu\text{g/L}$ with no concentrations greater than 34 $\mu\text{g/L}$.

8.4.5 Results Evaluation

The potential sources of petroleum related contamination in the Building 1065 area include unsubstantiated underground tank(s) under or near Building 1065 and the above ground fuel oil tank and associated fuel oil distribution lines northwest of Building 1040 and south of Building 1065. In addition, a sump immediately northeast of Building 1065 and stained areas in the pavement to the south of Building 1065 have the potential to have contributed to soil contamination in the area. In this section, the analytical results are assessed with respect to

these potential sources to evaluate the nature and extent, as well as fate and transport, of contamination in soil and groundwater.

From the available data, it is not possible to pinpoint the sources responsible for TPH detections in groundwater. None of the soil samples analyzed contained detectable TPH-D or TPH-G, although one subsurface soil sample (0.5 ft-bgs sample from Boring 1065SB02) analyzed by immunoassay was reported to have TPH at $>100 \mu\text{g/g}$. TPH was not detected in either the 0.5 ft or 10.0 ft-bgs samples collected from this boring, indicating the limited distribution of the TPH.

There is no pattern to the TPH concentrations in groundwater that would indicate the location of the source of TPH in groundwater. The highest TPH concentrations in groundwater are spread out spatially between Borings 1065SB04, located south-southeast of Building 1065, Boring 1065SB05, located north of Building 1065, and Boring 1065SB06, located east of Building 1065 (Figure 8.4-1). TPH concentrations in groundwater are also variable in the vertical direction. In some borings, TPH concentrations increase with depth while in other borings concentrations decrease with depth. The data indicate that TPH-D and TPH-G are present in groundwater above their respective SDCs to the south, east and north of Building 1065. The lack of detectable TPH-D and TPH-G in water samples from Borings 1065SB01 and 1065SB07 in between other borings with detectable TPH suggests that there may be more than one TPH plume in the Building 1065 area. The presence of relatively high TPH-D in Borings 1065SB04 and 1065SB09 located upgradient of Building 1065 suggests that unsubstantiated underground tanks under or near Building 1065 are not likely the primary source of TPH contamination in the area. Rather, the above ground fuel oil tank and associated pipelines located next to and north of Building 1040 (Figure 8.2-1) appear to be the more likely source(s) of TPH in groundwater.

The higher concentrations of TPH-D as opposed to TPH-G are consistent with the fuel oil tank and associated pipelines being the primary source of contamination. However, concentrations of TPH-D in discrete groundwater samples collected from Boring 1065SB09, located immediately downgradient of the fuel oil tank, increased with depth. TPH-D was $460 \mu\text{g/L}$ in the 40-ft sample from this boring relative to $66 \mu\text{g/L}$ in the sample collected at 15 ft bgs. No borings have been drilled immediately upgradient of the above ground fuel oil tank.

At Fill Site 6 located south of the fuel oil tank, TPH-D was detected above SDCs in discrete groundwater samples collected from Borings LF6SB10 and LF6SB11; the highest concentration was 250 µg/L (Section 9.4). However, TPH-D was not detected in any soil samples collected from Fill Site 6.

A comparison of lead concentrations in soil and groundwater with corresponding TPH-D and TPH-G concentrations in soil and groundwater shows no correlation. That is, high lead concentrations are not associated with high TPH-D and TPH-G. TPH was not detected in the sample with the highest lead concentrations. Similarly, eight detections of lead in groundwater exceeded the SDC (or action level) of 15 µg/L, up to a maximum concentration of 12,000 µg/L in 1065SB01; but neither TPH-D nor TPH-G were detected in this sample. It is believed that the elevated lead concentrations in groundwater are caused, at least in part, by the turbid nature of the depth-discrete groundwater samples. Data collected in other study areas, including Crissy Field and DEH, also support this interpretation. These comparisons suggest that the high lead concentrations are not directly related to leakage of petroleum fuels in the area. However, it is also possible that lead in soil and in groundwater is related to historic use of leaded gasoline when Building 1065 was used as a service station and that most of the volatile components of gasoline have volatilized or degraded.

This site is in the Northeastern Groundwater Area and beneficial uses of the groundwater include municipal and domestic supply (SFRWQCB, 1996), which is why lead concentrations in groundwater are compared to MCLs. No quantitative evaluation has been made as to whether or not groundwater could potentially provide sufficient flow to a well to support an average, sustained yield of 200 gpd, as defined in RWQCB Resolution No. 89-39 for assessing groundwater as a resource for domestic or municipal water supply. However, it is unlikely that the groundwater would be used for drinking water, because of the availability of a public water supply and the proximity of the bay. There are no plans in the GMPA for developing groundwater in the vicinity of PSF as a municipal water supply.

8.4.6 Conclusions

Soil and groundwater samples were collected to evaluate potential sources of petroleum-related contamination in the Building 1065 area. These potential sources include

unsubstantiated underground tank(s) under or near Building 1065 and the above ground fuel oil tank and associated fuel oil distribution lines northwest of Building 1040 and south of Building 1065. TPH-G and TPH-D were detected above SDCs and lead was detected above the MCL (action level) in discrete groundwater samples collected both upgradient and downgradient of Building 1065. Analytical data from soil samples are inconclusive as to the source(s) of contamination. TPH (immunoassay) was detected at $>100 \mu\text{g/g}$ in only one soil sample collected immediately south of Building 1065. The vertical and lateral extent of lead and TPH in groundwater have not been fully delineated in either the upgradient or downgradient directions. However, it is possible that the elevated levels of lead in the discrete groundwater samples are associated with the turbid nature of the samples collected using a depth-discrete groundwater sampling device and that groundwater samples, particularly filtered samples, collected from monitoring wells would have significantly reduced lead concentrations.

Building 1065 will not be considered in the BRA. Considering that the primary contaminants at this site are petroleum hydrocarbons and that Building 1065 was formerly a gasoline service station, it has been determined that future investigations of the nature and extent of contamination and any necessary remedial actions will be conducted under the COE basewide petroleum cleanup program

8.5 BUILDING 1167

Building 1167, a former furniture repair and paint shop, was added to the RI as part of the Follow-on field program on the basis of the NPS-directed review and CERFA research. Samples were collected to evaluate the potential release of contaminants associated with U.S. Army activities. The following sections describe the Building 1167 field program and its results.

8.5.1 Area Description

Building 1167 is located in the east-central portion of the Main Post Study Area immediately southwest of U.S. Highway 101 and northeast of Gorgas Avenue (Figure 8.0-1). Building 1163 adjoins Building 1167 to the southwest (Figure 8.5-1). The area is relatively flat at an

elevation of about 10.5 ft-PLL. Surface drainage is to the northeast toward a series of storm drains between Building 1167 and U.S. Highway 101. The area around Building 1167 is covered with pavement except for an area to the northwest of Building 1168 which is covered with grass.

Building 1167 was constructed in 1919. It is described as a former Department of Logistics furniture shop where painting and stripping operations were conducted (HLA, 1994). The Enhanced PA (ANL, 1989) noted that the shop was used for stripping and painting of furniture and a small amount of woodwork. Alcohol-based paint thinner was brushed onto furniture, and the resulting residue was rinsed off with water or scraped off. Approximately 5 gal of this residue were generated per week and disposed of through the postwide hazardous-waste disposal program.

The Enhanced PA described a wet curtain spray paint booth in Building 1167 that discharged recirculated water to the PSF sanitary sewer after filtration (ANL, 1989). Accumulated sludge from the spray booth was disposed of as solid waste in a nearby dumpster. No estimate of the quantities are available (ANL, 1989). During the NPS site inspection in January 1994, three former paint spray booths were observed inside the north side of the building. Two of the booths had a 6-in diameter floor drain. The other booth had a 10 ft by 4 ft by 2 ft deep metal trough in the floor, without an apparent outlet. The booths were approximately 10 ft by 10 ft by 12 ft high and open on one side (HLA, 1994).

Stains, paints, lacquers, adhesives, and solvents associated with furniture repair were noted to be stored in drums in this building (TETC, 1994). The building is used by the NPS to store furniture (TETC, 1994; HLA, 1994).

8.5.2 Sample Location Rationale

The potential sources of contamination in the Building 1167 area are the spray booths that were used in the former furniture repair and paint shop. With respect to the conceptual model, the primary sources at the site would have been releases from the floor drains or trough associated with the spray booths. Releases from the floor drains could potentially impact soils in the area and possibly affect shallow groundwater. Three borings were drilled immediately outside of Building 1167 adjacent to the locations of the spray booths along the

inside of the northeastern wall of the building. Soil samples were analyzed for VOCs and inorganics.

8.5.3 Geologic Setting

Information regarding the soils and geology of the Building 1167 area is taken from the logs of three shallow borings drilled for the RI Follow-on sampling program and the results of other borings drilled at nearby sites for the RI. The locations of the three borings drilled in the Building 1167 area are shown on Figure 8.5-1. Boring logs are contained in Appendix F.8.

All three borings encountered artificial fill deposits immediately below the ground surface. Fill deposits consist of gravelly sand, sand, and silt with wood fragments in some places. The thickness of fill ranges in the three borings from about 1.8 to 4.5 ft. Directly underlying the fill materials are clayey deposits interpreted to be bay mud. The bay mud deposits consist of dark gray clay, sandy clay, and clayey sand with some roots and other organic matter. Little or no sandy beach deposits were encountered in the three borings to the maximum depth penetrated of 11 ft.

Groundwater was encountered at a depth of 1.5 to 3 ft bgs in each of the three borings. No wells were installed in the Building 1167 area but information from wells in the Building 231 and DEH areas suggests that the groundwater gradient at Building 1167 is very shallow and to the north-northeast.

8.5.4 Analytical Results

Borings 1167SB01, 1167SB02, and 1167SB03 were drilled adjacent to the northeast side of Building 1167 opposite of the spray booths located inside the building. One soil sample from Boring 1167SB01, two samples from Boring 1167SB02, and three samples from Boring 1167SB03 were analyzed for VOCs and inorganics. With the exception of the uppermost sample in each boring, all soil samples were collected in saturated soils. The results of these analyses are listed in Table 8.5-1 for those analytes that were detected above the RLs. No VOCs were detected in any of the samples.

All of the samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussion of soil results. All other inorganics detected in soil were compared to ambient concentrations in either fill or beach-dune sediments as appropriate, as described in Section 3.7.

All of the soil samples contained at least one inorganic analyte above ambient concentrations. Aluminum, arsenic, cyanide, iron, lead, manganese, mercury, selenium, vanadium, and zinc were detected above ambient in at least one sample. Lead was detected above the SDC of 300 $\mu\text{g/g}$ at a concentration of 586 $\mu\text{g/g}$ in the 0.5-ft sample from Boring 1167SB03. The 0.5-ft and 5.0-ft samples from this boring had the most inorganics above ambient. These samples were considered to be fill for the ambient comparison; however, the dark gray clayey sand in the 5.0 ft sample is similar in appearance to the bay mud deposits in other samples from this site. Selenium concentrations were above ambient in every sample with concentrations ranging from 1.80 to 5.37 $\mu\text{g/g}$.

8.5.5 Results Evaluation

The potential sources of contamination that were investigated at the Building 1167 site were the spray booths that were used in the former furniture repair and paint shop. Soil samples were collected from three borings located outside of Building 1167 but immediately adjacent to the locations of the spray booths along the inside of the northwestern wall of the building (Figure 8.5-1). The COPCs that were investigated were VOCs and inorganics that may have migrated to the subsurface as a result of spray booth operations. No VOCs were detected in any of the samples. Several inorganics were detected in the subsurface above ambient concentrations. Those inorganics detected above ambient concentrations that may be associated with potential site sources include lead, mercury, and zinc.

Lead, mercury, and zinc were detected above ambient in only the 0.5 ft bgs sample from Boring 1167SB03. This sample was categorized as fill and described as sand with a piece of wood noted in the interval. Concentrations of lead, mercury, and zinc were reported as 586 $\mu\text{g/g}$, 1.04 $\mu\text{g/g}$, and 897 $\mu\text{g/g}$, respectively. These three analytes were not detected above ambient in the two deeper samples from this boring, indicating that vertical migration of these analytes in the soil below 5 ft bgs is limited by the clayey layers. None of the samples from the borings to the north had ambient exceedences for these three inorganics. This distribution suggests a possible anthropogenic source of lead, mercury, and zinc. All of the other inorganics detected above ambient are considered to be representative of naturally occurring concentrations as described in the following paragraphs.

Aluminum ambient exceedences were in clay and clayey sand samples collected from 6.5 ft-bgs in Boring 1167SB02 and 5.0 ft-bgs in Boring 1167SB03. Arsenic also exceeded ambient in the 5.0 ft-bgs sample from Boring 1167SB03 and in the 10.0 ft-bgs sample, described as bay mud. The highest concentrations of aluminum and arsenic were detected in the 5.0 ft-bgs sample from 1167SB03, which also had elevated concentrations of several other inorganics, including magnesium and iron. These two inorganics are indicative of the mafic composition (composed of dark minerals and rich in magnesium and iron) of this sample; it is inferred that the elevated concentrations of the other metals in this sample are associated with the natural composition of the sample and not site sources. Furthermore, aluminum as well as arsenic concentrations tend to be elevated in clayey sediments. The arsenic exceedences were in saturated samples, which were diluted for analysis, and the concentrations are considered to be estimated values. These associations, the spatial distribution of the arsenic, and the inclusion of these concentrations within regional ambient ranges (Table 3.7-1) indicates that aluminum and arsenic are not likely to be site-derived.

Three other inorganics, including iron, manganese, and vanadium, were detected above ambient concentrations in only one sample from the site, the 5.0 ft-bgs sample from Boring 1167SB03. It follows that the ambient exceedences of iron, manganese, vanadium in this sample also are likely reflective of the mafic nature of the sedimentary material which is derived from serpentinite and are not associated with site contaminants. As an example, the

concentrations of iron and manganese in this sample are near the range of concentrations detected in background samples of serpentinite.

Cyanide was detected in two samples, one of which was the 5.0 ft-bgs sample from 1167SB03. The other detection was reported in the 0.5 ft-bgs sample from 1167SB01. Concentrations in the two samples were similar, ranging from 0.465 $\mu\text{g/g}$ in 1167SB03 to 0.482 $\mu\text{g/g}$ in 1167SB01, slightly above the RL of 0.25 $\mu\text{g/g}$. Any cyanide detection is initially considered to be above ambient; however, because of the absence of a pattern that would indicate site activities as a source, the other naturally elevated levels of inorganics in the 5.0 ft-bgs sample from 1167SB03, the dissimilar pattern from other COPCs, and the occurrence of these detections within the range of regional ambient concentrations (Table 3.7-1), cyanide is not considered a COPC.

Selenium was detected in all samples at concentrations ranging from 1.80 to 5.37 $\mu\text{g/g}$. The spatial analysis did not indicate any trend in concentration with depth or lithology, between the fill samples collected at the surface and the bay mud collected at a maximum depth of 10 ft bgs. Many of the samples were saturated and all samples in the analytical lot were diluted by 4 or 8 times, indicating that the concentrations may be estimated. In addition, all but one of the lot results exceeded ambient levels for all lithologic categories. This information, in addition to the absence of a potential selenium source at the site based on historical activities, the occurrence of these detections within the range of regional ambient concentrations (Table 3.7-1), and a dissimilar pattern from other COPCs, indicates that selenium is not a COPC.

8.5.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1167 area, including the risk assessment results, as presented in detail in Section 15.

8.5.6.1 Conclusions

Investigation of potential contamination related to the spray booths at Building 1167 documented the presence of several inorganics at concentrations above ambient in shallow subsurface soil, but no VOCs were detected in any of the soil samples. Detections of lead, mercury, and zinc in the 0.5 ft bgs sample from Boring 1167SB03 were considered to be

potentially associated with previous site activities. Migration to deeper soil appears to be limited to 5 ft bgs. However, because the groundwater is shallow in this area (1.5 to 3.5 ft bgs during the field investigation), migration of these inorganics to groundwater is possible. This pathway was not assessed through field sampling; however, any impact of these inorganics on the groundwater is expected to be minimal, based on the minor exceedences (less than an order of magnitude) of ambient values, the relative immobility of inorganics, and the clayey subsurface lithologies which tend to inhibit migration.

8.5.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1167 area are summarized in the following sections.

8.5.6.2.1 Human Health

The GMPA identified institutional (industrial) use around Building 1167. Under the industrial scenario, exposures to surface (0 to less than 0.5 ft bgs) and subsurface (0.5 to less than 15 ft bgs) soil are possible. At this site, all soil samples were collected within the subsurface soil interval and COPCs are lead, mercury, and zinc. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for subsurface soil was also performed as a preliminary assessment of a residential scenario. This assessment is very conservative and

does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 1167 area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

8.5.6.2.1.1 Quantification of Cancer Risks

Subsurface soil samples from Building 1167 had lead determined as the only COC and this was assessed along with the COCs in the PSF water supply (Lobos Creek and Well 13) for the institutional worker at this site. These COCs are not considered carcinogenic and therefore, it is unlikely that exposure to the institutional worker to them will result in an excess cancer risk. The COCs for Buildings 1167 are not considered carcinogenic in the residential PRG ratio screening assessment.

8.5.6.2.1.2 Quantification of Noncarcinogenic Effects

COCs in the PSF water supply (lead, manganese, and nitrate) were assessed for ingestion and dermal exposure. No hazard indices are greater than 1E+00, indicating that it is unlikely that exposure to the COCs in the media at these sites will result in noncarcinogenic adverse health. Residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00 at Building 1167.

The maximum detected lead value in subsurface soil at Building 1167 is 586 mg/kg which is less than the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

8.5.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 1167 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure

pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Lead, mercury, and zinc were the soil COPCs evaluated in the ecological risk assessment for Building 1167. The results of the risk evaluation for the terrestrial target receptors are:

- The HIs for American robin, mourning dove, western harvest mouse, and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{Low} values.
- The HIs only for American robin and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{High} values.
- Lead in soil resulted in HQs greater than 1 for the American robin when exposure was compared to the TBV_{Low} or the TBV_{High} , whereas lead HQs for the mourning dove exceeded 1 based only on the TBV_{Low} .
- Mercury concentrations predicted in diet resulted in HQs greater than 1 for the American robin when exposure was compared to the TBV_{Low} . HQs were less than 1 on the basis of the TBV_{High} . Mercury HQs also exceeded 1 for plants and soil fauna when exposure was compared to the TBV_{Low} , but not the TBV_{High} .
- Zinc in soil is of concern to the American robin, mourning dove and western harvest mouse when comparisons are made to the TBV_{Low} values. No HQs for zinc for exposure by any pathway exceeded 1 when exposure was compared to the TBV_{High} .

This site is immediately adjacent to a building, as well as next to a highway. Therefore, although ecological risk was evaluated, there is a very low potential for ecological receptors to be present. Thus, further evaluation at this location for ecological risk is not warranted.

8.6 BUILDING 1151

Building 1151 is located in the northeast portion of the PSF (Figure 8.0-1). The focus of the first investigations in this area was a transformer pad, designated as Building 1153, located between Buildings 1151 and 1152. An Engineering Evaluation/Cost Analysis (EE/CA) and additional supporting field investigations have been completed for this portion of the site (U.S. Army, 1996). An additional area of concern noted during the NPS site inspection in 1994 was a small metal storage shed, approximately 30 ft southwest of the transformer pad, which was observed to hold containers of paint and paint thinner. This section describes the Building 1151 field investigation and its results.

8.6.1 Area Description

Buildings 1151 and 1152 are located immediately southwest of U.S. Highway 101 along Gorgas Avenue. Building 1152 is 50 ft northwest of Building 1151, and Building 1153 is between Buildings 1151 and 1152 (Figure 8.6-1). The site area is flat, at an elevation of approximately 13 ft-PLL. Surface drainage is to the southeast, to a storm drain system on Gorgas Avenue. Both the building and the transformer pad are separated from pavement on all sides by a narrow strip of grass.

Prior to 1987, Building 1153 was used for transformer storage. After a 1987 PCB investigation, the inactive transformers and the building were removed (ECJC, 1990a). The site currently contains a concrete pad with active transformers surrounded by a chain-link fence.

A PCB Sampling and Analysis Report, dated February 9, 1987, is discussed in the Enhanced PA (ANL, 1989). Wipe samples, concrete surface samples, concrete core samples, and soil borings were collected. The building and four transformers that contained PCB fluids were removed after sample results were received (ECJC, 1990a). No post-removal confirmation samples were collected prior to the RI (ECJC, 1990a).

8.6.2 Sample Location Rationale

The transformer pad adjacent to Building 1151 is considered a potential source of contamination because of the 1987 detections of PCBs. In the context of the conceptual

model (Section 3.1), the primary source at the site would be leaks or spills from transformers on the pad. Releases from transformers by leaks or spills could potentially impact soils in the area. To assess the presence, distribution, and concentration of PCBs in shallow subsurface soils, three hand auger borings were drilled (Figure 8.6-1). One sample was collected from each boring at a depth of less than 1 ft bgs. Each sample was analyzed for PCBs.

During the NPS site inspection in January 1994, an additional area of concern was noted. Approximately 30 ft southwest of the transformer pad is a small metal storage shed with a dirt floor. The 4-ft by 4-ft shed contained approximately 20 1-gal metal containers of paint and paint thinner and one 55-gal drum of paint thinner. None of the containers appeared to be leaking but the walls of the shed were covered with paint (HLA, 1994). To evaluate potential contamination associated with the shed, two shallow hand auger borings were drilled and sampled on either side of the shed (1151SB01 and 1151SB02). Two soil samples were collected from the upper two ft of soil in each boring. Samples were analyzed for inorganics and VOCs.

8.6.3 Geologic Setting

The surficial geology northwest of Building 1151 consists of artificial fill deposits. Five hand auger borings were drilled at the transformer pad and metal storage shed to obtain soil samples. Borings to a depth of 2 ft bgs penetrated fill material composed of dark grayish-brown silty sand and reddish black sandy clay. Soil boring locations are shown in Figure 8.6-1, and field logs of borings are presented in Appendix F.7.

8.6.4 Analytical Results

Three hand auger borings were drilled next to the transformer pad in the Building 1151 area to a depth of 0.6 to 0.8 ft bgs and sampled for PCBs. PCB detections in these samples are presented in Table 8.6-1. The only PCB isomer detected, PCB 1260, was found in all three samples at concentrations ranging from greater than 2 to 11 $\mu\text{g/g}$.

Two hand auger borings were drilled on either side of a small metal paint storage shed. Soil samples collected from the borings were analyzed for VOCs and inorganics. As shown on Table 8.6-2, no VOCs were detected in any of the four samples. All four samples contained

inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussion. All other inorganics detected in soil were compared to ambient concentrations in samples of fill material collected across the PSF, as described in Section 3.7. Cyanide was the only inorganics detected above ambient levels. Cyanide was detected in 3 of 4 samples, at concentrations ranging from 0.282 to 0.559 $\mu\text{g/g}$. The ambient fill concentration for cyanide is any detection above the lowest RL (0.25 $\mu\text{g/g}$).

8.6.5 Results Evaluation

Soil samples were collected in a stained area near Building 1151 to characterize soils near a concrete transformer pad. PCB 1260 was detected in all three subsurface samples (depths up to 0.8 ft bgs), with concentrations ranging from 2 to 11 $\mu\text{g/g}$. Subsequent sampling conducted by Montgomery Watson in 1996 has further assessed the vertical and lateral extent of contamination. Concentrations greater than 1 $\mu\text{g/g}$ in the surface soil extend from between Buildings 1152 and 1151 north to Highway 101 and south to near the southern edges of Buildings 1151 and 1152 (U.S. Army, 1996). The extent of PCB concentrations above 1 $\mu\text{g/g}$ in soil collected from 1 ft bgs is limited to a small area surrounding the transformer pad. The vertical extent is defined by the absence of detections above 1 $\mu\text{g/g}$ in samples collected from a depth of 2 ft.

PCBs adsorb readily to soils and are difficult to mobilize. They are generally insoluble, and it is unlikely that leaching to deeper soil and groundwater has occurred. This is supported by subsequent sampling conducted in 1996 by Montgomery Watson. However, a potential migration pathway that is likely prevalent at this site is transport of particulates in surface water runoff. Further investigation of the extent and removal of PCBs is addressed under the EE/CA document, which has been approved by the DTSC.

Soil samples collected near a small metal paint storage shed did not contain VOCs. With the exception of cyanide, inorganics detected in the samples were below ambient concentrations for fill material in all four samples. For all PSF lithologic groups, any cyanide detection is initially considered to be above ambient. However, for the Building 1151 site, the cyanide detections do not appear to be related to a site source and are generally similar, occurring slightly above the RL of 0.25 µg/g. Therefore, cyanide is considered to be present at naturally occurring concentrations and is not a COPC for this site.

8.6.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1151 area, including the risk assessment results, as presented in detail in Section 15.

8.6.6.1 Conclusions

The primary source(s) of contamination at the site was transformers containing PCBs. No contamination was detected associated with the metal paint storage shed. Past transformer operations resulted in leaks and/or spills of PCBs to concrete pads, fence posts, and soils. The transformers containing PCBs were removed following a sampling program in 1987. Assuming that quantities of PCBs leaked or spilled were small, there is little potential for PCB migration downward through the soil column. This is supported by subsequent sampling conducted in 1996 by Montgomery Watson. Further investigation and removal of PCB-contaminated soil is addressed under an EE/CA document which has been accepted by DTSC.

8.6.6.2 Risk Assessment Summary

As presented in Section 3.7, the COPCs in soil (only PCB 1260 at this site) were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

In the human health risk assessment, the concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs and MCLs. If these values are exceeded and the frequency of detection is greater than 5%, the analyte is

considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1151 area are summarized in the following sections.

8.6.6.2.1 Human Health

The GMPA identified institutional (industrial) use around Building 1151. Under the industrial scenario, exposures to surface (0 to less than 0.5 ft bgs) and subsurface (0.5 to less than 15 ft bgs) soil are possible. At this site, the soil samples collected are within the subsurface soil depth interval. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for subsurface soil was also performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected

carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 1151 area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

8.6.6.2.1.1 Quantification of Cancer Risks

PCB 1260 was the only COC determined for soil samples to 2 feet at the Building 1151 site. Incidental ingestion of and dermal contact with PCB 1260 to the recreational visitor resulted in a total cancer risk of $3E-05$, indicating an excess risk of cancer from exposure to PCB 1260 in surface soil. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

8.6.6.2.1.2 Quantification of Noncarcinogenic Effects

COCs in the PSF water supply (lead, manganese, and nitrate) were assessed for ingestion and dermal exposure. No hazard indices are greater than $1E+00$, indicating that it is unlikely that exposure to the COCs in the media at these sites will result in noncarcinogenic adverse health. Residential PRG ratio screening assessment resulted in a total hazard index less than $1E+00$ at Buildings 1151/1152.

8.6.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 1151 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors

selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Aroclor 1260 was identified as the only COPC for soil at Building 1151. The results of the risk assessment indicated the following:

- The HIs for American robin, mourning dove, and western harvest mouse exceed 1 based on comparison of exposure to the TBV_{Low} values.
- Only the HIs for American robin exceed 1 based on comparison of exposure to the TBV_{High} values. The largest HQ was based on the dietary exposure pathway.
- The soil ingestion exposure route is of potential concern only for the American robin and mourning dove based on the conservative TBV_{Low}, whereas dietary exposure is of potential concern only for the American robin and western harvest mouse.
- There were no HQs for the remaining pathways and receptors evaluated that exceeded 1.

Due to development of this area by the YMCA, habitat for potential ecological receptors will be lacking, and therefore the number and types of potential receptors will be minimal. However, PCBs in soil are being addressed as part of the PCB EE/CA. This site is not recommended for further evaluation from the perspective of ecological risk.

9. FILL SITES AND LANDFILLS

This section describes the RI activities at Fill Site 1 and Landfill 2, Transfer Station, Landfill 4 and Fill Site 5, Fill Site 6, Graded Area 9, and Landfill E.

Landfilling has occurred at the PSF throughout the installation's history. There are no current filling operations on the PSF. The collection and disposal of solid wastes generated at the PSF is conducted by licensed contractors who transport wastes to off-site sanitary landfills. The Transfer Station most recently served as the solid waste collection/transfer area for the entire facility, as described in the Enhanced PA (ANL, 1989).

Filling activities at the PSF fall into two broad categories: fill with building debris, and fill composed of various solid wastes (ANL, 1989). According to PSF personnel, the fill with building debris was disposed of without documentation (ANL, 1989). Solid waste disposal activities at the PSF are also largely undocumented, and these materials are of unknown composition. Specific areas where filling operations have occurred were identified in aerial photographs, by surficial mapping, and as noted in the Enhanced PA (ANL, 1989).

Most of the disposal sites functioned as general disposal sites for the entire installation, rather than dedicated disposal sites for wastes from a specific activity (ANL, 1989). For the purpose of the RI, sites described as fill sites or graded areas were found to contain artificial fill consisting of mixed lithologies of native material, or debris fill typical of building demolition (e.g., brick, tile, wood, glass). Asbestos, which is often associated with building debris, was not identified during site investigations as a source of concern. Sites described as landfills contain materials which would be expected from disposal of household trash, often intermixed with debris fill or artificial fill.

The Enhanced PA designated sites as landfills and disturbed areas primarily on the basis of examination of aerial photographs and personnel interviews. No subsurface exploration was done to determine the contents of these sites. Examination of field logs from the initial and supplemental phases of the RI indicated that the names assigned to sites during the Enhanced PA did not always accurately reflect the contents of the sites. For this reason, along with known historical uses of some sites, several of the sites were renamed for the RI. Table 9.0-1

summarizes the old and new names for fill sites and landfills, and presents estimates of size and volumes of debris and landfill materials contained at each site.

Since documentation of the contents of fill areas is not available, this investigation was undertaken to evaluate conditions at Fill Sites 1, 5, and 6, Graded Area 9, Landfills 2, 4, and E, and the Transfer Station (Figure 1.2-1). Fill Site 7 is discussed in Section 5.0 (Crissy Field Study Area). Landfills 8 and 10 were studied as part of the PHSH Remedial Investigation (RLSA, 1992d). Sites discussed in this section are distributed throughout the upland area of the PSF. Because of the dispersed locations, diversity in soils, geology, and hydrogeology exists among sites.

9.1 FILL SITE 1 AND LANDFILL 2

Fill Site 1 and Landfill 2 are located near the southeastern corner of the PSF (Figure 1.2-1). Fill Site 1 was used for disposal of building debris, and landscape waste, and Landfill 2 was used for disposal of debris and landfill materials prior to use of the sites being discontinued.

9.1.1 Area Description

The following sections describe the location and physical features, and history and land use of Fill Site 1 and Landfill 2.

9.1.1.1 Location and Physical Features

Fill Site 1 is situated at the south end of El Polin Loop (Figure 9.1-1). The Julius Kahn Public Playground lies to the south and an athletic field lies to the east. A dirt road extends along the eastern part of the site. The fill site surface is essentially flat, but the ground surface slopes steeply downward north of the site, leveling out at El Polin Loop. Surface-water runoff from the fill site drains to the northwest. Land surface elevations range from approximately 100 to 150 ft-PLL. Sparse grass and annual plants cover the surface of the site.

Landfill 2, approximately 350 ft west of Fill Site 1, lies upslope and southwest of El Polin Loop (Figure 9.1-1). El Polin Spring is located about 300 ft downslope to the northeast of Landfill 2. The only access to Landfill 2 is via Quarry Road, a dirt road frequently used as a

walking trail by local residents. Most of the area immediately surrounding Landfill 2 is hilly and forested. Ground surface in the area of the landfill slopes upward to the west-southwest; elevations are between 160 and 200 ft-PLL. Surface-water runoff from the site drains to the east-northeast. Eucalyptus trees and brush constitute the majority of the vegetation; grass covers the remainder of the landfill area.

9.1.1.2 History and Land Use

Fill Site 1 was used for disposal of debris fill and landscape materials. Landfill 2 was used for disposal of building debris and landfill wastes. The exact dates when filling activities were initiated and terminated at these sites is unknown. However, aerial photographs show that activity began at Fill Site 1 between 1948 and 1955 and lasted at least until 1973 (Ringden and Sitton, 1990). Landfill 2 was active periodically as seen in aerial photos dating from 1946 through at least 1973 (Ringden and Sitton, 1990). Disposal may have occurred at both sites as late as 1981, when landfilling ceased facility-wide. The Enhanced PA (ANL, 1989) states Landfill 2 received clean fill in 1987.

Fill Site 1 and Landfill 2 are not in use, but are frequently traversed by pedestrians. There are no buildings in either area, and there are no known storm drains or sewers in the vicinity of these sites.

9.1.2 Sample Location Rationale

This section describes the sample location rationale for samples collected at Fill Site 1 and Landfill 2. In the context of the conceptual model (Section 3.1), fill materials were investigated as potential sources of contaminants which could potentially migrate downward to soils and groundwater.

The first step in the investigation was to determine the areal and vertical extent and composition of fill materials. This was accomplished by describing the physical characteristics of samples collected from soil borings, well borings, and test pits. In addition, aerial photographs were closely examined to aid in the delineation of the lateral extent of fill materials.

As noted in the conceptual model (Section 3.1) several primary release mechanisms may be associated with fill sites or landfill areas. A variety of media were sampled to evaluate the potential for contaminant transport via these mechanisms. Contaminated soil particles may be transported in surface-water runoff. To evaluate the potential for contaminant transport by this mechanism, surface soil samples were collected for chemical analysis. Target analytes in fill materials may infiltrate into the soil column beneath the fill areas and percolate down to the water table. Samples of fill materials, and of native materials beneath the fill, were collected for chemical analysis to evaluate the extent to which chemicals may be infiltrating into underlying soils. Groundwater samples were collected from wells upgradient, within, and downgradient of fill materials (where groundwater was present) to evaluate the potential for groundwater transport of target analytes.

Results of the Initial RI field program at Fill Site 1 indicated a need for subsequent sampling within the context of the conceptual model. Detected concentrations of metals in Fill Site 1 fill material exceeded ambient values, and an additional soil boring was drilled during the Supplemental RI to confirm the extent of the elevated metals. Groundwater elevations measured during the initial round of sampling for the RI indicated that the groundwater flow direction does not follow surface topography. Thus, some of the wells installed during the initial round of sampling may not be monitoring downgradient water quality. To better define groundwater flow direction and quality, two additional wells were installed: one downgradient during the Supplemental RI, and one upgradient during the Follow-on RI.

The Initial RI at Landfill 2 also demonstrated a need for further sampling. Samples taken from test pits in Landfill 2 during the Initial RI contained SVOCs and inorganic analytes above ambient levels. Two soil borings were drilled in Landfill 2 during the Supplemental RI to confirm these detections, and four follow-on borings were drilled to define vertical and lateral extent. Groundwater was not encountered during the attempted installation of two upgradient monitoring wells, but one well was successfully completed adjacent to the landfill during the Follow-on RI. A well was never installed immediately downgradient of the landfill because of restricted access to protect a sensitive plant habitat.

9.1.3 Geologic Setting

Geologic interpretations at Fill Site 1 and Landfill 2 are based on field mapping, aerial photographs, published reports (Kashiwagi and Hokholt, 1985, and Schlocker, 1974), and lithologic descriptions from test pits, soil borings, and surface soil samples. Resistivity and EM geophysical studies were completed at the sites, but were of little value due to the lack of contrast in electrical conductivity between fill and native materials. All sample locations are shown on Figure 9.1-1, all logs and well construction data are presented in Appendices G.1 and G.2, and all geophysical data are presented in Appendix N.

Fill Site 1 surface soils are classified as Orthents associated with cut-and-fill or urban land (Kashiwagi and Hokholt, 1985). Two surface soil samples, one discrete and one composite, were collected from within the fill site boundary. Subsurface exploration in Fill Site 1 included trenching four test pits, drilling two soil borings, installing seven monitoring wells, and completing three resistivity survey lines. Test pits encountered surficial soils and fill materials. Boreholes were drilled into fill, a sand, silt, and clay unit (probably the Colma Formation); and weathered serpentinite of the Franciscan Formation (Schlocker, 1974).

During all drilling and subsurface excavation, a PID was used to check for the presence of volatile gases. The highest PID reading recorded at Landfill 1, 285 ppm, was recorded during the drilling of Well LF1GW03. Although this was the highest reading recorded, it occurred in headspace samples collected from native soil below the base of the landfill at a depth of approximately 50 ft bgs and did not affect drilling activities.

Cross sections A-A' and B-B' (Figures 9.1-2 and 9.1-3) show the interpreted stratigraphy in Fill Site 1. Cross section locations are shown on Figure 9.1-1. The uppermost unit encountered at the site was fill material consisting of sand and gravel of various lithologies, tile, brick, wood, concrete, pipe, burlap, plastic, glassware, roofing material, and asphalt. The maximum encountered depth to the base of the debris fill was 34 ft bgs (Well LF1GW03). In much of the area, the fill is underlain by silts and sands of the Colma Formation. Bedrock was encountered in the boring for Well LF1GW07 at a depth of 67 ft bgs.

Surface soils at Landfill 2 have been classified as Typic Argiustolls associated with urban land use (Kashiwagi and Hokholt, 1985), and five surface soil samples were collected from

within the landfill boundary. Subsurface exploration in the Landfill 2 area included trenching three test pits, drilling 11 soil borings, three of which were completed as monitoring wells, and completing two resistivity lines. Combustible and volatile gases were monitored during drilling and excavation activities using a CGI and PID respectively. Explosive conditions were not encountered. The highest PID reading was 0.04 ppm.

Cross sections C-C' and D-D' (Figures 9.1-4 and 9.1-5) show the interpreted stratigraphy in the Landfill 2 Area. Fill material encountered was a mixture of artificial fill, debris fill, and landfill material. These materials were described in field logs as glassware, charred wood ash, possible hospital debris, bottles, and general building debris such as concrete, brick, slate, piping, and metal roofing materials. The maximum depth of fill material is approximately 20 ft bgs (LF2SB02). A sandy silt/clay unit, probably the Colma Formation, was found beneath fill materials in Borings LF2SB01 and LF2SB02, adjacent to the fill at Well LF2GW04 and downgradient of the landfill in Well LF2GW02. This unit probably underlies the entire Landfill 2 Area, extending beneath El Polin Loop. Serpentinite bedrock lies at a depth of approximately 12 ft bgs at the upslope end of the landfill and was encountered at 28.5 ft bgs farther downslope (LF2GW04). In the vicinity of El Polin Loop, to the northeast, bedrock was encountered at 16.5 and 20 ft bgs (LF2GW02 and LF2GW01).

Isopachs of fill material in Fill Site 1 and Landfill 2 are shown in Figure 9.1-6. Isopachs were drawn using cross section interpretations of the areas and thickness data from all lithology logs. Based on the isopachs in Figure 9.1-6, the total volume of debris fill in Fill Site 1 is approximately 44,096 yd³; it is estimated that Landfill 2 contains 5,735 yd³ of debris fill and 7,850 yd³ of landfill material.

9.1.4 Hydrogeology

Ten monitoring wells have been completed in the Fill Site 1 and Landfill 2 vicinity, and water levels indicate groundwater flows to the northeast. A complete round of water level measurements was made in both September 1992 and March 1995 (Figures 9.1-7 and 9.1-8). The 1995 data show increases in groundwater elevations ranging from 3.9 to 13.8 ft over

the September 1992 data. In each case, however, the gradient in the vicinity of El Polin Loop was approximately 0.25.

Groundwater beneath Landfill 1 is unconfined within silty sand of the Colma Formation. Well LF1GW04 was installed as an upgradient well at Fill Site 1 during the Initial RI field program, when the groundwater flow was assumed to mirror surface topography. Subsequent evaluation of the area hydrogeology indicated that groundwater flow is controlled by the bedrock surface, and Well LF1GW07 was installed to evaluate true upgradient conditions. During March, 1995, depth to groundwater was approximately 57 ft bgs upgradient of the fill site, 50 ft bgs, or approximately 15 ft below the base of fill, within the fill site boundary (LF1GW03), and 4 ft bgs downgradient (LF1GW01). Depth to water increased to approximately 33 ft bgs farther downgradient (LF1GW02), reflecting the increased depth to bedrock. These conditions are similar to those found in September 1992, but with a slight increase in water level.

Two attempts were made to install an upgradient well at Landfill 2, Well LF2GW03 in October, 1990 and Well LF2GW05 in December, 1994, but both borings reached bedrock without encountering groundwater. Because of sensitive plant habitat, it was not possible to install a well immediately downgradient of the landfill. However, Well LF2GW04 was installed adjacent to the downgradient portion of the landfill. First groundwater at LF2GW04 was encountered at 26 ft bgs, approximately 19 ft below the adjacent fill material. This groundwater was encountered within a 3 ft thick water bearing zone of sand and gravel, at the bottom of the Colma Formation, just above bedrock. The water bearing zone at this location is confined by overlying clayey deposits of the Colma Formation (Figure 9.1-5). Groundwater downgradient of Landfill 2 intersects the ground surface at El Polin Spring.

Estimated well yields for the Fill Site 1 and Landfill 2 areas are included in Section 2.3.5.3. Results of individual well yield calculations are shown on Table 2.3-2. The results indicate an average estimated yield of 128 gpd for Landfill 2, and 211 gpd for Fill Site 1 (Table 2.3-3). Although these results are approximate relative to more comprehensive testing techniques, the results indicate that the yield at Landfill 2 does not meet the 200 gpd requirement for a drinking water supply as specified in California Resolution 89-39.

9.1.5 Analytical Results

This section presents the analytical results of sampling performed at Fill Site 1 and Landfill 2 during the RI. All sampling locations are shown on Figure 9.1-1. Inorganic results are compared to appropriate ambient concentrations as described in Section 3.7. Most of the soil and sediment samples contained elements commonly found in the environment, including calcium, potassium, magnesium, and sodium. These compounds are not usually evaluated as part of risk assessments and are not discussed in this section because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Results affected by blank contamination will not be discussed.

9.1.5.1 Fill Site 1 Soil Sampling Results

Two surface soil samples were collected at Fill Site 1 during the Initial RI; one sample was analyzed only for VOCs (LF1SS02), and the second, which was collected as a composite sample, was analyzed for inorganics and SVOCs (LF1SS01). All detections above the CRLs are shown in Table 9.1-1. Numerous inorganics were detected, however, none were at concentrations above ambient levels. No VOCs were detected. Only one SVOC, bis(2-ethylhexyl)phthalate, was detected, at a concentration of $>6.2 \mu\text{g/g}$.

Three test pits were excavated at Fill Site 1 during the Initial RI. One sample was collected from the fill material at each test pit and analyzed for inorganics, VOCs, and SVOCs. All detections above the CRLs are shown on Table 9.1-2. Numerous inorganics were detected in each test pit, however, inorganics were not detected above ambient fill values in either Test Pits LF1TP02 or LF1TP03. Inorganics detected above ambient fill concentrations in Test Pit LF1TP01 include aluminum, barium, chromium, iron and nickel. The sample from this test pit contained serpentinite gravel. Compared to ambient serpentinite values, only aluminum and barium exceed ambient values. No VOCs were detected in any of the three samples. Two of the three samples contained detectable SVOCs: phenanthrene ($0.18 \mu\text{g/g}$) in Test Pit LF1TP01 and fluoranthene ($0.050 \mu\text{g/g}$) in Test Pit LF1TP02.

During the Supplemental RI, one boring (LF1SB01) was drilled at Fill Site 1. Two samples were collected, one in fill material (3.0 ft bgs) and one in the Colma Formation below fill material (22.5 ft bgs). Both samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. All detections above the CRLs or RLs are shown on Table 9.1-3. Numerous inorganics were detected in both samples, with arsenic and selenium detected at concentrations slightly above ambient values in the fill sample collected at 3.0 ft bgs. Nickel was the only inorganic detected above ambient Colma levels in the sample from native soil below fill collected at 22.5 ft bgs. The concentration of nickel in this sample was 106 µg/g. The corresponding ambient concentration for nickel is 105 µg/g. No VOCs, SVOCs, OCPs, PCBs, or chlorinated herbicides were detected above the CRLs or MDLs. TPH-D was detected in both samples, at concentrations of 9.00 and 1.00 µg/g in fill and native materials, respectively.

The sample of native Colma soil collected at 22.5 ft bgs from Boring LF1SB01 was also analyzed by the WET method for STLC, chromium, nickel, and lead. Chromium was detected at a concentration of 0.08 mg/L, nickel was detected at 0.7 mg/L, and lead was not detected above the RL of 1 mg/L. Sample results are provided in Appendix O.

9.1.5.2 Landfill 2 Soil Sampling Results

Soil samples were collected at Landfill 2 during all three RI field programs. Initial RI samples were collected from test pits and analyzed for inorganics, VOCs, and SVOCs. Supplemental work included analyzing samples from soil borings for an extended analytical suite. During the Follow-on RI, subsurface samples were collected to help define the extent of specific compounds, and surface soil samples were collected to fill a perceived data gap.

Three test pits were excavated at Landfill 2 during the Initial RI. One sample was collected from fill material in each test pit and analyzed for inorganics, VOCs, and SVOCs. All detections above the CRLs are shown on Table 9.1-2. Numerous inorganics were detected in each test pit sample. Inorganics exceeding ambient fill concentrations in Test Pits LF2TP01 and LF2TP02 include barium, copper, lead, mercury, silver, and zinc. Antimony was also detected above ambient concentrations in Test Pit LF2TP02. The detection of zinc in the sample from Test Pit LF2TP03 was the only ambient exceedence in this sample. No VOCs

were detected in any of the three samples. There were seven detections of five SVOCs, the greatest of which was phenanthrene at 0.38 $\mu\text{g/g}$ detected in the sample from LF2TP03.

During the Supplemental RI, two borings (LF2SB01 and LF2SB02) were drilled at Landfill 2. Two samples were collected from each boring. The 3.0 ft bgs samples from each boring were collected from within the fill material. The deeper samples from each boring were collected from the Colma Formation below the fill material. All samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-G, and TPH-D. All detections above the CRLs or MDLs are shown on Table 9.1-3. Numerous inorganics were detected in each sample, however, none were detected above ambient levels in the samples collected from fill material. Inorganics above Colma ambient concentrations in the samples from below fill material include barium, chromium, manganese, and selenium in the 6.5 ft bgs sample from Boring LF2SB01, and chromium, cobalt, nickel, and selenium in the 23.0 ft bgs sample from Boring LF2SB02. No detections of VOCs above the CRLs or MDLs were reported. One SVOC, benzo(k)fluoranthene, was detected once, at a concentration of 0.039 $\mu\text{g/g}$. No OCPs, PCBs, or chlorinated herbicides were detected above the CRLs or MDLs. TPH-D was detected in all four samples, at concentrations ranging from 1.00 to 100 $\mu\text{g/g}$.

The deep sample of native materials below fill from Boring LF2SB02 was also analyzed by the WET method for STLC, chromium, nickel, and lead. Chromium was detected in both samples, at a concentration of 0.23 mg/L, nickel was detected at 4.4 mg/L, and lead was not detected above the MDL of 1 mg/L. Sample results are provided in Appendix O.

Follow-on RI samples were collected from five soil borings to define the extent of the lead and antimony detected in test pits during the Initial RI field program. Boring LF2SB03 was drilled in the same location as Test Pit LF2TP02 and sampled at a depth of 8.0 ft bgs. Borings LF2SB04 through LF2SB07 were drilled surrounding Test Pits LF2TP01 and LF2TP02. Samples were collected from approximately 0, 5, and 10 ft bgs in Borings LF2SB04 through LF2SB06 and analyzed for lead and antimony. Samples from Boring LF2SB05 were also analyzed for TOC. Samples were collected for lead analysis only from 18.0 ft bgs in Boring LF2SB06, and 0.0, 5.0, and 19.0 ft bgs in Boring LF2SB07. Samples collected from 18.0 ft bgs in Boring LF2SB06 and 19.0 ft bgs in Boring LF2SB07 were from the Colma Formation below the base of the fill material. All detections are shown on

Table 9.1-4. Lead was detected in all but two of the samples, and exceeded ambient values in five samples from three borings: LF2SB03 (331 µg/g at 8.0 ft bgs), LF2SB04 (451 µg/g at 0.0 ft bgs), LF2SB06 (904 µg/g at 4.7 ft bgs and 2,090 µg/g at 9.7 ft bgs), and LF2SB07 (253 µg/g at 5.0 ft bgs). None of the samples contained antimony at concentrations above ambient values. TOC concentrations ranged from 1,070 to 5,480 µg/g.

Five surface soil samples (LF2SS01 through LF2SS05) were also collected from fill material during the Follow-on RI. Two were collected from the upper, or southwest, portion of the landfill, and the other three were collected in the vicinity of Test Pits LF2TP01 and LF2TP02. All samples were analyzed for inorganics, VOCs, SVOCs, OCPs, chlorinated herbicides, and TPH. All detections are shown on Table 9.1-5. Numerous inorganics were detected in all surface soil samples, however, fill ambient concentrations were exceeded only in Samples LF2SS01, LF2SS02, and LF2SS03. Ambient levels were not exceeded in Samples LF2SS04 and LF2SS05. Inorganics detected above ambient fill values include barium in Samples LF2SS01 and LF2SS02. Barium, copper, lead, vanadium and zinc were detected at concentrations above ambient fill values in Sample LF2SS03. VOCs were not detected in any of the samples. The SVOCs chrysene, fluoranthene, phenanthrene, and pyrene were detected in Sample LF2SS03. Fluoranthene and pyrene were also detected in Sample LF2SS04. The OCP ppDDT was detected in Samples LF2SS01, LF2SS02, and LF2SS03. The chlorinated herbicide MCPP was detected in Samples LF2SS01 and LF2SS02 at concentrations of 3.63 and 4.85 µg/g, respectively. TPH was not detected in any of the samples.

9.1.5.3 Fill Site 1 Groundwater Sampling Results

Groundwater samples were collected from five wells in the vicinity of Fill Site 1 during the Initial RI. All samples were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, and pesticides. All detections above the CRLs or RLs are summarized in Table 9.1-6.

All wells sampled during the Initial RI were sampled again during the Supplemental RI program. One new well, LFIGW06, downgradient of Fill Site 1, was also sampled. Groundwater samples collected during the Supplemental RI field program were analyzed for

inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. All detections are presented in Table 9.1-7.

During the Follow-on RI field program, a seventh well, LF1GW07, was installed upgradient of Fill Site 1. Samples from all seven wells were analyzed for inorganics, chromium VI, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. All detections are presented in Table 9.1-8.

Inorganic analytes and miscellaneous parameters were detected above CRLs or RLs in all samples from the three field programs. Filtered and unfiltered samples for metals were collected from selected wells during the Supplemental RI sampling program and from all wells during Follow-on RI. With few exceptions, metals concentrations in filtered samples were lower than those in unfiltered samples (Tables 9.1-8 and 9.1-9). The exceptions noted during the Supplemental RI were arsenic and potassium in Well LF1GW03 and lead in Well LF1GW06. During the Follow-on RI sampling of Well LF1GW07, antimony and chromium VI were the exceptions.

The only VOC detected in Initial RI samples was acetone, which was detected once. No VOCs were detected in the Supplemental RI sampling. Follow-on RI groundwater sampling detected 1,2-dichloroethane in samples from Wells LF1GW02, LF1GW04, LF1GW05, and LF1GW06.

SVOCs were not detected in samples from the Initial RI field work. In Supplemental RI samples only one detection of bis(2-ethylhexyl)phthalate was reported. No pesticides were reported in either Initial or Supplemental RI samples. No PCBs or chlorinated herbicides were detected in Supplemental RI samples; analyses for these compounds were not performed on Initial RI samples. TPH-D was not detected in any of the Supplemental RI samples. TPH was not analyzed in initial RI samples. No SVOCs, OCPs, PCBs, chlorinated herbicides, TPH or TPH-G were detected in the Follow-on RI groundwater samples.

9.1.5.4 Landfill 2 Surface-Water/Groundwater Sampling Results

Surface water from El Polin Spring, downgradient of Landfill 2, was sampled for inorganics, VOCs, and SVOCs during the Initial RI. All detections are presented in Table 9.1-10. The

spring was sampled again as part of the Supplemental and Follow-on RI programs, during which samples were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. The Follow-on RI sample was also analyzed for chromium VI. Supplemental RI detections are presented with the groundwater results in Table 9.1-7. Follow-on RI detections are shown on Table 9.1-11. Inorganic and miscellaneous parameters were detected in all samples. VOCs and SVOCs were not detected in any of the samples. OCPs, PCBs, chlorinated herbicides, and TPH-D were not detected in either the Supplemental or Follow-on RI samples; these analyses were not run on the Initial RI sample. Unknown VOCs totaling 593 µg/L and SVOCs totaling 20 µg/L were also reported from the Supplemental RI sampling.

Groundwater samples were collected from two wells downgradient of Landfill 2 (LF2GW02 and LF2GW03) during the Initial RI. Both samples were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, and pesticides. All detections are shown in Table 9.1-6. Both wells were sampled again during the Supplemental RI field program. Samples from the Supplemental RI field program were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. All detections are presented in Table 9.1-7. During the Follow-on RI both wells were resampled, and a new well (LF2GW04) was installed and sampled. The new well was installed adjacent to the greatest volume of landfill material. The analyte suite for the Follow-on RI samples was the same as that for the Supplemental RI, with the addition of chromium VI. All of these detections are presented in Table 9.1-12.

Inorganic analytes and miscellaneous parameters were detected above CRLs or RLs in all groundwater samples from the three programs. Filtered and unfiltered samples for metals were collected from Well LF2GW01 during the Supplemental RI sampling program and from all wells during the Follow-on RI. With two exceptions, cadmium and selenium, metals concentrations in the Supplemental RI filtered sample were lower than those in the unfiltered sample (Table 9.1-9). During the Follow-on RI sampling, all filtered concentrations were less than unfiltered concentrations (Table 9.1-12).

There were no VOCs, SVOCs or pesticides detected in the Initial or Supplemental RI samples. No PCBs or chlorinated herbicides were detected in the Supplemental RI samples;

analyses for these compounds were not performed on Initial RI samples. TPH-D was detected in one of the two Supplemental RI samples at a concentration of 70.0 µg/L. TPH was not detected in Initial RI samples. VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH were not detected in Follow-on samples.

9.1.6 Results Evaluation

The following sections evaluate the results of sampling performed during the RI at Fill Site 1 and Landfill 2. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent, and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For sites containing fill material identification of sources is difficult due to the random distribution of source material within the fill.

For groundwater and surface water all detected analytes are considered COPCs. In the following discussions, detections of compounds are compared with California Primary and Secondary MCLs (Tables 3.8-2 and 3.8-5) to provide the reader with a frame of reference. If an analyte is present in surface or groundwater at concentrations above MCLs, the source, nature and extent, and fate and transport of the analyte are evaluated.

Due to the random distribution of source material in the fill, a random chemical distribution would also be expected. If source material in the fill is contributing chemicals, isolated hot spots within the fill would be likely. Depending on the nature of the chemicals present, these hot spots within the fill material could leach to the underlying native soil and groundwater.

For the purpose of defining the extent of COPCs detected in fill material, the following sections will focus on the impact on the subsurface soil and groundwater rather than defining the extent of a particular chemical within an area of the fill material.

9.1.6.1 Fill Site 1 Results Evaluation

Numerous inorganics were detected in all soil samples collected at the site. Inorganics detected in soil above ambient values include aluminum, arsenic, barium, chromium, iron, nickel, and selenium. Figures 9.1-9 through 9.1-22 show the concentrations of several inorganic analytes in soil. Although these analytes were detected above ambient values, inorganics in soil at Fill Site 1 are not considered COPCs because the detections only slightly exceed the corresponding ambient values and the number of ambient exceedences for these analytes is limited. With the exception of nickel, which was detected in two samples at concentrations slightly above ambient fill levels, all ambient exceedences were limited to one sample each. In addition, the analytes chromium and nickel have naturally high concentrations in serpentinite. Since the logs for these samples (Appendix G) indicate the presence of serpentinite gravel throughout the fill material, the elevated concentrations of these analytes is likely due to serpentinite. Table 3.7-1 presents background/ambient soil concentrations for regional sites. Comparing concentrations for inorganics which exceed ambient conditions with the values presented for other regional soils indicates that the concentrations of these analytes are within the range of other regional soils.

Numerous inorganics were detected in groundwater at the site, however, most were below California MCLs. Figures 9.1-24 through 9.1-28 show the concentrations of several inorganics in groundwater. Manganese and nitrate were detected above MCLs in groundwater samples from the Initial RI. Manganese was above the secondary MCL of 50 $\mu\text{g/L}$ in Well LF1GW01, and nitrate was above the USEPA Primary MCL of 10,000 $\mu\text{g/L}$ in this well in addition to two other wells. Concentrations of these analytes are shown on Table 9.1-6. During the Supplemental RI, inorganics or miscellaneous target analytes reported at values exceeding MCLs were manganese in one well, nitrate in one well, and TDS in two wells (Table 9.1-7). Although nitrate and manganese concentrations exceed California MCLs, some of the highest concentrations of these analytes were detected in the upgradient wells (Wells LF1GW04 and LF1GW07), suggesting that nitrate and manganese

are naturally occurring and not related to fill material at Fill Site 1. In addition, as shown on Figure 9.1-29, concentrations of manganese in the filtered samples are consistently lower than in the unfiltered samples. This suggests that the high concentrations of manganese in the unfiltered samples is due to the amount of sediment in the sample rather than the actual dissolved concentration.

An additional set of filtered and unfiltered samples was collected from two wells located in the fill material during the Supplemental RI (Table 9.1-9). Of the metals detected, aluminum, cadmium, chromium, iron, manganese, and nickel were detected above MCLs in the unfiltered samples, however, the concentrations of these metals were below MCLs in the filtered samples. This pattern was confirmed by Follow-on RI sampling (Table 9.1-8), where several inorganics were detected above MCLs in the unfiltered, but below MCLs in the filtered sample. The exceptions during the Follow-on RI were antimony and chromium VI which were above MCLs in the filtered samples. Antimony in filtered samples has been attributed to the filters used during sampling. The source of chromium VI is not clear, however, it was not detected in the corresponding unfiltered sample. The miscellaneous parameters chloride, nitrate, and TDS were detected above MCLs during the Follow-on RI sampling. The relatively few inorganics detected above MCLs in filtered groundwater suggests that debris fill material in Fill Site 1 is not impacting groundwater at the site. This should be expected since most inorganics are not highly mobile, and tend to remain sorbed to soil rather than dissolve into groundwater.

Quarterly groundwater sampling performed by Montgomery Watson following the Follow-on RI confirmed the presence of several inorganics and miscellaneous parameters above MCLs in several filtered samples, including cadmium, iron, manganese, and nitrate (Montgomery Watson, 1996g).

VOCs were never detected in soil samples from Fill Site 1, however, one VOC, acetone, was detected in groundwater samples from the Initial RI fieldwork. This detection was not repeated in Supplemental or Follow-on RI samples. The VOC 1,2-dichloroethane was detected in four of the seven wells sampled during the Follow-on RI. Concentrations ranged from 0.85 to 1.32 $\mu\text{g/L}$. Quarterly sampling conducted by Montgomery Watson following the Follow-on RI failed to confirm the presence of this compound in groundwater at the site

(Montgomery Watson, 1996g). The source of the compound during the Follow-on RI is not clear. 1,2-Dichloroethane was also detected during the Follow-on RI at several other study areas where it had previously not been detected. In addition, it has not been detected in any of the other samples collected at Fill Site 1 in either soil or groundwater. 1,2-Dichloroethane is generally detected with associated parent and breakdown products of chlorinated solvents, none of which have ever been detected at the site.

Three detections of SVOCs were reported above the CRLs in soil samples consisting of fill material at Fill Site 1. The greatest value was $>6.2 \mu\text{g/g}$ for bis(2-ethylhexyl)phthalate in a surface soil sample. The other SVOCs detected were PAHs, which tend to sorb strongly to soils, and thus would not be expected to migrate through unsaturated soils. This is reflected in the sample of Colma material below fill, where no SVOCs were reported. Further evidence of the lack of SVOC impacts from the debris fill is provided by the groundwater results. SVOCs were not reported in groundwater samples collected during the Initial RI samples. One detection of bis(2-ethylhexyl)phthalate, at a value of $1.30 \mu\text{g/L}$, was reported from one well in the 1992 Supplemental RI groundwater samples; this is below the California Primary MCL of $4 \mu\text{g/L}$. SVOCs were not detected in groundwater during the Follow-on RI. Bis(2-ethylhexyl)phthalate and phenol were detected in several samples collected by Montgomery Watson during the subsequent quarterly sampling (Montgomery Watson, 1996g).

No OCPs, PCBs, or chlorinated herbicides were detected in samples analyzed for these target groups in fill material, native soils below fill, or groundwater at Fill Site 1.

TPH-D was detected in both soil samples analyzed for this compound. TPH-D in soil at Fill Site 1 is considered a soil COPC. The concentration in a sample from debris fill material was $9.0 \mu\text{g/g}$, and the concentration in native material below fill in the same boring was reported at the CRL of $1.00 \mu\text{g/g}$. The chromatograms for the two samples are quite different, and neither resemble chromatograms for a variety of common petroleum products including diesel fuel and motor oil. This indicates that the source of the detected TPH-D is most likely not the same for the two samples. In addition, the chromatogram for the sample from native materials is similar to that of samples for native materials at other locations, indicating that naturally occurring organics could be the cause of the TPH-D detection in native sands.

TPH-D was not detected above the CRL in any of the groundwater samples from Fill Site 1 monitoring wells collected during the RI, or in samples from the subsequent quarterly sampling conducted by Montgomery Watson (Montgomery Watson, 1996g).

9.1.6.2 Landfill 2 Results Evaluation

Numerous inorganics were detected in soils at Landfill 2. Inorganics detected above ambient values include antimony, barium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc. Of these, antimony, barium, copper, cyanide, lead, mercury, silver, and zinc are considered soil COPCs. Figures 9.1-9 through 9.1-22 show the concentrations of these analytes in soil. Several inorganics have naturally high concentrations in serpentinite including chromium, cobalt, manganese, and nickel. Because serpentinite gravel was identified throughout the fill material at Landfill 2 (see boring logs, Appendix G), these analytes are believed to be associated with serpentinite, and are not considered soil COPCs. Selenium and vanadium were also detected above ambient values, however, these analytes are not considered soil COPCs due to the limited number of detections and the proximity of their concentrations to ambient levels.

Detections of inorganic COPCs in soil at Landfill 2 are randomly distributed throughout the landfill. Because of the random nature of potential source material within the fill, it is difficult to associate a particular source with a given COPC. All of the inorganic soil COPCs were detected at concentrations significantly above ambient levels in at least one sample. In some cases, such as the lead detection of 12,000 $\mu\text{g/g}$ (fill ambient lead level is 221 $\mu\text{g/g}$) in the 5.0 ft bgs sample from Test Pit LF2TP02, the concentrations were an order of magnitude above the corresponding ambient level. Some samples contained numerous inorganic COPCs at concentrations above ambient levels. In other samples ambient concentrations were exceeded for only one COPC. Within the fill material, concentrations of inorganic COPCs vary with depth, however, with the exception of barium, inorganic COPCs were not detected above ambient levels in the underlying native material. Barium was detected slightly above ambient Colma levels in one sample (6.5 ft bgs in Boring LF2SB01). The lack of ambient exceedences in the underlying native soil suggests that potential sources within the fill material are not impacting the underlying native soil. This is as expected since most

inorganics have high affinities for soil and tend to remain sorbed to soil rather than leach to underlying material.

As described in Section 9.1.3, both debris fill and landfill material are present in Landfill 2. Figure 9.1-6 shows that the western half of Landfill 2 is comprised primarily of debris fill, while the eastern half of Landfill 2 is mainly landfill material. Because the materials found in the two different fill materials is likely to be different, the chemicals detected in the two areas are also likely to be different. Analysis of data posted on Figures 9.1-9 through 9.1-22 confirm that the majority of elevated analyte concentrations occur in samples collected from the landfill material in the eastern half of Landfill 2. The inorganic COPCs discussed in the previous paragraph confirm this assessment. Of the soil inorganic COPCs, only lead and zinc were detected above ambient in the debris fill portions of the site. Both analytes were detected in one sample each. All other ambient exceedences of inorganic COPCs occurred in samples collected from the landfill portions of the site.

In the monitoring well samples from the Initial RI, manganese was reported above the secondary MCL in Well LF2GW02. During the Supplemental RI, cadmium in Well LF2GW01 was detected above the USEPA Primary MCL, and manganese and TDS in Well LF2GW02 were reported above California secondary MCLs (recommended secondary MCL for TDS). Cadmium was not reported above the CRL in any earlier groundwater samples or soil samples from Landfill 2, indicating that fill materials in Landfill 2 are not the source of cadmium in groundwater. Also, cadmium was not reported above the MCL in El Polin Spring, located in very close proximity to Well LF2GW01. This well is screened at the bedrock surface, and serpentinite clasts were noted in the boring log for the screened interval. Manganese is mobile in water (USEPA, 1991b) and manganese in water samples may be from the manganese oxide coatings which were frequently observed on fractures in serpentinite at other locations at the PSF.

During the Follow-on RI, numerous inorganics were detected at values above Primary MCLs in unfiltered samples. In most cases, the concentrations of these inorganics were below MCLs in the filtered samples. This suggests that inorganics detected in groundwater are associated with sediment, and are not actually dissolved in groundwater. Chloride, nitrate, and TDS were also detected above MCLs in groundwater during the Follow-on RI.

Manganese and nitrate were detected at concentrations above MCLs in several filtered groundwater samples collected during Montgomery Watson's quarterly sampling program (Montgomery Watson, 1996g). Figures 9.1-24 through 9.1-28 show the concentrations of several inorganics in groundwater.

VOCs, OCPs, and PCBs were not detected in any Landfill 2 soil or groundwater samples collected during the Initial, Supplemental, or Follow-on RI. SVOCs were reported in several samples of both debris fill and landfill material. All SVOCs detected were PAHs, which generally sorb to soil and, in small quantities would not be expected to migrate through unsaturated soils. No SVOCs were reported above the CRLs in native materials, indicating that PAHs are not migrating from fill materials. This is further supported by the absence of SVOCs in all groundwater samples collected during the RI. The SVOC, bis(2-ethylhexyl)phthalate was detected in one sample from Well LF2GW02 during quarterly sampling performed by Montgomery Watson (Montgomery Watson, 1996g). One chlorinated herbicide, ppDDT, was detected in two surface soil samples, but was not detected in any soil samples collected at depth, and was not detected in groundwater. Concentrations of ppDDT are plotted on Figure 9.1-23.

TPH-D was detected in debris and landfill material, as well as, native soil samples collected in Landfill 2 and is considered a soil COPC. Concentrations downward decreased from fill materials to native soils. Chromatogram patterns of the samples in fill material were similar to chromatograms for common petroleum oils. However, the chromatograms for the samples in native soils were dissimilar to those in fill materials, suggesting different TPH-D sources. Also, the chromatograms for samples in native materials were similar to those from samples in native fill below Fill Site 1, suggesting that the TPH-D detections in native soils may be related to naturally occurring hydrocarbons in the C₈-C₃₁ range.

In groundwater, TPH-D was detected only in Well LF2GW01, at a value of 70.0 µg/L, less than twice the MDL. The sample from El Polin Spring, in close proximity to Well LF2GW01, did not contain TPH-D above the MDL in 1992. The chromatogram for Well LF2GW01 was not similar to a variety of common petroleum products. Given that only one well was reported to contain TPH-D, and that the method is non-specific and will detect any

hydrocarbon in the C₈-C₃₁ range, it is possible that this detection is the result of naturally occurring hydrocarbons.

Groundwater released to the surface at El Polin Spring does not indicate any impact from Landfill 2. During the Initial RI, analytes were not detected above Primary or Secondary MCLs, however, barium, exceeded freshwater criteria for protection of aquatic life. Freshwater criteria are shown on Table 3.6-7. During the Supplemental RI, iron and manganese were the only analytes detected at values above secondary MCLs. During this sampling round, barium, iron, lead, and manganese were detected at concentrations exceeding freshwater criteria for protection of aquatic life. These inorganics were not above MCLs in Well LF2GW01, located near the spring. During the Follow-on RI, antimony in the filtered sample was the only analyte detected above MCLs. This inorganic was not detected in the unfiltered sample, and its presence is believed to be due to the filters used during sampling. During the Follow-on RI, freshwater criteria for the protection of aquatic life were exceeded for barium in the filtered sample.

During the Spring of 1996, a seep was observed emanating from the toe of Landfill 2, southwest and uphill of El Polin Loop. Flow out of the seep was estimated to be several gallons per minute and is attributed to the heavy rainfalls during the winter and spring of 1996. The seep was not observed during the RI field programs. Water flowing out of the seep joined with the natural flow from El Polin Spring approximately 250 ft to the northeast. In late March 1996, IT Corporation (IT) was directed to collect surface water samples from the area of the seep (IT, 1996). Four liquid samples were collected from the Landfill 2 area. Two of the samples (LF2SW02 and LF2SW03) were collected from the seep at the base of the landfill. A third sample (LF2SW04) was collected from an exposed steel drum located near the northeast edge of the landfill. The drum was partially buried and was rusted through in several spots. Liquid in the drum was likely surface water rather than the original contents. The fourth sample (LF2SW04) was collected from surface water runoff near the upslope (southwest) edge of the landfill. Samples LF2GW02, LF2GW03, and LF2GW04 were analyzed for pH, conductivity, common anions, pesticides, PCBs, and select metals. The drum sample was analyzed for pesticides, PCBs, and SVOCs including total extractable hydrocarbons in the diesel and motor oil range.

Results of the IT sampling indicated a pH between 7.2 and 7.7. The highest pH was found in the upgradient sample (LF2SW01). Conductivity values ranged from 246 to 2610 $\mu\text{mhos/cm}$. The highest values were found in the samples emanating from the seep, where both samples exceeded the recommended California Secondary MCL of 900 $\mu\text{mhos/cm}$. The common anions bromide, chloride, nitrate, and sulfate were detected at maximums of 1,100, 423,000, 1,500, and 153,000 $\mu\text{g/L}$ respectively. The chloride detection of 423,000 $\mu\text{g/L}$ exceeded the recommended secondary MCL of 250,000 $\mu\text{g/L}$. Concentrations of all four anions were highest in the downgradient seep samples. Pesticides and PCBs were not detected. Barium and zinc were the only metals detected. Maximum concentrations of these two analytes were 160 and 110 $\mu\text{g/L}$ respectively, both of which are below California MCLs. Barium was highest in the seep samples, while zinc was higher in the upgradient sample. SVOCs, TPH-Diesel, and TPH-motor oil were not detected. One unknown hydrocarbon was detected in the drum sample. The chromatogram pattern did not match any of the standard reference chromatograms.

Results of the IT liquid sampling confirm the conclusions drawn from the RI sampling. Groundwater released to the surface downgradient of Landfill 2, both at the seep and at El Polin Spring does not indicate any impact from Landfill 2.

9.1.7 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Fill Site 1 and Landfill 2 areas, including the risk assessment results, as presented in detail in Section 15.

9.1.7.1 Conclusions

The potential source(s) of contamination at Fill Site 1 and Landfill 2 are debris fill and/or landfill materials deposited during use of the sites. To evaluate the impact of fill material on the environment, surface and subsurface soils, surface water, and groundwater samples were analyzed.

Chemicals detected in debris fill samples at Fill Site 1 include several inorganics above ambient concentrations, several SVOCs at concentrations near the detection limit, and one detection of TPH-D at 10 $\mu\text{g/g}$. These analytes were either not detected, or had lower

concentrations in the underlying native material. Several VOCs, and one SVOC were detected in groundwater, however, VOCs were not detected in any soil samples at the site, and the SVOC detected was not the same as those detected in soils. In addition, the VOC 1,2-dichloroethane was detected in only one sampling round, and the associated parent and breakdown products were not detected in any samples at Fill Site 1. 1,2-Dichloroethane was a common anomaly in groundwater samples collected during the Follow-on RI. Quarterly sampling of these following the Follow-on RI failed to confirm the presence of these compounds.

Soil COPCs identified at Fill Site 1 include all detected organics.

At Landfill 2, analytes detected in debris fill or landfill material include inorganics, several SVOCs, one OCP, and TPH-D. These analytes were not detected or were at lower concentrations in the underlying native material or groundwater except for TPH-D. TPH-D was detected in both native material and groundwater, however, its presence is not believed to be associated with fill due to different chromatogram patterns.

Soil COPCs identified at Landfill 2 include all detected organics and the inorganics antimony, barium, chromium, copper, cyanide, lead, mercury, silver, and zinc.

In surface water from El Polin Spring several inorganics were detected at concentrations exceeding MCLs. Several of these inorganics were also above MCLs in groundwater samples from nearby upgradient wells near the base of Landfill 2. All detected analytes in groundwater and surface water are assessed as part of the risk assessment.

9.1.7.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. Analytes in groundwater and surface water are also assessed in the human health risk assessment. The detected surface water analytes also were assessed in the ecological risk assessment.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead

screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Fill Site 1 and Landfill 2 Areas are summarized in the following sections.

9.1.7.2.1 Human Health

Fill Site 1 and Landfill 2 were assessed as distinct disturbed areas in the human health risk assessment due to the geographic separation of the sites. Surface water from El Polin Spring was also evaluated independently from the other two sites. The GMPA identified open space (recreational) use for both the Fill Site 1 and Landfill 2 Areas, and only exposure to surface soil from 0.0 to less than 0.5 ft bgs is assumed. Exposure to surface water from El Polin Spring was also evaluated under an open space(recreational) scenario.

A residential PRG ratio screening assessment for surface and subsurface soil, and groundwater was performed as a preliminary assessment of a residential scenario at both Fill Site 1 and Landfill 2. A residential PRG ratio screening assessment was also performed for surface water at El Polin Spring. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section

15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with both Fill Site 1 and Landfill 2 are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead soil screening values, are identified.

9.1.7.2.1.1 Quantification of Cancer Risks

At Fill Site 1, no analytes remained COCs following the COPC screening. Therefore, it is unlikely that exposure to surface soil to recreational visitors at this sites will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than 1E-06.

Landfill 2 had phenanthrene, ppDDT, and MCPPE as the COCs in surface soil samples. The future recreational visitor scenario with ingestion of and dermal contact with surface soil

resulted in a total cancer risk of $1E-06$ from ppDDT, the only carcinogenic COC. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Antimony, beryllium, chromium, cyanide, lead, and manganese were the COCs in surface water samples for El Polin spring, which is part of the Landfill 2 site. The total carcinogenic risk is $2E-07$, indicating that incidental ingestion of or dermal contact with the COCs in surface water to the recreational teen (age 9 through 18) is unlikely to result in excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

9.1.7.2.1.2 *Quantification of Noncarcinogenic Effects*

At Landfill 2 and El Polin spring, all of the hazard indices are less than $1E+00$ and, therefore, it is unlikely that exposure to media at these sites to the future recreational visitors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices that are greater than $1E+00$.

9.1.7.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

In addition, surface water data from El Polin Spring were evaluated as a source of drinking water for all terrestrial receptors, with the exception of pocket gophers, although true aquatic habitat is not currently present at the spring. However, the NPS has discussed plans to return this area to a natural riparian state. Exposure by aquatic receptors (e.g., aquatic plants, invertebrates, or amphibians) was evaluated by comparing surface water concentrations to AWQC.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals was also evaluated. Direct contact for plants, invertebrates and amphibians was evaluated. The HQs were estimated

using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

For Fill Site 1, soil COPCs identified for the ecological risk assessment include bis(2-ethylhexyl)phthalate and fluoranthene. Comparison of exposure to TBVs for the terrestrial receptors for soil ingestion, dietary, and dermal exposure produced HQs and HIs less than 1. This area does not present an ecological risk and further investigation is not warranted based on the results of the ERA.

For Landfill 2, soil COPCs identified for the ecological risk assessment include barium, copper, lead, zinc, PAHs, ppDDT and MCPP. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 for at least one exposure pathway when exposure was compared to the TBV_{Low} values.
- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 for at least one exposure pathway when exposure was compared to the TBV_{High} values.
- Copper, lead, ppDDT, and zinc resulted in HQs greater than 1 for the American robin and the mourning dove based on the TBV_{Low} . In addition, the barium HQ exceeded 1 for the robin. HQs were higher for the dietary ingestion pathway (e.g., 20 or greater) than the soil ingestion pathway (e.g., 3 or greater) for these receptors.
- Copper, lead, ppDDT, and zinc resulted in HQs greater than 1 for the American robin based on the TBV_{High} .
- Barium, copper, and zinc produced HQs greater than 1 for plants and soil fauna when exposure was compared to the TBV_{Low} ; only barium produced an HQ greater than 1 when exposure was compared to the TBV_{High} .

Because some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted given the TBV_{High}), the ecological risk assessment should be considered further to determine if this site should be evaluated in the FS.

For El Polin Spring, surface water COPCs were inorganics (e.g., aluminum, antimony, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride, iron, lead, manganese, mercury, nickel, vanadium and zinc). Exposure by aquatic receptors (e.g., aquatic plants, invertebrates, or amphibians) was evaluated by comparing surface water concentrations to the AWQC. Surface water ingestion by all terrestrial receptors except pocket gophers was evaluated. Significant results indicate the following:

- Levels of copper, barium, cyanide, nickel, cadmium, chromium, iron, lead and manganese in the surface water exceed chronic AWQC values for the protection of aquatic life.
- There are no risks to terrestrial receptors ingesting surface water from El Polin Spring.
- There are no risks to raccoons utilizing the area for either feeding or drinking.

The surface water data for the spring included filtered and unfiltered samples. Therefore, risks to aquatic life may be overestimated. In addition, only the chronic AWQC were used for screening. Because the spring is so small, it is unlikely to support significant populations of aquatic life; therefore, potential risks to aquatic life, even though the HQs range between 10 and 100, are not as relevant as risks to terrestrial receptors utilizing the spring. Based on the results of the ERA, this site is not recommended for further evaluation.

9.2 TRANSFER STATION

Prior to transfer of the PSF to the NPS, the Transfer Station served as the waste collection/transfer area for off-site disposal of wastes. Operation of the Transfer Station was discontinued after transfer of the PSF to the NPS in 1994. The site was the sole waste collection/staging area for the facility for approximately 9 years; documentation regarding use of the site prior to that time is not available. There is no indication the site was ever used for waste disposal, and only artificial and debris fill materials were encountered during drilling.

9.2.1 Area Description

The following sections describe the location and physical features, and history and land use of the Transfer Station Site.

9.2.1.1 Location and Physical Features

The Transfer Station covers approximately 1 ac of the west-central portion of the PSF, on the southeastern edge of Wright Loop (Figure 1.2-1). The elevation of the area is generally between 280 and 300 ft-PLL (Figure 9.2-1). Most of the area is flat, with a slight slope downhill to the northeast. Surface water draining from the site would travel to the northeast by overland flow; there is no storm drain system in the area. The majority of the site consists of cleared areas with a hard-packed dirt surface. There are isolated clumps of trees. Man-made features include a fire hydrant, and a loading ramp (with associated retaining wall) for waste transfer in the west-central portion of the site. The area was apparently graded and filled to facilitate waste collection/staging activities. A dirt road provides access to the site from Park Boulevard.

9.2.1.2 History and Land Use

The Transfer Station was most recently used as the sole solid-waste collection/staging area for the entire Presidio installation (ANL, 1989). The site was used for this purpose for approximately 9 years prior to transfer of the site to the NPS in 1994. Use of the site prior to 1985 is unclear; however, aerial photos show construction in the area in July 1948 (Pacific Aerial Surveys, Miscellaneous Photographs, 1948, AV17-05-04 and AV17-05-05). A 1973 aerial photograph shows additional clear cutting in the Transfer Station area (Ringden and Sitton, 1990). These periods of construction may be unrelated to use of the site as a transfer facility.

Operations at the site involved transfer of wastes from collection trucks into open-top roll-off storage containers. Collection trucks would empty their loads into open-top roll-off storage containers staged on the lower side of a retaining wall. The retaining wall is approximately 150 ft long and 7 ft high. As the open-top roll-off containers became full they were shipped off-site for disposal into a municipal solid waste landfill. The site was not intended for on-site waste disposal; however, surface releases may have resulted from solid-waste transfers.

Hazardous wastes and other inappropriate materials were routinely removed from the containers and temporarily stored on the site (ANL, 1989).

9.2.2 Sample Location Rationale

This section describes the sample location rationale for samples collected at the Transfer Station. Media to be sampled were selected based on the use of the site for waste-transfer. Potential release mechanisms associated with waste transfer/temporary storage activities would include leaks and/or spills, and contaminant transport via surface-water runoff. As presented in the conceptual model (Section 3.1), these release mechanisms could impact sediments and soils in and near the site.

Analysis of surface soil samples collected during the Initial RI indicated the presence of SVOCs, pesticides, and inorganic analytes above ambient levels in some of the samples of fill material. Due to the potential for these target analytes to infiltrate into native soils, subsurface soil samples were collected during the Supplemental RI from four soil borings in the area where target analytes were detected in surface samples. TPH detections in two of these borings resulted in Follow-on RI sampling to define the vertical and lateral extent.

9.2.3 Geologic Setting

Subsurface and surface soils were collected for lithologic description and chemical analysis from 12 surface soil samples and 11 soil borings (Figure 9.2-1). The soils in the vicinity of the Transfer Station are classified as Sirdrak sands, with surface slopes of 5 to 50 percent (Kashiwagi and Hokholt, 1985). Schlocker (1974), has mapped the surficial deposits in the area as Quaternary dune sand.

Eleven soil borings, ranging in depth from 6.5 to 40.0 ft bgs, were drilled at the Transfer Station. All logs for soil borings are presented in Appendix G.3. Cross sections A-A' and B-B' show subsurface relationships as interpreted from soil borings (Figure 9.2-2 and 9.2-3). Fill materials were found in all borings, with encountered thicknesses varying from 0.5 ft in Boring LF3SB08 to 6.5 ft in Boring LF3SB01, which did not completely penetrate the fill. Fill materials encountered in borings were primarily artificial fill composed of sand and silt with gravel-sized fragments of serpentinite and chert. Three of the 11 borings encountered

minor concrete, and one of these borings contained evidence of chain-link fencing material. These materials are classified as debris fill, but their inconsistent distribution and relative scarcity (three of 11 borings) suggest isolated mixing with the artificial fill used to construct the transfer facility. For example, Borings LF3SB06 and LF3SB11 were drilled immediately adjacent to one another in approximately 6 ft of fill, and Boring LF3SB06 encountered concrete while LF3SB11 did not. Thus, the presence of the debris fill is not considered evidence of on-site disposal of building debris. Those borings which did encounter debris fill are noted on the isopach map (Figure 9.2-4). Fine-grained, well-sorted, dune sand was encountered below the fill materials in all borings except Boring LF3SB01, which terminated in fill. Colma Formation, consisting primarily of sandy silt and sandy clay, was found to underlie dune sand at a depth of 17.0 ft bgs in Boring LF3SB11.

Neither bedrock nor groundwater was encountered in any borings, to a maximum depth of 40 ft bgs. The regional structure contour map of bedrock (Figure 2.3-4) indicates that depth to bedrock is approximately 55 ft bgs in the area.

Figure 9.2-4 presents isopachs of artificial/debris fill at the Transfer Station. Isopachs were constructed using data from soil borings, as well as cross section interpretation of the area. From the isopach thicknesses in Figure 9.2-4, it is estimated that approximately 2,462 yd³ of artificial/debris fill were used in the construction of the Transfer Station site, at least a portion of which was simply relocated from on site.

During drilling at the Transfer Station Site, a PID and CGI were used to determine the presence of landfill gasses. The highest PID reading recorded was 0.4 ppm. LEL readings did not exceed 0.0 %.

9.2.4 Analytical Results

This section summarizes sample locations, analyses, and analytical results of sampling performed at the Transfer Station during the RI. Inorganics results are compared to appropriate ambient concentrations as described in Section 3.6.2. Most of the soil samples contained elements commonly found in the environment, including calcium, potassium, magnesium, and sodium. These compounds are not usually evaluated as part of risk assessments and are not discussed in this section because they are ubiquitous in the

environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Results affected by blank contamination are also excluded from further evaluation.

During the Initial RI, 12 surface soil samples were collected from fill material and analyzed for inorganics, VOCs, SVOCs, and pesticides. Detections above the CRLs are presented in Table 9.2-1. Inorganic target analytes were detected in all surface soil samples, however, only aluminum, arsenic, barium, iron, lead, mercury, and vanadium were detected at concentrations above ambient fill levels. One VOC, toluene, was detected once, in Sample LF3SS06. Nine SVOCs were detected above the CRLs, with a total of 17 SVOC detections for all samples. Twelve OCPs were detected above the CRLs; the greatest detection was 0.113 $\mu\text{g/g}$ of chlordane in sample LF3SS06.

During the Supplemental RI, eight subsurface soil samples were collected from four borings and analyzed for inorganics, VOCs, SVOC, OCPs, PCBs, chlorinated herbicides, and TPH. All samples were collected in debris fill or native sand immediately below debris fill. Detections of target analytes above the CRLs or RLs are presented in Table 9.2-2. Inorganic target analytes were detected above the CRLs in all samples, with barium, manganese, and vanadium detected at concentrations above ambient values in two beach/dune samples. Inorganics were not detected above ambient values in any of the fill samples.

VOC detections were limited to acetone and MEK, each of which was detected once. Nine different SVOCs were detected, but only twelve SVOC detections were noted for all eight samples. OCPs were detected three times; the highest concentration detected was 0.040 $\mu\text{g/g}$ of ppDDT, which is below the SDC. No PCBs or chlorinated herbicides were detected above the CRLs. TPH-D was detected above the CRL in all samples; the highest detection was 250 $\mu\text{g/g}$, and two other detections exceeded the SDC of 100 $\mu\text{g/g}$. Six of 12 surface soil samples contained unknowns with concentrations totaling greater than 100 $\mu\text{g/g}$ in each sample.

WET method analyses for chromium, nickel, and lead were performed on debris fill material from LF3SB02 at 5 ft bgs. Results reported from these analyses were 0.11 mg/L chromium, <0.2 mg/L nickel, and <1.0 mg/L lead. All results are provided in Appendix O.

Samples were collected from six borings during the Follow-on RI to define the extent of TPH concentrations detected in the supplemental samples. A confirmation analysis from the 5.0 ft bgs sample from Boring LF3SB09 was made for TPH-D and TPH-G fraction using Method 8015. All other samples (LF3SB08 through LF3SB10) were analyzed using immunoassay method 4030. Samples from Boring LF3SB07 were also analyzed for TOC. The results for these samples are shown in Table 9.2-3.

Two borings, LF3SB05 and LF3SB06, were drilled adjacent to Borings LF3SB02 and LF3SB01, respectively, which had contained the elevated detections of TPH-D. Samples of dune sand were collected from these two borings at 8.0 ft bgs. In the remaining borings, LF3SB07 through LF3SB10, samples were collected at 0.0, 5.0, and 8.0 ft bgs. In all but Boring LF3SB09, the surface sample was collected in fill material while the deeper samples were collected in dune sand; the 5.0 ft bgs sample from Boring LF3SB09 was collected in fill, and the 8.0 ft bgs sample consisted of dune sand. All samples were analyzed for TPH, and there were no detections above the RL. The 5.0 ft bgs sample from Boring LF3SB09 was also analyzed for TPH-D and TPH-G, with a detection of 21.4 µg/g TPH-D and no detectable concentration of TPH-G. TOC analysis was run on the samples from Boring LF3SB07. TOC concentrations ranged from 1,060 to 9,420 µg/g.

9.2.5 Results Evaluation

The following section evaluates the results of sampling performed during the RI at the Transfer Station Site. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent, and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes

are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For sites containing fill material identification of sources is difficult due to the random distribution of source material within the fill.

Debris and artificial fill materials are present in portions of the Transfer Station Site from ground surface to 8 to 10 ft bgs. Artificial and debris fill materials contained concrete, gravels of serpentinite and chert, chain-link fence, and road base materials. There are an estimated 2,462 yd³ of debris fill at the site. Fill materials are underlain by dune sand (Figures 9.2-2 through 9.2-4), which is underlain by sandy silt and clay of the Colma Formation. Groundwater was not encountered at a depth of 40 ft bgs, and the facility-wide water table map (Figure 2.3-5) indicates that there are no saturated unconsolidated materials beneath the site.

Potential sources of contamination at the site are accidental spills during transfer of waste to roll-off containers used to transport wastes off site, and potential sources located in the debris fill material placed during site construction.

Inorganics detected above ambient values in surface and subsurface soils include aluminum, arsenic, barium, iron, lead, manganese, mercury, and vanadium. Posting maps for these analytes are included as Figures 9.2-5 through 9.2-10. Ambient exceedences generally occur near staging areas for roll-off containers rather than in relatively unused portions of the site. Concentrations of inorganics generally decrease with depth, and the number of ambient exceedences is significantly greater in fill material than in native deposits. In Boring LF3SB04, however, most inorganics were detected at higher concentrations in the deep sample in native material than in the shallow sample of debris fill. Despite this exception, the data tend to support the conclusion that many of the inorganic analytes detected in the subsurface generally are insoluble in unsaturated soils and remain close to source areas.

Surface spills associated with waste transfer and storage in roll-off containers are the likely sources of inorganics in soils at the site. Inorganics detected above ambient levels that will be considered soil COPCs include aluminum, barium, lead, mercury, and vanadium. Arsenic, iron, and manganese are not included as soil COPCs because of their limited number of detections.

Toluene was the only VOC detected in surficial soils. Acetone and MEK were detected below or very near the CRLs in subsurface soils. These compounds are relatively volatile and soluble and do not tend to sorb to soils. They would be expected to volatilize quickly from surficial soils and readily leach through the soil column if sufficient volume were spilled. The limited number of VOC detections, the difference in detected compounds from surface to subsurface soils, and the absence of detectable VOCs below fill material suggest the volume of soil potentially affected by VOCs is small.

Nine SVOCs were detected in surface soils. Five SVOCs were detected in more than one sample, but none were detected in more than three. Most of these detections are in the waste transfer area, and all were in areas where roll-off containers have been staged. This suggests that these detections most likely result from small accidental spills. In addition, most of the ambient exceedences of inorganic COPCs occurred in this area. In subsurface soils, 12 SVOC detections were reported; detections were divided among nine SVOCs, four of which were also detected in surface soil samples. Three of the SVOCs were detected in more than one sample. Two of these detections (phthalates in Boring LF3SB02 at 5.0 ft bgs) were in native materials below fill, though they were not detected in the overlying fill material in the same boring. All other detections were in fill material. Additionally, all of the SVOC detections were limited to two borings, and eight were in the deep sample of debris fill in Boring LF3SB01 at 5.0 ft bgs. Concentrations of benzo(a)anthracene and benzo(a)pyrene are plotted on Figures 9.2-11 and 9.2-12 respectively.

SVOCs detected in soils were either PAHs or phthalates. PAHs tend to sorb to soils and be non-volatile. Therefore, these compounds are not likely to leach from soils and migrate deeper with infiltration of precipitation. The only SVOCs detected in native materials were phthalates. The phthalates detected, which have been reported as naturally occurring compounds (Dragun, 1988), were not reported in the shallow sample in the same boring. All

PAH detections were reported in samples from fill materials. Since SVOC detections did not occur in all surface soil samples and were limited to two of the four borings, the volume of soil affected by these compounds is most likely limited.

Pesticides were detected in nine of 12 surface soil samples, with a total of 36 detections reported. In all, 12 pesticides were detected. Only six of the 36 detections occurred at levels greater than five times the CRLs. Approximately half of the detections were in areas where roll-off containers are staged, the remaining detections are in other portions of the site.

Though several pesticides were detected at the surface, only ppDDE and ppDDT were detected in subsurface soils. For pesticides in surface soils, human contact may occur by direct contact with soils. Compounds in subsurface soils may potentially migrate with water percolating through fill materials; however, migration by this mechanism would tend to be very limited because pesticides generally sorb strongly to soils. This is supported by data at the site which indicate a wide variety and larger number of detections of pesticides in surface soils than in subsurface soils, and by the lack of pesticide detections in native materials below fill.

Only three detections of OCPs were reported in subsurface soils, and no chlorinated herbicides were detected above the CRLs. The OCPs were detected in two samples of debris fill material in Borings LF3SB01 and LF3SB02. No OCPs or chlorinated herbicides were detected above the CRLs in native sands below fill material.

TPH-D was detected in all subsurface soil samples from the supplemental program. Three of the detections exceeded the Follow-on RI SDC of 100 $\mu\text{g/g}$, two in fill material from the same boring and one in native dune sand. Notably, the TPH concentration in the fill above the dune sand sample did not exceed the SDC. Additional samples were collected, mainly in native dune sand, and the extent of concentrations above the SDC was fully defined by non-detections beneath and surrounding the locations of the previous samples. No site-wide pattern in the distribution of TPH-D is apparent, and the sample chromatograms vary. This distribution suggests isolated, low-volume spills or leaks most likely associated with waste transfer activities on site. Comparison of sample chromatograms with standard chromatograms for a variety of petroleum hydrocarbons revealed no distinct similarities.

Because the TPH-D method used is non-specific and covers hydrocarbons from C₈ to C₃₂, the possibility exists that the TPH-D detections are a function of naturally occurring organic matter in soils.

9.2.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Transfer Station Site, including the risk assessment results, as presented in detail in Section 15.

9.2.6.1 Conclusions

The potential source(s) of contamination at the Transfer Station include leaks and spills during waste transfer operations. The purpose of the RI at the Transfer Station was to investigate if waste transfer activities and the artificial/debris fill used in the construction of the site have had an impact on the environment.

To investigate the potential impact of surface spills associated with waste transfer activities, surface and subsurface soils were collected across the site. Several groups of contaminants were detected in surface soils, including inorganics, VOCs, SVOCs, OCPs, chlorinated herbicides, and TPH-D. Laterally, detections at the surface are generally concentrated near the base of the retaining wall and in the areas where roll-off containers were stored. At this location, concentrations generally decrease with depth.

To investigate the fill material used to level the ground surface during construction of the site, subsurface soil samples were collected from within and beneath the fill material. Target analytes detected in the fill include inorganics, VOCs, SVOCs, pesticides, OCPs, and TPH-D. The number of detections and concentrations were lower in the underlying native material.

Results of the RI sampling indicate that operations at the Transfer Station site have released several groups of contaminants to surface soils at the site and that concentrations generally decrease with depth. The fill material used to level the ground surface does not appear to be impacting the underlying soil.

Soil COPCs identified at the Transfer Station include all detected organics and the inorganics aluminum, barium, lead, mercury, and vanadium.

9.2.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Transfer Station Site are summarized in the following sections.

9.2.6.2.1 Human Health

The GMPA identified open space as the future land use of the Transfer Station Site. Based on this future land use, exposure to surface soil from 0.0 to less than 0.5 ft bgs is assumed. Inorganic COPCs present in soils in this depth range include aluminum, barium, lead, mercury, and vanadium.

A residential PRG ratio screening assessment for surface and subsurface soil was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA

to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Transfer Station Site are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead soil screening values, are identified.

9.2.6.2.1.1 Carcinogenic Risk

Several PAHs, bis(2-ethylhexyl) phthalate, and isodrin were determined as COCs in surface soil samples at the Transfer Station following COPC screening. A future recreational scenario was assessed with incidental ingestion of and dermal contact with surface soil COCs. A total cancer risk of 3E-06 was calculated, mostly from ingestion of and dermal

contact with bis(2-ethylhexyl) phthalate. The residential PRG ratio screening assessment resulted in total cancer risk greater than $1E-06$.

9.2.6.2.1.2 *Non-carcinogenic Risk*

At the Transfer Station, the hazard index is less than $1E+00$ and, therefore, it is unlikely that exposure to media at this site to the future recreational visitors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in a total hazard index greater than $1E+00$.

9.2.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for the Transfer Station included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and invertebrates were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified for the ecological risk assessment of the Transfer Station include several inorganics, VOCs, PAHs and other SVOCs, and OCPs. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna were greater than 1 for at least one pathway based on evaluation against the TBV_{Low} .
- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna were greater than 1 for at least one pathway based on evaluation against the TBV_{High} .
- Lead and vanadium were the major risk factors for the American robin and the mourning dove due to soil or dietary ingestion. Lead HQs ranged from 40 to 300 for these receptors based on a TBV_{Low} , whereas lead HQs based on the TBV_{High} were only 2.
- Mercury resulted in HQs greater than 1 for the American robin, mourning dove and western harvest mouse.

The magnitude of the HQs exceeds 100 for some COPCs. Because some estimates of risk exceed the upper bound of the gray zone, further examination of the data is recommended. The ecological risk assessment for Transfer Station will be further evaluated to determine whether this site is warranted for inclusion in the FS.

9.3 LANDFILL 4 AND FILL SITE 5

Landfill 4, used for disposal of debris and landfill materials, and Fill Site 5, used for disposal of debris fill materials, were in use from approximately 1946 to 1981 when use of both sites was discontinued. Neither site has a formal use at this time. The following sections describe the area, sample location rationale, geologic setting, hydrogeology, analytical results, results evaluation, and conclusions.

9.3.1 Area Description

The following sections describe the location and physical features, and history and land use of Landfill 4 and Fill Site 5.

9.3.1.1 Location and Physical Features

Landfill 4 and Fill Site 5 are located in the west-central portion of the PSF, about 600 ft apart (Figure 1.2-1). Topography ranges from about 280 to 325 ft-PLL in the two areas (Figure 9.3-1). Landfill 4 is situated to the west of Wright Loop, between Central Magazine Road and Hitchcock Street. Most of the area is flat with a slight downhill slope to the north; surface-water runoff is to the north. Large eucalyptus trees and brush cover the area. Fill Site 5 is located between Lincoln and Washington Boulevards, directly south of the West Coast WWII Memorial. The land surface slopes generally downhill to the west. Any surface-water runoff would flow to the west from the site. A relatively flat area, composed of graded material, gravel, concrete slabs, and patches of grass, forms the main portion of the site. Trees border the site to the north and southwest. Concrete slabs and tree debris are scattered along the western edge of the site.

9.3.1.2 History and Land Use

Landfill 4 is one of two sites most recently used for on-site disposal of solid wastes at PSF. Use of the site was discontinued by PSF in 1981. The site encompasses approximately 5 ac. Some areas of the site are reported to contain up to 14 ft of deposited debris of unknown composition, which was dumped into an existing depression and periodically covered with fill dirt (ANL, 1989). PSF personnel indicated this area received a variety of wastes, including some chemical wastes from various PSF facilities. A soil cap, approximately 3 ft thick, was added when fill activities ceased (ANL, 1989). The area is currently vegetated and unused.

Fill Site 5, used concurrently with Landfill 4, is the other site most recently used for disposal of fill materials. It was used for disposal during inclement weather when Landfill 4 was not accessible (ANL, 1989). Waste of unknown composition was dumped down a steep ravine and periodically covered with soils. The only visible environmental effect observed during the Enhanced PA was the damage to trees at the base of Fill Site 5 due to the addition of dumped material (ANL, 1989). The exact dates that filling activities were initiated and ceased are unknown; however, aerial photos indicate activity in 1973 for Landfill 4 and photographs dated 1946 and 1959 show activity in Fill Site 5 (Ringden and Sitton, 1990).

The Enhanced PA states that use of both Landfill 4 and Fill Site 5 was discontinued in 1981 (ANL, 1989).

9.3.2 Sample Location Rationale

This section describes the sample location rationale for samples collected at both Landfill 4 and Fill Site 5. In the context of the conceptual model (Section 3.1), landfill and debris fill materials in Landfill 4, and debris fill materials in Fill Site 5 were investigated as potential sources of contaminants which could migrate to soils beneath fill materials.

The first step was to determine the areal and vertical extent as well as the composition of fill materials. This was accomplished by describing the physical characteristics of samples collected from soil borings and test pits. In addition, aerial photographs were closely examined to aid in the delineation of the lateral extent of fill materials.

Several media were sampled to identify potential release mechanisms of fill materials. Contaminated soil particles may be transported in surface-water runoff. To evaluate the potential for contaminant transport by this mechanism, surface soil samples were collected for chemical analysis. Target analytes in fill materials may infiltrate into the soil column beneath the fill areas, and percolate downward toward the water table. Samples of fill material, and native material beneath the fill, were collected for chemical analysis during the Initial RI to evaluate the nature of the fill and determine the extent to which potential contaminants may be infiltrating into native soils beneath fill materials.

Results of the soil sampling during the Initial RI demonstrated a need for further sampling at both sites. Lead detections in Landfill 4 test pits resulted in Follow-on RI soil sampling to define vertical and lateral extent. Samples collected at Fill Site 5 during the Initial RI contained target analytes above ambient levels. Additional samples were collected during the Supplemental RI to further characterize fill materials and their impact on vegetation.

Groundwater was not initially encountered in the unconsolidated soils beneath these sites, and, therefore, groundwater was not considered a viable pathway for contaminant transport. Well installation efforts during the Follow-on RI field program confirmed the absence of groundwater in the underlying unconsolidated groundwater at Fill Site 5. At Landfill 4,

however, a downgradient well was successfully installed during the Follow-on RI. Though the boring for the corresponding upgradient well was dry, this downgradient well allows an evaluation of potential releases from the fill material to groundwater.

9.3.3 Geologic Setting and Hydrogeology

This section describes the geologic and hydrogeologic settings for both Landfill 4 and Fill Site 5. Geology and soils for these two areas were investigated using test pits, soil borings, surface soil samples, and geophysics (Figure 9.3-1). All logs for borings and test pits are presented in Appendices G.4 and G.5. Geophysical studies included resistivity and EM surveys. These surveys did not add substantially to understanding of the sites due to a lack of contrast between fill and native materials, but all geophysical data are presented in Appendix N. Cross sections of the area are presented on Figures 9.3-2 through 9.3-5, and Figures 9.3-6 through 9.3-8 show fill material isopachs.

9.3.3.1 Landfill 4 Soils and Geology

The surficial soils in the Landfill 4 area are classified as Sirdrak sand (Kashiwagi and Hokholt, 1985). Fill materials, fine-grained dune sand, sandy clay of the Colma Formation, and serpentinite bedrock were found in the test pits and soil borings.

Cross sections A-A' and B-B' (Figures 9.3-2 and 9.3-3) show the interpreted stratigraphy at Landfill 4. A layer of debris fill was found to cover the area, with landfill materials present in the western half of the site. The debris fill appears to be part of the 3-ft cap emplaced after landfilling operations had ceased. Debris fill was described in logs as containing brick, glassware, gravels, concrete, and pipes, whereas landfill materials also included battery caps and plastic. Maximum depth to the base of the landfill material is approximately 12 ft. Isopachs of landfill material and debris fill are presented in Figures 9.3-6 and 9.3-7, respectively. Fill thickness determinations were based on subsurface investigations and stratigraphic interpretations shown in cross sections A-A' and B-B'. The volume of landfill material at Landfill 4 is estimated to be 1,744 yd³, and the volume of debris fill is estimated to be 3,931 yd³.

Native deposits underlying fill materials at Landfill 4 are fine to medium sand, interpreted as dune sand. The dune sand is approximately 20 ft thick and underlain by a thick (greater than 10 ft) clay layer belonging to the Colma Formation. Bedrock beneath the site is serpentinite of the Franciscan Formation, and it was encountered in three borings at depths between approximately 35 and 50 ft bgs.

During subsurface exploration at Landfill 4, a PID and CGI were used to determine the presence of landfill gasses. The highest PID reading recorded was 4 ppm. LEL readings did not exceed 0.0 %.

9.3.3.2 Landfill 4 Hydrogeology

Attempts were made to investigate groundwater at Landfill 4 during both the Initial and Follow-on RI field programs. There was no evidence of groundwater at the site during the Initial RI, but a small water-bearing sand unit was encountered downslope from the landfill during the Follow-on RI.

During the Initial RI, Boring LF4GW01 was drilled to bedrock upslope of the landfill for the installation of a monitoring well. The borehole was dry, and a well was not installed. During the same program, three borings, LF4SO01 through LF4SO03, were drilled just inside the downslope landfill boundary. Each of these borings fully penetrated the dune sand and continued a minimum of 6.5 ft into clay of the Colma Formation. None of these borings contained significant moisture in any of the lithologic samples collected during drilling.

Follow-on RI drilling was performed during a period of heavy rainfall, and another effort was made to determine whether groundwater was present at the site. A second upslope boring, LF4GW02, was drilled to bedrock, and two piezometers were installed, one in a sand underlain by bedrock, and the second in dune sand above clay of the Colma Formation. Neither piezometer produced water over a 48 hour period, and both were abandoned.

Groundwater was encountered downslope of the site (LF4GW03) during the Follow-on RI field program. During drilling, the water-bearing unit was determined to be a thin (1 ft thick) sand layer within the Colma Formation. This sand layer is separated from the overlying dune sand by a clay layer approximately 1 ft thick, and the moisture content in lithologic samples

indicated a potential for confined conditions (Appendix G.4). Two piezometers were installed, one across the sand layer, and a second in clayey sand just above bedrock. The deeper piezometer was dry, but the upper one ensured that a well would produce sufficient water for sampling. Subsequently, a monitoring well was installed and screened across the sand layer. The water level in the well in March 1995 (Figure 9.3-3) showed that the water-bearing unit is, in fact, confined.

While the subsurface investigations in the area do provide evidence that this sand is the only water-bearing unit above bedrock, the areal extent of the groundwater, in relation to Landfill 4, is uncertain. Neither groundwater nor a similar sand unit was found in any of the three initial RI borings, each of which penetrated between 10 and 30 ft into the Colma clay beneath landfill material. It has been conclusively shown that groundwater is not present upslope of the landfill. Well LF4GW03 is most likely monitoring a seasonal groundwater condition caused by the heavy rainfall that occurred during the Follow-on RI field program.

9.3.3.3 Fill Site 5 Soils and Geology

The surficial soils in Fill Site 5 are classified as Typic Argiustolls associated with urban land (Kashiwagi and Hokholt, 1985). Test pits and soil borings found fill materials and slope debris/ravine fill, composed of clay, silt, and sand, overlying serpentinite bedrock.

Cross-sections C-C' and D-D' (Figures 9.3-4 and 9.3-5) show the interpreted stratigraphy beneath Fill Site 5. Fill material thickness ranged from 0 ft to greater than 13 ft, with the greatest thickness found in Test Pit LF5TP05. Debris fill appears to have been disposed in two primary locations, one in the northern portion of the site and the other to the south. Fill materials were described in logs from test pits and borings as plastic, soda cans, cut wood, pipes, barbed wire, gravel, and concrete and serpentinite fragments. Isopachs of debris fill are presented in Figure 9.3-8. Fill thickness determinations were based on subsurface investigations and stratigraphic interpretations. The volume of debris fill at Fill Site 5 is estimated to be 3,518 yd³.

A silty to sandy clay layer was described below fill materials in all borings and test pits that fully penetrated fill deposits. With the exception of LF5SO01, a silty to sandy clay was described at land surface in borings and test pits in which no fill material was encountered.

This clay layer appears to mark the top of a slope debris/ravine fill unit, composed primarily of clay, sand, and gravel in this area. Serpentinite from the Franciscan Formation was encountered in four borings at depths between 6 and 20 ft bgs. Depth to bedrock generally decreases from east to west. Groundwater was not encountered during drilling at the site.

During subsurface exploration at Fill Site 5, a PID and CGI were used to determine the presence of landfill gasses. The highest PID reading recorded was 18 ppm. LEL readings did not exceed 0.0 %.

9.3.4 Analytical Results

The following sections discuss the sample locations, analyses, and analytical results of sampling performed at both Landfill 4 and Fill Site 5 during the RI. Inorganics results are compared to appropriate ambient concentrations as described in Section 3.7.2. Most of the soil samples contained elements commonly found in the environment, including calcium, potassium, magnesium, and sodium. These compounds are not usually evaluated as part of risk assessments and will not be discussed in this section because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Results affected by blank contamination will not be discussed.

9.3.4.1 Landfill 4 Soil Sampling Results

Two surface soil samples (LF4SS01 and LF4SS02) were collected from fill material during the Initial RI field work. One sample was analyzed only for VOCs, and the second sample was analyzed for inorganics, SVOCs, and pesticides. All detections are shown in Table 9.3-1. Inorganics were not detected above ambient levels. VOCs were not detected above the CRLs. One SVOC, 4-methylphenol, was detected, at a concentration of 0.63 $\mu\text{g/g}$. Several pesticides were detected above the CRLs. The highest pesticide detection was 0.120 $\mu\text{g/g}$ of chlordane, slightly less than twice the CRL.

Five test pits (LF4TP01 through LF4TP05) were excavated during the Initial RI. One sample was collected from each test pit and analyzed for inorganics, VOCs, SVOCs, and pesticides. All detections above the CRLs are shown on Table 9.3-2. All samples consisted of fill material (the 3.0 ft bgs sample from Test Pit LF4TP01 was also classified as beach/dune sand), and each contained detectable concentrations of several inorganics. Inorganics detected at concentrations above ambient fill values (or ambient beach/dune sand values for the 3.0 ft bgs sample from Test Pit LF4TP01) in at least one sample include aluminum, barium, copper, iron, lead, manganese, mercury, and zinc. The sample from Test Pit LF4TP04 did not contain any inorganic analytes at concentrations above ambient levels. The samples from Test Pits LF4TP01 and LF4TP05 contained lead at concentrations of 599 and 555 $\mu\text{g/g}$, respectively. VOCs were not detected in any of the five samples. One SVOC, phenanthrene at a concentration of 0.11 $\mu\text{g/g}$, was detected once. Thirteen pesticides were detected in four of the five samples, the fifth sample had no pesticide detections. The maximum pesticide detection was chlordane at 5.47 $\mu\text{g/g}$. Two PCBs were detected in Landfill 4 test pits using the pesticide method; the highest concentration was of Aroclor 1016 at 0.151 $\mu\text{g/g}$.

Three borings (LF4SO01, LF4SO02, and LF4SO03) were drilled during the Initial RI. One sample was collected from each boring and analyzed for inorganics, VOCs, SVOCs, and pesticides. All detections above the CRLs are shown on Table 9.3-3. All of the samples were collected at 10 ft bgs in native sand below fill. The only inorganic detected above ambient beach/dune sand values was aluminum, which was only slightly higher than the ambient value in the sample from Boring LF4SO01. No VOCs, SVOCs, or pesticides were detected above the CRLs. The PCB Aroclor 1260 was detected once, in sample LF4SO01, at the detection limit, 0.048 $\mu\text{g/g}$.

Three additional soil borings (LF4SB01 through LF4SB03) were drilled in Landfill 4 during Supplemental RI field work. Two samples were collected from Boring LF4SB03 (5.0 and 13.0 ft bgs) and analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. All detections are shown on Table 9.3-4. The 5.0 ft bgs sample was collected from fill material and the 13.0 ft bgs sample was collected from native dune sand. Inorganics detected above ambient values include antimony and beryllium in the 5.0 ft bgs

sample. Inorganics were not detected above ambient values in the native sample. Five SVOCs were detected in the shallow sample, none in the deeper sample. OCPs, PCBs, and chlorinated herbicides were not reported above the CRLs or RLs. TPH-D was reported in both samples, at 210 $\mu\text{g/g}$ in the shallow sample, and at 2.00 $\mu\text{g/g}$ in the deeper sample.

Samples from Borings LF4SB01 and LF4SB02 at a depth of 5.8 ft bgs were collected and analyzed for STLC lead using the WET method. Lead was detected at concentrations of 8,000 $\mu\text{g/L}$ and 6,000 $\mu\text{g/L}$, respectively. An additional sample from Boring LF4SB03 at 5.0 ft bgs was analyzed using the WET method for STLC chromium, nickel and lead. Chromium was detected in Boring LF4SB03 at a concentration of 590 $\mu\text{g/L}$, nickel was detected at a concentration of 3,500 $\mu\text{g/L}$, and lead was not detected. STLC data are provided in Appendix O.

Follow-on RI soil sampling was conducted to further define the vertical and lateral extent of the lead concentrations detected in Test Pits LF4TP01 and LF4TP05. Samples were analyzed for lead; the results for samples associated with Test Pit LF4TP01 are presented on Table 9.3-5, while those associated with Test Pit LF4TP05 are shown in Table 9.3-6. A deeper sample was collected from the location of both test pits. The sample beneath Test Pit LF4TP01 did not contain detectable lead concentrations, and the concentration in the sample from Boring LF4SB07, beneath Test Pit LF4TP05, did not exceed the SDC of 300 $\mu\text{g/g}$. Samples were collected at 0.5, 3.0, and 5.0 ft bgs from Borings LF4SB05 and LF4SB06, to the east and south of Test Pit LF4TP01. Both 0.5 ft bgs samples contained lead at concentrations above ambient beach/dune concentrations, but the RL was not exceeded in the deeper samples. All three samples from Boring LF4SB05 were analyzed for TOC. TOC concentrations in these samples ranged from 1,440 to 21,200 $\mu\text{g/g}$. The highest TOC detection was in the 0.5 ft bgs sample.

Five borings (LF4SB08 through LF4SB10, LF4SB19, and LF4SB20) were drilled in the vicinity of Test Pit LF4TP05 and sampled at several depths. Ambient lead levels were exceeded in five samples from three borings, but in each case deeper samples were collected which did not contain detectable lead concentrations or were below ambient levels. The samples from Borings LF4SB08 and LF4SB09 were comprised of fill material, and the rest

consisted of native materials. These five ambient exceedences include a method 7421 confirmation result that is discussed further in Section 3.8.

One to two unknown VOCs were identified in several samples from Landfill 4. Unknown SVOCs were identified which fit the criteria for discussion of unknowns in Section 3.5. These unknown SVOCs were tentatively identified by the laboratory as unknown hydrocarbons.

9.3.4.2 Landfill 4 Groundwater Sampling Results

Groundwater was encountered downgradient of Landfill 4 during Follow-on RI drilling, and a monitoring well was installed. A groundwater sample was collected from the well during April 1995, and analyzed for inorganics, chromium VI, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G.. All detections above RLs are presented in Table 9.3-7. Filtered and unfiltered samples for metals were collected during the Follow-on RI. With the exception of antimony, potassium, and sodium, metals concentrations in the filtered samples were lower than those in the unfiltered samples (Table 9.3-7).

There were no VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, or TPH detected in Well LF4GW03.

9.3.4.3 Fill Site 5 Soil Sampling Results

Two surface soil samples were collected from fill material at Fill Site 5 during the Initial RI. One sample was analyzed for VOCs, and the second sample was analyzed for inorganics, SVOCs, and pesticides. All detections above the CRLs in surface soil samples are shown in Table 9.3-1. Inorganics were not detected at concentrations above ambient fill values. VOCs were not detected above the CRLs. One SVOC was detected, fluoranthene at a concentration of 0.080 µg/g. Several pesticides were detected above the CRLs. The highest pesticide concentration was 0.010 µg/g of ppDDT.

Five test pits were excavated during the Initial RI. One sample was collected from each test pit and analyzed for inorganics, VOCs, SVOCs, PCBs, and pesticides. All detections above the CRLs are shown on Table 9.3-8. Numerous inorganics were detected in each sample,

however, inorganics were only above ambient levels in the 1.5 ft bgs sample from LF5TP04. Inorganics detected at concentrations above ambient levels include aluminum, beryllium, iron, manganese, and vanadium. VOCs were not detected in any of the five samples. One SVOC, di-n-butyl phthalate, was detected at a concentration of 6.0 $\mu\text{g/g}$. Seven pesticides were detected in two of the five samples; the other three samples had no pesticide detections. The highest pesticide concentration reported was 0.900 $\mu\text{g/g}$ of chlordane.

Three soil borings were drilled at Fill Site 5 during the Initial RI. One sample was collected from each boring and analyzed for inorganics, VOCs, SVOCs, pesticides, and PCBs. All detections above the CRLs are shown on Table 9.3-3. All of the samples were collected in native slope debris materials derived from Colma and Franciscan Formation deposits; therefore inorganic detections in these samples were compared to ambient levels for both Colma and serpentinite materials. Inorganics detected above Colma ambient levels in at least one sample include aluminum, barium, chromium, cobalt, iron, manganese, mercury, nickel, and vanadium. Of these, aluminum, barium, mercury, and vanadium were above ambient serpentinite values. VOCs, SVOCs, pesticides, and PCBs were not detected above the CRLs.

Two soil borings, LF5SB01 and LF5SB02, were drilled in Fill Site 5 during Supplemental RI field work. Samples were collected for STLC analysis using the WET method for chromium and/or lead. Chromium was detected in both borings, at concentrations of 330 and 150 $\mu\text{g/L}$, respectively. Lead was detected in sample LF5SB02 at a concentration of 3,000 $\mu\text{g/L}$. STLC analytical results are presented in Appendix O.

In samples from Fill Site 5, unknown SVOCs were identified which fit the criteria for discussion of unknowns presented in Section 3.5. These unknown SVOCs were tentatively identified by the laboratory as unknown hydrocarbons.

9.3.5 Results Evaluation

The following sections evaluate the results of sampling performed during the RI at Landfill 4 and Fill Site 5. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent, and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For sites containing fill material identification of sources is difficult due to the random distribution of source material within the fill.

For groundwater and surface water all detected analytes are considered COPCs. In the following discussions, detections of compounds are compared with California Primary and Secondary MCLs (Tables 3.8-2 and 3.8-5) to provide the reader with a frame of reference. If an analyte is present in surface or groundwater at concentrations above MCLs, the source, nature and extent, and fate and transport of the analyte are evaluated.

Due to the random distribution of source material in the fill, a random chemical distribution would also be expected. If source material in the fill is contributing chemicals, isolated hot spots within the fill would be likely. Depending on the nature of the chemicals present, these hot spots within the fill material could leach to the underlying native soil and groundwater. For the purpose of defining the extent of COPCs detected in fill material, the following sections will focus on the impact on the subsurface soil and groundwater rather than defining the extent of a particular chemical within an area of the fill material.

9.3.5.1 Landfill 4 Results Evaluation

Inorganics were not detected above ambient values in the composite surface soil sample collected at Landfill 4. In subsurface soil samples, inorganics show higher concentrations in fill material than in the underlying native material. The inorganics aluminum, antimony, barium, beryllium, copper, iron, lead, manganese, mercury, and zinc were detected above ambient values in fill material, however, none of these were above ambient values in the underlying native material. As expected in a fill site, there are no spatial patterns to inorganic concentrations. Of the inorganics detected in fill material, most concentrations are near

ambient values. Exceptions include antimony, lead, and mercury. For this reason, these three analytes are considered soil COPCs. Posting maps showing concentrations for several inorganics are included as Figures 9.3-9 through 9.3-12.

Lead detections in Test Pits LF4TP01 and LF4TP05 during the Initial RI were considered high enough to warrant further investigation during the Follow-on RI program. The objective of the sampling was to fully define the vertical and lateral extent of lead concentrations above the established SDC of 300 $\mu\text{g/g}$ and to assess whether underlying native deposits have been affected by fill material. The vertical extent at Test Pit LF4TP01 was defined by a non-detection in deeper sampling, from native materials, in the same location. Deeper sampling from fill material at Test Pit LF4TP05 resulted in a lead detection below the SDC. In each case, the lateral extent was defined by a combination of Follow-on samples, existing samples, and landfill boundaries. No samples comprised of native materials contained lead concentrations above the SDC. Sources of lead within the fill material were not identified.

Antimony and mercury were detected in one sample each at concentrations exceeding ambient levels. Both exceedences occurred within the fill material. All other detections of these two analytes both within the fill and in the underlying native material were below ambient values. Sources of antimony and mercury were not identified within the fill material.

The lack of inorganics in the underlying native material suggests that inorganics detected in fill material are not migrating. This is as expected since most of the inorganics detected in fill are relatively immobile and tend to sorb to soil. For this reason infiltration and percolation are not considered primary migration pathways for inorganics at Landfill 4. Particulate transport and surface water runoff are also not likely to be significant migration pathways due to the fact that the site is covered with vegetation. The lack of inorganics detected in downgradient groundwater also suggests that inorganics are not migrating. Although several inorganics were detected above MCLs in unfiltered samples, all were below MCLs in the filtered samples except for antimony. The antimony in filtered samples has been attributed to the filters used during sampling. Quarterly groundwater sampling performed by Montgomery Watson following the Follow-on RI confirm the lack of analytes at concentrations above MCLs (Montgomery Watson, 1996j).

Seven SVOCs were reported in samples from fill materials; the greatest concentration detected was 0.63 $\mu\text{g/g}$ of 4-cresol. All SVOC detections were contained in three samples of fill material; no pattern in the distribution of SVOCs was clearly discernible. It should be noted that one of the SVOCs detected, naphthalene, was detected at a concentration within the range reported for naturally occurring organic chemicals in soils (Dragun, 1988).

Most of the SVOCs detected above reporting limits were PAHs, which tend to sorb strongly to soils, and would therefore not be expected to migrate in unsaturated sediments, assuming small quantity releases. This is supported by data showing that no SVOCs were reported above the CRLs in any sample of native materials below fill. SVOCs were also not detected in downgradient groundwater.

Thirty-seven detections of pesticides were reported in samples of fill material in Landfill 4. Concentrations of pesticides in soils are plotted on Figures 9.3-13 through 9.3-17. The highest concentration detected in fill material was 5.74 $\mu\text{g/g}$ of chlordane. Most of the pesticides detected in fill materials would be expected to sorb to soils; thus, rapid migration in unsaturated soils would not be expected. This is supported by data from native materials below fill, from which only one of four samples was reported to contain pesticides; the highest concentration reported was 0.23 $\mu\text{g/g}$ of chlordane. It should be noted that this sample of native material was collected very close to the contact between fill and native materials. Also, the greatest depth at which pesticides were detected was 3.0 ft bgs. Pesticides were not detected in downgradient groundwater.

PCBs were detected in one sample of fill and two samples of native sand below fill. All three detections were less than three times the CRL. Also, the three samples are not grouped closely together and other samples in the area did not contain PCBs, suggesting that the detections are isolated and that the volume of soil potentially affected is small. Potential for migration of PCBs from the site is limited because PCBs tend to sorb to soils. Downgradient groundwater did not contain PCBs.

Analyses for TPH were performed on two samples from Boring LF4SB03 in Landfill 4. TPH-D was reported above the CRL at 210 $\mu\text{g/g}$ in the shallow sample, and 2.00 $\mu\text{g/g}$ in the deeper sample. Chromatograms from the two samples were quite dissimilar, suggesting that

the source(s) of the petroleum hydrocarbons detected may not be the same for both samples. Also, comparison of sample chromatograms with standard chromatograms for a variety of petroleum hydrocarbons revealed no distinct similarities. Because the TPH-D method used is non-specific, the possibility exists that the TPH-D detections are a function of naturally occurring organic matter in the range of C₈ - C₃₂. TPH was not detected in downgradient groundwater.

9.3.5.2 Fill Site 5 Results Evaluation

Inorganics were detected above ambient values in only four of the twelve samples collected at Fill Site 5. Three of these samples were collected from borings (LF5SO01, LF5SO02, and LF5SO03) which encountered only native Colma and Franciscan Formation deposits. Fill material was not identified in these borings, therefore, fill material at Fill Site 5 is not believed to be the source of elevated inorganic concentrations in these samples. Inorganics detected above ambient Colma levels in these samples include aluminum, barium, chromium, cobalt, iron, manganese, mercury, nickel, and vanadium. Because the detections of these analytes do not appear to be associated with fill material, these analytes are not considered soil COPCs at Fill Site 5. Inorganic concentrations in soil are posted on Figures 9.3-18 through 9.3-23.

The fourth sample containing ambient exceedences was collected from fill material in Test Pit LF5TP04. Landfill material was not identified in this boring, however, the fill material was noted as containing gravel, and silty clay. Since landfill material or other potential sources were not identified adjacent to the sample, the source of these inorganics is not known and may be representative of ambient conditions. Inorganics detected above ambient fill concentrations include: aluminum, beryllium, iron, manganese, and vanadium. These analytes were detected at concentrations only slightly above ambient levels, within the range of concentrations typical for other PSF and regional soils, therefore, inorganics are not considered soil COPCs at Fill Site 5.

Two detections of SVOCs were reported in soil samples from Fill Site 5. The maximum concentration reported was 6.00 µg/g of di-n-butyl phthalate. Both SVOCs have been reported as naturally occurring either at or slightly below the detected concentrations (Dragun, 1988). The fact that each compound was detected only once, at low levels,

indicates that their distribution is limited and the volume of potentially affected soil is probably small.

Eleven different pesticides were detected a total of 13 times in surface and subsurface samples of fill material. There were no detections of pesticides in native materials beneath fill materials, indicating that these compounds have not migrated downward from surficial and/or fill materials. Concentrations of several pesticides are shown on Figures 9.24 through 9.3-26.

9.3.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Landfill 4 and Fill Site 5 Areas, including the risk assessment results, as presented in detail in Section 15.

9.3.6.1 Conclusions

The potential source(s) of contamination at Landfill 4 and Fill Site 5 are debris fill and/or landfill materials deposited during use of the sites. Surface and subsurface soils, and downgradient groundwater were analyzed to evaluate the distribution of target analytes at Landfill 4. At Fill Site 5, surface and subsurface soil were analyzed.

In Landfill 4, pesticides, PCBs, and TPH-D were detected in native materials beneath fill; in general the number of detections and concentrations decreased with depth. Groundwater downgradient of Landfill 4 does not show any impact associated with the fill material. In the Fill Site 5 area, inorganics and TPH-D were reported in native materials.

Soil COPCs identified for Landfill 4 include all detected organics and the inorganics antimony, lead, and mercury. Groundwater COPCs include all detected target analytes.

For Fill Site 5, soil COPCs include all detected organics. Inorganics were not identified as COPCs.

9.3.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Landfill 4 and Fill Site 5 Areas are summarized in the following sections.

9.3.6.2.1 Human Health

The GMPA identified open space (recreational) as the future use of both Landfill 4 and Fill Site 5. Under this scenario, the human health risk assessment evaluates only exposure to COPCs present in surface soil from 0.0 to less than 0.5 ft bgs. COPCs present in soil at Landfill 4 and at Fill Site 5 at depths less than 0.5 ft bgs include all detected organics.

A residential PRG ratio screening assessment for surface and subsurface soil was performed as a preliminary assessment of a residential scenario at both Landfill 4 and Fill Site 5. A residential PRG ratio screening assessment of groundwater at Landfill 4 was also assessed. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with both Landfill 4 and Fill Site 5 are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead screening values, are identified.

9.3.6.2.1.1 Quantification of Cancer Risks

Delta-BHC and isodrin were the COCs determined following the COPC screening in the surface soil at Landfill 4. A recreational visitor scenario with exposure to surface soil via ingestion and dermal contact resulted in a total risk of 4E-08, which indicates that exposure

to the COCs is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in total cancer risk greater than $1E-06$.

At Fill Site 5, no analytes remained COCs following the COPC screening. Therefore, it is unlikely that exposure to surface soil to recreational visitors at this sites will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

9.3.6.2.1.2 Quantification of Noncarcinogenic Effects

At Landfill 4, the hazard index is less than $1E+00$ and, therefore, it is unlikely that exposure to media at this site to the future recreational visitors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in a total hazard index less than $1E+00$ for Fill Site 5 and greater than $1E+00$ for Landfill 4.

9.3.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft at Landfill 4 and at Fill Site 5. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and invertebrates were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

For Landfill 4, soil COPCs evaluated in the ecological risk assessment include lead, 4-methylphenol, and several OCPs. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 based on the TBVLow .
- HIs for the American robin and mourning dove, exceeded 1 based on the TBVHigh.
- Some HQs exceeded 100 based on comparison to TBVLow values. HQs based on the TBVHigh values were much lower (i.e., 10) for total exposure for the American robin.

The ecological risk assessment for Landfill 4 will be further evaluated to determine whether the results of the ERA warrant inclusion of the site into FS.

For Fill Site 5, soil COPCs evaluated in the ecological risk assessment include fluoranthene and several OCPs. Results of the risk assessment indicate the following:

- HQs for ppDDT for dietary ingestion exceed 1 for the American robin based on comparison to the TBVLow.
- There were no HQs or HIs that exceeded 1 for any receptor based on comparison to TBVHigh values.

The only risk driver for the American robin is ppDDT exposure via the diet. In addition, the dietary pathway is conservative in that risks are more likely to be over-estimated than under-estimated. While some isolated individual birds may experience adverse effects, the populations do not appear at risk. This site is not warranted for further evaluation in the FS from the standpoint of ecological risk.

9.4 FILL SITE 6

Fill Site 6 is located beneath a parking lot adjacent to the Enlisted Women's Barracks (Building 1028) in the northeastern portion of the PSF (Figure 1.2-1). Fill Site 6 is reported to contain building debris from the demolition of the original LAMC, which was demolished in 1975. During construction of the parking lot in the 1980s, building debris was discovered. Documentation regarding the types and amounts of material deposited at Fill Site 6 were not available, therefore, the site was investigated during the RI to determine the type and extent of fill, and if any adverse impacts to the environment have resulted due to its presence. The site is currently used as a parking lot.

9.4.1 Area Description

This following sections describe the location and physical features, and history and land use of Fill Site 6.

9.4.1.1 Location and Physical Features

Fill Site 6 is located beneath a parking lot adjacent to the Enlisted Women's Barracks (Building 1028) in the northeastern portion of the PSF (Figure 1.2-1). The topography ranges from approximately 25 to 40 ft-PLL (Figure 9.4-1). Torney Avenue, Gen. Kennedy Avenue, Edie Road, and Girard Road surround the landfill. Pavement covers the entire area and a variety of underground utilities are present. Surface runoff is controlled by a storm drain network that empties into San Francisco Bay.

9.4.1.2 History and Land Use

Fill Site 6 is reported to contain building debris from the demolition of the original LAMC, which was demolished in 1975. There are no reports of hazardous debris being placed in this fill area; however, asbestos is expected to be present in the building debris (ANL, 1989). Neither aerial photographs from this period nor other documentation on the nature of the fill material were available. The first time the parking lot, which still covers the site, is visible in available aerial photos is 1988 (Ringden and Sitton, 1990).

9.4.2 Sample Location Rationale

This section describes the sample location rationale for samples collected at Fill Site 6. As described in the conceptual model (Section 3.1), debris fill material is a potential primary source of contamination. Primary release mechanisms are limited at Fill Site 6, due to the inactive status of the site and the asphalt cap, which essentially isolates the debris fill materials from the surface environment. Contaminants in fill materials could infiltrate through the soil column beneath the fill if a water source such as a leaky water line were beneath the asphalt cap. Soil samples were collected for lithology descriptions and chemical analysis to evaluate the debris fill material as a potential source of contaminants. Discrete groundwater samples were collected at the site to evaluate the potential for secondary releases to the groundwater.

9.4.3 Geologic Setting

The soils at the Fill Site 6 are classified as urban land (Kashiwagi and Hokholt, 1985). Subsurface exploration at the site consisted of 26 soil borings, four of which were logged by CPT in conjunction with the collection of discrete groundwater samples. Geophysical studies included a resistivity survey; however, this survey did not further define fill boundaries due to a lack of contrast between fill and native materials. Sample locations are shown on Figure 9.4-1, boring logs are located in Appendix G.6, and geophysical data are in Appendix N.

Cross sections A-A' and B-B' (Figures 9.4-2 and 9.4-3) show stratigraphic relationships determined from the soil borings at the site. Below pavement or surface soils, debris fill was found to overlie native deposits interpreted as belonging to the Colma Formation. Debris fill materials are described in field logs as containing wood, brick, concrete, ceramic tiles, and asphalt roofing materials, with a maximum encountered thickness of approximately 7 ft. The Colma deposits were described as clayey silty sand to well sorted sand with minor clay layers. Bedrock, not encountered in any of the soil borings, is estimated to occur at 175 ft bgs based on the regional structure contour map of bedrock (Figure 2.3-4).

Depth to groundwater during drilling was approximately 23 ft bgs in Boring LF6SO01 in November 1990. In November 1994, the water table was encountered during Follow-on RI drilling at approximately 7.5 ft bgs in Boring LF6SB10 and 12 ft bgs in Boring LF6SB07. While the depth to water was not measured in the same location from one field program to the next, it is apparent that the water table rose significantly over the two year period. The change is likely due to the heavy rainfall during the period preceding the Follow-on RI. The water levels in Borings LF6SB10 and LF6SB07, in conjunction with regional groundwater flow data (Figure 2.3-2), suggest the primary groundwater flow direction is to the north, with a gradient on the order of 0.025.

Estimated well yields for Fill Site 6 were not calculated due to the lack of monitoring wells, however, based on the regional potentiometric surface map (Figure 2.3-2), it is likely that the 200 gpd criteria for establishing a drinking water supply would be met in this area.

Isopachs of debris fill thickness in Fill Site 6 are presented in Figure 9.4-4. Fill thickness determinations were based on subsurface investigations and stratigraphic interpretations

shown in cross sections A-A' and B-B'. Based on isopachs in Figure 9.4-4, the volume of debris in Fill Site 6 is estimated to be 7,672 yd³.

During drilling at Fill Site 6, a PID was used to determine the presence of landfill gasses. The highest PID reading recorded was 0.05 ppm.

9.4.4 Analytical Results

Fill Site 6 was used for disposal of debris from a building demolished and buried on location. Three soil borings were drilled and six subsurface soil samples collected during the Initial RI. During the Follow-on RI, three soil samples were collected from each of seven soil borings, and discrete groundwater samples were collected at four locations. This section includes a summary of sample locations, analyses performed, and the analytical results from the two sampling programs.

9.4.4.1 Soil Sampling Results

During the Initial RI, three borings were drilled throughout the center of the parking lot that covers the site. Two samples were collected from each boring. The shallow sample in each boring was comprised of fill material. The deep samples were from native Colma Formation material below fill. All samples were analyzed for inorganics, VOCs, and SVOCs.

Detections of target analytes above the CRLs or RLs are presented in Table 9.4-1. Inorganic target analytes were detected above the CRLs in all samples. Inorganics were not detected above ambient fill values in any of the fill samples. In the underlying native material, chromium and vanadium were detected at concentrations slightly above ambient values. Two VOCs were detected above the CRL. 1,1,1-trichloroethane and trichlorofluoromethane were detected in the deep sample from Boring LF6S003. VOCs were not detected in any of the fill samples. Trichlorofluoromethane was also detected in the shallow sample. SVOCs were not detected above the CRLs.

Additional samples were collected during the Follow-on RI to further assess the soil at the site and to evaluate the extent of the VOCs detected during the Initial RI. Three borings were drilled to the north of the initial boring locations, and three were drilled to the south. Soil samples were collected from each of these borings at approximately 3, 8, and 20 ft bgs. The

samples were analyzed for inorganics, TCE and its breakdown products, trichlorofluoromethane, PAHs, TPH-D, and TPH-G. All detections above the RLs are shown in Table 9.4-2. With the exception of the shallow samples from Boring LF6SB01 and LF6SB04, which consisted of fill material, all samples were collected from native Colma deposits below fill. Inorganics were not detected above ambient fill values in the fill samples. Cadmium was detected above ambient Colma values in several samples collected from the underlying native material. No other compounds were detected in these samples.

A seventh boring was drilled during the Follow-on RI for sample collection in the northeast portion of the parking lot. Samples were collected at 5.0, 20.0, and 43.5 ft bgs and analyzed for TOC. The results of this analysis are presented in Table 9.4-3. TOC concentrations ranged from 123 to 268 $\mu\text{g/g}$.

9.4.4.2 Discrete Groundwater Sampling Results

Follow-on RI sampling included the collection of discrete groundwater samples at four locations, Borings LF6SB08 through LF6SB11. Three of the locations are at the assumed downgradient edge of the site, and one, Boring LF6SB10, is in the vicinity of LF6SO03. Samples were collected from two depths in Borings LF6SB09 and LF6SB11, and from one depth in LF6SB08 and LF6SB10. All samples were analyzed for inorganics, TCE and its breakdown products, trichlorofluoromethane, SVOCs, TPH-D, and TPH-G. Results are presented in Table 9.4-4. Inorganics detected at concentrations above MCLs include aluminum, arsenic, barium, beryllium, chromium, lead, and nickel. TCE and breakdown products were not detected. Two SVOCs were detected, however, the detections are the result of lab contamination. There were no detections of TPH-G above the RL, but there were two TPH-D detections: 250 $\mu\text{g/L}$ in the sample from LF6SB10 and 84 $\mu\text{g/L}$ in the shallow sample from Boring LF6SB11.

Unknown SVOCs totaling in excess of 100 $\mu\text{g/L}$ were detected in discrete groundwater samples from Borings LF6SB08, LF6SB09, LF6SB10, and LF6SB11.

9.4.5 Results Evaluation

The following section evaluates the results of sampling performed during the RI at Fill Site 6. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent, and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For sites containing fill material identification of sources is difficult due to the random distribution of source material within the fill.

For groundwater and surface water all detected analytes are considered COPCs. In the following discussions, detections of compounds are compared with California Primary and Secondary MCLs (Tables 3.8-2 and 3.8-5) to provide the reader with a frame of reference. If an analyte is present in surface or groundwater at concentrations above MCLs, the source, nature and extent, and fate and transport of the analyte are evaluated.

Due to the random distribution of source material in the fill, a random chemical distribution would also be expected. If source material in the fill is contributing chemicals, isolated hot spots within the fill would be likely. Depending on the nature of the chemicals present, these hot spots could migrate to the underlying native soil and groundwater. For the purpose of defining the extent of COPCs detected in fill material, the following sections will focus on the impact on the subsurface soil and groundwater rather than defining the extent of a particular chemical within the fill site.

As noted in Section 9.4.4, cadmium, chromium, and vanadium were the only inorganics detected in soil at concentrations above ambient values. All three exceedences occurred in samples of native Colma material below the fill and were not detected at concentrations above ambient levels within the fill material. Although all three analytes were above Colma ambient values in several samples, ambient levels were only slightly exceeded. Therefore, these analytes likely represent ambient conditions and are not considered soil COPCs. Concentrations of several inorganics are plotted on Figures 9.4-5 through 9.4-11.

In groundwater, numerous inorganics were detected above California Primary and Secondary MCLs, including aluminum, arsenic, barium, beryllium, chromium, iron, lead, manganese, and nickel. Concentrations of several inorganics in groundwater are plotted on Figures 9.4-12 through 9.4-16. As mentioned in the previous paragraph inorganics were not detected above ambient levels in soil samples collected from within the fill material. This suggests that the fill material at Fill Site 6 is not leaching inorganics into the underlying groundwater. Three inorganics were detected above Colma ambient levels in the underlying native Colma material, however, of these, only chromium was detected above the California Primary MCL in groundwater. The elevated concentrations of other inorganics are likely associated with sediment in the samples. As observed at other locations at the Presidio, sediment in unfiltered groundwater samples generally results in higher inorganic concentrations than in unfiltered samples where the sediment is removed (Section 3.7-5). At Fill Site 6, all discrete groundwater samples were unfiltered.

A potential source upgradient of Fill Site 6 is the LAMC/LAIR which is located to the southeast. Results of groundwater sampling performed at this location in 1995 also indicate the presence of several inorganics in groundwater at concentrations above MCLs (Appendix A). These include aluminum, total chromium, iron, manganese, and nickel, all of which were also present above MCLs in samples from the Fill Site 6 area. The presence of these analytes in upgradient groundwater supports the conclusion that fill material at Fill Site 6 is not impacting the underlying groundwater. Other analytes detected above MCLs in the LAMC/LAIR samples include TDS and the SVOC bis(2-ethylhexyl)phthalate. TDS was not analyzed in the RI sampling at Fill Site 6. Bis(2-ethylhexyl)phthalate was detected in the groundwater samples from Fill Site 6.

Two VOCs were detected in Initial RI subsurface soil samples; 1,1,1-trichloroethane was detected once and trichlorofluoromethane was detected twice. A duplicate sample did not confirm the detection of 1,1-trichloroethane. There were no detections of organic target analytes in Follow-on RI soil samples, all but two of which were collected from native deposits. VOCs were not detected in groundwater. TPH-D was not detected in any soil samples at the site.

9.4.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Fill Site 6 Area, including the risk assessment results, as presented in detail in Section 15.

9.4.6.1 Conclusions

The primary source of contamination at Fill Site 6 is debris fill and artificial fill materials from demolition of the original LAMC. Subsurface soils and groundwater were analyzed to evaluate the distribution of target analytes at the site.

Only inorganic and VOC target analytes were detected in samples of native materials below fill. Concentrations of inorganic analytes generally decreased with depth, with the exception of silver, which was similar in both fill and native material. Two VOCs were detected in native material samples collected during the Initial RI. The detections of these compounds were not confirmed in other samples collected at the site, and were not detected in groundwater. Based on these results, fill material at Fill Site 6 has not had a significant impact on underlying soils or groundwater.

Soil COPCs for Fill Site 6 include all detected organics.

9.4.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, all detected analytes in groundwater were evaluated for the human health risk assessment. Because no COPCs were identified in soil within the 0 to 3 ft-bgs depth interval, an ecological risk assessment was not performed for this site.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The human health evaluation for the Fill Site 6 Area is summarized in the following sections.

The GMPA identified institutional (industrial) as the future land use at Fill Site 6. Under this scenario, subsurface soil at depths between 0.5 and 15 ft bgs, and all detected analytes in groundwater are evaluated.

In addition to the future land use scenario evaluated for Fill Site 6, a residential PRG ratio screening assessment for groundwater was performed as a preliminary assessment of a residential scenario. A PRG ratio screening assessment for subsurface soil could not be performed since COPCs were not identified in this media. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A $1E-06$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with Fill Site 6 are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead screening values, are identified.

9.4.6.2.1 Carcinogenic Risk

Fill Site 6 had no analytes determined as COCs following the COPC screening in the subsurface soil samples. Therefore, it is unlikely that exposure to soil to institutional workers at Fill Site 6 will result in an excess cancer risk. When groundwater was assumed to be the water source, nine inorganics were determined to be COCs. An institutional worker scenario with ingestion of groundwater as water in addition to the PSF water supply resulted in a total cancer risk of $3E-03$ from ingestion of the inorganics chromium (assumed to be 100% hexavalent chromium), arsenic, and beryllium from the groundwater. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

9.4.6.2.2 Non-carcinogenic Risk

At Fill Site 6, all inorganic COCs except barium, beryllium, and silver resulted in hazard indices greater than 1E+00 for the industrial worker from ingestion of groundwater as a water source. This indicates that the groundwater is not a good source for municipal water at Fill Site 6.

9.5 GRADED AREA 9

Graded Area 9, located in the southwestern portion of the PSF, was reportedly a low area which was filled and graded to create a flat surface for a soccer field. Backfilling and grading have occurred sporadically since 1958, as determined from aerial photos.

9.5.1 Area Description

This section describes Graded Area 9, including the location and physical features, and history and land use.

9.5.1.1 Location and Physical Features

Graded Area 9 is situated in the southwestern corner of the PSF, northwest of the former PHS complex (Figure 1.2-1). The graded area is bordered to the north by trees and the west by enlisted family housing (Figure 9.5-1). Wedemeyer Street bounds the area to the east, and the area to the south is covered by trees and grasses. The topographic relief ranges from approximately 220 to 240 ft-PLL. The land surface in the area slopes to the south, except in the area comprising Graded Area 9. Dirt and gravel with sparse grass cover the surface of the study area. There is no storm drainage system in the area; any surface-water runoff from the area would flow overland to the south-southwest.

9.5.1.2 History and Land Use

According to the Enhanced PA clean fill and building rubble were deposited at Graded Area 9 (ANL, 1989). The graded area was reportedly created by depositing fill materials over the edge of an embankment to create a flat surface for recreation. The exact dates that filling occurred are unknown; however, the cleared area at Graded Area 9 appears in aerial photos as early as 1958 (Pacific Aerial Surveys, 1958).

9.5.2 Sample Location Rationale

This section describes the sample location rationale for samples collected during the RI at Graded Area 9. In the conceptual model (Section 3.1), fill material deposited within Graded Area 9 is a potential primary source of contamination. Potential release mechanisms associated with this site would include contaminant transport in surface-water runoff, and infiltration of contaminants through the soil column. Test pits were dug and samples of fill materials were collected for chemical analysis to evaluate the potential for contaminant transport by surface-water runoff or infiltration into the soil column.

SVOCs were detected in Test Pit LF9TP03 from samples collected during the Initial RI. A soil boring was drilled in the vicinity of Test Pit LF9TP03 during the Supplemental RI to confirm whether SVOC detections are related to surface activities, and whether they are migrating down to soils beneath fill materials.

9.5.3 Geologic Setting

The surficial soils at Graded Area 9 are classified as Sirdrak sand (Kashiwagi and Hokholt, 1985). Three test pits were excavated at Landfill 9 during the Initial RI, and one boring was drilled during the Supplemental RI (Figure 9.5-1). All field logs are in Appendix G.7. Test Pit LF9TP01 contained approximately 7 ft of debris fill, and the upper 1 to 2 ft of Test Pits LF9TP02 and LF9TP03 consisted of debris fill. Fill materials were described in field logs as wood, gravels and cobbles. Dune sand was encountered below the fill in all test pits. Bedrock was not encountered. Resistivity and EM geophysical surveys were completed at the site. These surveys did not further delineate the extent of fill as determined from subsurface exploration and air photo interpretation. Geophysical data are located in Appendix N.

Fill thickness determinations were based on subsurface investigations and stratigraphic interpretations shown in cross section A-A' (Figure 9.5-2). Fill materials appear to be thickest in the southwestern portion of the site, thinning rapidly to the east, north, and south. Fill material thickness in Graded Area 9 ranged from approximately 1 ft to 7 ft. The volume of debris fill at Graded Area 9 is estimated to be 2,110 yd³. Isopachs of debris fill in Graded Area 9 are presented in Figure 9.5-3.

During subsurface exploration at Graded Area 9, a PID was used to determine the presence of landfill gasses. The highest PID reading recorded was 20 ppm.

9.5.4 Analytical Results

This section summarizes the sample locations, analyses performed, and the analytical results from the two sampling programs at Graded Area 9. Fill materials were placed in Graded Area 9 to provide a level surface for recreation. Fill material samples from test pits were collected and analyzed during the Initial RI; additional samples were collected from a soil boring during the Supplemental RI.

Samples of fill material were collected from test pits during the Initial RI and analyzed for inorganics, VOCs, and SVOCs. Detections of target analytes above the CRLs are shown in Table 9.5-1. Inorganic analytes were detected in all samples, with aluminum, beryllium, iron, and vanadium detected above ambient fill values in at least one sample. VOCs were not detected above the CRLs. SVOCs were detected above the CRLs only in Test Pit LF9TP03, where six SVOCs were detected at a depth of approximately 1 ft bgs.

During the Supplemental RI, Boring LF9SB01 was drilled in the vicinity of Test Pit LF9TP03 to confirm the SVOC detections. Samples were collected at depths of 1.0 and 4.0 ft bgs and analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. Detections of target analytes above the CRLs or MDLs in soil boring samples are presented in Table 9.5-2. Inorganic analytes were detected in both samples. The sample at 1 ft bgs was in fill material. The sample at 4.0 ft bgs was in sand. Inorganic target analytes were not detected above ambient levels in either sample. VOCs were not detected in either sample. Two SVOCs were detected above the CRLs in the sample consisting of fill material. The greatest concentration was 0.480 $\mu\text{g/g}$ of bis(2-ethylhexyl)phthalate. SVOCs were not detected in the underlying native material. Two OCPs were each detected once above the CRLs. Dieldrin was detected at a concentration of 0.40 $\mu\text{g/g}$ in the fill sample, and ppDDT was detected at a concentration of 0.005 $\mu\text{g/g}$ in the native material sample. PCBs and chlorinated herbicides were not detected. TPH-D was detected in both samples; the highest concentration was 50 $\mu\text{g/g}$.

9.5.5 Results Evaluation

The following section evaluates the results of sampling performed during the RI at Graded Area 9. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent, and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For sites containing fill material identification of sources is difficult due to the random distribution of source material within the fill.

Graded Area 9 was a low area that was filled with artificial and debris fill to create a level surface for recreation. The area contains 1 to 7 ft of artificial/debris fill, underlain by dune sand. Sparse vegetation covers the dirt and gravel surface. Within the context of the conceptual model (Section 3.1), the debris fill is a potential primary source of contamination.

Inorganics detected above ambient levels in samples from fill materials include aluminum, beryllium, iron, and vanadium. Aluminum and vanadium are considered soil COPCs, however, beryllium and iron were detected at concentrations only slightly above ambient fill levels and are not considered soil COPCs. The concentrations of beryllium and iron, although higher than fill ambient levels, were lower than ambient levels for other soil types such as serpentinite. Since serpentinite gravel is present throughout the fill material at Graded Area 9, the presence of these analytes is believed to represent ambient conditions. Inorganics were not detected above ambient values in the underlying native material.

SVOCs were detected in the Initial RI, prompting the drilling of Boring LF9SB01 during the Supplemental RI. Results of the chemical analysis of soil samples collected from this boring confirmed the presence of one SVOC in the fill material; there were no detections of SVOCs in the sample collected from native material beneath the fill. The SVOC bis(2-ethylhexyl)phthalate, detected in one soil sample, was also detected in the laboratory blank and is considered a laboratory contaminant. Two OCPs were detected in the Supplemental RI soil boring samples. The pesticide dieldrin was detected in the shallow sample from fill material, and ppDDT was detected in the deep sample from native materials below fill. ppDDT was detected in a background surface soil sample at a concentration of 0.020 µg/g.

TPH-D was detected in both samples from Boring LF9SB01. The concentration is greater in the shallow sample, collected from fill materials.

Four chemical groups were detected in fill materials from Graded Area 9; these are inorganics, SVOCs, OCPs, and TPH-D. Only one OCP and TPH-D were detected in native soil. The inorganics, SVOCs, and OCPs detected generally have a strong affinity to soils and would not be expected to be readily transported by infiltration of surface water; this is reflected in the lack of detections in native materials beneath fill material. TPH-D represents the heavier, and therefore, less mobile range of the petroleum compounds. This limited mobility is demonstrated by the decreased concentrations at depth.

9.5.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for Graded Area 9, including the risk assessment results, as presented in detail in Section 15.

9.5.6.1 Conclusions

The primary source of contamination at Graded Area 9 is debris fill deposited during leveling of the site. Subsurface soils were analyzed to evaluate the distribution of target analytes at the site.

The lateral and vertical extent of target analytes is sporadic and generally appears to be limited to fill materials. Inorganics were not detected above ambient values in the underlying native material. No VOCs, SVOCs, PCBs, or chlorinated pesticides were reported from a

sample of native material below fill. ppDDT was reported in native material below fill, but was not detected in the overlying fill material. TPH-D was reported in both fill and native materials; concentrations of TPH-D decreased with depth. Based on the results of RI sampling at Graded Area 9, debris fill material does not appear to be impacting the underlying native soils.

Soil COPCs identified for Graded Area 9 include all detected organics and the inorganics aluminum and vanadium.

9.5.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. The human health and ecological evaluations for Graded Area 9 are summarized in the following sections.

9.5.6.2.1 Human Health

The GMPA identified open space (recreational) as the future land use for Graded Area 9. Under this scenario, only exposure to surface soil from 0.0 to less than 0.5 ft bgs is evaluated. Since only subsurface soil was analyzed at Graded Area 9 the open space scenario was not assessed.

A residential PRG ratio screening assessment for subsurface soil was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A $1E-06$ cancer risk represents a one in one

million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ >1E+00, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with Graded Area 9 are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

9.5.6.2.1.1 Carcinogenic Risks

Only subsurface soil was sampled at Graded Area 9. There is no complete pathway to these samples for the recreational visitors at Graded Area 9 and, therefore, no quantitative HHRA assessment was performed for the future land use scenario. The residential PRG ratio screening assessment resulted in a total cancer risk greater than 1E-06.

9.5.6.2.1.2 Non-carcinogenic Risks

The residential PRG ratio screening assessment resulted in a total hazard index less than 1E+00 for Graded Area 9.

9.5.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft at Graded Area 9. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and invertebrates were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs evaluated in the ecological risk assessment include aluminum, vanadium, bis(2-ethylhexyl)phthalate, PAHs, dieldrin, and TPH-D. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna exceeded 1 based on the TBV_{Low} and the TBV_{High} .
- HQs for aluminum and vanadium in soil exceeded 1 for the American robin, mourning dove, western harvest mouse, pocket gopher, plants and soil fauna based on a comparison of exposure to the conservative TBV_{Low} .
- The HQ for dieldrin for the American robin dietary ingestion pathway exceeded 1 based on the TBV_{Low} , but not the TBV_{High} .
- The remaining receptors and exposure pathways evaluated did not indicate a potential for risk.

The ecological risk assessment for Graded Area 9 will be further evaluated to determine whether the results of the ERA warrant inclusion of this site into the FS.

9.6 LANDFILL E

Landfill E is situated in the east-central portion of the PSF. Examination of aerial photographs indicates that activity occurred at the site from approximately 1946 to 1965, and possibly until 1973.

9.6.1 Area Description

This section describes the area of Landfill E including the location and physical features, and history and land use.

9.6.1.1 Location and Physical Features

Landfill E, situated in the east-central portion of the PSF, is bounded on the northwest by Hicks Road and Barnard Avenue, on the north by Fernandez Street, and on the southeast by Quarry Road (Figure 1.2-1). Topographic relief ranges from 75 to 120 ft-PLL (Figure 9.6-1). The landfill area is generally flat and covered by grass; a large portion of the site is covered by a baseball field and parking area. There is a very slight slope to the north-northeast; the surrounding area also slopes to the northeast. The site is bounded to the west and south by a wooded hillside; trees and housing are located to the east. A steeply sloping valley wall forms the northern edge of the fill area, south of Fernandez Street. Any surface-water runoff from the site would drain to the northeast, toward Fernandez Street. There are no known USTs at the site; utilities in the area include sanitary sewer, irrigation, and overhead electric lines.

9.6.1.2 History and Land Use

Aerial photographs show that filling activity at Landfill E began before 1946 and ceased at some time between 1965 and 1973. Documentation of the nature of fill materials is not available. A building is visible on the northernmost portion of the site in photos from 1946 through 1955 (Rindgen and Sitton, 1990; Pacific Aerial Surveys, 1955). The building is no longer present in a 1959 photo (Rindgen and Sitton, 1990). The same photos show that a well-maintained road linked Landfill E with Landfill 2 from approximately 1946 until a time between 1968 (Pacific Aerial Surveys, 1968) and 1973 (Rindgen and Sitton, 1990), when

Quarry Road was built. Fill activities ceased prior to 1973, and a baseball field was built on the site (Rindgen and Sitton, 1990); the baseball field still occupies the site.

9.6.2 Sample Location Rationale

This section describes the sample location rationale for samples collected at Landfill E during the RI. Within the context of the conceptual model (Section 3.1), the debris fill and landfill materials at Landfill E are considered to be a potential primary source of contamination. The sampling program at Landfill E was designed to evaluate the presence and distribution of contaminants which may be present in fill materials. The areal and vertical extent and composition of fill materials was determined by describing the physical characteristics of samples collected from soil borings, well borings, and test pits.

Several media were sampled to identify potential release mechanisms for any contaminants present in fill material. Soil particles may be transported in surface-water runoff. Though topsoil and grass, which cover the fill material, would largely isolate fill material from runoff water, surface soil samples were collected to evaluate this transport mechanism. Target analytes in fill materials may infiltrate into the soil column beneath the fill and percolate downward to the water table. Samples were collected from fill materials for chemical analysis, and from native materials beneath the fill for evaluation of the extent to which chemicals may be infiltrating into underlying sediments. Groundwater samples were collected from wells in the area (where groundwater was present) to evaluate the potential for groundwater transport of target analytes.

9.6.3 Geologic Setting

Geologic outcrops in the area surrounding Landfill E are mapped as Quaternary Colma Formation by Schlocker (1974). Kashiwagi and Hokholt (1985) classified surficial soils in the area as Orthents associated with cut and fill.

Subsurface exploration for the RI was completed over the course of three field programs and consisted of trenching five test pits, drilling 24 soil borings, and completing three resistivity survey lines and an EM survey. Six of the 20 soil borings encountered groundwater and were completed as monitoring wells. All sample locations are shown in Figure 9.6-1, and field

logs and well construction details are presented in Appendix G. Geophysical data are presented in Appendix N.

The resistivity data did not add substantially to delineation of fill due to a lack of contrast between fill and native materials, and because thickness of fill deposits frequently exceeded the effective depth of the method. EM contours correspond approximately with the thickest contours of landfill material as determined from soil borings and cross section interpretation.

Cross sections A-A' and B-B' (Figures 9.6-2 and 9.6-3) show the relationship of the deposits in Landfill E. In general, fill materials were found overlying dune sand and clay, silt, and sand of the Colma Formation. Serpentine bedrock of the Franciscan Formation was encountered at depth in several borings.

The uppermost lithologic unit in the landfill area consists of debris fill with some areas of artificial fill. The artificial fill was probably deposited to level the ground surface after the termination of filling activities. Debris fill materials are described in field logs as glass, brick, tile, and other general construction debris. In the southeastern half of the site, debris fill is underlain by landfill materials described as newspaper, rubber syringe stoppers, cans, bottles, and plastic. Frequently, landfill materials had a black, nondescript appearance. Isopachs of debris fill and landfill material are shown in Figures 9.6-4 and 9.6-5, respectively. The greatest combined thickness of fill material (37.5 ft) was encountered in Boring DAEGW05. The greatest encountered thickness of landfill material was 28 ft in Boring DAESB08. The volume of debris fill is estimated to be 45,363 yd³, and there is an estimated 31,221 yd³ of landfill material.

Native materials below fill are interpreted to be Colma Formation deposits comprised predominantly of sand with some layers of silt and clay. At least 25 ft of Colma Formation separate fill deposits from the bedrock surface. Bedrock, described as serpentine, was encountered in Boring DAEGW02 and the borings for Wells DAEGW03, DAEGW05, and DAEGW06. Depth to bedrock ranged from approximately 40 ft bgs in DAEGW06 to 79 ft bgs in DAEGW05. Auger refusal occurred in Boring DAEGW01 at approximately 40 ft bgs in a unit described as claystone. This claystone is probably a relatively competent interval within the Colma Formation, and not bedrock. Using calculated elevations of bedrock

intercepts in Wells DAEGW02, DAEGW03, and DAEGW05, it was determined that, in the central portion of the landfill, the bedrock surface slopes to the northeast (approximately N 60° E), at <5°.

During subsurface exploration of Landfill E, a PID and CGI were used to determine the presence of landfill gasses. The highest PID reading recorded was 5500 ppm. LEL readings exceeded 100%.

9.6.4 Hydrogeology

This section provides a detailed account of the various hydrogeologic conditions at the site. The hydrogeology in the Landfill E area is more complicated than at the other fill sites and landfills. Over the course of the three RI field programs, a single, complex water-bearing unit was encountered. The upgradient, or southwest, portion of the aquifer is confined and consists of a clayey sand in the Colma Formation. The confining unit is absent downgradient in the central area of Landfill E as the groundwater flows into sand. Additionally, perched groundwater is present above the unconfined, downgradient portion of the aquifer.

The majority of the groundwater beneath the landfill sits atop bedrock in the sand and silty sand of the Colma Formation. During the Initial RI field work, borings were drilled as deep as 56.5 ft bgs without encountering groundwater. During the Supplemental RI, three borings drilled to similar or greater depths in other areas of the landfill did encounter groundwater, and three monitoring wells were installed. Two more wells were completed during the Follow-on RI. The screened intervals of these wells vary in their relationships to both bedrock and the water table. Comparisons of water level measurements to lithology suggest the groundwater is confined in the southwest corner of the site and unconfined farther downgradient. In addition, although not observed during the Follow-on RI, the lithology and subsequent COE water-level measurements for Well DAEGW08 suggest that groundwater near the northeastern area of the landfill is partially confined by a clayey sand. The upper confining unit in the southwest corner of the site is a clay layer that can be seen in the lithology for Well DAEGW06, possibly continuing as far northeast as Boring DAESB09 (Figure 9.6-2) but terminating before Well DAEGW03 (Appendix G.8). The high hydraulic head in Well DAEGW06 is likely due to the steep hill southwest of the site and the low

hydraulic conductivity of the water bearing unit, as evidenced by the well's slow recovery during development (Appendix G.8). Water-level fluctuations, likely to be seasonally related, have been observed in this well, with an initial water level measured in DAEGW06 approximately 18 ft lower than the March 1995 measurement. A similar low water level was observed in December 1995 during the COE's quarterly monitoring (Montgomery Watson, August 1996).

During the Follow-on RI, perched groundwater was encountered in the Colma Formation north of the site (Well DAEGW07) where a clay layer is present beneath a silty sand. The clay is approximately 5 ft thick, and a corresponding 15 ft thick clay was logged at Well DAEGW08. The clay apparently grades into a 12 ft thick layer of silt at Boring DAEGW02 and a 5 ft layer of silt at Well DAEGW05. The fine-grained deposits are not present at Well DAEGW03. Well DAEGW07 was installed in the silty sand with a screened interval from 3.5 to 7.5 ft bgs. The presence of this perched groundwater may be seasonal; however, it has been measured in subsequent rounds under the COE's quarterly monitoring program (Montgomery Watson, August 1996). The lateral extent of perched groundwater is uncertain, but given the proximity of Well DAEGW07 to the landfill boundary, it can be assumed that it extends into the debris fill. A corresponding sand layer encountered in the boring for Well DAEGW08 was not saturated during drilling, perhaps indicating an eastern limit to the groundwater in this unit.

The potentiometric surface of the unconfined portion of the aquifer in October 1992, is presented on Figure 9.6-6. Figure 9.6-7 shows the potentiometric surface, both confined and unconfined, in March, 1995. The exact location of the transition from confined to unconfined conditions is uncertain, and these figures do not contour the perched groundwater. Depth to non-perched water is a minimum of 20 ft below the base of fill material. The flow direction inferred from the October 1992 data (Figure 9.6-6) is approximately N 10° E, toward Fernandez Street, and the gradient is approximately 0.006. This flow direction diverges from the calculated direction of dip of the bedrock surface by approximately 50° to the north, and the gradient of the water table surface is substantially flatter than the calculated gradient of the bedrock surface. In March, 1995, the water table was nearly 5 ft higher, and while the gradient in the unconfined zone is still only about 0.01, the flow direction is approximately N

60° E. It is most likely that the change in inferred flow direction is due to the additional data point (DAEGW08), rather than the higher water table. These observations suggest that groundwater flow beneath the site is controlled by the bedrock surface, but not as strongly as in the Fill Site 1 and Landfill 2 sites. The gradient in the confined portion of the aquifer is approximately 2.2 ft/ft.

Estimated well yields for Landfill E are included in Section 2.3.5.3. Results of individual well yield calculations are shown on Table 2.3-2. The results indicate an average estimated yield of 268 gpd (Table 2.3-3). Although these results are approximate relative to more comprehensive testing techniques, the results indicate that the yield at Landfill E does meet the 200 gpd requirement for a drinking water supply as specified in California Resolution 89-39.

9.6.5 Analytical Results

Potential contaminant sources at Landfill E are debris fill and/or landfill material disposed of while the site was active. Surface soil, subsurface soil, and groundwater samples were collected to evaluate the impacts of these materials. Sampling was conducted over the course of all three RI field programs and in conjunction with the Feasibility Study which will be published as a separate report. This section summarizes sample locations, analyses performed, and analytical results.

9.6.5.1 Soil Sampling Results

To investigate potential surface soil contamination at Landfill E, one surface soil sample was collected during the Supplemental RI (0.0 ft bgs sample from Boring DAEGW04), and analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated pesticides, and TPH. All detections above the CRLs are included in Table 9.6-1. The sample was composed of topsoil. Inorganics were not detected above Colma ambient values. One VOC, toluene, was detected at a concentration of 0.007 µg/g. No SVOCs were reported above the CRLs. Three OCPs were reported above the MDLs; the highest concentration was 0.005 µg/g of endrin aldehyde. PCBs and chlorinated herbicides were not reported above the MDLs. TPH-D was reported at 6.00 µg/g.

During the Follow-on RI, five additional surface soil samples were collected (0.0 ft bgs sample from Boring DAESB17 and surface soil samples DAESS01 through DAESS04). A subsurface sample was also collected at 3.5 ft bgs from Boring DAESB17. The samples were from throughout the central portion of the landfill, with one sample collected in the vicinity of the baseball field. All samples were collected from debris fill and analyzed for inorganics, VOCs, SVOCs, OCPs, chlorinated herbicides, TPH-D, and TPH-G. All detections above CRLs or RLs are presented in Table 9.6-2. Numerous inorganics were detected in all samples, however, ambient fill values were only exceeded in two samples. Mercury and silver were detected above ambient fill levels in Sample DAESS01, and zinc was detected above the ambient value in Sample DAESS04. VOCs and SVOCs were not detected in any samples. Two OCPs, ppDDE and ppDDT, were detected in the Sample DAESS01. Chlorinated herbicides, TPH-D, and TPH-G were not detected in any samples.

To investigate subsurface soils at Landfill E, four test pits were excavated during the Initial RI field program. One sample was collected from each test pit and analyzed for inorganics, VOCs, and SVOCs. All detections above the CRLs are shown in Table 9.6-3. All samples were composed of fill material. Inorganics detected above ambient fill values include barium, copper, lead, mercury, silver, and zinc. Lead was detected at an order of magnitude above ambient values in the sample from Test Pit DAETP04. VOCs were not detected in any of the four samples. Seven SVOC target analytes were detected, with a total of seven detections in the four samples. Five of the seven detections were in a sample in which the holding time for analysis was exceeded; these results are provided for comparison only. One of the SVOCs detected was endrin aldehyde, a breakdown product of the pesticide endrin, which was detected once at a concentration of 3.6 $\mu\text{g/g}$. This detection was confirmed using a second-column confirmation.

Additional subsurface soil samples were collected from six borings during the Supplemental RI. Two samples were collected from each boring, one in fill material and one in native material below fill. Boring DAEGW04 was drilled adjacent to the landfill. The shallow sample from this boring was a surface soil sample. Results for this sample were discussed above. The deep sample from this boring was from native material. Fill material was not encountered in this boring. All samples were analyzed for inorganics, VOCs, SVOCs, OCPs,

PCBs, chlorinated herbicides, and TPH. All detections above the CRLs or MDLs are shown on Table 9.6-1.

Inorganics detected above ambient values in samples consisting of fill material include arsenic, barium, beryllium, cadmium, cobalt, copper, iron, lead, mercury, selenium, silver, zinc, and vanadium. Concentrations of lead ranged from 1,400 to 8,200 $\mu\text{g/g}$. The concentrations of inorganics in samples from underlying native material were generally lower, with only beryllium, cadmium, cobalt, chromium, nickel, and selenium detected above Colma ambient values.

Five VOCs were detected in the 11 samples, with a total of 10 VOC detections for all samples. VOCs detected include acetone, benzene, MEK, toluene, and trichlorofluoromethane. VOCs were not detected in any of the underlying native samples. Sixteen SVOCs were detected, with a total of 28 SVOC detections. All SVOC detections were reported from four samples; seven of the samples had no SVOC detections. SVOCs were not detected in the underlying native soil. Eleven detections of seven OCPs were reported; the highest concentration was 0.026 $\mu\text{g/g}$ of ppDDD in a sample of landfill material. None of these detections were samples from native material. The PCB Aroclor 1254 was detected twice at the CRL of 0.082 $\mu\text{g/g}$ from two samples from the same boring. No chlorinated herbicides were reported above the MDL. TPH-G was not reported above the CRL. TPH-D was reported above the CRL in 10 of 11 samples, at a highest concentration of 38.0 $\mu\text{g/g}$.

Supplemental samples of fill materials in Borings DAESB01 and DAESB04 were analyzed using the WET test for chromium, nickel, and lead. Chromium was detected in both samples, at concentrations of 0.87 and 0.62 mg/L, respectively. Nickel was detected in Boring DAESB01 at 1.1 mg/L, and in DAESB04 at 1.3 mg/L. Lead was detected at 72.0 and 26.0 mg/L in DAESB01 and DAESB04, respectively. Analytical results for STLC analyses are presented in Appendix O.

During the feasibility study, samples were collected from three borings in the central portion of the landfill. Samples were collected at approximately 10 and 16 ft bgs in each boring and consist of either debris fill (DAESB07) or landfill material (DAESB06 and DAESB08). All

samples were analyzed for inorganics, organic lead, and diesel and gasoline fractions of TPH. All results are presented in Table 9.6-4. Each sample contained detectable concentrations of several inorganics. Inorganics were not detected above ambient fill values in either of the samples from Boring DAESB07, which contained debris fill material. Inorganics detected above ambient fill values in samples from landfill material include antimony, barium, cadmium, copper, iron, lead, mercury, vanadium, and zinc. Lead concentrations in landfill material samples ranged from 450 to 5,300 $\mu\text{g/g}$. Organic lead detections ranged from 0.26 $\mu\text{g/g}$ in DAESB07 to 7.3 $\mu\text{g/g}$ in DAESB08. TPH-G was detected twice, with a maximum concentration of 3.5 $\mu\text{g/g}$. TPH-D was detected in each sample, at concentrations between 1.3 and 150 $\mu\text{g/g}$.

Additional soil sampling was performed during the Follow-on RI to further assess the extent of lead concentrations above the SDC. Eleven samples of fill material were collected from seven borings, at depths of either 10.0 or 18.0 ft bgs. Borings were typically located adjacent to or surrounding previous test pits and soil borings. All samples were analyzed for lead, and the results are shown in Table 9.6-5. Lead was detectable in all but two of the samples. Detected concentrations ranged from 33.6 $\mu\text{g/g}$ to 6200 $\mu\text{g/g}$, and the ambient fill value was exceeded in five of the samples. The samples from Boring DAESB14 were also analyzed for TOC, and these results are included in Table 9.6-5.

Eight to 10 unknown VOCs were identified in samples from Borings DAESB01, DAESB02, DAESB03 and DAESB04. In each case the unknowns summed greater than 100 $\mu\text{g/g}$ for each sample. One sample from DAETP04 identified 43 unknown SVOC hydrocarbons, totaling in excess of 100 $\mu\text{g/g}$. A groundwater sample from DAEGW04 identified two unknown SVOCs, totaling 109 $\mu\text{g/L}$.

9.6.5.2 Groundwater Sampling Results

Groundwater samples were collected at Landfill E during the Supplemental and Follow-on RI field programs. Supplemental samples were collected from Wells DAEGW03 through DAEGW05. These wells were sampled again during the Follow-on RI, along with three new wells, DAEGW06 through DAEGW08. Supplemental samples were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, TPH-D, and TPH-G. The analytical suite for the Follow-on RI samples was expanded to include both

filtered and unfiltered metals, and the samples from Well DAEGW06 through DAEGW08 were also analyzed for filtered and unfiltered chromium VI.

Detections above CRLs and RLs for the Supplemental RI samples are presented in Table 9.6-6. Eighteen inorganic analytes and miscellaneous parameters were reported above CRLs in the three groundwater samples. Of these, manganese and TDS were reported at concentrations above California Secondary MCLs (recommended Secondary MCL for TDS) in all three samples. All other reported detections were either below MCLs, or were for chemicals for which MCLs have not been established. VOCs were not reported above MDLs or CRLs. One SVOC, bis(2-ethylhexyl)phthalate, was reported in two samples; the greatest concentration was 5.100 µg/L, approximately five times the CRL. Two OCPs, beta-BHC and delta-BHC, were each reported once in the sample from Well DAEGW05. Both concentrations were less than twice the CRL. PCBs and chlorinated herbicides were not detected. TPH-G was not detected. TPH-D was reported in one sample, at a value of 70.0 µg/L.

The results for the Follow-on RI samples are shown in Table 9.6-7. Manganese and TDS were confirmed as being above MCLs. Several other inorganics were above MCLs in the unfiltered samples, however, with the exception of antimony, all concentrations were below MCLs in the filtered samples. Antimony in filtered samples has been attributed to the filters used during sampling. The VOC 1,2-dichloroethane was detected in one well (DAEGW05) at a concentration of 1.42 µg/L. The SVOC bis(2-ethylhexyl)phthalate was detected in one well. OCPs, PCBs, and chlorinated herbicides were not detected in any samples. TPH-G and TPH-D were not detected.

Four additional rounds of groundwater sampling have been conducted since completion of the Follow-on RI field program. Results of the groundwater sampling indicate that the data are generally consistent with the RI data (Montgomery Watson, 1996k). Chromium, iron, manganese, nickel, TPH-diesel, and bis(2-Ethylhexyl)phthalate were detected above MCLs in at least one sample during the quarterly monitoring periods. 1,2-Dichloroethane, which was detected during the Follow-on RI field program, was also detected in Wells DAEGW05 and DAEGW06 at a concentration of 0.6 µg/L during the April 1996 sampling event. 1,2-

Dichloroethane was not detected in any other samples collected during the four quarterly sampling events.

9.6.6 Results Evaluation

The following section evaluates the results of sampling performed during the RI at Landfill E. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For sites containing fill material identification of sources is difficult due to the random distribution of source material within the fill.

For groundwater and surface water all detected analytes are considered COPCs. In the following discussions, detections of compounds are compared with California Primary and Secondary MCLs (Tables 3.8-2 and 3.8-5) to provide the reader with a frame of reference. If an analyte is present in surface or groundwater at concentrations above MCLs, the source, nature and extent, and fate and transport of the analyte are evaluated.

Due to the random distribution of source material in the fill, a random chemical distribution would also be expected. If source material in the fill is contributing chemicals, isolated hot spots within the fill would be likely. Depending on the nature of the chemicals present, these hot spots could migrate to the underlying native soil and groundwater. For the purpose of defining the extent of COPCs detected in fill material, the following sections will focus on

the impact on the subsurface soil and groundwater rather than defining the extent of a particular chemical within the landfill or fill site.

Examination of aerial photographs indicates that filling activity occurred at Landfill E from approximately 1946 to 1965. Artificial debris and landfill materials were deposited in a valley and covered with several inches of topsoil. The surface of the fill area is now flat; a portion of the area is occupied by a baseball diamond and the remainder of the site is covered by grass.

Debris and landfill materials are present from approximately ground surface to a maximum depth of 37 ft bgs. The site covers approximately 3.8 ac, and contains an estimated 45,363 yd³ of debris fill and 31,221 yd³ of landfill material. Debris fill is typically described in boring and test pit logs as glass, brick, tile, and general construction debris. Landfill material is typically described in field logs as black nondescript material with newspaper, rubber syringe stoppers, cans, bottles, and plastic. Fill materials are underlain by native unconsolidated sand. At least 25 ft of sand separates fill deposits from the serpentinite bedrock surface. The water table surface is within unconsolidated sands, approximately 20 ft below fill deposits.

In the conceptual model (Section 3.1), debris fill or landfill material are potential primary sources of contamination. Surface and subsurface soil samples were collected to assess the distribution of target analytes in soils at the site. Also, samples were collected from monitoring wells to characterize groundwater beneath the site. Distribution of chemicals in soils may be expected to be sporadic, due to the discontinuous way in which fill materials were probably deposited.

As stated in Section 9.5.5, the inorganics antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver, vanadium, and zinc were detected above ambient values in at least one surface or subsurface soil sample. Of these, barium, cadmium, copper, iron, lead, mercury, silver, and zinc are considered soil COPCs that will be evaluated further. Concentrations of some of these analytes are shown on Figures 9.6-8 through 9.6-23. These analytes were selected as COPCs because of the magnitude of the detections above ambient levels. The remaining inorganics (antimony,

arsenic, beryllium, chromium, cobalt, nickel, selenium, and vanadium) were detected at concentrations only slightly above ambient levels in a limited number of samples. The detections of these analytes are believed to represent ambient soil conditions rather than contamination from a source within the fill. Boring logs (Appendix G) indicate the presence of serpentinite gravel throughout the fill material. Since serpentinite has naturally high concentrations of chromium, cobalt, and nickel, the elevated detections of these analytes in the fill material is likely due to the presence of serpentinite.

Inorganic soil COPC detections are laterally discontinuous as would be expected in fill material. Vertically, there are no trends in detections within fill material, however, concentrations of almost all inorganics are lower in the underlying native material. This is as expected, since most of the inorganics detected in fill tend to be insoluble (USEPA, 1991b), and would not be expected to migrate through unsaturated soils. Of the soluble inorganics (barium, manganese, and mercury), only manganese is present in groundwater beneath the site at concentrations exceeding Primary or Secondary MCLs.

Numerous inorganics were reported in groundwater samples during the Supplemental and Follow-on RI. Concentrations of several inorganics in groundwater are plotted on Figures 9.6-28 through 9.6-32. Of these, manganese and TDS were reported at concentrations exceeding California Secondary or recommended Secondary MCLs in several wells during both sampling rounds. Manganese was not detected above ambient levels in either the fill or the underlying native material. During the subsequent quarterly monitoring performed by Montgomery Watson, chromium, iron, manganese, and nickel were detected above MCLs in at least one sample during the quarterly monitoring periods (Montgomery Watson, 1996k).

VOCs were detected only in soil samples collected in fill material. No detections of VOCs above the MDLs or CRLs were reported in native materials below fill. One detection of 1,2-dichloroethane occurred in a groundwater sample collected from Well DAEGW05 during the Follow-on RI. Quarterly sampling performed by Montgomery Watson immediately following the Follow-on RI (July and October 1995, and January 1996) did not confirm the presence of 1,2-dichloroethane in groundwater at the site (Montgomery Watson, 1996k). However, the compound was detected in Well DAEGW05 again in April 1996. 1,2-Dichloroethane was also detected in Well DAEGW06 during the April 1996 sampling round. All detections of

the compound were below Primary MCLs. The source of this compound is not clear. 1,2-Dichloroethane is usually associated with other parent and degradation products of chlorinated solvents, none of which were detected at the site in either soil or groundwater. Because the compound was not detected in any other samples, fill material at Landfill E is not believed to be the source.

Most of the VOCs detected in samples of fill material are volatile and soluble, and would be expected to volatilize into the atmosphere from near-surface soils, or leach downward through the soil column if any leachate is migrating from fill materials. VOCs were not detected in native soils or groundwater below fill materials, indicating that these compounds probably are not leaching from fill materials.

All of the detections of SVOCs at Landfill E were in fill material; SVOCs were not detected in native materials below fill. Concentrations of several SVOCs in soil are plotted on Figures 9.6-24 and 9.6-25. The only SVOC reported in groundwater was bis(2-ethylhexyl)phthalate, which was detected during the Supplemental RI in Wells DAEGW04 and DAEGW05 at concentrations of 1.3 and 5.1 $\mu\text{g/L}$, respectively. It was also detected in one Follow-on RI sample at a concentration of 53.4 $\mu\text{g/L}$. Quarterly sampling performed by Montgomery Watson also detected bis(2-ethylhexyl)phthalate in several wells during several sampling rounds (Montgomery Watson, 1996k). The Primary California MCL for bis(2-ethylhexyl)phthalate is 4 $\mu\text{g/L}$.

All but three of the SVOCs detected in fill materials are PAHs. These compounds tend to sorb strongly to soils, and would not be expected to leach downward from fill materials. This is reflected in data from native materials below fill, where SVOCs were not reported. One detection of bis(2-ethylhexyl)phthalate was reported in groundwater, but was not detected in native materials above groundwater.

OCPs were detected in five of six samples from fill materials. No detections of OCPs were reported in native materials below fill. Concentrations of several OCPs in soil are shown on Figures 9.6-26 and 9.6-27.

The OCPs beta-BHC and delta-BHC were detected during the Supplemental RI in groundwater from well DAEGW05, at concentrations of 0.090 and 0.040 $\mu\text{g/L}$ respectively. These detections are less than twice the MDLs. Neither of these compounds were detected in the soil samples collected from this location, or in other groundwater samples at the site. They were also not detected in any of the Follow-on RI groundwater samples.

The PCB Aroclor 1254 was detected twice, in a sample of fill and a sample of native material below fill from the same boring. Both detections were at the CRL. It should be noted that the sample of native material underlying fill materials was collected just below the contact of these two media. The fact that both detections of PCBs were from one site, and at the CRL, indicates that the lateral extent of PCBs is probably limited.

PCBs tend to sorb strongly to soils; given that both detections were from the same boring at very low concentrations, migration through the soil column would not be expected. This is supported by the observation that PCBs were not detected above the CRL in groundwater samples at the site.

TPH-D was detected in most soil samples from the site. The highest concentration reported was 38.0 $\mu\text{g/g}$. In all cases, the concentrations from samples in native materials were lower than concentrations in fill materials from the same boring. In general, deflections on chromatograms appear to indicate that the hydrocarbons detected are dominantly straight-chain hydrocarbons, but other hydrocarbon structures such as cyclic, saturated, and unsaturated hydrocarbons may also be present locally.

TPH-D was detected in one of three groundwater samples, at a concentration less than twice the CRL. The single detection was in Well DAEGW03, near the center of the landfill. TPH-D was not detected in Well DAEGW05, located within the landfill area, and downgradient of DAEGW03. TPH-D was not detected in groundwater samples collected during the Follow-on RI, but was detected in several samples collected during the subsequent quarterly sampling performed by Montgomery Watson (Montgomery Watson, 1996k).

9.6.7 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for Landfill E, including the risk assessment results, as presented in detail in Section 15.

9.6.7.1 Conclusions

Debris fill and landfill materials deposited in Landfill E are potential sources of contaminants. Surface and subsurface soil samples and groundwater samples were analyzed to evaluate the distribution of target analytes at the site.

Inorganic analytes, one PCB Aroclor, and TPH-D were reported in native soil underlying fill materials. VOCs, SVOCs, OCPs, and chlorinated herbicides were not reported in samples of native materials below fill.

Soil COPCs identified for Landfill E include all detected organics and the inorganics barium, cadmium, copper, iron, lead, mercury, silver, and zinc.

Manganese and TDS were reported above Secondary MCLs in groundwater samples; manganese was not above ambient values in any soil samples collected at the site. The VOC 1,2-dichloroethane was detected in one well, however, its presence was not confirmed by any other samples collected at the site, or by quarterly groundwater sampling performed following the RI. PCBs and chlorinated herbicides were not reported in groundwater samples. Bis(2-ethylhexyl)phthalate, beta-BHC, delta-BHC, and TPH-D were reported above MDLs or CRLs in groundwater. The two OCPs detected in groundwater were not detected in overlying soil samples from the same location.

9.6.7.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate

compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for Landfill E are summarized in the following sections.

9.6.7.2.1 Human Health

The GMPA identified open space (recreational) as the future land use for the Landfill E Area. Under this scenario, only COPCs present in surface soil from 0.0 to less than 0.5 ft bgs are evaluated.

A residential PRG ratio screening assessment for surface and subsurface soil and groundwater was performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one

million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with Landfill E are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to the PSF lead screening value of $840 \mu\text{g/g}$, are identified.

9.6.7.2.1.1 Carcinogenic Risk

Silver and several pesticides were determined as COCs in surface soil samples for Landfill E following the COPC screening. The future land use recreational scenario with oral and dermal exposure to surface soil has a total cancer risk of $8E-07$, indicating that it is unlikely that exposure to COCs in surface soil to recreational visitors will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

9.6.7.2.1.2 Non-carcinogenic Risk

For the recreational scenario, Landfill E has hazard indices greater than $1E+00$ for silver ($2E+00$). All other hazard indices are less than $1E+00$, indicating that exposure to COCs in the media for the future land use scenarios at these sites is unlikely to result in noncarcinogenic adverse health effects.

9.6.7.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Landfill E included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and invertebrates were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified for the ecological risk assessment for Landfill E included silver, mercury, zinc, toluene, several OCPs, one chlorinated herbicide, and TPH-D. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceed 1 based on a comparison of exposure to the TBV_{Low} .
- HIs for the American robin and plants and soil fauna exceeded 1 based on a comparison of exposure to the TBV_{High} .
- HQs for mercury, ppDDE, ppDDT, silver, and zinc in soil or diet exceeded 1 for the American robin.
- HQs for ppDDT and silver in soil exceeded 1 for the mourning dove when exposure was compared to the TBV_{Low} , but there were no HQs or HIs that exceeded 1 for this receptor when exposure was compared to the TBV_{High} .

- HQs for mercury, silver and zinc in soil exceeded 1 for plants and soil fauna when exposure was compared to the TBVLow, but only silver produced an HQ in excess of 1 when exposure was compared to the TBVHigh.
- The remaining receptors and exposure pathways evaluated did not indicate a potential for risk to these receptors.

The ecological risk assessment for Landfill E will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

10. MISCELLANEOUS SITES

The Miscellaneous Sites are individual areas not associated with any of the study areas discussed in previous sections. Miscellaneous Initial RI sites identified in the Enhanced PA (ANL, 1989) as requiring further investigation included Lobos Creek, Mountain Lake, and four buildings: 662, 680, 1244, and 1351. The FPCGS was added to the RI in the Fall of 1990 when it reverted to PSF control. The area descriptions, sample location rationale, geologic setting, analytical results, results evaluation and conclusions for each site are presented in the following sections.

10.1 BUILDING 662

Building 662 was an automobile hobby shop located in the northwestern portion of the PSF. Surface soil, subsurface soil, and discrete groundwater samples were collected at Building 662 to evaluate the potential release of contaminants associated with automobile maintenance activities. The following sections describe the Building 662 field program and its results.

10.1.1 Area Description

Building 662, situated on a leveled area with Buildings 661 and 663, is located in the northwestern portion of the PSF at the intersection of McDowell Avenue and Cowles Street (Figure 10.1-1). Elevated portions of State Highway 1 and U.S. Highway 101 are within 500 ft to the west and the north, respectively. San Francisco Bay is approximately 1,700 ft to the north.

Building 662 is at an elevation of approximately 65 ft-PLL, with vegetation consisting of trees, shrubs, and grasses. The 16,892-ft² building is constructed of concrete and brick (Nakata, 1985) with a concrete floor 10-in thick (Appendix H-1). A steel UST, approximately 10 ft in length and having a volume of 500 gal lies below a concrete pad west of the southwest corner of the building (J.M. Montgomery, 1992b). A steel AST, approximately 10 ft in length and having a volume of approximately 300 gal was located 5 ft northeast of the UST (Figure 10.1-1).

Topography in the vicinity of the building generally slopes to the northeast. According to PSF Basic Information Maps, there is a storm drain line under Building 662 running roughly parallel to the northwest wall. The nearest catch basin is on Cowles Street, north-northwest of Building 662. Surface drainage on the south, east, and northeast side of Building 662 flows to the east toward the catch basin on McDowell Avenue, while surface drainage on the west and north side of the building flows to the catch basin on Cowles Street. These drain lines connect approximately 125 ft north of Building 662. The impact of stormwater runoff on aquatic receptors in the bay is evaluated under the ESAP.

Building 662 was constructed in 1913-1914 in a complex of five buildings, numbered 661 through 665 (ANL, 1989). Originally used as a horse stable, Building 662 became an automobile hobby shop for military personnel who worked on privately owned vehicles (ECJC, 1990a; ANL, 1989). Operations performed in the shop were intermittent in nature and included oil servicing, engine tune-up and repair, tire and battery replacement, brake repair, and limited body work and painting. Two hydraulic lifts inside the west end of the building were used in performing the maintenance work (Figure 10.1-1). A wash rack located near Building 662 is equipped with an oil/water separator, the drain of which eventually discharges to the PSF sanitary sewer (ANL, 1989; ECJC, 1990b) (Figure 10.1-1). The UST near the building was used to store waste oil from vehicular maintenance activities at Building 662 (ECJC, 1990a). The AST was used to store waste oil and was removed in April 1994. The UST and AST locations are included in the basewide petroleum cleanup program.

10.1.2 Sample Location Rationale

The Enhanced PA (ANL, 1989) identified Building 662 as a potential environmentally significant area based on the maintenance operations performed at the site. Three types of samples were collected during the RI field programs: surface soil, subsurface soil, and discrete groundwater. Sample locations were based on the conceptual model presented in Section 3.1. Soil samples were collected from three distinct areas that were possible contaminant sources: the UST/AST area, stained areas along the south edge of the building, and the hydraulic lifts within the building. The groundwater sample was collected downgradient of the potential building sources.

Staining observed near the UST and AST indicated that waste oil spills potentially occurred during the process of filling or emptying the tanks (Figure 10.1-1). At Building 662, sand was placed on and around the concrete pad that covers the UST to absorb leaked or spilled oil. During the Initial RI, this sand was sampled to determine what types of spills or leaks may have occurred. No further investigation of this UST/AST area was performed during later RI field work because any additional work would be conducted under the basewide petroleum cleanup program.

Leaks or spills from the maintenance area have also resulted in stained surface soil along the south perimeter of the building. During the Initial RI surface soil samples were collected from these stained areas (662SS01 and 662SS02) and from an area where miscellaneous maintenance-related items were observed (662SS03) (Figure 10.1-1). During the Follow-on RI surface and subsurface soil samples were collected. These Follow-on RI soil samples were obtained to further define the nature and extent of potential contamination based on the surface soil data collected during the Initial RI.

The potential for leakage from the hydraulic lifts to the soil underlying the building was investigated during the Follow-on RI. Two borings were drilled through the 10-inch concrete floor, and soil samples were collected directly below the concrete.

Also during the Follow-on RI, a discrete groundwater sample was collected downgradient of the site to assess if vertical migration of chemicals found in the stained areas south of Building 662 had reached the unconfined aquifer below Building 662.

10.1.3 Geologic Setting

The investigation of Building 662 included the collection of five surface soil samples, seven soil borings, and one discrete groundwater sample. The lithologic logs from the borings and discrete groundwater sample (Appendix H.1) are the basis for the following discussion of the geology at the site.

The soil in the vicinity of Building 662 has been classified as Urban Land (fill) by the SCS (Kashiwagi and Hokholt, 1985). Surface soils immediately surrounding the shop consist of gravelly, silty sand south of the building and silty sand to the west. Soils encountered at the

surface probably represent reworked materials placed during or after construction of the building. Surficial sediments in this area are mapped by the USGS as dune sand (Schlocker, 1974).

The soil boring for the discrete groundwater sample collected at Boring 662SB08 penetrated a homogenous layer of sand at least 33 ft thick (Appendix H.1). This sand is interpreted to be dune sand. Groundwater was found at 29 ft bgs and a discrete groundwater sample was collected at 33 ft bgs. The groundwater flow in the vicinity of Building 662 is thought to be to the north-northeast following the trend of the sloping valley in which the site is located (Figure 2.3-2). Bedrock was not encountered beneath the site. Depth to bedrock is greater than 33 ft bgs (the maximum depth of investigation) and is estimated to be on the order of 36 ft bgs (Figure 2.3-4).

10.1.4 Analytical Results

To assess the nature and extent of potential contamination from the stained areas at Building 662, five surface soil samples were collected during the Initial RI along the perimeter of Building 662 in noticeably stained areas. Two of these, Samples 662SS04 and 662SS05, were collected in the vicinity of the UST and AST. All five surface samples were analyzed for inorganics, VOCs, and SVOCs shown in the target analyte list (Section 3.3). Those compounds with detections above the CRL are listed in Table 10.1-1. Table 10.1-2 shows the analytical results for soil samples from five borings drilled during the Follow-on RI to further assess the areas along the south side of the building. These samples were analyzed for inorganics, PAHs, and TPH. Table 10.1-3 contains the data for the two samples collected to investigate leakage from the hydraulic lifts. Both were analyzed for lead and TPH, and one was also analyzed for TOC. Results for the downgradient groundwater sample, which was analyzed for lead and TPH, are presented in Table 10.1-4.

All of the soil samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an

essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussions.

10.1.4.1 Building 662 UST/AST Area

Two samples of sand placed on and around the concrete pad covering the UST (662SS04 and 662SS05) were collected in this area during the Initial RI. Cadmium, copper, lead, and zinc were detected above ambient fill concentrations in both samples, and mercury was detected above the ambient fill concentration in 662SS05. Lead was above the Follow-on RI SDC of 300 $\mu\text{g/g}$ in both samples, ranging from a concentration of 708 $\mu\text{g/g}$ to 1,400 $\mu\text{g/g}$ (Table 10.1-1). Two VOCs, xylene and toluene, and one SVOC, dimethyl phthalate, were detected above the CRL in Sample 662SS05. There was no further investigation of the analytes detected in these samples because this area is under the basewide petroleum cleanup program.

10.1.4.2 South Perimeter of Building 662

Two of the three Initial RI surface soil samples that were collected to assess contamination potentially associated with staining along the south edge of Building 662 had detections of lead and zinc above ambient fill concentrations. The exceedences were in the two samples collected from stained areas, one of which was located near the wash rack area. No exceedences were in Sample 662SS03, which was collected from an area where miscellaneous maintenance items were observed, such as pipe, oil, and cleaning fluid. Lead was detected above ambient and slightly above the SDC of 300 $\mu\text{g/g}$ in 662SS01 and 662SS02 (Table 10.1-1). Zinc concentrations in these two samples were 479 $\mu\text{g/g}$ and 749 $\mu\text{g/g}$, respectively, above the ambient fill concentration of 280 $\mu\text{g/g}$. Sample 662SS01 contained four SVOCs above the CRLs: bis(2-ethylhexyl)phthalate and three PAHs - chrysene, fluoranthene, and pyrene. Bis(2-ethylhexyl)phthalate was detected in Sample 662SS03.

Unknowns that meet the criteria established in Section 3.5 include: 39 unknown SVOC hydrocarbons and primarily straight-chain saturated hydrocarbons. These unknowns were identified in surface Sample 662SS02. The total concentration equals 150 $\mu\text{g/g}$, with an

average concentration of approximately 4 µg/g. For further discussion of unknown SVOCs, see Section 3.5.

Additional soil samples were collected during the Follow-on RI to further delineate the vertical and lateral extent of lead and PAHs south of Building 662. TPH was also analyzed because the area has a history of vehicle maintenance, therefore there was the possibility that TPH could be present. Three Follow-on RI soil borings (662SB03, 662SB04, 662SB05) were drilled surrounding the lead detections at Samples 662SS01 and 662SS02 and the stained areas (Figure 10.1-1). Both surface and subsurface soil samples were collected from these borings. In addition, subsurface soil samples were collected from two soil borings (662SB06 and 662SB07) to investigate the vertical extent of contamination. They were drilled in the stained areas adjacent to the original surface soil samples. Lead concentrations were less than the SDC of 300 µg/g in all eight soil samples. Lead was only detected in two surface soil samples, at concentrations of 2.33 µg/g and 56.7 µg/g (Table 10.1-2). PAH and TPH concentrations (including confirmatory TPH-D and TPH-G analyses) were below RLs in all samples.

10.1.4.3 Hydraulic Lift Area

Because of the potential for contamination due to possible leaks from the hydraulic lift, two soil borings (662SB01 and 662SB02) were drilled inside Building 662 adjacent to the hydraulic lift as part of the Follow-on RI (Figure 10.1-1). One subsurface soil sample was collected from each boring, directly below the concrete floor. Each sample was analyzed for lead and TPH. Sample 662SB01 was also analyzed for TOC. Lead and TPH concentrations were below RLs in both samples (Table 10.1-3). TOC was reported at a concentration of 865 µg/g in the sample from Boring 662SB01.

10.1.4.4 Downgradient Groundwater

In addition to the soil samples, a discrete groundwater sample (662SB08) was collected during the Follow-on RI approximately 20 ft north of Building 662 to assess the possibility of groundwater contamination from vehicular maintenance activities at the site (Figure 10.1-1). Because the UST/AST and potentially associated soil and groundwater contamination is

assessed under the basewide petroleum cleanup program, the location was not selected to address those sources.

Groundwater was encountered at 29 ft bgs and a sample was collected at 33 ft bgs (Appendix H.1). The groundwater sample was analyzed for lead, TPH-D, and TPH-G. The analyses show lead was below the SDC of 15 $\mu\text{g/L}$ and the primary MCL of 50 $\mu\text{g/L}$, TPH-D was below both the SDC (50 $\mu\text{g/L}$) and the RL, and TPH-G was below the RL (Table 10.1-4).

10.1.5 Results Evaluation

Vehicle maintenance operations within and around Building 662 have generated concern over potential contaminant release to soil surrounding the building and subsequent migration to groundwater. Surface soil, subsurface soil, and discrete groundwater samples were collected to assess potential leaks or spills and to characterize the nature and extent of the releases in impacted media. An evaluation of the potential impacts to soil in three potential source areas and the downgradient groundwater is presented in this section.

10.1.5.1 Building 662 UST/AST area

Two surface samples collected to assess leakage associated with the UST and AST indicated that sand which was intended to absorb spills in the area had been impacted by releases of petroleum product. Lead was detected at a maximum concentration of 1,400 $\mu\text{g/g}$ outside the center of the building's west wall in surface Sample 662SS05 (Figure 10.1-1). This was the highest lead concentration detected in any of the samples from the Building 662 site, and above both the ambient fill concentration and the SDC for lead. The lead concentration in Sample 662SS04 was 708 $\mu\text{g/g}$, also above the ambient fill concentration and the SDC for lead. Other inorganics detected above ambient fill concentrations in both samples include cadmium, copper, lead, and zinc. Mercury was detected above ambient in 662SS05. Two of the three organics detected in 662SS05 also indicate potential release of petroleum to the surface sand in the area. These BTEX compounds, toluene and xylene, could reasonably be expected in a spill or leak associated with automobile maintenance or the UST or AST. Bis(2-ethylhexyl)phthalate was detected above the CRL in this sample. This compound was a common laboratory contaminant detected in method blanks and it is not considered to be a

contaminant at this site. It is likely that the impacted media is confined to this area along the west side of Building 662, where staining around the UST and AST was noted. Subsurface soil samples were not collected to assess the vertical extent of these analytes. However, this area will be addressed by the basewide petroleum cleanup program. Therefore, these results will not be discussed in further detail in this RI or considered in the BRA or FS.

10.1.5.2 South Perimeter of Building 662

All Initial RI samples in the Building 662 area were taken at biased locations; each stain was discrete. In such a situation, a discussion of lateral extent cannot be based upon sample distribution. Rather, the extent of each individual stain must be addressed. At Building 662, the three surface soil samples along the southern wall were taken from areas that appear to have been stained by small-scale leaks or spills, possibly associated with cars parked along the perimeter of the building or with maintenance activities conducted at the site. The Initial RI data indicated that further investigation of the area where miscellaneous maintenance materials were present (Sample 662SS03) was not warranted, as no ambient exceedences occurred, the SDC for lead was not exceeded, and the only organic that was detected was bis(2-ethylhexyl)phthalate, a typical laboratory contaminant. However, the SDC and ambient exceedences of lead and the ambient exceedence of zinc in the two stained areas to the east of 662SS03 and the detections of PAHs in one of the samples indicated that further investigation was warranted. The correlation of elevated lead, zinc, and PAH concentrations suggests that all of these analytes are potentially associated with maintenance activities.

Under the Follow-on RI, the maximum vertical and lateral extent of lead and PAHs associated with the two stained areas, originally investigated by Samples 662SS01 and 662SS02, was defined. This was accomplished by collecting soil samples from borings around the entire stained area on the south side of Building 662 (Figure 10.1-1). Analytical results for these surface and subsurface samples suggest that elevated lead and PAH concentrations are only associated with the stained surface soil. Lead concentrations in all Follow-on RI samples were below the SDC (300 $\mu\text{g/g}$) and the ambient fill concentration, all PAHs were below RLs, and TPH concentrations were below both the RL and the SDC (Table 10.1-2). Confirmatory analyses also show TPH-D and TPH-G to be below RLs. The Initial RI zinc concentrations appear to correlate with the lead concentrations and the

mobility of the analytes are similar; therefore, the extent of ambient zinc exceedences is inferred to be similar to the lead extent.

The maximum areal extent of soils in which lead and PAHs exceed SDCs was estimated based on the analytical results and the extent of stained surface soil. This area was estimated to be a maximum of 22 ft by 100 ft. The area is defined to the north by Building 662, to the east by Boring 662SB05, to the west by Boring 662SB03, and to the south by Boring 662SB04. It is believed that the actual area of SDC exceedences is probably much smaller but additional borings between Borings 662SB06 and 662SB07 would be needed to verify this. The maximum vertical extent of SDC exceedences is 5 ft bgs, as defined by Borings 662SB03 through 662SB07 (Table 10.1-2).

The limited distribution of lead and PAHs is consistent with the physical properties of these contaminants. Their physical properties show that both lead and PAHs have a high affinity for soil.

10.1.5.3 Hydraulic Lift Area

Neither lead nor TPH were detected in the two samples collected under the concrete floor of Building 662 adjacent to the hydraulic lifts. Therefore, it can be concluded that the hydraulic lifts are not likely sources of contamination of these compounds.

10.1.5.4 Downgradient Groundwater

Groundwater data suggest that migration of potential contaminants through the unsaturated zone is very limited. The depth-discrete groundwater sample collected in Boring 662SB08 contained lead below the SDC (15 µg/L) and TPH-D and TPH-G were below RLs. These results suggest that the uppermost saturated zone downgradient of Building 662 has not been impacted by activities associated with Building 662. As discussed above, the groundwater location was not selected to address potential UST or AST contaminants; this potential source will be addressed under the base-wide petroleum cleanup program.

10.1.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 662 site, including the risk assessment results, as presented in detail in Section 15.

10.1.6.1 Conclusions

Vehicle maintenance operations within and around Building 662 have resulted in the release of COPCs to shallow soils in the area. Contamination associated with the UST and AST locations on the west side of Building 662 will be addressed under the basewide petroleum cleanup program. COPCs associated with stained soil on the south side of Building 662 include lead, zinc, bis(2-ethylhexyl)phthalate, and three PAHs, including chrysene, fluoranthene, and pyrene. These contaminants appear to be limited to above 5.0 ft bgs based on the results of samples collected from Borings 662SB06 and 662SB07. No contamination associated with the hydraulic lifts was found. Groundwater did not appear to be impacted by the soil contaminants in the stained areas, and lead is the only groundwater COPC for the human health risk assessment. The ESAP stormwater and sediment data indicated that there was no significant toxicity to aquatic receptors associated with the outfall that is connected to the storm drain at this site (Outfall 11; D&M, 1996a, b).

10.1.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. Inorganics, miscellaneous parameters, and organics in groundwater are considered in the human health risk assessment. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, and the PSF lead screening value (for soil). If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 662 site are summarized in the following sections.

10.1.6.2.1 Human Health

The Building 662 site was assessed as one area in the human health risk assessment, with the AST/UST location excluded because of its inclusion in the USCOE petroleum program. The GMPA identified institutional (industrial) use for the entire area, and exposure to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are both possible. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

Two additional assessments of risk were performed for the Building 662 site that are not based on the planned future use of the site. These include assessment of groundwater as drinking water and a residential PRG ratio screening assessment. Groundwater was assessed as drinking water on a site-wide basis although it is considered an unlikely potable water supply for the industrial worker in the area.

A residential PRG ratio screening assessment for surface and subsurface soil and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ >1E+00, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 662 site are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

10.1.6.2.1.1 Quantification of Cancer Risks

Lead in groundwater was the only COC for Building 662. In addition, the PSF water supply COCs (lead, manganese, and nitrate) are assessed with ingestion and dermal contact to institutional workers at Building 662. No analytes were determined to be COPCs in surface soil. The COCs in subsurface soil are not considered carcinogenic so it is unlikely that exposure to COCs in the subsurface and the PSF water supply will result in an excess cancer risk to the institutional worker at Building 662. The residential PRG ratio screening assessment resulted in a total cancer risk less than 1E-06.

10.1.6.2.1.2 *Quantification of Noncarcinogenic Effects*

The hazard index was below 1E+00, which indicates that exposure to the receptors at this site is unlikely to result in noncarcinogenic adverse health. The residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00.

10.1.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 662 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified at Building 662 for the ecological risk assessment include lead, zinc, bis(2-ethylhexyl)phthalate, and PAHs. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, and plants and soil fauna exceeded 1 based on a comparison to the TBV_{Low} values.
- No HIs exceeded 1 for a comparison to the TBV_{High} values.
- Lead and zinc dietary ingestion HQs for the American robin and mourning dove exceeded 1 when exposure was compared to the TBV_{Low} values.
- Lead HQs for soil ingestion for the robin and dove exceeded 1 when exposure was compared to the TBV_{Low} values.

- The zinc HQ for plants and soil fauna exceeded 1 when exposure was compared to the TBV_{Low} values.

Because the risks estimated at this location fall within the gray zone (i.e., risk is predicted based on the conservative TBV_{Low} values, but not the TBV_{High} values), this site is unlikely to be a significant threat to populations of these receptors. In addition, ecological receptors are unlikely to be present at this location due to its small size and proximity to buildings.

Therefore, the results of the ERA indicate that further evaluation at this site is not warranted.

10.2 BUILDING 680

Wipe, surface, and subsurface soil samples were collected at Building 680 to evaluate the potential release of PCBs from transformers stored in the area. The Building 680 field program and its results are described in the following sections. An Engineering Evaluation/Cost Analysis (EE/CA) and additional supporting field investigations have been completed for this site (U.S. Army, 1996).

10.2.1 Area Description

Building 680 is located in the northwest portion of the PSF at the intersection of Park Boulevard and Schofield Road (Figure 10.2-1). An elevated portion of State Highway 1 is located approximately 350 ft to the west. The Religious Activities Center lies approximately 100 ft to the north.

Constructed of wood and brick, Building 680 covers an area of approximately 1,900 ft². A three-sided shed with a concrete-bermed floor is adjacent to the eastern side of Building 680. A transformer pad, designated Building 684, is located less than 30 ft from the southeastern corner of the building. The area to the east of the building, approximately 1,800 ft², is fenced to the south and east and bordered by the shed to the north.

The terrain surrounding Building 680 is gently sloping to the northeast. Building 680 is at an elevation of approximately 140 ft-PLL. Surface drainage from this area is to the south toward Park Boulevard. Vegetation consists of large trees, shrubs, and low grasses.

Building 680 was constructed in 1908 and was used to store electrical equipment. Leaking or unserviceable transformers awaiting PCB test results were stored in the shed adjacent to Building 680 (ANL, 1989). Transformers that exceeded the PCB disposal concentration limit were removed by a hazardous-waste contractor. Observations made in the field indicate that the shed was used to store transformers in the west half and POL in the east half.

A PCB sampling and analysis program was conducted by American Environmental Management Corp. in 1987 (ECJC, 1990a). Concrete borings and concrete surface samples were collected from the interior of the building, and soil borings were drilled and samples collected outside on the perimeter of the building. The results from the 1987 program indicated that very low concentrations (< 1 ppm) of PCBs were detected in the area. However, PSF maintenance personnel said that the area investigated in 1987 was not extensive enough to assess potential contamination and that up to 50 transformers were removed from the fenced area in the spring of 1989 (ECJC, 1990b). The detection of PCBs in previous studies and the reported volume of transformers removed in 1989 justified additional investigation at the site (ECJC, 1990a).

10.2.2 Sample Location Rationale

The investigation at Building 680 was designed to identify and evaluate the extent of PCB contamination associated with the transformers stored at the site. Three types of samples were collected during the original field program: wipe, surface soil, and subsurface soil samples. Sample locations at Building 680 were based on the conceptual model presented in Section 3.1, and are shown in Figure 10.2-1.

Wipe sampling was conducted to determine if chemical residues from stored transformers were present in the shed area of Building 680. Wipe samples were collected from stained areas on the concrete floor of the shed.

Surface and subsurface soil samples were collected to identify other potential contamination that may have occurred due to leaking transformers. Soil sample locations were selected based on communications with site personnel and evidence of surface staining in the vicinity of the storage shed area. Subsurface soil samples were obtained to further define the nature and extent of potential contamination.

10.2.3 Geologic Setting

The general soil classification of the Building 680 area is described by the SCS as loamy Typic Argiustolls with an Urban Land (fill) association (Kashiwagi and Hokholt, 1985). This soil is characterized by sand with clay and fill material. Soil borings drilled at the site penetrated fill material composed of dark brown silty sand with serpentinite gravel to depths of approximately 1 to 3 ft. Dune sand was encountered in Boring 680SO02 at a depth of 4.5 ft. Since Boring 680SO02 was only drilled to a depth of 4.85 ft bgs, thickness of the dune sand layer is not available. The surficial sediments in the area have been mapped by the USGS as dune sand (Schlocker, 1974). Neither groundwater nor bedrock were encountered during the investigation of Building 680. However, based on the regional groundwater contour map (Figure 2.3-2) and the structure contour map of the bedrock surface (Figure 2.3-4), groundwater is approximately 10 ft bgs, and bedrock is approximately 20 ft bgs.

10.2.4 Analytical Results

Building 680 was used to store electrical equipment, and PCBs are the suspected contaminants in this area. Twelve samples were collected in the Building 680 area during the Initial RI: four wipe samples, three surface soil samples, and five subsurface soil samples from the unsaturated zone. An effort was made to drill three borings and sample each at two depths. In Boring 680SO03, only the shallow sample was collected due to auger refusal at a depth of less than 1 ft bgs. Because of the site's history as a transformer storage area, all samples were analyzed for the PCBs shown in the target analyte list (Section 3.3). Only Aroclor 1260 was detected at levels above the CRL. Aroclor 1260 was detected in one wipe sample (Table 10.2-1), and this concentration is used for qualitative purposes only. All three surface soil samples and four of the five subsurface soil samples contained concentrations of PCBs ranging from 0.719 to 13.6 $\mu\text{g/g}$ (Tables 10.2-2 and 10.2-3). Only one of the subsurface soil samples was below the CRL. This sample (680SO02B) was also the deepest, at 4.6 ft bgs (Table 10.2-3).

10.2.5 Results Evaluation

The source of potential concern in this area is leakage of PCBs from stored transformers. The possibility of leaks in the shed was investigated by collecting wipe samples from the

concrete floor. The only detection at a concentration greater than the CRL was Aroclor 1260 in one wipe sample (680W04) collected in the western half of the shed.

According to PSF personnel, transformers were stored in the shed (Building 684) and in the yard. Soil samples were collected from stained areas and areas suggested by PSF personnel. Surface soil sample detections of Aroclor 1260 ranged from 6.21 to 13.6 $\mu\text{g/g}$. A sample collected at 0.8 ft bgs contained Aroclor 1260 at a concentration of 1.80 $\mu\text{g/g}$, demonstrating a decrease in concentration with depth.

Samples were also collected outside the storage area, to the north of the shed. Aroclor 1260 concentrations decreased with depth, and no PCBs exceeding the CRL were detected at a depth of 4.6 ft bgs (Table 10.2-3).

Subsequent sampling conducted by Montgomery Watson in 1996 has further assessed the vertical and lateral extent of PCB contamination. Concentrations greater than 1 $\mu\text{g/g}$ in the surface soil extend from southeast of Building 680 to approximately 40 ft north of the concrete-bermed shed (U.S. Army, 1996). The eastern edge of Building 680 defines the western extent; the eastern extent is a maximum of 25 ft east of the east fence line. The extent of PCB concentrations above 1 $\mu\text{g/g}$ in soil collected from 1 ft bgs was limited to two samples, which were collected near the east edge of Building 680. The vertical extent is defined by the absence of detections in the 2 ft bgs sample from one of the locations and the 3 ft bgs sample from the other location. As noted above, the RI samples from Boring 680SO01, also showed PCB concentrations above 1 $\mu\text{g/g}$ north of the concrete-bermed shed in subsurface soil. However, the concentrations decreased to 1.16 $\mu\text{g/g}$ in the 2.2 ft-bgs sample.

PCBs have a strong affinity for soil that increases with both the organic content of the soil and the degree of chlorination of the compound. Aroclor 1260 contains approximately 60 percent chlorine by weight and has the strongest soil affinity of all PCBs. The low mobility of Aroclor 1260 is supported by the observed decrease in concentrations with depth. The data collected by Montgomery Watson also showed a decrease in concentrations with depth. However, a potential migration pathway that is likely prevalent at this site is transport of

particulates in surface water runoff. Further investigation of the extent and removal of PCBs is addressed under the EE/CA document, which has been approved by the DTSC.

10.2.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 680 site, including the risk assessment results, as presented in detail in Section 15.

10.2.6.1 Conclusions

Building 680 was used to store electrical equipment including transformers. Transformer leaks have resulted in the presence of detectable concentrations of the PCB Aroclor 1260 in the soils surrounding Building 680. PCBs are evaluated in both the human health and ecological risk assessments.

Further investigation and removal of PCB-contaminated soil is addressed under an EE/CA document which has been accepted by DTSC.

10.2.6.2 Risk Assessment Summary

As previously described, the only analyses performed on samples from this area were for PCBs. All detected PCBs in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. Wipe samples were not evaluated because the results can not be used quantitatively. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source for the industrial worker in the area.

In the human health risk assessment, the PCB concentrations were first screened against USEPA Region IX residential PRGs. If the appropriate value was exceeded and the frequency of detection was greater than 5%, the analyte was considered a COC and quantitatively evaluated. This initial screening was not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk. The ecological risk assessment also quantitatively assessed the detected PCBs without any initial screening. The human health and ecological evaluations for the Building 680 site are summarized in the following sections.

10.2.6.2.1 Human Health

The Building 680 site was identified in the GMPA for institutional (industrial) uses, under which exposures to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are possible. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for surface and subsurface soil was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for

noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 680 site are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

10.2.6.2.1.1 Quantification of Cancer Risks

For Building 680, the only COC in both surface and subsurface soil is PCB 1260. In addition, the PSF water supply COCs (lead, manganese, and nitrate) were assessed. The future land use institutional worker scenario with ingestion of and dermal exposure to surface and subsurface soil and the PSF water supply resulted in a total risk of 6E-05, mostly from both ingestion of and dermal exposure to PCB 1260 in surface soil. The residential PRG ratio screening assessment resulted in total cancer risk greater than 1E-06.

10.2.6.2.1.2 Quantification of Noncarcinogenic Effects

The hazard index was below 1E+00, which indicates that exposure to the receptors at this site is unlikely to result in noncarcinogenic adverse health. The residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00.

10.2.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 680 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity

benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

The only soil COPC identified in soils at Building 680 for the ecological risk assessment was Aroclor 1260. Results of the risk assessment indicate the following:

- The observed concentration of Aroclor 1260 in soil is a potential concern to the American robin, mourning dove, and western harvest mouse based on comparison of exposure to the TBV_{Low} values. HI values were above 100 for the American robin, but 10 or less for the mourning dove and western harvest mouse.
- The HI for total exposure for the American robin exceeded 1 based on the TBV_{High}. However, the magnitude of the HI was low (e.g., only 3), and was due to the dietary ingestion pathway only.

The remaining receptors and pathways evaluated did not indicate any potential for risk at Building 680. Although some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), there is little likelihood of ecological receptors actually being present at this location due to the future industrial use planned for Building 680. Therefore, further evaluation of this site from the standpoint of ecological risk is not warranted. However, this site is included in the PCB EE/CA for the protection of human health.

10.3 BUILDING 1244

This section describes the results of investigations conducted at Building 1244. Building 1244 was formerly a field printing plant that housed lithographic and film processing equipment. Wipe and soil samples were collected inside Building 1244. Wipe samples were collected during the Initial RI to evaluate the potential release of chemicals associated with film processing. Soil samples were collected during the Follow-on RI from the trench inside

Building 1244 to primarily assess the potential for waste and hydraulic oil contamination. The following sections describe the Building 1244 field program and its results.

10.3.1 Area Description

Building 1244 is located in the northwestern portion of the PSF, approximately 700 ft southwest of the elevated intersection of State Highway 1 and U.S. Highway 101. It is bordered on the north and east by enlisted family housing, on the south by officer family housing, and on the west by Warehouses 1241, 1242, and 1243.

Building 1244 sits on an east-facing hillslope at approximately 180 ft-PLL and is surrounded by a paved parking lot that exits to Appleton Street and Schofield Road (Figure 10.3-1). Surface drainage flows to the east across the parking lot. The vegetation consists mainly of large trees located primarily in the southern portion of the site.

Building 1244 is an approximately 50 ft by 300 ft one-story wood building. The building is mainly empty except for equipment (sinks, camera, enlarger) left in rooms in the southwest corner. There is also a gravel filled concrete lined trench located approximately 50 ft south of the north wall. The trench is 2.3 ft wide, 8.66 ft long, 2.0 ft deep.

Building 1244 was constructed in 1941. It served as a field printing plant and housed lithographic machines and an automatic film processor for developing photographic film (ECJC, 1990a). A 1945 plan indicates it was a "Motor Vehicle Repair Shop" with motor vehicle maintenance and engine classrooms. The building is currently inactive (HLA, 1994).

The film processing generated 50 to 60 gals of waste developing-solution per month. Prior to 1974, this waste solution was discharged directly to the sanitary sewer. From 1974 to 1979, the waste solution was transported in 5-gal cans to the DPDO, currently known as the DRMO, for recovery. After 1979 the plant recycled its waste solution for silver recovery and discharged the effluent to the sanitary sewer, which ultimately entered the San Francisco sanitary sewer system (ECJC, 1990a).

10.3.2 Sample Location Rationale

The primary sources identified at Building 1244 were solutions associated with the film developing process. The primary release mechanism for these solutions would have been spillage. Three wipe samples were obtained from visually stained areas on the concrete floors of the darkroom and the adjacent room where fixing agent was stored (Figure 10.3-1).

Another source identified at Building 1244 is the gravel-filled concrete trench inside the building which may have been used for oil collection or a recessed hydraulic lift (HLA, 1994), or in association with the printing activities. The primary release mechanisms would have been direct dumping or leakage of oil or other chemicals into the trench, or leakage of the hydraulic lift. The trench was specifically selected for sampling because it is a likely place where chemicals may have been released and also because it potentially provides a migration pathway for chemicals from inside the building to the exterior. Two analytical sample borings and one lithology boring were drilled through the trench to assess the nature and extent of potential contamination.

The sanitary sewer for Building 1244 was designed to handle the disposal of the photographic chemicals. Although a camera survey of the sanitary sewer system of the PSF was completed by Dames & Moore in 1994 for the NPS to assess the integrity of the sewer lines, the line from building 1244 was not included.

10.3.3 Geologic Setting

The investigation of Building 1244 included the drilling of three soil borings. The lithologic logs from these borings (Appendix H.3) are the basis for the following discussion of the geology at the site.

The soil in the vicinity of Building 1244 has been classified by the SCS as Urban Land (fill) and loamy Typic Argiustolls (dry sandy soil with a clay horizon) (Kashiwagi and Hokholt, 1985). Soil borings drilled at the site penetrated sandy clay overlying weathered serpentinite with clay. Serpentinite bedrock was encountered at 4.0 ft in Boring 1244SB01 and 6.0 ft in Boring 1244SB03. Boring 1244SB02 was drilled to a depth of 6 ft bgs and bedrock was not encountered. This suggests that the top of the serpentinite bedrock slopes to the east. The

surficial sediments in the area are mapped by the USGS as slope debris and ravine fill (Schlocker, 1974). Groundwater was not encountered in any of the borings.

10.3.4 Analytical Results

Building 1244 was a film processing plant, and developing solution was a potential source of contamination due to potential release by leaks or spills. During the Initial RI, three wipe samples were collected from visibly stained areas on the concrete floor of Building 1244. All wipe samples were analyzed for the inorganics, SVOCs, and pesticides listed in the target analyte list (Table 3.3-2). Compounds with detections above the CRLs are listed in Table 10.3-1. In addition to a number of inorganics, each sample contained the SVOC bis(2-ethylhexyl)phthalate at a level above the CRL. This compound has been detected in method blanks from other PSF sites and may be related to laboratory contamination. No pesticides were detected above the CRLs.

To evaluate the concerns that the trench inside Building 1244 was a collection area for chemicals inside the building and a potential migration pathway to media outside the building, five soil samples were collected from two soil borings during the Follow-on RI. All samples were analyzed for lead, VOCs, SVOCs, TPH-D, and TPH-G. VOCs, SVOCs, TPH-G and TPH-D were not detected in any of the samples from the borings. Lead was detected in both soil samples collected above the concrete floor of the trench (Table 10.3-2). The lead concentration in the 1.5 ft sample from Boring 1244SB01 was 350 $\mu\text{g/g}$, which is above both the SDC of 300 $\mu\text{g/g}$ and the ambient fill concentration of 221 $\mu\text{g/g}$. The lead concentration in the other sample collected above the concrete floor of the trench (189 $\mu\text{g/g}$) was below both the SDC for lead and the ambient fill concentration for lead. Lead was not detected in any of the three soil samples collected below the concrete floor of the trench.

10.3.5 Results Evaluation

Wipe samples were collected to assess the presence or absence of contaminants at Building 1244. All of the wipe samples contained numerous inorganics, including silver, and the SVOC bis(2-ethylhexyl)phthalate (Table 10.3-1). Sample 1244W02, which was collected from beneath the rinse basin in the darkroom, contained the greatest number of detections at concentrations above the CRLs. Sample 1244W01 was collected from under the cutting

table in the darkroom, and it contained the fewest detections. Sample 1244W03 was collected next to vats of fixing agent in the adjacent room. All of these samples were collected from discrete stains in areas where the likelihood of spillage would be greatest. The mobility of these compounds is limited, in large part due to the lack of migration pathways. Migration through the concrete floor is unlikely, and volatilization is not an important mechanism for any of the detected compounds.

Soil samples were collected from within and below the trench inside Building 1244 to assess the presence or absence of contaminants. The trench is 2.3 ft wide, 8.7 ft long, 2.0 ft deep and filled with dry sandy gravel (0.0 to 1.8 ft bgs) and wet silt (1.8 to 2.0 ft bgs); the bottom of the trench is a 0.5 ft layer of concrete (2.0 to 2.5 ft bgs.). Three borings were drilled inside the trench; two for analytical sampling and one between the two for lithology purposes (Appendix H.3). One sample from each boring was collected above the concrete floor of the trench (1.5 ft bgs). Lead was detected in both of these samples, with the highest concentration of 350 $\mu\text{g/g}$ detected in the 1.5-ft sample from Boring 1244SB01 (Table 10.3-2). This concentration was above both the SDC and the ambient fill value. Two samples from Boring 1244SB02 and one sample from Boring 1244SB01 were collected below the concrete. Serpentinite was encountered at 4 ft bgs in Boring 1244SB01, thus preventing collection of a deeper sample. Lead was below the RL of 25 $\mu\text{g/g}$ in all samples collected below the concrete floor of the trench. This indicates that the integrity of the trench floor was maintained. The absence of VOCs, SVOCs, TPH-D, and TPH-G in all soil samples further indicates that the trench is not a potential source area for organic compounds.

Soil samples were collected where the potential for finding contamination would be the greatest. The migration of the lead through the floor of the trench is highly unlikely. This assumption is supported by the analytical results for samples collected below the trench and the observations that there was water in the bottom of the trench and that the soil underneath the concrete trench floor was dry.

10.3.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1244 site, including the risk assessment results, as presented in detail in Section 15.

10.3.6.1 Conclusions

The only soil COPC detected at the Building 1244 site was lead in soil samples collected within the gravel-filled concrete trench. However, it appears that the concrete floor of the trench is limiting potential downward migration, as lead was not detected in soil samples collected below the concrete floor of the trench.

10.3.6.2 Risk Assessment Summary

As previously described, the only detected target analyte in soil samples collected from this site was lead. It was only a COPC in soil from within the trench, which is assessed as subsurface soil. Therefore, all subsurface soil samples were considered in the human health risk assessment. Wipe samples were not assessed because they can not be used quantitatively. In addition, the PSF water supply (Lobos Creek and Well 13) is evaluated as a drinking water source for the area. No ecological risk assessment was performed for this site, as an exposure pathway to soil from within or below the trench is unlikely.

In the human health risk assessment, lead concentrations are first screened against the PSF screening value for lead in soil. If the screening value is exceeded and the frequency of detection is greater than 5%, lead is considered a COC. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1244 site are summarized in the following sections.

10.3.6.2.1 Human Health

The Building 1244 site was identified in the GMPA for institutional (industrial) uses, under which exposures to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are possible. At this site, soil from within the trench and below the concrete-lined trench were collected; they are assessed as subsurface soil. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for subsurface soil was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that

was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening was performed, as presented in detail in Section 15.1, lead was determined not to be a COC.

10.3.6.2.1.1 Quantification of Cancer Risks

Building 1244 had only the PSF water supply (Lobos Creek and Well 13) assessed with ingestion and dermal contact to commercial/office workers as there were no COCs determined in the subsurface soil following COPC screening. The PSF water supply COCs (lead, manganese, and nitrate) are not considered carcinogenic and, therefore, it is unlikely that exposure of these COCs to commercial/office workers at Building 1244 will result in an excess cancer risk. The COPCs for the residential PRG ratio screening assessment are not considered carcinogenic for Building 1244.

10.3.6.2.1.2 Quantification of Noncarcinogenic Effects

The hazard index was below 1E+00, which indicates that exposure to the receptors at this site is unlikely to result in noncarcinogenic adverse health. The residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00.

10.3.6.2.2 Ecological

No ecological risk assessment was performed for this site, as an exposure pathway to soil from within or below the trench is unlikely.

10.4 BUILDING 1351

Wipe, surface soil, and subsurface soil samples were collected from in and around the concrete bermed area next to Building 1351 to evaluate the potential release of contaminants

associated with vehicle maintenance activities. The following sections describe the Building 1351 field program and its results.

10.4.1 Area Description

Building 1351 is located within a fenced area in the west-central portion of the PSF. It is bordered on the north by Battery Dynamite, on the south by Kobbe Avenue, on the east by Ralston Avenue, and on the west by Battery Saffold. The facility may be entered from either Battery Dynamite Road or Battery Saffold Road.

Building 1351 is located at an elevation of approximately 290 ft-PLL on a relatively flat portion of a north-trending ridgeline, which slopes northward toward Battery Dynamite. Surface drainage from the area is to the east. North of the building is a large paved parking area. The entire area is surrounded by trees.

Building 1351 is a 5,382-ft² concrete and metal structure (Nakata, 1985). A concrete bermed area formally used for waste oil storage is located approximately 20 ft northeast of the building. There are two wash racks to the north of this storage area (Figure 10.4-1). The floor and walls of the wash racks and bermed area are in good condition.

Building 1351 was constructed in 1960 for use as a vehicle maintenance shop. It was used mostly for limited maintenance and small parts replacement and it appears to be well maintained (ANL, 1989). A low-pressure, solvent-recirculating parts degreaser used at the shop was serviced by a private company. No other information regarding the degreaser, such as the former location or solvents used, is available. Brakes were removed in the shop, but not dismantled, thereby minimizing potential asbestos hazards (ECJC, 1990a). As noted on early plans for the building (1959), although not confirmed, there may have been other equipment or features that were associated with maintenance activities, such as an acid neutralizing tank, a sand and soil trap, hydraulic hoists, and a battery room.

During the Initial RI, the concrete bermed area contained many drums and tanks. Five-gallon cans of petroleum liquids were stored in five metal storage containers outside the building. Also, the bermed area had many drums and tanks full of waste oil. The wastes generated from the shop were removed by a private hazardous waste contractor every three months.

During the Initial RI, heavy staining was noted within the berm but no staining was noted in the surrounding area (ECJC, 1990a). The bermed area was empty during the Follow-on RI, and staining was still present inside the berm.

Two wash racks equipped with curbing and oil/water separators were installed adjacent to the waste oil storage area in early 1989. They replaced the old wash racks which were not equipped with oil/water separators. Debris from the old wash racks occasionally clogged the sanitary sewer, necessitating periodic cleanup by a private contractor (ECJC, 1990a). The old wash racks were no longer present during the Initial RI. Therefore, it was not possible to determine if and where overflow would have occurred.

10.4.2 Sample Location Rationale

The primary potential sources of contamination at Building 1351 are the concrete bermed storage area and the wash racks. Three types of samples were collected during the field programs: wipe, surface soil, and subsurface soil samples. Sample locations were based on the conceptual model presented in Section 3.1.

During the Initial RI, wipe samples were used to determine what types of spills or leaks may have occurred when POLs were stored inside the concrete bermed area. Leaks or spills from the POLs previously stored inside the bermed area resulted in staining of the concrete. During the Initial RI, wipe samples were collected from these stained areas (Figure 10.4-1). To assess the potential contamination outside the bermed area, four surface and 12 subsurface soil samples were collected during the Initial RI. The subsurface soil samples were collected from six soil borings, (two samples per boring). The purpose of these samples was to further assess the nature and extent of potential contamination from either infiltration or leakage from the storage area. Two of the Initial RI borings were drilled to bedrock to aid in the geologic characterization of the site. During the Follow-on RI, surface and subsurface soil samples were collected. These Follow-on RI soil samples were obtained to further define the nature and extent of potential lead and TPH contamination. Follow-on RI sample locations were based on surface and subsurface soil data collected during the Initial RI.

Soil samples were collected east and south of the existing wash racks during the Initial RI to evaluate potential impacts on the soil (Figure 10.4-1). The wastewater from the wash racks joins the sewer line in the immediate vicinity of Boring 1351SO03.

10.4.3 Geologic Setting

The investigations of Building 1351 included the drilling of 11 soil borings, four surface samples, and four wipe samples. The lithologic logs from the soil borings (Appendix H.4) are the basis for the following discussion of the geology at the site.

The soils in the vicinity of Building 1351 have been classified by the SCS as Urban Land (fill) and loamy Typic Argiustolls (dry sandy soil with a clay horizon) (Kashiwagi and Hokholt, 1985). The surficial sediments in the area are mapped by the USGS as dune sand and slope debris/ravine fill (Schlocker, 1974). Soil borings drilled at the site penetrated sand and sandy silt overlying clay and silty clay. The thickness of the sand and sandy silt layer varied from 4 ft to 5 ft, while the clay layer had a thickness of approximately 12 ft. The sand is interpreted to be dune sand in borings at the northern area of the site (Figure 10.4-2). The clay is interpreted as possible Colma Formation. Shale bedrock was encountered below the clay at 16.8 ft bgs in Boring 1351SO01, and 15.5 ft bgs in Boring 1351SO02 (Appendix H.4).

Groundwater it is interpreted to be absent in unconsolidated materials in the area, as it was not observed in the borings, two of which penetrated bedrock. During the Follow-on RI, water was encountered at 4 ft bgs in the northernmost boring (1351SB05), however, this was most likely associated with concurrent construction on a water main next to the fire hydrant located approximately 15 ft north of Boring 1351SB05. This construction consisted of a 4 ft by 6 ft trench about 7 ft deep with an exposed water main pipe under 3 ft of water. The fire hydrant was leaking water into the trench during the drilling of Boring 1351SB05.

10.4.4 Analytical Results

During the Initial RI, wipe, surface soil, and subsurface soil samples were collected along the perimeter of the bermed area and the wash racks. Four wipe samples were collected on the concrete bermed area, while four surface and 12 subsurface soil samples were collected

east and south of the wash racks and surrounding the berm (Figure 10.4-1). Those analytes with detections above the CRLs are listed in Tables 10.4-1 through 10.4-4.

During the Initial RI four wipe samples were collected and analyzed for inorganics and SVOCs. Analytes with detections above the CRL are shown in Table 10.4-1. Inorganics were detected above the CRLs in all four samples, as was the SVOC bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant and is not believed to be related to site activities.

Four surface soil samples (1351SS01 through 1351SS04) and 12 subsurface soil samples, collected during the Initial RI, were analyzed for inorganics, VOCs, and SVOCs. Target analytes with detections above the CRLs are shown in Tables 10.4-2 and 10.4-3. All of the samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussions. All other inorganics detected in soil will be compared to ambient concentrations, as described in Section 3.7.

Concentrations of inorganics were compared to ambient concentrations in similar types of material (fill, beach-dune sediments, Colma Formation, or serpentinite). With the exception of Sample 1351SS01, all of the surface samples were collected in fill material described as beach-dune sediments. Surface Sample 1351SS01 was collected in beach-dune sediments. The sample from 1351SB07 was not categorized into one of the four lithologic categories, but is also likely similar to beach-dune materials. All other soil boring samples were categorized as beach-dune sediments for the ambient evaluation, with the exception of two deep samples (from 15 and 17 ft bgs) that were serpentinite; however, further review of the geology indicates that the subsurface samples from 1351SB01 through 1351SB05 and the 4.5 ft bgs sample from 1351SO06 (a total of 11 samples) may be more representative of the Colma Formation. A comparison of the inorganic data for these samples to the ambient

Colma values does not result in any change to the conclusions, as the only differences are two fewer exceedences for aluminum and one additional minor exceedence for barium.

Numerous inorganic analytes were detected at concentrations above ambient in one or more samples including: aluminum, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, lead, vanadium, and zinc. Aluminum and vanadium both were detected above ambient concentrations in eight of the 15 samples analyzed for inorganics. The number of aluminum exceedences is reduced to six when the deeper samples are compared to ambient Colma values as described above. All of the other inorganics listed above, with the exception of copper, were detected above ambient concentrations in two or more of the soil samples. Copper was above ambient concentrations in one sample.

Each of the four surface soil samples contained the VOC toluene at concentrations above the CRL. Samples 1351SS01 and 1351SS04 had concentrations of bis(2-ethylhexyl)phthalate that exceeded the CRL. Bis(2-ethylhexyl)phthalate was detected in method blanks and is considered to likely be due to laboratory contamination. Surface Sample 1351SS01 also had detections of 4-methylphenol/4-cresol and pyrene that were above the CRLs (Table 10.4-2). Subsurface soil samples were also analyzed for VOCs and SVOCs. The VOC methylethylketone/2-butanone was detected above the CRL in Sample 1351SO05A. SVOCs detected above the CRLs include bis(2-ethylhexyl)phthalate in Samples 1351SO04A and 1351SO06A, fluoranthene in Samples 1351SO02A and 1351SO05A, and chrysene and pyrene in Sample 1351SO05A (Table 10.4-3).

Three samples from Boring 1351SB04 were analyzed for total organic carbon. TOC ranged from 13,910 $\mu\text{g/g}$ in the surface soil sample to 1,500 $\mu\text{g/g}$ in the sample collected at 9.0 ft bgs.

The following discussion of unknowns is based on criteria established in Section 3.5. Sample 1351W02 contained 230 $\mu\text{g/g}$ of tentatively identified unknown SVOC hydrocarbons, primarily straight-chain saturated hydrocarbons. Sample 1351W03 contained 170 $\mu\text{g/g}$ of unknown SVOC hydrocarbons, and Sample 1351W04 contained 160 $\mu\text{g/g}$ of unknown SVOC hydrocarbons, primarily straight-chain saturated hydrocarbons. The total concentration of unknown SVOC hydrocarbons tentatively identified in Sample 1351SS01

equals 5,200 $\mu\text{g/g}$. These were primarily polycyclic hydrocarbons with a maximum concentration of 2,500 $\mu\text{g/g}$. The total concentration of unknown SVOC hydrocarbons tentatively identified in Sample 1351SS02 was 1,000 $\mu\text{g/g}$, with a maximum concentration of a single unknown of 200 $\mu\text{g/g}$. Forty unknown SVOC hydrocarbons were tentatively identified in Sample 1351SO01A with an average concentration of approximately 2 $\mu\text{g/g}$. For further discussion of unknown SVOCs, see Section 3.0.

During the Follow-on RI, one surface soil sample was collected and five soil borings were drilled to better define the vertical and lateral extent of contaminants in the vicinity of the bermed area. Three subsurface soil samples were collected from each of the five soil borings (1351SB01 through 1351SB05). These 15 subsurface soil samples were analyzed for lead and TPH. The surface soil sample was analyzed for lead only. Sample 1351SB01 (0.0 ft) was the only sample collected during the Follow-on RI that had a lead concentration (473 $\mu\text{g/g}$) greater than the SDC (300 $\mu\text{g/g}$) (Table 10.4-4). The surface and subsurface samples had lead concentrations below the SDC and TPH concentrations below the RLs (Table 10.4-4).

10.4.5 Results Evaluation

Automobile maintenance activities within and around Building 1351 have generated concern over potential releases of contaminants to the soil in the vicinity of the concrete bermed area and the wash racks. During the Initial RI, wipe, surface soil, and subsurface soil samples were collected to assess whether leaks or spills had occurred in the area and to characterize any material that was released. Four wipe samples were collected during the Initial RI from stained areas along the berm. Four surface and 12 subsurface soil samples were also collected during the Initial RI. These soil samples were collected adjacent to the wash racks and bermed area. A total of 15 subsurface soil samples and one surface soil sample were collected during the Follow-on RI to further define the vertical and lateral extent of contaminants of concern detected during the Initial RI (Figure 10.4-1).

Leaks or spills could have potentially released contaminants to the concrete surface of the storage area. Each of the four wipe samples contained several inorganics as well as bis(2-ethylhexyl)phthalate above the CRL. The detections in these samples indicate the presence of

the analytes but do not quantify their concentrations. Downward mobility of these compounds is greatly limited by the underlying concrete.

Numerous subsurface and surface soil samples were collected in the area to the northeast of Building 1351 to characterize potential releases associated with both the wash racks and the storage area. Bedrock is at a depth of approximately 16 ft bgs and is overlain by native sediments and fill. The fill surrounding the bermed area is comprised mostly of locally derived native material that has been reworked. Fill material was found in Borings 1351SO04 and 1351SO05. Barbed wire was found in Boring 1351SO04 at a depth of 3 ft bgs which indicates that the soil above this depth is fill (Appendix H).

10.4.5.1 Inorganic Ambient Evaluation

The results of inorganic analyses were compared to ambient concentrations for the corresponding soil type as described above. Thirteen inorganic analytes were detected at concentrations above ambient levels in one or more samples. These include aluminum, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc. Inorganic posting maps are presented for all of these analytes, with the exception of mercury, in Figures 10.4-3 through 10.4-14. As described in Section 3.7, a spatial analysis was performed to assess if the ambient exceedences represented natural variability or were potentially associated with site sources. This analysis resulted in designating seven of these inorganics as site COPCs: barium, cadmium, copper, lead, manganese, mercury, and zinc. The following discussion first focuses on inorganics excluded as site COPCs, then discusses the extent of inorganic COPCs.

Many of the inorganics excluded as COPCs, including aluminum, tended to increase in concentration with depth. This is not unexpected as the deeper samples are closer to Franciscan Formation bedrock which suggests that the higher inorganic concentrations at depth are related to the proximity to bedrock. Aluminum was detected above the ambient beach/dune concentration in seven samples. When selected samples, as described above in Section 10.4.4, are compared to the Colma ambient value for aluminum, there are only three exceedences of the beach/dune ambient concentration and two exceedences of the ambient Colma Formation value. The ambient serpentinite concentration was exceeded in one sample. Concentrations tended to increase with depth and exceedences did not tend to occur in

association with other potential site-related analytes (Figure 10.4-3). The range of ambient concentrations for the four lithologic types at the PSF, ranging from 11,600 $\mu\text{g/g}$ in beach/dune sediments to 25,300 $\mu\text{g/g}$ in fill, indicates that aluminum concentrations vary widely. The maximum aluminum concentration in beach/dune or Colma material at Building 1351 was 19,300 and the maximum concentration in serpentinite was 33,100 $\mu\text{g/g}$ (15 ft bgs). Neither of these exceedences or other exceedences are likely to be associated with site-derived contamination. Therefore, the aluminum concentrations are thought to be associated with natural variations in lithology, and aluminum is not considered a site COPC.

Beryllium was detected marginally above the ambient beach/dune sediment concentration of 0.889 $\mu\text{g/g}$ in four samples, at concentrations ranging from 0.914 to 1.27 $\mu\text{g/g}$. Comparison of selected samples to the Colma ambient value, as described above in Section 10.4.4, does not result in any changes. The spatial analysis indicates that beryllium was detected at similar concentrations across the site, and concentrations tended to increase slightly with depth, rather than decrease, as would likely be the case if there was a site source (Figure 10.4-5). Beryllium is therefore not considered a COPC for this site.

Chromium was detected essentially at the ambient beach dune concentration of 111 $\mu\text{g/g}$ in the 1.0 ft bgs samples from 1351SO05 (112 $\mu\text{g/g}$). The other chromium ambient exceedence was for a serpentinite sample collected at 15 ft bgs from Boring 1351SO02, in which there was also a nickel exceedence. A chromium concentration of 1,270 was reported, in comparison to an ambient level of 930 $\mu\text{g/g}$. Neither of these exceedences appear to be associated with a site source based on the chromium concentration pattern (Figure 10.4-7); therefore, chromium is not considered a COPC.

Similar to aluminum, iron tends to naturally vary in PSF samples, with ambient concentrations ranging from 35,100 $\mu\text{g/g}$ to 63,400 $\mu\text{g/g}$. A similar range of concentrations was found at the site, although there was one exceedence each of the beach/dune and the serpentinite ambient concentrations (Figure 10.4-9). Iron was detected above the ambient beach/dune concentration in Sample 1351SS01 (43,400 $\mu\text{g/g}$) and above the ambient serpentinite concentration in the deep sample from Boring 1351SO02 (94,300 $\mu\text{g/g}$). Because the exceedences are within the range of ambient concentrations at the PSF and there

is no indication of a potential site source of iron associated with these exceedences, iron is not considered a COPC.

As mentioned above, nickel exceeded the ambient serpentinite concentration in the deep sample from 1351SO02 (Figure 10.4-12). The other nickel exceedence was in the other serpentinite sample from this site, the 17 ft bgs sample from Boring 1351SO01. Both of these concentrations are likely related to the natural variability and high nickel concentrations associated with serpentinite. Therefore, nickel is not a COPC.

Vanadium, detected above ambient concentrations as frequently as aluminum at the Building 1351 site, is also considered to be present at naturally occurring concentrations. As indicated by the variability in a pair of duplicates collected from the site, the range of vanadium concentrations were generally similar, and exceedences did not appear to be associated with potential site sources based on the distribution (Figure 10.4-13). The exceedences of the beach/dune ambient concentration (81.9 $\mu\text{g/g}$ maximum as compared to 68.6 $\mu\text{g/g}$ ambient) were minor, and a background sample of beach/dune (BKGDSB02) had a higher concentration (85.4 $\mu\text{g/g}$) than was reported in these samples. Therefore, vanadium is not considered a COPC.

Inorganics considered to be soil COPCs include barium, cadmium, copper, lead, mercury, and zinc. Lead was the most widespread of these inorganics, with ambient exceedences in six samples. Lead was detected above the SDC of 300 $\mu\text{g/g}$ in two surface soil samples (Figure 10.4-10). However, all subsurface samples below a depth of 1.0 ft had lead detections that were either below the RL or were below the SDC. The highest lead concentration of 473 $\mu\text{g/g}$ was reported in the surface soil sample from 1351SB01, which is located adjacent to the south edge of the concrete oil storage pad. Lead was below the RL in the deeper samples from this boring. The other concentration above 300 $\mu\text{g/g}$ (321 $\mu\text{g/g}$) was reported in Sample 1351SS01, which is near the fence at the southeast end of the site. No subsurface soil samples were collected in this area. Cadmium and zinc also were elevated in both of these areas, as noted by the ambient exceedences in 1351SS02 and 1351SS01, in addition to the area east of the wash racks (1351SS04) (Figures 10.4-6 and 10.4-14). The highest concentrations were found in 1351SS01, with zinc reported at 499 $\mu\text{g/g}$ and cadmium reported at 17.5 $\mu\text{g/g}$. Deeper samples were not collected from these locations; however, it is

expected that these inorganics would remain in the surface or near surface soil, similar to lead.

Barium, manganese, and mercury are considered COPCs primarily on the basis of the exceedences in Sample 1351SS01 (Figures 10.4-4 and 10.4-11). There were ambient exceedences of these three analytes in one to three other samples; however, these other concentrations do not appear to be associated with site sources but are probably related to variation in lithology. Copper also exceeded ambient in Sample 1351SS01 (Figure 10.4-8). This sample was collected from a depth of 0.5 ft bgs; no deeper samples were collected. Based on the low mobility potential of these inorganics, as indicated by the distribution of similar compounds at the site, such as lead, they are expected to remain in near-surface soils (above 5 ft).

10.4.5.2 Organic Compound Evaluation

Two VOCs and three SVOCs were detected in one or more surface and near surface soil samples. Toluene was detected in four surface soil samples at concentrations ranging from 0.30 to 0.52 $\mu\text{g/g}$. SVOCs chrysene, fluoranthene, and pyrene were detected at concentrations less than 1 $\mu\text{g/g}$ in the 1.0 ft sample from Boring 1351SO05.

Methylethylketone/2-butanone was also detected at a concentration of 6.3 $\mu\text{g/g}$ in this sample. Fluoranthene was also detected in the 1.5 ft bgs sample from Boring 1351SO02 at a concentration of 0.062 $\mu\text{g/g}$. 4-Methylphenol/4-cresol and pyrene were detected in surface soil Sample 1351SS01. None of these VOCs and SVOCs were detected in any of the deeper samples collected from the borings. Therefore, it appears that these compounds are limited in extent to surficial sediments in the vicinity of bermed concrete oil storage pad. Toluene is common in gasoline and would be expected in surface samples from an area associated with vehicle maintenance. Methylethyl ketone can be found in solvents and lube oil fractions of petroleum hydrocarbons, and is also a common laboratory contaminant. Should there have been any downward migration of contaminants, the clay layer at 4 to 5 ft bgs would be expected to retard any vertical movement. There were no detections of these contaminants in samples collected just above the clay layer, both next to the bermed area and in the immediate vicinity. Therefore, it is believed that the migration potential of these

contaminants is very low. Volatilization is the primary migration pathway for most of these contaminants, and detections at depth would be unexpected and were not found.

10.4.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1351 site, including the risk assessment results, as presented in detail in Section 15.

10.4.6.1 Conclusions

To evaluate potential contamination associated with vehicle maintenance activities in and around Building 1351, wipe, surface soil, and subsurface soil samples were collected to the east and northeast of the building. Sampling was focused around a bermed concrete oil-storage pad, an oil/water separator, two wash racks, and the area near the fence southeast of the building. Several inorganics were detected above ambient concentrations and several VOCs and SVOCs were detected at low concentrations in surface and near surface soil. The characterization of part of this site may not be to the extent desired, because the exact location of the degreaser, a potential source of solvents, is unknown. However, because no additional information on the degreaser is available, and the most likely sources of contaminants have been addressed, further investigation at this site is not warranted.

10.4.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected VOCs and SVOCs in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source. Wipe samples were not evaluated because they can not be used quantitatively.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very

conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1351 site are summarized in the following sections.

10.4.6.2.1 Human Health

The GMPA identified institutional (industrial) use for the entire Building 1351 area, and exposure to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are both possible. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

In addition to the risk assessments that are based on the planned future use of the site, a residential PRG ratio screening assessment for surface and subsurface soil was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as

a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 1351 site are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

10.4.6.2.1.1 Quantification of Cancer Risks

COCs in the soil samples for Building 1351 are lead (surface soil), cadmium and bis(2-ethylhexyl) phthalate (subsurface soil). A future land use industrial worker scenario with ingestion of and dermal contact with surface and subsurface soil and the PSF water supply was assessed. The industrial worker scenario resulted in a total risk of $4E-07$, indicating that exposure to the COCs at this site is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

10.4.6.2.1.2 Quantification of Noncarcinogenic Effects

The hazard index is below $1E+00$, which indicates that exposure to the respective receptors at this site is unlikely to result in noncarcinogenic adverse health. The residential PRG ratio screening assessment resulted in a total hazard index greater than $1E+00$. The maximum detected lead value at Building 1351 surface soil is 473 mg/kg. This value is less than the lead soil screening value of 840 mg/kg.

10.4.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 1351 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified in the soils from Building 1351 for the ecological risk assessment include several inorganics, VOCs, and SVOCs, including three PAHs. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 based on the TBV_{Low} .
- HIs for the American robin and plants and soil fauna exceeded 1 based on the TBV_{High} .
- Cadmium and lead in soil and diet resulted in HQs greater than 1 for the American robin based on a comparison to TBV_{Low} values. Only cadmium resulted in HQs greater than 1 for the American robin when the HQs were based on TBV_{High} values.
- Cadmium and lead in diet resulted in HQs greater than 1 for the mourning dove based on TBV_{Low} values. HQs were less than 1 for the mourning dove when the TBV_{High} values were used.
- Cadmium in diet produced an HQ greater than 1 for the western harvest mouse; however, there were no HQs in excess of 1 based on the TBV_{High} values.

- Cadmium, copper, and zinc produced HQs greater than 1 for plants and soil fauna based on a comparison of exposure to the TBVLow values; however, there were no HQs that exceeded 1 based on a comparison to the TBVHigh values.

The remaining receptors and pathways evaluated at Building 1351 did not indicate a potential for ecological risk. The ecological risk assessment for Building 1351 will be further evaluated to determine whether the assessment warrants inclusion of this site into FS.

10.5 FORT POINT U.S. COAST GUARD STATION

The FPCGS was added to the RI in the fall of 1990 when the land and permanent buildings reverted to PSF control. The following sections describe the FPCGS field program and its results. An asbestos survey, the results of which will be presented under separate cover, was also performed at the FPCGS during the Initial RI.

10.5.1 Area Description

The FPCGS is west of Crissy Field Study Area and east of the Building 900s Series Study Area on the shore of San Francisco Bay. The area is relatively flat, at an elevation of approximately 13 ft-PLL. Vegetation consists of a few small landscaped grounds with lawns, palms, and cypress trees.

The FPCGS consists of nine buildings and a pier that extends into the bay northeast of Building 991 (Figure 10.5-1). Seven of the buildings at the FPCGS are located on shore, and the other two, Buildings 998 and 999, are located on the pier. The on-shore buildings are separated from the beach by a low-lying seawall northwest of Building 995 and a 6-ft chain-link fence southeast of Building 995. The area southwest of the beach is paved, with the exception of the lawns and a small gravelly surface east of Building 996.

The FPCGS was established in 1889 to provide support and rescue to ships entering the bay. The original station was located on what is now the Crissy Field Study Area and consisted of two buildings: a boathouse with a ramp out to the bay and a combination residence and office. In 1914 or 1915, the station was moved to its present location, approximately 700 ft to the west. At about the same time, a new larger station house, Building 991, was built with

a rail system out to the end of the pier for moving boats between the building and the water. The original station house, Building 992, became the quarters for the officer in charge, and the old boathouse, Building 993, was used as a garage (USCOE, 1990).

With the introduction of larger-hulled boats, the rail system could no longer be used; its last remnants were removed in 1976. With no way of removing boats from the water, the USCG was forced to leave them moored at the pier, where they were continually damaged by rough water. With this in mind, the USCG decided to abandon the station in 1990, and the land and permanent buildings reverted to U.S. Army control.

Over time, several buildings were added. On the pier, Building 998 was used to refuel USCG boats, and Building 999 is a meteorological data collection site. Buildings 995 and 996 have been used for storage and maintenance, and Building 997 houses a generator. Building 994 was used by the U.S. Army for parachute maintenance.

Throughout its history, several aboveground storage tanks have been located in the FPCGS area. An aboveground fuel oil tank for the generator housed in Building 997 is located just north of that building. A 10 ft by 5 ft rectangular container labeled lube oil is located east of Building 996. The wooden lid was removed, and it was found to contain water with an oil sheen on top. An AST was located in the fenced area next to the southeastern wall of Building 996. This tank has been removed, but the storage tank support structure is still intact. An additional AST may have existed near the northwest corner of Building 995. It is not known when the ASTs were removed.

In addition to the ASTs, four USTs of various sizes were once located in an area southwest of the seawall and north of Building 991 (Figure 10.5-1). There were 600-, 300-, and 200-gal waste oil tanks that may have contained diesel fuel in the past and one 2,000-gal diesel fuel tank. All tanks were made of steel and estimated to be 20 years old (RLSA, January 1991). On May 11, 1990, the four USTs were pumped out and excavated by Petroleum Engineering of Santa Rosa and removed from the site by H & H Ship Service Company of San Francisco. It was noted at the time of the UST removal that one or more of the tanks had leaked. Holes 5 to 7 inches in diameter were found in the bottom of the UST waste oil tanks when they were removed (Tetra Tech, 1993). An UST Unauthorized Release/ Contamination

Site Report was prepared for the USCG by the City of San Francisco, and the site was remediated. Four soil samples and one water sample were collected in the former location of the tanks to confirm that cleanup was complete. The results of these confirmation soil samples are described Section 10.5.4.

10.5.2 Sample Location Rationale

Four primary sources were identified at the FPCGS: the former location of the four USTs, storage and maintenance activities in Building 995, the AST at Building 996, and the AST at Building 997. Four types of samples were collected at the FPCGS: surface soil, subsurface soil, discrete groundwater, and groundwater from monitoring wells. This section will describe, in terms of the conceptual model described in Section 3.1, the rationale behind the sampling plan. Sample locations are shown in Figure 10.5-1.

The USTs were removed by the USCG, and the associated stained soil was remediated. In addition to the samples collected by USCG personnel in 1990, four soil samples and one discrete groundwater sample were collected in the former location of the tanks to confirm that cleanup was complete.

Staining was noticed near the north corner of Building 995, outside a door in the northwest wall. The stained material was assumed to be the result of spills or leaks associated with activity inside the building. A surface soil sample was collected during the Initial RI to characterize the nature of the potential contamination. The primary release mechanism for such a secondary source would most likely be infiltration deeper into the soil column and eventually to the groundwater. As part of the Supplemental RI, monitoring Well CGGW02 was installed at the site of the staining. During drilling, analytical soil samples were collected from different depths to further define the nature and extent of potential contaminants and evaluate the extent of infiltration. Groundwater from Well CGGW02 was sampled in 1992 and 1994. During the Follow-on RI, additional soil samples were collected surrounding Well CGGW02.

The primary release mechanism for the two ASTs would be leakage to the surface soil. Staining was noted on the surface near the tank at Building 996. Surface and subsurface soil samples were collected to evaluate potential contamination of the soil and the extent of

contaminant infiltration and percolation. During the Supplemental RI, Well CGGW03 was installed east of Building 996. Groundwater samples were collected in 1992 and 1994 to determine the effects of potential surface contamination on the groundwater. A surface soil sample was collected during the Initial RI near the fuel oil tank beside Building 997 to determine if leakage had occurred.

In addition to the source-related sampling, Well CGGW01 was installed in the expected upgradient direction from the other two wells. The location was chosen based on the assumption that the groundwater gradient is toward the bay. The well was installed to monitor any potential contaminants entering the FPCGS area through the groundwater and to provide background water-quality data.

10.5.3 Hydrogeologic Setting

The investigation of the FPCGS included the collection of five surface soil samples, the drilling of 12 soil borings and three discrete groundwater borings, and the installation of three monitoring wells. The lithologic logs from these borings (Appendix H.5) are the basis for the following discussion of the geology at the site.

10.5.3.1 Soils and Geology

The surficial sediments in the FPCGS area, as shown on Figure 2.3-3, are mapped by the USGS as modern beach deposits and artificial fill (Schlocker, 1974). Prior to infilling, part of the area was swamp, and the remainder was inundated by the San Francisco Bay (Figure 5.1-3). Cross sections A-A' and B-B' (Figures 10.5-2 and 10.5-3) show subsurface relationships as interpreted from the soil borings drilled at the site. At the surface, borings penetrated fill composed of sandy clay and gravel, with a maximum encountered thickness of 2.5 ft. Immediately underlying the fill material are native deposits consisting of fine-grained, well sorted sand with some gravelly beach sand (Appendix H.5). Silty sand layers were encountered in the deeper borings at depths ranging from 16 to 20 ft bgs (Appendix H.5). These silty layers are interpreted to represent bay mud deposits similar to those seen in the Crissy Field Study Area, but there are insufficient data from soil borings to indicate that these layers are laterally continuous. Although borings were drilled as deep as 38 ft bgs, bedrock was not encountered, and the depth to bedrock in this area remains unknown. The

bedrock structure contour map of the Building 900s Series Study Area (Figure 6.3-5) suggests that depth to bedrock in the FPCGS area is at least 40 ft bgs and increases toward the bay. Borings drilled to bedrock in the Building 900s Series Study Area suggest that bedrock beneath the FPCGS area is serpentinite.

10.5.3.2 Hydrology

Depth to groundwater in the FPCGS area ranges from 5 to 7 ft bgs. The area is underlain by an unconfined water-bearing zone consisting of sand and silty sand extending to a depth of at least 26 ft bgs (Figures 10.5-2 and 10.5-3). The water-bearing zone extends into the Building 900s Series Study Area to the west and the Crissy Field Study Area to the east. Tidal influence on water levels in the area ranges from 0.02 to 0.26 ft (Appendix H.5). Based on water level measurements, the hydraulic gradient in the area was 0.001 ft/ft in 1992, and 0.0125 ft/ft in 1995. The groundwater flow direction is generally to the northeast, based on water levels measured at low tide (Figure 2.3-9). Recharge is primarily through infiltration of precipitation and runoff.

Since the Initial RI in 1992, the tidal influence on groundwater flow direction appears to have decreased significantly. Water table elevations were measured in 1992 and 1995 during high and low tide from Wells CGGW01, CGGW02, and CGGW03. The 1992 water levels show high tide groundwater flow was to the west-southwest, and low tide groundwater flow was to the south-southeast. However, in 1995 groundwater flow during both high and low tide was to the northeast toward the bay. A possible explanation for the change in groundwater flow direction is that the groundwater recharge was much greater in 1995 than in 1992 due to the much higher levels of precipitation.

10.5.4 Analytical Results

This section presents the analytical results for samples collected during the Initial, Supplemental, and Follow-on field programs of the RI. These samples were collected to assess the impacts of each of the four identified potential sources at the site:

- the former location of four USTs north of Building 991
- storage and maintenance at Building 995

- a former AST at Building 996
- an AST at Building 997.

The tables of analytical results include only those compounds detected at concentrations above the CRLs or RLs. A complete list of target analytes can be found in Table 3.3-1 and 3.3-2. Most of the samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients. Therefore, these inorganics are excluded from the following discussions. All other inorganics detected in soil will be compared to ambient concentrations, as described in Section 3.7.

10.5.4.1 UST Area North of Building 991

Four soil samples and one water sample were collected from the former UST area by USCG personnel in May 1990. The soil samples were analyzed using USEPA methods 8240, 3550/8015, and 8020 for organic compounds. The results are contained in a report by Tetra Tech (1993) and are described below. Acetone was detected in two of the four soil samples (2,220 and 3,400 ppb). Xylene was detected at 1,430 ppb in one soil sample and all the soil samples displayed the presence of diesel fuel with a range of 12 ppm to 2,800 ppm. The water sample had a concentration of 83 ppm diesel, 13,000 ppb light hydrocarbons, 270 ppb ethylbenzene, 500 ppb toluene, and 1,100 ppb total xylene (RLSA, 1991). The soil surrounding the sample locations was removed when the tanks were excavated. Additional information regarding the effectiveness of UST removal and remediation is contained in the USCG Work Plan (Tetra Tech, 1993).

Four soil borings were drilled at the site of the removed UST during the Initial RI field program to verify that remediation of the site had been complete. Two soil samples were collected from Borings CGSO02, CGSO03, and CGSO04, and one sample was collected from CGSO01. All seven samples were analyzed for inorganics, VOCs, SVOCs, and TPH; detections above the CRLs are shown on Table 10.5-3.

All samples were collected from native sediments, and all inorganics detections were compared to ambient beach/dune sand concentrations. Mercury, which was detected in the 3.0 ft bgs sample from Boring CGSO03B at a concentration of 0.098 $\mu\text{g/g}$, was the only inorganic analyte detected above ambient levels.

Toluene was detected above the CRL in two samples collected from Boring CGSO04, both at a concentration of 0.33 $\mu\text{g/g}$. Trichlorofluoromethane was not a requested analyte but was reported above the CRL in Boring CGSO01A, at 2.0 ft bgs. No SVOCs were detected above the CRL. TPH was detected at a concentration of 20 $\mu\text{g/g}$ in Boring CGSO03A at a depth of 2.0 ft bgs (Table 10.5-3).

During the Follow-on RI, samples were collected to define the vertical and lateral extent of contamination associated with the removed USTs. Because of the shallow water table, soil samples had not been previously collected below the former UST location. Therefore, to assess the vertical extent of potential contamination at the former UST location, a discrete groundwater sample boring was drilled through the location of the former USTs. Three groundwater samples were collected from discrete depths. To assess the lateral extent of contamination, two additional discrete groundwater borings were drilled northwest and southwest of the original discrete groundwater boring (Borings CGSB02 and CGSB03, respectively). Groundwater samples were collected from three discrete intervals in each boring. Groundwater data from Well CGGW02 were used to define the southeast extent of potential groundwater contamination. No borings could be drilled to the northeast of the site because of the presence of San Francisco Bay (Figure 10.5-1).

The discrete groundwater samples were each analyzed for lead, TPH-D, and TPH-G. Each of the upper- and mid-level discrete groundwater samples in the three borings (CGSB01, CGSB02, CGSB03) had lead concentrations above the SDC of 15 $\mu\text{g/l}$. The unfiltered discrete water samples that were analyzed were turbid, and some of the lead in the samples may have been sorbed to soil particles in the samples. The deepest sample from Boring CGSB01 had lead concentrations below the SDC, and the lead results for the deepest samples from Borings CGSB02 and CGSB03 were below the RL. Borings CGSB01 and CGSB02 had TPH-D concentrations above the SDC in both the upper- and mid-level discrete groundwater samples, but TPH-D was not detected above the RL in the deepest

samples. TPH-D concentrations did not exceed the RL for any of the three discrete groundwater samples from Boring CGSB03. Borings CGSB01 and CGSB02 had TPH-G concentrations above the SDC for all three depth discrete groundwater samples (Table 10.5-2). TPH-G hold times were exceeded for all three samples from Boring CGSB03, and the results are, therefore, unusable. Lab data show that the TPH-D found in Boring CGSB02 and TPH-G found in the upper sample of Boring CGSB01 did not have a gas or diesel fingerprint. This could be due to product degradation, or to the different solubilities and migration rates of different components of gasoline causing vertical separation over time. In addition, the specific types of fuels stored in the USTs were not documented, so fuels other than gasoline and diesel may have been stored in the USTs.

The analyte suites for groundwater samples collected from Well CGGW02 during the Supplemental and Follow-on RI programs both included TPH-D and TPH-G. These results were used to define the lateral extent of contamination to the southeast of the UST location. The Supplemental RI sample had a detected TPH-D concentration of 80 µg/L. TPH-G was not detected above the RL. In the follow-on sample, neither analyte was detected above its respective RL.

10.5.4.2 Building 995

Building 995, used for storage and maintenance, had surface staining visible on the pavement outside the door in the northwest corner of the building. During the Initial RI, a surface soil sample, CGSS03, was collected at the site of the staining to evaluate the possibility of contaminant release to the paved surface. The sample was analyzed for inorganics, VOCs, SVOCs, and TPH. All detections above the CRLs are shown in Table 10.5-4. The sample was collected in fill material. Inorganic concentrations in this sample were compared to ambient inorganic concentrations in samples of fill collected across the PSF as discussed in Section 3.7, and no inorganics were detected above these ambient concentrations. Toluene, at 0.38 µg/g, was the only VOC detected above the CRL. Ten PAHs at concentrations above the CRLs were contained in this sample. TPH was detected at a concentration of 300 µg/g (Table 10.5-4).

During the Supplemental RI, Boring CGGW02 was drilled at the site of the staining to evaluate any potential migration of the previously detected PAHs into the soil. Soil samples

were collected at depths of 2.0 and 3.5 ft from the boring, and the samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Compounds detected at concentrations above the CRLs or RLs are listed on Table 10.5-1. Both of the soil samples were collected from native sediments, and inorganic concentrations were compared to ambient beach/dune sand concentrations. Thallium was detected above ambient in the samples collected at 2.0 and 3.5 ft bgs, but these thallium data are considered unreliable. Both arsenic and cadmium were detected above ambient in the 3.5 ft sample. Arsenic was detected at a concentration of 5.33 $\mu\text{g/g}$, and cadmium was detected at a concentration of 0.690 $\mu\text{g/g}$. No VOCs, SVOCs, OCPs, PCBs, or chlorinated herbicides were detected at concentrations above the CRLs or RLs. TPH-D was detected at a concentration of 1.00 $\mu\text{g/g}$ in both samples.

To assess the lateral extent of the PAH and TPH contamination detected in CGSS03, three soil borings (995SB01, 995SB02, 995SB03) were drilled during the Follow-on RI surrounding the original surface soil sample. The boring locations are 10 ft northeast, northwest, and southwest of the original surface soil sample (Figure 10.5-1). No samples were collected to the southeast because of the location of Building 995. The five soil samples collected from the three borings were analyzed for PAHs, TPH-G, and TPH-D. The analytical results of the samples from Borings 995SB01, 995SB02, and 995SB03 are listed in Table 10.5-5. No analytes were detected above the RL in any of the samples.

Well CGGW02 was installed to assess the potential impacts of surface activities on the groundwater. Groundwater was sampled from Well CGGW02 during the Supplemental and Follow-on RI. The Supplemental RI groundwater sample was analyzed for inorganics and miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH fractions listed on the target analyte list (Table 3.3-1). All detections above the CRLs or RLs are shown in Table 10.5-6. The sample collected for inorganic analyses was filtered in the field. Several inorganics and miscellaneous parameters exceeding CRLs were detected. No VOCs, SVOCs, OCPs, PCBs, or chlorinated herbicides were detected above the CRLs or RLs. TPH-D was detected at 80 $\mu\text{g/L}$, though chromatograms indicate the detected compound was a longer-chain hydrocarbon than diesel fuel. The Follow-on groundwater

sample was analyzed for TPH-D and TPH-G, and neither analyte was detected above its respective RL (Table 10.5-7).

10.5.4.3 Building 996

Building 996 was considered to be a potential source of contamination based on surface staining in the fill material near the former location of the AST. Surface soil, subsurface soil, and groundwater samples were collected during the Initial, Supplemental, and Follow-on RI field programs.

Three surface soil samples (CGSS01, CGSS02, CGSS05) were collected from the area during the Initial RI. These surface soil samples were collected from fill material within discrete stains on an unpaved soil area. The maximum areal extent of stains in the area was 1 ft². The samples were analyzed for inorganics, VOCs, SVOCs, and TPH, and detections above the CRLs are shown in Table 10.5-4. Inorganic concentrations in the samples were compared to ambient inorganic concentrations in fill sediments from across the site. Lead and zinc were both detected at concentrations greater than ambient in all three samples. Sample CGSS01 contained 1,3-dimethylbenzene, toluene, and xylene above the CRLs. Sample CGSS02 contained no VOCs above the CRLs, and Sample CGSS05 contained toluene above the CRL. Five PAHs, benzo[a]anthracene, chrysene, fluoranthene, phenanthrene, and pyrene, were detected above the CRLs in one or more of the samples. TPH was detected in all three samples at concentrations ranging from 10,000 to 20,000 µg/g (Table 10.5-4).

Subsurface soils were also sampled during the Initial RI. Two subsurface soil samples, CGSO05A and CGSO06A, were collected at 1.0 ft bgs from locations adjacent to Samples CGSS01 and CGSS02, respectively. These samples were analyzed for inorganics, VOCs, SVOCs, and TPH. Detections exceeding the CRLs are listed on Table 10.5-3. Both samples were collected in fill material, and inorganic concentrations were compared to ambient fill concentrations. Barium, at 373 µg/g in the sample from Boring CGSO05, was the only inorganic that exceeded ambient fill levels. Toluene was detected at a concentration above the CRL in both samples. Trichlorofluoromethane, which was not a requested analyte, was detected above the CRL in the sample from Boring CGSO05A, the boring closest to the tank

(Figure 10.5-1). No SVOCs were detected above the CRLs, and detected TPH values were 400 to 3,000 $\mu\text{g/g}$, with the higher detection in Boring CGSO05A.

During the Supplemental RI, an additional boring was drilled near the tank for the installation of Well CGGW03. Soil samples were collected from the boring at 0.5 and 5.0 ft bgs to further evaluate the nature and extent of contamination in the area. These samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Detections above the CRLs or RLs are listed on Table 10.5-1. The upper sample was collected in fill material while the deeper sample was collected in native sand. Thallium was detected above ambient (detection limit) in both samples, but the thallium results are considered to be unreliable. Chromium and silver were both detected in the 5.0 ft sample at concentrations above their respective ambient levels in sediments. No VOCs were detected at concentrations exceeding the CRLs. The shallow sample contained five PAHs at concentrations above the CRLs: benzo[a]anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene. The deeper sample had no SVOCs detected above the CRLs. The OCP, ppDDT was reported in the shallow sample at a concentration of 0.05 $\mu\text{g/g}$. No PCBs or chlorinated herbicides were detected above their RLs in either sample. TPH-D was detected at 380 $\mu\text{g/g}$ in the shallow sample and at 1.00 $\mu\text{g/g}$ in the deep sample. In addition to the normal analysis suite, a WET was run on the 0.5 ft bgs sample, yielding the following results: soluble chromium at 0.750 mg/L, soluble lead at 4.00 mg/L, and soluble nickel at 1.00 mg/L (Appendix O).

Because lead and TPH were detected at concentrations greater than action levels, three additional soil borings (996SB01, 996SB02, 996SB03) were drilled surrounding the existing samples during the Follow-on RI to assess the lateral extent of contamination (Figure 10.5-1). Two samples were collected from each boring and analyzed for lead and TPH. Lead exceeded the ambient beach/dune sand concentration in the 3.5 ft bgs sample from Boring 996SB03. TPH was not detected above the RL in any of the six subsurface soil samples (Table 10.5-8).

Well CGGW03 was installed to assess the potential impacts of surface activities on the groundwater. Groundwater samples were collected from Well CGGW03 during the Supplemental and Follow-on RI. The Supplemental RI sample was analyzed for inorganics

and miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH fractions, as listed on the target analyte list (Table 3.3-1). Detections above the CRLs are shown in Table 10.5-6. Two samples were collected for inorganics analysis: one was filtered in the field, and the other was not. Several inorganics were detected above the CRLs in both samples. With the exception of nickel, which was reported below the CRL, all reported concentrations were greater in the unfiltered sample than in the filtered sample. Numerous miscellaneous parameters were detected above the CRLs. No VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, or TPH fractions were detected above the CRLs or RLs. The Follow-on RI groundwater sample was analyzed for TPH-D and TPH-G, and neither analyte was detected above the RLs (Table 10.5-7).

Sample CGSS05 met the criteria for the discussion of unknowns. Thirty-nine unknown SVOC hydrocarbons were tentatively identified, with a total concentration of 210 $\mu\text{g/g}$ and an average concentration of 3 $\mu\text{g/g}$.

10.5.4.4 Building 997

The AST near Building 997 was a potential source of contamination through release by spills or leaks. Several stains, with a maximum areal extent less than 1 ft^2 , were noted in the area, and a surface soil sample was collected from one of these stains to evaluate the possibility of contaminant release to the soil. Sample CGSS04 was collected in fill material and analyzed for inorganics, VOCs, SVOCs, and TPH. Those compounds detected at concentrations above the CRLs are listed in Table 10.5-4. Detected inorganics concentrations were compared to ambient fill levels, and there were no ambient exceedences. Toluene was detected at 0.31 $\mu\text{g/g}$. Fluoranthene and phenanthrene were detected above the CRLs, at 0.9 $\mu\text{g/g}$ and 0.8 $\mu\text{g/g}$, respectively. TPH was reported at a concentration of 100 $\mu\text{g/g}$.

The transformer at Building 997 was sampled by Watkins-Johnson environmental as part of a separate project in 1993. No PCBs were detected, and the transformer was described as being in good condition. Therefore, this transformer is not considered a likely source of PCBs to the soil.

10.5.4.5 Inland Well CGGW01

During the Supplemental RI, a third monitoring well, CGGW01, was installed inland from the other two wells. This was done so that upgradient groundwater could be analyzed and to confirm the suspected groundwater flow direction. A groundwater sample was collected from this well during both the Supplemental and Follow-on RI field programs. The Supplemental RI sample was analyzed for inorganics and miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH fractions, as listed on the target analyte list (Table 3.3-1). Detections above the CRLs or RLs are shown on Table 10.5-6. The sample collected for inorganic analysis was filtered in the field. Several inorganic and miscellaneous parameters were detected above the CRLs. No VOCs or SVOCs were detected above the CRLs or RLs. A detection of the OCP beta-BHC was reported, but at a concentration below the RL. No PCBs, chlorinated herbicides, or TPH compounds were detected above the CRLs or RLs. The Follow-on RI groundwater sample was analyzed for inorganics and miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH fractions, and the results are shown in Table 10.5-7. Both filtered and unfiltered samples were collected for inorganics analysis. Several inorganics and miscellaneous parameters were detected above RLs, but there were no detections of organic analytes.

10.5.5 Results Evaluation

This section presents the evaluation of the sampling results for the FPCGS site. The intent of this evaluation is to describe the nature and extent and fate and transport of contaminants associated with the sources in the area and to determine which data should be entered into the Risk Assessment. The sources evaluated in this area were the former location of the four USTs, storage and maintenance activities in Building 995, the AST at Building 996, and the AST at Building 997; both soil and groundwater samples were collected.

The first step in evaluating the soils results involves the determination of which analytes are COPCs (see Section 3.7), which will be evaluated in the Risk Assessment. Once COPCs are identified, the nature and extent and fate and transport of these analytes will be discussed. Analytes that are not considered COPCs will not be discussed further. RI samples were analyzed for inorganic and organic analytes. Inorganic analytes are naturally occurring, and their presence at a site may or may not be anthropogenic. In determining which inorganic

analytes are COPCs, several factors are considered. These include the magnitude and number of detections above ambient values, the spatial distribution of these exceedences, the type of soil in the sample, and comparison with concentrations typical of soils in other areas of the region. In addition, the absence or presence of potential sources is assessed. The RI assumes that all organic analytes are anthropogenic, and all detected organic compounds are, therefore, considered COPCs. Posting maps were prepared for inorganic and organic analytes and are presented as Figures 10.5-4 through 10.5-10.

In order to provide a frame of reference for the discussion of groundwater results, the concentrations of inorganics and organics in groundwater are compared to Primary MCLs and saltwater aquatic standards (Table 3.8-6). The saltwater aquatic standards may only be applicable to groundwater within 150 ft of the shoreline, in the area that has been designated a Saltwater Ecological Protection Zone by the SCR (California Regional Water Quality Control Board, 1996). In addition, comparison to MCLs does not imply that groundwater in the FPCGS site is suitable for domestic or industrial use. In fact, the GMPA for the PSF prepared by the NPS (1994) does not include development of groundwater in this area for either a drinking water source or industrial use. In addition, California recommended secondary MCLs for TDS and chloride are exceeded at the site because of saltwater intrusion, as was discussed previously in Section 2.3 of this RI report. Groundwater at the site also has exceeded the TDS standard of 3,000 mg/L set forth in California Resolution 88-63 for potential municipal or domestic water supplies. The groundwater chemistry is used to evaluate whether chemicals in soils are leaching to the groundwater or fluctuations of water-table elevations result in adsorption of dissolved chemicals onto soil particles.

According to PSF Basic Information Maps, there is a storm drain running roughly parallel to the east wall of Buildings 994 and 996, with catch basins south of Buildings 991, 992, 993, and 994. None of the locations sampled at the FPCGS during the RI appear likely to drain into this storm drain system. However, sediment samples collected at Outfall 12 during the ESAP may have been impacted by groundwater discharging from this area. Analytical and bioassay testing data for sediments indicated that although low levels of PAHs and pesticides were associated with samples from Outfall 12, there was no significant effect on the toxicity of the sediments to the tested species. The compounds detected in the Outfall 12 samples

were also detected in FPCGS soils, but not in any of the groundwater samples. The results of sampling at this outfall are discussed in detail in the ESAP report (D&M, 1996a, b).

Monitoring Well CGGW01 was installed to aid in determining the direction of groundwater flow in the FPCGS area and to identify any groundwater contamination migrating into the FPCGS from the south. Water level measurements indicate a relatively flat northeasterly hydraulic gradient. Therefore, the possibility exists that mobile COPCs from the Building 900s Series Study Area could be detected in a groundwater sample from this well. However, the only organic target analyte detected in this well during either the Supplemental or Follow-on RI sampling was beta-BHC at a concentration below the CRL (Table 10.5-6). Antimony was detected above the Primary MCL in the filtered Follow-on RI sample, lead exceeded water quality objectives and criteria for the protection of saltwater aquatic life in the Supplemental RI sample, and copper and nickel exceeded water quality objectives and criteria for the protection of saltwater aquatic life in the filtered Follow-on RI sample. Chloride, manganese, and TDS exceeded California Secondary MCLs (Table 10.5-9). Quarterly sampling results for this well (Montgomery Watson, 1996i) do not include the detection of any analytes above MCLs or criteria for the protection of saltwater aquatic life.

10.5.5.1 Underground Storage Tanks

Subsurface soil, discrete groundwater, and monitoring well groundwater samples were collected near the former UST location to evaluate the completeness of previous remediation conducted in this area. In the event that remediation of the tank area was not complete, it would be expected that BTEX, PAHs, and TPH would still be present in soil. Initial RI investigations conducted in 1992 found toluene in two subsurface soil samples collected from the sand on the beach side of the seawall. TPH was detected at a concentration of 20 µg/g at 2.0 ft bgs in Boring CGSO03, which was drilled to the west of the former UST location (Table 10.5-1).

During the Supplemental RI, Boring CGGW02 was drilled southeast of the former UST site, and subsurface soil samples were collected from two depths. The only organic target analyte detected above the CRLs was TPH-D, at a concentration of 1 µg/g in both samples.

Subsequent groundwater sampling was used to further define the vertical and lateral extent of possible contamination from the former USTs. Groundwater data from Well CGGW02 can be used to characterize the southeastern corner of the former UST area. This well was sampled during both the Supplemental and Follow-on RI field programs. The Supplemental RI samples had several inorganics and general chemical parameters above the CRLs, but organic target analytes were below RLs except TPH-D which was detected at a concentration of 80 µg/L. Nickel was the only inorganic detected at a concentration above the water quality objectives and criteria for the protection of saltwater aquatic life (Table 3.8-6). Both chloride and TDS exceeded recommended secondary California MCLs (Table 10.5-9). The elevated chloride and TDS levels are attributable to natural saltwater intrusion due to the proximity of the bay.

Groundwater samples collected from Well CGGW02 during the Follow-on RI sampling program continued to show high nickel, chloride, and TDS, but TPH-D and TPH-G were not detected above RLs. The copper concentration in the filtered sample from this event also exceeded water quality objectives and criteria for the protection of saltwater aquatic life. There were no Primary MCL exceedences in the Supplemental RI sample from this well, but aluminum and antimony were detected above the Primary MCLs in the sample collected during the Follow-on RI program. Quarterly sampling results for this well (Montgomery Watson, 1996i) do not include the detection of any analytes above MCLs, and the only exceedence of criteria for the protection of saltwater aquatic life was lead in an unfiltered sample collected during the Fall of 1995.

The discrete groundwater sampling conducted during the Follow-on RI in 1995 was designed to further define the vertical and lateral extent of possible contamination in directions away from Well CGGW02. This was accomplished by collecting three depth-discrete groundwater samples from each of three borings. One boring (CGSB01) was located at the former UST location, and the other two were approximately 80 ft to the northwest (CGSB02) and southwest (CGSB03). Sample collection to the northeast was not feasible because of the proximity to the bay. The discrete groundwater samples contained lead at concentrations above the Primary MCL and water quality objectives and criteria for the protection of saltwater aquatic life in both the upper and middle samples from all three borings. TPH-D

was detected in the upper and middle samples from the boring at the former tank site and the boring to the northwest. The detected concentrations were higher at the former tank site and showed a decrease with depth. The detected TPH-D concentrations in the northwest boring did not decrease with depth. TPH-G was detected in all three samples from both of these borings and did not show a consistent decrease or increase with depth. The southwest boring, CGSB03, which was drilled in the upgradient direction, did not contain detectable concentrations of either TPH-D or TPH-G.

The distribution of contaminant concentrations in the depth-discrete groundwater samples suggests that the silty layer encountered below 16 ft bgs beneath the FPCGS area tends to inhibit contaminant mobility. The discrete groundwater sample results for Borings CGSB01 and CGSB02 (Table 10.5-3) show that the silt layer does keep TPH-D and lead from migrating downward as far as the 19.5 and 21.5 ft bgs samples, which were collected within the silty sand layer. TPH-G concentrations did not follow the same pattern as TPH-D and lead. Instead, the concentrations of TPH-G were very similar between the three sample depths. This may be due to the fact that the migration rate of the longer chain hydrocarbons (TPH-D) is generally much slower than that of the shorter chain hydrocarbons (TPH-G); therefore, the gasoline fraction migrated farther in the same amount of time. The possibility that the TPH-G detections are due to an upgradient source in the Building 900s Series Study Area is deemed unlikely. TPH detections in groundwater in the Building 900s Series Study Area have generally been limited to wells that are screened across the water table. It would, therefore, be reasonable to expect that any migration into the FPCGS site would be detected through the sampling of Well CGGW01, which has never contained detectable concentrations of TPH-D or TPH-G.

In summary, the extent of contamination from the former USTs is defined to the southeast by soil samples collected during drilling of the monitoring wells and by water samples collected from Well CGGW02. If contamination from the USTs were to migrate in this direction, organic target analytes would have been found in the soil samples collected during well construction and in the groundwater during monitoring well sampling. UST contamination is defined to the southwest by discrete groundwater samples collected in Boring CGSB03. If contamination from the USTs were to migrate in this direction, TPH-D and TPH-G would

have been detected. The extent of contamination has not been defined to the northwest or to the northeast toward the bay.

10.5.5.2 Building 995

Building 995 was previously used for storage and maintenance. Surface staining visible on the pavement outside a door in the northwest wall made this area a potential source of contamination. A surface sample collected from an unpaved section of the otherwise paved parking area outside the northwest door in Building 995 contained toluene, 10 PAHs, and TPH. In order to assess the vertical migration of these COPCs, subsurface soil samples were collected at 2.0 and 3.5 ft bgs from Boring CGGW02. The analyses for inorganics showed that arsenic and cadmium were present in the 3.5 ft bgs sample at concentrations greater than ambient beach/dune sand levels. In the 2.0 ft bgs sample, however, arsenic was below ambient, and cadmium was not detected. This suggests that the concentrations detected at 3.5 ft bgs are not related to surface activities; arsenic and cadmium are not considered COPCs. The only COPC detected in the subsurface above the RL was TPH-D at a concentration of 1 $\mu\text{g/g}$. A direct comparison between the detected TPH-D concentration and the TPH in the surface sample cannot be made due to the difference between the analytical methods, but this indicated that the toluene and PAHs had not migrated downward.

To assess the lateral extent of contamination, three soil borings (995SB01, 995SB02, 995SB03) were drilled during the Follow-on RI surrounding the original surface soil sample. The five soil samples collected from the three borings were analyzed for PAHs, TPH-G, and TPH-D. No analytes were detected above the RLs in any of the samples.

A groundwater sample from Well CGGW02 further supported the relatively limited migration of the COPCs. This well was sampled during both the Supplemental and Follow-on RI field programs. The Supplemental RI sample contained several inorganics and general chemical parameters above the CRLs. All of the surface COPCs, however, were below RLs except TPH-D, which had a concentration (80 $\mu\text{g/L}$) above both the RL and the SDC. The groundwater sample collected from this well during the Follow-on RI sampling program did not contain detectable concentrations of TPH-D and TPH-G. The inorganics results for this well are described in Section 10.5.5.1.

10.5.5.3 Building 996

The area southeast of Building 996 was considered a potential source of contamination due to the presence of stained surface soil near the former location of an AST that was used to store waste oil. Anticipated COPCs associated with this source include inorganics, BTEX, PAHs, and TPH. Lead and zinc were both detected above ambient fill concentrations in all three of the surface soil samples collected from this area during the Initial RI. During the Follow-on RI program, lead was also detected above the ambient concentration for beach/dune sand at 3.5 ft bgs in Boring 996SB03. Both of these inorganics will be evaluated as COPCs in the BRA. During Supplemental and Follow-on RI sampling, nickel in groundwater exceeded water quality objectives and criteria for the protection of saltwater aquatic life. The Follow-on RI sample also contained cadmium and copper (filtered) above water quality objectives and criteria for the protection of saltwater aquatic life. The cadmium concentration also exceeded the Primary MCL.

Toluene was detected in two surface soil samples, and xylenes were present in one. Toluene was also detected in two subsurface samples collected during the Initial RI, but was not detected above the CRL in either of the subsurface samples collected during Supplemental RI. Migration of toluene in soil to groundwater is possible, but no VOCs were detected above the RLs in the groundwater samples collected from Well CGGW03 during the Supplemental or Follow-on RI field programs. This well is located in the immediate vicinity of the stained surface soil.

Five PAHs were detected in one or more of the surface soil samples. These compounds have limited mobility in the unsaturated zone, and no SVOCs were detected below 0.5 ft bgs. TPH was detected in surface soil samples at concentrations on the order of 10,000 $\mu\text{g/g}$. At a depth of 1.0 ft bgs in Sample CGSO05 (close to the tank bottom), TPH was 3,000 $\mu\text{g/g}$. TPH was 400 $\mu\text{g/g}$ further to the east in Sample CGSO06. During the Supplemental RI, TPH was analyzed for different fractions. All detections in the area were in the diesel fraction. Two subsurface soil samples were collected during the drilling of Well CGGW03. These soil samples contained TPH-D at a concentration of 380 $\mu\text{g/g}$ at 0.5 ft bgs, and 1.00 $\mu\text{g/g}$ at a depth of 5.0 ft bgs. None of the Follow-on RI soil samples contained detectable TPH concentrations. Groundwater sampled from Well CGGW03 did not contain TPH-D

above CRL or RL in either the Supplemental or Follow-on RI sampling rounds. TPH-D was detected at a concentration of 66 $\mu\text{g/L}$ during the Fall 1995 quarterly sampling, but it has not been detected since (Montgomery Watson, 1996i).

In summary, the location of the former AST is surrounded by subsurface soil and groundwater samples that define the vertical and areal extent of contamination. The analytical results from these samples suggest a limited spill with minimal vertical and areal extent.

10.5.5.4 Building 997

The AST at Building 997 was used to store fuel for a generator, and one surface soil sample was collected from a small stain in the area. Contaminants expected to be associated with a spill would include inorganics, BTEX, PAHs, and TPH. No inorganics were detected above ambient fill concentrations. The only VOC detected in the area was toluene at a concentration of 0.31 $\mu\text{g/g}$. Two PAHs, fluoranthene and phenanthrene, were detected above the CRLs, each at a concentration less than 1 $\mu\text{g/g}$. TPH was also detected at a concentration of 100 $\mu\text{g/g}$. Toluene is most likely to volatilize or migrate downward with soil moisture, and the water table in the area is at approximately 6 ft bgs. PAHs have a strong affinity for soil and are unlikely to migrate far from the source. TPH migration depends, in general, upon chain length. Lighter hydrocarbon compounds migrate more readily to the groundwater, whereas heavier compounds have a greater soil affinity. The sampling in the area included only surface soils, but the detected analytes do not have a high likelihood of mobility in the unsaturated zone. The sample was collected from a stain less than 1 ft^2 in area, and the concentrations detected are most likely limited to the stained surface material.

10.5.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the FPCGS site, including the risk assessment results, as presented in detail in Section 15.

10.5.6.1 Conclusions

The investigations in the FPCGS site were designed to assess the chemical impact of U.S. Army activities at the site. Potential sources were identified, and analytical samples were

collected from various media. Four potential sources of COPCs were identified at the FPCGS.

A former UST site north of Building 991 was evaluated through collection of soil and groundwater samples in the area. These samples included isolated detections of toluene, trichlorofluoromethane, and TPH, all presumably released by the former tanks and associated piping. Any future investigations of the former UST area north of Building 991 will be managed under the USCG UST management program.

Maintenance activities in Building 995 resulted in the release of PAHs and long-chain hydrocarbons to the paved surface outside a door in the building. Subsurface samples indicated detectable concentrations of TPH in the soil and the groundwater, but migration of the PAHs had not occurred. An AST formally located near Building 996 apparently released toluene, xylene, PAHs, and TPH to the surface soil. Surface soils near an AST at Building 997 contained PAHs and TPH. All of the stains at Building 997 were of limited extent both laterally and vertically, and contaminants detected in surface soil in the area (toluene, TPH, and PAHs) are likely limited to the stained surface soil.

10.5.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the FPCGS site are summarized in the following sections.

10.5.6.2.1 Human Health

The FPCGS site was assessed as one area in the human health risk assessment, with the former UST location excluded because of its inclusion in the USCG program. The GMPA identified open space (recreational) uses for the entire area, and only exposure to surface soil from 0.0 to less than 2.0 ft bgs is assumed. No exposure to groundwater was assumed, and the PSF drinking water supply was not assessed in this area.

A residential PRG ratio screening assessment for surface soil and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions

used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ $>1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ $<1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the FPCGS site are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

10.5.6.2.1.1 Quantification of Cancer Risks

TPH-gas fraction and several PAHs were the COCs determined in surface soil samples at the FPCGS. The recreational visitor scenario with ingestion of and dermal contact with surface soil to 2 feet was assessed and resulted in a total carcinogenic risk of $8E-05$, mostly from ingestion and dermal exposure of the PAHs. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

10.5.6.2.1.2 Quantification of Noncarcinogenic Effects

At FPCGS, n-hexane and naphthalene (both TPH-gas fractions) were the only COCs with a hazard indices greater than $1E+00$ with values of $1E+00$ each from ingestion of and dermal contact with TPH-gas fraction in the surface soil samples to the recreational visitor.

10.5.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for the FPCGS included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified in soils for the ecological risk assessment include lead, zinc, VOCs, SVOCs including PAHs, ppDDT, and TPH. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 based on the TBV_{Low} values.
- Only the HIs for plants and soil fauna exceeded 1 based on the TBV_{High} values.
- Zinc and lead in soil, and lead, ppDDT, and zinc in diet resulted in HQs greater than 1 for the American robin based on a comparison to TBV_{Low} values. There were no risks for the American robin when the TBV_{High} values were used.
- Lead in soil and zinc in diet resulted in HQs greater than 1 for the mourning dove based on TBV_{Low} values. There were no risks for the dove when the TBV_{High} values were used.
- No HQs were greater than 1 for the western harvest mouse; only the sum of the chemical-specific HQs (the cumulative HI).
- Several PAH compounds (fluoranthene, pyrene, and phenanthrene), and zinc produced HQs greater than 1 for plants and soil fauna relative to the TBV_{Low} ; however, no HQs exceeded 1 for these receptors based on the TBV_{High} values.

The remaining receptors and pathways evaluated at FPCGS did not indicate a potential for ecological risk. Only plant and soil fauna estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted based on the TBV_{High}). The magnitude of the HI is low

(between 1 and 10) for plants and soil fauna. The risk assessment assumptions are conservative (i.e., use of total soil metals as opposed to bioavailable metals as the basis of the EPC, sampling design biased towards impacted areas), and as such, are likely to overestimate risk at this site. In addition, the area is disturbed. It is unlikely that significant chemical-related effects would occur at this site. Further evaluation at this location is not warranted from the perspective of ecological risk.

10.6 LOBOS CREEK

Lobos Creek is the only significant natural stream at the PSF. Water from the creek has historically been diverted to the water plant on Baker Beach for use as potable water on the PSF. As discussed in Section 2.3.8, the water plant has been upgraded, and, as of December, 1996, is not in operation. Lobos Creek was assessed to determine if water quality is being impacted by potential sources in the area. This section describes the Lobos Creek field program and its results.

10.6.1 Area Description

Lobos Creek originates approximately 800 ft west of State Highway 1 near the southern boundary of the PSF (Figure 10.6-1). Approximately 85 percent the drainage basin that feeds Lobos Creek and Mountain Lake is located outside the PSF (Figure 10.6-2) and is not discussed in this RI report. The PSF portion of the Lobos Creek watershed is bounded to the north by a topographic ridge that runs from Washington Boulevard to the water treatment plant at Baker Beach, to the east by the western edge of the PSF Golf Course, and to the west by the Pacific Ocean.

Lobos Creek is approximately 1.3 mi long, originating at an elevation of approximately 125 ft-PLL (Figure 10.6-3). The creek flows to the west where it discharges into the Pacific Ocean. The creek's adjoining hillsides are steep and the general drainage aspect is to the west. The total Lobos Creek watershed area within the PSF is 146 ac. The largest portion of the Lobos Creek watershed is located south of the PSF boundary, and encompasses much of the Richmond District residential area. Dense vegetation in the creek channel consists of grasses, vines, shrubs, and trees.

Lobos Creek has been used to supply over 90 percent of the PSF potable water (Nolte and Associates, 1993). When the water plant was in operation, most of the water in the stream was diverted to the water plant at Baker Beach. This resulted in very low flow in the creek downstream of the water plant intake, with the remaining water discharging into the Pacific Ocean. Treated water was pumped to an aboveground reservoir where it was stored for use on the PSF. The water plant recently was upgraded; operations had not resumed as of December 1996.

Two Main Installation RI sites or study areas representing potential contaminant sources, including the Nike Facility and the Building 1750 site (Golden Gate U.S. Army Reserve Center), are located in the Lobos Creek watershed area. Also in the watershed area are PHSR RI sites, including Landfills 9 and 10 and the former PHSR facility. Portions of the Wherry Housing complex and officer family housing adjacent to Washington Boulevard, the Presidio Golf Course, the former Lobos Creek Target Butt, and the Lobos Creek Protected Range also could impact Lobos Creek. The latter two sites are being investigated under the Sacramento Corps of Engineers; the Sampling Investigation Report for the Small Arms Firing Ranges is in progress. All of these areas lie upgradient of Lobos Creek. Excluding dry cleaning businesses and gas stations, the portion of the Lobos Creek watershed south of the PSF in the Richmond District residential area appears to be isolated from industrial activities.

Sampling of Lobos Creek occurred during 1988 as part of a city-wide water quality assessment. The Lobos Creek sample was analyzed for pesticides and herbicides; no detections were reported (EE, 1989). The water from Lobos Creek typically was chlorinated to control the high organic carbon levels related to non-point runoff from the vegetated hillsides adjacent to the creek (ANL, 1989). This resulted in high levels of trihalomethanes (THM) from the reaction of free available chlorine with organic compounds during prolonged storage and distribution (USAEHA, 1981).

In the Fall of 1989, the PSF initiated a sampling program to monitor the water quality of Lobos Creek. Water samples are analyzed quarterly for organic compounds. Inorganic and radioactive compounds were also analyzed for occasionally. Detections of various organic compounds have occurred inconsistently and were not confirmed by the Initial RI. The

intermittent nature of detections of organic compounds suggests that they may be related to stormwater runoff and/or introduced during laboratory analysis.

10.6.2 Sample Location Rationale

Although Lobos Creek is not considered a contaminant source, sediments and surface water were sampled to determine if the creek has been impacted by any potential source areas. Development of the sampling program for Lobos Creek was based upon the conceptual model presented in Section 3.1. Nearby areas within the PSF portion of the Lobos Creek watershed that could represent potential sources are Landfills 9 and 10, the former PHS area, the Nike Facility, the Building 1750 site, the Presidio Golf Course, the Lobos Creek Target Butt, and the Lobos Creek Protected Range. The residential region south of the PSF may also be a potential source area that could affect the quality of water and sediments in Lobos Creek. Potential contaminants could be released to Lobos Creek through stormwater runoff, infiltration and percolation, and to a lesser extent airborne particulate transport. During the Initial RI, sediment samples were collected at three locations. Three surface water samples, collocated with the sediment samples, and two downstream surface-water samples also were collected (Figure 10.6-3). During the PHS RI, an additional surface-water sample was collected at the furthest upstream sample location.

10.6.3 Hydrogeologic Setting

Stream flow is perennial in Lobos Creek and comes from groundwater seepage and runoff from storm events. During wet years, water normally contained by Mountain Lake may overflow into Lobos Creek.

The discharge of Lobos Creek averages 1.9 million gpd (2.25 cfs) (EE, 1989). Stream discharge measurements were recorded at five surface-water sampling points during October 1990 (Figure 10.6-3). Stream flow increases in the downstream direction until water is diverted to the water plant. Downstream of the diversion inlet to the water plant, stream flow decreases toward the Pacific Ocean. At LCSW01, 150 ft below the creek source, a discharge of 0.21 cfs was measured (Appendix H.6). At points LCSW02 and LCSW03 the measured discharges were 2.55 cfs and 3.16 cfs, respectively. At LCSW04, located below the inlet to

the water treatment plant, the discharge was 0.11 cfs. The final downstream measuring point at LCSW05 had a discharge of 0.03 cfs.

The surficial sediments in the area are mapped by the USGS as dune sand (Figure 2.3-3) (Schlocker, 1974).

10.6.4 Analytical Results

Three sediment samples and five surface-water samples were collected from Lobos Creek as part of the Initial RI (Figure 10.6-3). An additional surface-water sample was collected during April 1992 as part of the PHSI RI (RLSA, 1992d) at sample location LCSW01 (Figure 10.6-3).

Three sediment samples (Samples LCSD01, LCSD02, and LCSD03) were collected at the same locations as the three upstream surface-water samples (Figure 10.6-3). These samples were analyzed for inorganics, VOCs, SVOCs, and OCPs. The surface-water samples were obtained at five different points along the stream. Samples were collected approximately midway between the creek bed and stream surface. These samples were analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, and OCPs. The sample collected during April 1992 was analyzed for inorganics, miscellaneous parameters, VOCs, OCPs, PCBs, and TPH. Table 10.6-1 summarizes detections above the CRLs/RLs in sediments. Table 10.6-2 summarizes the target analyte detections above the CRLs/RLs in surface water, and Table 10.6-3 summarizes filtered and unfiltered metal detections in surface water.

All of the sediment samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussions of sediment data. Because the surrounding surficial deposits are mapped as dune sand (Figure 2.3-3) (Schlocker, 1974), the concentrations of inorganics in the sediment samples collected from

the creek bed were compared to ambient beach/dune concentrations for perspective, as described in Section 3.7.

Although fifteen different inorganics were detected above CRLs in one or more of the sediment samples collected from Lobos Creek, only vanadium in Sample LCSD01 and arsenic in Sample LCSD02 exceeded ambient beach/dune concentrations. Vanadium in Sample LCSD01 was 69.4 $\mu\text{g/g}$ relative to the ambient concentration of 68.6 $\mu\text{g/g}$ and arsenic was 14.6 $\mu\text{g/g}$ relative to the ambient concentration of 5 $\mu\text{g/g}$. VOCs, SVOCs, and pesticides were not detected above the CRLs in any of the sediment samples.

Inorganics were detected above CRLs in all of the surface water samples, as shown on Tables 10.6-2 and 10.6-3. Miscellaneous parameters, including nitrate and coliform as well as other parameters, were detected above CRLs/RLs in most of the samples. VOCs were not detected above the CRLs in any of the surface-water samples. One SVOC, bis(2-ethylhexyl)phthalate (1.1 $\mu\text{g/L}$), was detected once in LCSW01. TPH was analyzed in one sample and was not detected above the RL.

The water in Lobos Creek was characterized as magnesium-bicarbonate through the use of ionic balance calculations. The resulting values were plotted on trilinear diagrams (Section 2.3.5).

10.6.5 Results Evaluation

Sample locations were selected along the length of Lobos Creek to characterize sediment and water quality and assess if they are being impacted by any potential source areas. Surface water was collected to determine if any chemical releases to the creek have occurred. Although Lobos Creek is not considered a source at the PSF, there are several potential migration pathways for chemicals in creek sediments or surface water. Transport of any released material could result in the volatilization of chemicals or in the sorption of chemicals onto stream sediments. Chemicals in the surface water and sediments could be transported to the Pacific Ocean or to the water plant. In addition, the surface water may infiltrate and percolate into the subsurface. Because there is the potential for direct contact with Lobos Creek sediments and water by human and ecological receptors, analytical results are compared to standards for protection of these receptors.

Sediment results are initially compared to ambient inorganic values to assess if the analytes are present at natural concentrations or if they reflect potential impacts of U.S. Army activities on the PSF, as described in Section 3.7. Any inorganic analyte that may be associated with a PSF source and all organics are considered COPCs. These COPCs are compared to aquatic sediment criteria to preliminarily assess exposure of ecological receptors to potentially impacted media.

Of the inorganics, only arsenic and vanadium were detected at concentrations above ambient beach/dune values in one sediment sample each. The detection of vanadium in sample LCSD01 was slightly above the ambient beach/dune concentration (69.4 versus 68.6 $\mu\text{g/g}$), although it is below the range of ambient concentrations for the other lithologic types. The duplicate for this sample had a concentration less than the ambient level, at 63.6 $\mu\text{g/g}$. Sample LCSD01 was collected upstream of the other sediment samples. It does not appear that the vanadium is associated with potential sources, but is occurring naturally at this site. This is supported by the absence of any other ambient exceedences or occurrences of organic compounds in this sample. Therefore, vanadium is not a COPC.

In contrast, the arsenic detection (14.6 $\mu\text{g/g}$) in LCSD02 exceeds both the ambient beach/dune concentration (5.0 $\mu\text{g/g}$) and all other arsenic ambient values. Arsenic was below the CRL of 2.50 $\mu\text{g/g}$ in both the upstream and downstream sediment samples. A specific source of the arsenic is not known based on the available data. A source could be on the PSF, but is more likely to be associated with the residential area south of the PSF, as more than 90 percent of the Lobos Creek drainage basin is located outside the PSF. Because it is not considered to occur naturally at this concentration, arsenic is a sediment COPC for this site. The concentration in this single sample is within the within the range of sediment criteria for protection of aquatic life (6 to 33 $\mu\text{g/g}$; Table 3.8-7), which indicates a potential impact on freshwater aquatic life. The migration potential for arsenic is low, as shown by the absence of any other elevated levels of arsenic in the sediment or surface water.

No VOCs, SVOCs, or OCPs were detected above the CRLs/RLs in any of the sediment samples.

As follows, surface water analytical results are compared to MCLs because of the potential municipal use of Lobos Creek. Surface water contained inorganics, miscellaneous parameters, and an SVOC (bis(2-ethylhexyl)phthalate). The only concentrations exceeding MCLs are those for iron (Secondary California and USEPA MCL), manganese (Secondary California and USEPA MCL), and nitrate (Primary USEPA MCL). Iron exceeded the Secondary MCL in one unfiltered sample; it was not detected in the filtered samples. Manganese exceeded the Secondary California MCL of 50 µg/L in three of the five sample locations, at concentrations ranging from 55.5 to 236 µg/L. The elevated iron and manganese values in water are likely due to groundwater contacting weathered serpentinite before discharging to Lobos Creek. The three upstream samples contained the manganese and concentrations decreased downstream to below the secondary MCL (and below the CRL) approximately 800 ft upstream of the water plant. The decreasing manganese concentrations may be due to dilution or may indicate that the analyte is sorbing to stream sediments.

Nitrate was the only miscellaneous parameter detected at concentrations exceeding the Primary USEPA MCL in the surface water samples. These elevated detections occurred in the three downstream samples. Coliform (both total and fecal) levels were elevated above California Water Quality Objectives for recreation, shellfish harvesting, and municipal supply (SFRWQCB, 1995) in most of the samples; however, these objectives are based on data for five consecutive samples equally spaced over a 30-day period. The data presented for Lobos Creek are for a single sampling event in 1990, and there is likely to be high variability in subsequent data collected from Lobos Creek, as shown by the absence of a concentration trend with sample location. Highest levels of both total and fecal coliform were detected in the furthest downstream sample (LCSW05), while the lowest levels of both were detected in the sample collected immediately upstream (LCSW04). As shown in Table 10.6-2, fecal coliform levels ranged from 300 to 20,000 MPNL (most probable number per 100 mLs), while total coliform levels ranged from 2,000 to greater than 20,000 MPNL. Coliform bacteria are commonly present at high levels in urban runoff and can be the result of several different sources such as vegetation, decaying organic matter, soil, animal feces, and human waste. Sources of nitrates are similar. Therefore, multiple sources (not related to U.S. Army activities) may be contributing to the elevated levels of nitrate and coliform.

VOCs were not detected above the CRLs in surface-water samples. One SVOC, bis(2-ethylhexyl)phthalate, was detected exceeding the CRL but was less than the MCL. It is commonly derived from plastics, such as those present in analytical laboratories. OCPs and TPH were not detected above the RLs/CRLs in surface water.

A comparison to standards for the protection of freshwater aquatic life (Table 3.8-7) indicates that the levels of barium and manganese in LCSW01 could potentially impact aquatic receptors. Levels of barium in all of the other surface water samples also exceeded the freshwater aquatic criteria for barium, but the standards are based on dissolved metals concentrations and only unfiltered data are available for the samples. However, barium levels in all of the samples are similar and are likely present at naturally occurring concentrations as they are not elevated with respect to surface water samples from Mountain Lake or groundwater samples within the Lobos Creek Groundwater Basin (such as the Nike Facility and Well 316GW01 near the Presidio Golf Course). As discussed above, the manganese is also likely present at natural levels associated with the serpentinite bedrock.

10.6.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for Lobos Creek, including the risk assessment results, as presented in detail in Section 15.

10.6.6.1 Conclusions

The only COPC detected in sediment samples from Lobos Creek is arsenic, which was elevated in one of the sediment samples. There were no detections of organics and all other inorganics are interpreted to occur at natural concentrations. The source of arsenic is not known; it could be from the PSF, but it is more likely to be the residential area south of the PSF, as more than 90 percent of the Lobos Creek drainage basin is located outside the PSF. The human health risk assessment will assess exposure to arsenic in sediments. The arsenic may be at a level of concern to aquatic receptors, based on comparison to aquatic sediment criteria; its associated risk will be further assessed in the ecological risk assessment.

Water from Lobos Creek contains several inorganic analytes and miscellaneous parameters, but most are at relatively low concentrations. The only organic detected was bis(2-

ethylhexyl)phthalate, a common compound associated with plastics and laboratory contaminant, at a concentration less than the MCL. Inorganics or miscellaneous parameters that exceeded MCLs in the surface-water samples were iron (California secondary MCL), manganese (California secondary MCL) and nitrate (USEPA MCL). In addition, elevated coliform levels were reported. The iron and manganese are likely derived from serpentinite. Coliform bacteria and nitrates are commonly present at high levels in urban runoff and can be the result of sources such as vegetation, decaying organic matter, soil, animal feces, and human waste. Sources of nitrates are similar. Therefore, multiple sources on and off of the PSF may be contributing to the elevated levels of nitrate and coliform in Lobos Creek samples. Nearly all of the water in the creek has been historically diverted to the Baker Beach water plant; a minor amount is discharged to the Pacific Ocean when the water plant is in operation. Comparison to standards for protection of freshwater aquatic life indicates that barium and manganese may be at levels of concern; however, these appear to be naturally occurring concentrations.

10.6.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs in sediment (arsenic), inorganics and miscellaneous parameters in surface water, and all detected organics in both media were considered in the human health and ecological risk assessments according to the exposure scenarios that were evaluated. At Lobos Creek, bis(2-ethylhexyl) phthalate was the only organic detected. It was detected in one surface water sample.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs and MCLs. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for Lobos Creek are summarized in the following sections.

10.6.6.2.1 Human Health

Lobos Creek is assessed under two future use scenarios, the open space recreational scenario, as identified by the GMPA, and also as a significant portion of the PSF water supply.

Exposures to surface water and sediment are possible by visitors to the PSF while engaging in recreational activities, such as wading in the creek or playing along the banks. Incidental ingestion and dermal contact were the exposure routes evaluated for surface water and sediment. Lobos Creek is not easily accessible because of its location in a ravine and the thick vegetation near the creek's bank. Therefore, exposures to these media were evaluated only for older children (ages 9 to 18) in the recreational scenario, as they represent the most likely age group that might participate in this type of activity. Because of the difficult access to Lobos Creek, younger children and adults will, most likely, not play in these water bodies. Surface water is not expected to be a significant pathway of exposure for workers, because these water bodies do not support any industrial or commercial activities that may result in incidental ingestion of water.

Lobos Creek has been used in the past and is assumed to be used in the future to provide 90 percent of the water supply for the PSF. The remaining 10 percent of the PSF water supply is assumed to be from Well 13. Industrial workers at the PSF may be exposed to the PSF water supply via ingestion or dermal contact during showering.

In addition to the risk assessments that are based on the potential future scenarios for Lobos Creek, a residential PRG ratio screening assessment for sediment and surface water was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ >1E+00, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with Lobos Creek are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

10.6.6.2.1.1 Quantification of Cancer Risks

Lobos Creek had surface water and sediment COCs of arsenic (sediment only) and lead, manganese and nitrite (surface water only) to assess for the older child (age 9 through 18) playing in the creek. The total cancer risk from ingestion and dermal contact with sediment in Lobos Creek is 5E-07, indicating that exposure to the COCs at this site is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than 1E-06.

Lobos Creek is also a source for the PSF water supply and conservatively is assumed to provide 90 percent of the PSF water supply in the industrial scenarios but PSF water supply COCs (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, it is unlikely that exposure to industrial workers to the PSF water supply will result in an excess

10.6.6.2.1.2 Quantification of Noncarcinogenic Effects

No hazard index is greater than 1E+00, which indicates that exposure at Lobos Creek to the respective receptors is unlikely to result in noncarcinogenic adverse health. The residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00.

10.6.6.2.2 Ecological

Potential exposure pathways evaluated in the ecological risk assessment included exposure of aquatic and terrestrial receptors to sediment and soil in Lobos Creek. Aquatic plants and invertebrates, fish, and amphibians were evaluated for direct contact. The mallard duck, sandpiper, and raccoon were evaluated for surface water, sediment, and dietary ingestion and also for dermal contact. The American robin, mourning dove, raptors, and western harvest mouse were also evaluated as they may ingest surface water.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Arsenic was the only sediment COPC evaluated in the ecological risk assessment. Several inorganics, miscellaneous parameters, and bis(2-ethylhexyl) phthalate were the surface water COPCs. Results of the risk assessment indicate the following:

- HIs exceeded 1 for aquatic life, mallard duck, and sandpipers when comparisons were made to the TBVLow.
- HIs exceeded 1 for aquatic life when comparisons were made to the TBVHigh. The TBVHigh for aquatic life is often the same criterion value as the TBVLow; therefore, a risk range cannot be developed for chronic exposures.
- Concentrations of barium, iron, manganese and lead in surface water are the COPCs of potential concern to aquatic receptors.
- Arsenic in sediment resulted in HQs greater than 1 for aquatic invertebrates based on sediment quality criteria.
- The HQ for lead for the dietary ingestion pathway for waterfowl and wading birds exceeds 1 based on the TBVLow, although surface water ingestion does not contribute to risk. When the TBVHigh was used as the basis of the risk comparison, there were no apparent risks.

There was no risk potential identified for the remaining receptors and pathways that were evaluated. Conservative methods were used for the HQ screen for aquatic life in that both filtered and unfiltered data were included in the exposure point concentration in order to increase available sample size information. The sample evidence does not suggest army-related contaminants at this site, however, the ecological risk assessment for Lobos Creek will be further evaluated to determine whether the results of the ERA warrant inclusion of this site into the FS.

10.7 MOUNTAIN LAKE

Mountain Lake is a spring-fed, natural lake located on the PSF. The lake is adjacent to the Mountain Lake Park recreation area located south of the PSF. The lake is a habitat for fish and birds and has been used in the past to irrigate the golf course. Water and sediment samples were collected to determine if the lake has been affected by nearby potential sources. The following sections describe the Mountain Lake field program and its results.

10.7.1 Area Description

Mountain Lake is located in the south-central portion of the PSF. It is bounded to the north and east by the Presidio Golf Course, to the west by State Highway 1 and to the south by Mountain Lake Park (Figure 10.6-3). The southern boundary of the PSF intersects a small portion of Mountain Lake. A residential area and Mountain Lake Park are located south of the PSF boundary. Mountain Lake is the only natural lake at the PSF and covers nearly 4 ac, with a maximum depth of 15 ft (ANL, 1989).

The watershed of Mountain Lake extends to the north and east of the lake, covering at least 192 ac, and includes almost the entire PSF Golf Course (Figure 10.6-1). A majority of the watershed also extends south of the lake to include the residential area south of the PSF. The southwest boundary of the watershed is not clearly defined, but is near Mountain Lake. The highest point within the watershed is Presidio Hill, which is occupied by a reservoir that supplies the entire PSF with potable water. A portion of officer family housing adjacent to Washington Boulevard lies within the watershed. Highway 1 enters a tunnel near the center of the watershed.

Topography in the vicinity of Mountain Lake is moderately sloping with a southwestern aspect. The elevation of Mountain Lake is approximately 129 ft-PLL. Surface drainage upgradient of the lake is to the southwest and overflow from the lake may drain into the Lobos Creek watershed to the west. Vegetation in the area of the lake consists of trees, shrubs, and grasses.

Mountain Lake has occasionally been used as an irrigation water supply for the PSF Golf Course. Bedrock wells on the northeast bank of Mountain Lake also have been used for irrigation of the Presidio Golf Course. These wells may draw shallow groundwater from both the water table aquifer zone and ultimately Mountain Lake, as indicated by a test well in the vicinity (Nolte & Associates, 1993). During October 1991, one of these wells, Well 316GW01, was sampled and analyzed for inorganics, miscellaneous parameters, and pesticides. None of the detections of inorganics and miscellaneous parameters exceeded Primary or Secondary MCLs. No pesticides were detected above the RLs (Table 10.7-1).

Mountain Lake Park, located south of the lake, is used as a recreational area. Waterfowl and non-game fish have been observed in the lake.

10.7.2 Sample Location Rationale

Although Mountain Lake is not considered a contaminant source, it was investigated to determine whether this pathway has been impacted by analytes from nearby potential source areas. Development of the sampling program for Mountain Lake was based on the conceptual model presented in Section 3.1. Sediment and surface-water samples were collected in Mountain Lake to assess any impacts. Discrete groundwater samples were collected upgradient of Mountain Lake to assess the potential effects of the golf course on water quality. Nearby areas that may be of concern as potential sources in addition to the golf course are Landfills 9 and 10, the former PHSH, the Nike Facility, and a portion of State Highway 1. Potential contaminants could be released to Mountain Lake through surface-water runoff, infiltration and percolation, and to a lesser extent, airborne particulate transport.

During the Initial RI, surface water was collected at one location, and sediment samples were collected at four locations. During the PHSH RI, an additional surface-water sample was collected at the location of the previous sample. During the Follow-on RI, additional surface-water samples were collected at the four locations of the original sediment samples. In addition, the NPS had concerns about the potential effects of herbicide use on the golf course on water quality in Mountain Lake. To address those concerns, discrete groundwater samples were collected at two locations between the golf course and the lake. (Figure 10.6-3).

10.7.3 Hydrogeologic Setting

The investigation of Mountain Lake included the collection of four sediment samples, six surface-water grab samples (two of which were collected from the same location), and the drilling of two borings to collect depth-discrete groundwater samples. The lithologic logs from the discrete groundwater borings (Appendix H.7) are the basis for the following discussion of the geology in the vicinity of Mountain Lake.

The soil in the vicinity of Mountain Lake has been classified as Orthents, cut and fill by the SCS (Kashiwagi and Hokholt, 1985). Soils encountered at the surface probably represent reworked materials placed during the construction of the PSF Golf Course. The surficial sediments in the area are mapped by the USGS as Colma Formation (Figure 2.3-3) (Schlocker, 1974). The borings for the discrete groundwater samples (Borings MLSB01 and MLSB02; Figure 10.6-3), penetrated a fairly uniform layer of silty-sand to depths of 32 and 34 ft bgs (Appendix H.7). None of the borings were deep enough to indicate depth to or composition of bedrock. The depth to bedrock is more than 80 ft bgs, based on a test well (MW-4) installed on the northeast bank of Mountain Lake, which penetrated Colma Formation to a total depth of 80 ft bgs (Nolte & Associates, 1993).

Limited hydrogeologic studies of Mountain Lake have determined that it is spring-fed (ANL, 1989). Presumably, groundwater seepage maintains the water level of the lake, although the exact nature of the hydraulic connection is unknown (ECJC, 1990a). This is also supported by information from the test well described above, as the water elevation in the test well was slightly higher than the lake elevation. A small spring that feeds the lake from the north was at approximately the same elevation as the lake (Nolte & Associates, 1993). Irrigation water used on 77.13 ac of golf course land may also be a source of recharge to the lake. Reportedly, 199.5 ac-ft of water is applied to the golf course from April through September. The City of San Francisco supplies 110.5 ac-ft of this water; the remainder is pumped from the well near Mountain Lake.

10.7.4 Analytical Results

Mountain Lake is used by nearby residents as a recreation area. Sediment, surface-water, and discrete groundwater samples were collected to determine whether chemicals are present which may effect public health or the environment.

Four sediment and one surface-water sample were collected from Mountain Lake during the Initial RI. An additional surface-water sample was collected at the location of the previous surface-water sample in April 1992. This additional surface-water sample was collected for the PHSR RI (RLSA, 1992). The four sediment samples were collected from various locations along the perimeter of the lake from a depth of approximately 2 ft. These sediment

samples were analyzed for inorganics, VOCs, SVOCs, and pesticides. Table 10.7-2 summarizes the detections above the CRLs/RLs in sediment samples at the site. Surface-water samples were collected at depths ranging from 0 to 2.0 ft during the Initial RI and analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, and herbicides. The PHSH-RI surface-water sample collected during April 1992 was analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, and TPH. Table 10.7-3 summarizes the target analyte detections above the CRLs/RLs in surface water for both sampling events. Table 10.7-4 summarizes filtered and unfiltered metal detections in surface-water samples collected during the PHSH RI.

Four surface-water and four discrete groundwater samples were collected during the Follow-on RI. The surface-water samples were analyzed for TPH-D and TPH-G. Depth-discrete groundwater samples were collected from two borings at two depths: first water and 10 ft below first water. Herbicides were analyzed in the two shallow groundwater samples from each boring and nitrates (as NO_3) were analyzed in all four samples. Table 10.7-5 summarizes the surface-water analyses and Table 10.7-6 summarizes the discrete groundwater analyses.

All of the sediment samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussion. The concentrations of inorganics in sediment samples collected from Mountain Lake were compared to ambient inorganic concentrations in Colma Formation due to the presence of Colma Formation around, and presumably below, Mountain Lake. Ambient inorganic concentrations were presented and discussed in Section 3.7.

In the sediment samples, lead was the only inorganic above ambient concentrations for the Colma Formation. It was detected above the ambient level of 24 $\mu\text{g/g}$ in two samples, at a

maximum concentration of 34.4 $\mu\text{g/g}$ in Sample MLSD03. VOCs and SVOCs were not detected above CRLs. The pesticides lindane (0.003 $\mu\text{g/g}$) and aldrin (0.003 $\mu\text{g/g}$) were detected in Samples MLSD01 and MLSD02, respectively.

Inorganics and miscellaneous parameters were detected in the surface-water samples collected from Mountain Lake during the Initial RI and for the PHSR RI. Inorganics detected in the Initial RI sample and not in the PHSR RI sample were cyanide, iron, and lead. Vanadium was detected in the PHSR RI sample, but not in the Initial RI sample. Both filtered and unfiltered samples were analyzed in 1992; concentrations were similar with the exception of iron, which was not detected in the unfiltered sample. Coliform was analyzed and detected in the Initial RI sample, with fecal and total coliform concentrations reported at 3,000 MPNL and 9,000 MPNL, respectively. VOCs were not detected in any of the surface-water samples. One SVOC, bis(2-ethylhexyl)phthalate (1.3 $\mu\text{g/L}$), was detected once. One pesticide, heptachlor (0.009 $\mu\text{g/L}$), was detected, and TPH was reported at a concentration of 1,000 $\mu\text{g/L}$ in the PHSR RI sample (Table 10.7-3). The water in Mountain Lake was characterized through the use of ionic balance calculations. The resulting values were plotted on trilinear diagrams (Figure 2.3-13). The water in Mountain Lake is generally characterized as magnesium-bicarbonate.

TPH-D was detected slightly above the SDC of 50 $\mu\text{g/L}$ in two of the four surface water samples collected during the Follow-on RI, at concentrations of 60 and 51 $\mu\text{g/L}$ (Table 10.7-5). No detections of TPH-G were reported.

Nitrate was reported in all four of the discrete groundwater samples collected during the Follow-on RI, at concentrations ranging from 3,560 to 11,900 $\mu\text{g/L}$. No herbicides were detected.

10.7.5 Results Evaluation

Mountain Lake was sampled to determine if sediments and water are being impacted by any potential source areas in the vicinity. If sediments and water were found to be impacted, chemicals in these media could potentially reach Lobos Creek. Sampling media consisted of sediments from the lake bottom, surface-water samples from five locations on the perimeter

of the lake, and two discrete groundwater samples collected east and northeast of the lake, between the lake and the Presidio Golf Course. This section discusses the nature and fate and transport of potential contaminants at Mountain Lake.

10.7.5.1 Nature and Extent

Sediment and surface-water samples from the same locations were collected around the perimeter of Mountain Lake to characterize sediment and water quality. Surface water was collected to evaluate if any chemical releases to the lake have occurred. Releases of materials to the lake could also result in the sorption of chemicals in lake-bottom sediments. Discrete groundwater samples were collected between Mountain Lake and the golf course to evaluate if any of the herbicides used on the golf course have impacted the groundwater adjacent to the lake. Because there is the potential for direct contact with Mountain Lake sediments and surface water by human and ecological receptors, analytical results are compared to standards for protection of these receptors, as appropriate, in the following paragraphs.

Sediment results are initially compared to ambient inorganic values to assess if the analytes are present at natural concentrations or if they reflect potential impacts of U.S. Army activities on the PSF, as described in Section 3.7. Any inorganic analyte that may be associated with a PSF source and all organics are considered COPCs. These COPCs are compared to USEPA aquatic sediment criteria to preliminarily assess exposure of ecological receptors to potentially impacted media.

The concentrations of inorganics in the sediment samples collected from Mountain Lake were compared to ambient inorganic concentrations in Colma Formation due to the presence of Colma Formation around Mountain Lake. Lead was the only inorganic detected above ambient concentrations. It was slightly above the ambient Colma value of 24 $\mu\text{g/g}$ in samples MLSD02 and MLSD03, at concentrations of 25.3 and 34.4 $\mu\text{g/g}$, respectively. These samples were collected from the perimeter of the lake that is adjacent to Highway 1. The most likely source of lead is the urban traffic on the highway, as concentrations in samples further away from the highway were lower. Therefore, lead is not considered a COPC, as the levels in the lake sediments are believed to be associated with the urban aspects of the PSF and not derived from U.S. Army activities.

Sources of the single detections of two herbicides in the sediments could be the Presidio Golf Course. However, it is more likely that the areas south of the PSF, such as Mountain Lake Park or the residential areas are potential sources because the detections were only in the sediments found along the south shore of the lake. A majority of the watershed for Mountain Lake is south of the PSF. These chemicals may have been applied to the grass in these areas, then transported in surface-water runoff to the lake, either in dissolved form or sorbed to suspended sediment. The detection of lindane is at the low end of the range of criteria for protection of aquatic life (0.003 to 1 $\mu\text{g/L}$; Table 3.8-7), which indicates a very low potential for impact on freshwater aquatic life.

As follows, surface water analytical results are compared to MCLs, water quality objectives, and aquatic standards for protection of freshwater aquatic life. Several inorganics were detected in the surface-water samples collected during the Initial and PHSR RIs. Manganese was detected in surface water during both sampling events in both filtered and unfiltered samples at concentrations ranging from 296 to 378 $\mu\text{g/L}$, exceeding the Secondary MCL of 50 $\mu\text{g/L}$. Manganese is also above the concentration for protection of freshwater aquatic life (Table 3.8-7). However, the elevated manganese levels in surface water are likely associated with naturally occurring levels of manganese in PSF soil or groundwater, contacting weathered serpentinite before discharging to the lake. Other inorganics exceeding freshwater aquatic criteria include barium, cyanide, and lead. As discussed for Lobos Creek, it is likely that the barium is present at naturally occurring concentrations. The exceedences for cyanide and lead only occur in the unfiltered samples (total analytes) and not filtered samples; therefore, because the criteria are based on dissolved concentrations, these analytes are not thought to be present at levels of concern. Additionally, the lead in the surface water, as in the sediment, is most likely associated with the highway traffic adjacent to the lake.

The miscellaneous parameter TDS exceeded the Recommended Secondary MCL of 500,000 $\mu\text{g/L}$ during the Initial RI, but not in the later sampling event. TDS is also likely associated with natural sources of dissolved metals. Coliform (both total and fecal) levels, which were analyzed in the Initial RI sample, were elevated above California Water Quality Objectives for recreation and municipal supply (SFRWQCB, 1995). However, these objectives are based on data for five consecutive samples equally spaced over a 30-day period, and there is

likely to be high variability in subsequent data collected from Mountain Lake. The concentration of fecal coliform was reported as 3,000 $\mu\text{g/L}$, and the total coliform concentration was 9,000 $\mu\text{g/L}$. Coliform bacteria are commonly present at high levels in urban runoff and can be the result of several different sources such as vegetation, decaying organic matter, soil, animal feces, and human waste.

Bis(2-ethylhexyl)phthalate was detected in surface water during the later sampling event; however the concentration did not exceed the MCL. This compound is commonly associated with plastics, such as those used in analytical laboratories. Heptachlor was detected in the Initial RI sample. The concentration was below the MCL, but slightly above the concentration for protection of freshwater aquatic life (0.0069 $\mu\text{g/L}$, Table 3.8-7), indicating a potential for minor effects on aquatic receptors.

A surface-water sample collected from Mountain Lake during the PHSR RI in 1992 contained TPH at a concentration of 1,000 $\mu\text{g/L}$. The TPH could be associated with the heavy road traffic in the area, however, this detection needed to be verified as real, because it was reported using a method that recognizes many naturally occurring hydrocarbons (USEPA Method 418.1). Therefore, during the Follow-on RI, four additional water samples from around the edges of the lake were analyzed for TPH-D and TPH-G by a modified USEPA Method 8015. TPH-D concentrations were slightly above the SDC (50 $\mu\text{g/L}$) in two of the surface-water samples (Samples MLSW02 and MLSW05, with 60 and 51 $\mu\text{g/L}$, respectively) collected during the Follow-on RI. The TPH-G concentrations were below both the RL and the SDC for all four samples (Table 10.7-5). A source of TPH in Mountain Lake may be stormwater runoff from Highway 1 to the west.

Groundwater was sampled from two borings drilled between the golf course and Mountain Lake. The purpose of these groundwater samples was to assess the potential effects of the golf course on water quality in Mountain Lake. Depth-discrete groundwater samples were collected from two borings at two depths: first water and about 10 ft below first water. Herbicides were analyzed in the two shallow groundwater samples from each boring and nitrates (as NO_3) were analyzed in all four samples. No herbicides were detected in either sample. Nitrates were detected at concentrations of 11,900 and 9,250 $\mu\text{g/L}$ in Boring MLSB01, and at 3,560 and 4,310 $\mu\text{g/L}$ in Boring MLSB02. The nitrate concentration

decreased with depth in Boring MLSB01. The concentration in the shallow sample from Boring MLSB01 exceeded the MCL goal of 10,000 µg/L for drinking water systems. Nitrates are commonly present at high levels in urban runoff and can be the result of sources such as vegetation, decaying organic matter, soil, animal feces, and human waste. An additional source is fertilizer, which is applied at the Presidio Golf Course, and likely applied to areas south of the PSF, such as Mountain Lake Park or residential areas. Therefore, multiple sources on and off of the PSF may be contributing to the elevated levels of nitrate in the groundwater.

10.7.5.2 Fate and Transport

Mountain Lake is not considered a contaminant source at the PSF; however, migration pathways have been identified and include:

- Runoff of surface water from overflow, potentially to Lobos Creek
- Infiltration and percolation into the subsurface
- Volatilization to the atmosphere
- Direct contact with sediments and water by human and ecological receptors.

Sediment samples collected in Mountain Lake contained low concentrations of the OCPs aldrin and lindane. OCPs in sediments tend to sorb to clay and organic material; therefore, migration of these analytes should be minimal. This is supported by other data, as neither of these OCPs were detected in Mountain Lake surface water, groundwater from Well 316GW01, or Lobos Creek sediments or surface water.

Inorganics or miscellaneous parameters detected at levels in surface water from Mountain Lake that exceed human health criteria include manganese, TDS, and coliform. These analytes are likely not associated with U.S. Army sources, as described above. As noted in Section 10.6, both manganese and coliform were also elevated in Lobos Creek surface water samples, although they were at higher concentrations in most Lobos Creek samples than in Mountain Lake surface-water samples. As discussed above, heptachlor is of potential concern in surface water to aquatic life. None of the analytes of concern were elevated in sediments in Mountain Lake or in groundwater from the Golf Course irrigation well (316GW01), indicating that the migration potential of these analytes is low and the extent is limited.

Another analyte thought to be of potential concern in surface water was TPH. TPH was detected in Mountain Lake at a concentration of 1,000 µg/L during the PHSI RI, although this detection was not confirmed by recent sampling and is unlikely to represent actual concentrations of anthropogenically-derived TPH. Surface-water samples collected from the lake during the Follow-on RI found TPH concentrations in the surface water to be approximately 20 times less than the PHSI RI samples collected three years earlier. This discrepancy may be due to the two types of methods used to analyze for TPH, with the more specific method used during the Follow-on RI. A source of TPH in Mountain Lake may be stormwater runoff from Highway 1 to the west. Volatilization and biodegradation are significant factors in the reduction of TPH concentrations in water, and migration from the lake due to overflow is unlikely. This is supported by other data, as TPH was not detected in Lobos Creek surface water.

Nitrates exceeded the MCL goal for drinking water systems in one of the shallow groundwater samples. None of the deep samples exceeded the MCL, including the sample collected from the Golf Course Irrigation Well. Nitrates are common constituents of groundwater with higher levels typically being related to decomposing plant debris, animal or human waste, and/or nitrate fertilizers used in agricultural areas. The levels of nitrates detected in groundwater east and northeast of Mountain Lake could be associated with natural sources or with fertilizer use at the Presidio Golf Course, since it is immediately upgradient of the wells. However, sources of nitrates to the south of the PSF can not be eliminated, as other upgradient or cross-gradient groundwater data surrounding the lake are not available. Still, considering that nitrate concentrations decreased with depth to below the SDC in Boring MLSB01, the uppermost sample (with nitrate slightly above the MCL goal for drinking water systems) was collected immediately below the water table, and three of four samples had nitrate concentrations below the MCL goal for drinking water systems, the data indicate that the groundwater downgradient of the Presidio Golf Course is not significantly impacted by nitrate contamination. The absence of elevated nitrate levels in Mountain Lake surface water also indicates that discharge of groundwater containing elevated levels of nitrate to the lake is not a significant migration pathway.

10.7.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for Mountain Lake, including the risk assessment results, as presented in detail in Section 15.

10.7.6.1 Conclusions

Groundwater and surface drainage from the north, east, and southeast contribute to Mountain Lake. This includes the upland areas and the golf course at PSF, as well as offsite areas. Although Mountain Lake is not considered a contaminant source at the PSF, sediment, surface water and discrete groundwater samples were collected to evaluate whether contaminants were present in these media. Detections were evaluated to assess the potential sources of the analytes.

Aldrin and lindane were found at concentrations of 0.003 $\mu\text{g/g}$ in sediment samples collected from the south edge of Mountain Lake during the Initial RI in 1990, but not in Supplemental RI samples collected in 1992. These pesticides were not found in water or sediment samples taken from Lobos Creek, indicating that the distribution is limited. Additionally, the source of the pesticides may be from areas south of the PSF, as a majority of the watershed is south of the lake.

Several naturally occurring constituents in surface water were found above human health criteria. These included manganese, detected above the California primary MCL, TDS, and coliform. Heptachlor and barium were above ecological criteria in surface water samples. None of these are believed to be derived from U.S. Army activities at the PSF. Detections of TPH-D may be associated with stormwater runoff from Highway 1.

Nitrates were detected above the USEPA MCL of 10,000 $\mu\text{g/L}$ in one of the four discrete groundwater samples but decreased below the MCL with depth. Nitrate levels in Mountain Lake surface-water samples were a minimum of an order of magnitude lower than in the groundwater samples. Sources on and off of the PSF may be contributing to the elevated levels of nitrate.

10.7.6.2 Risk Assessment Summary

As presented in Section 3.7, COPCs in sediment (aldrin and lindane), and inorganics, miscellaneous parameters, bis(2-ethylhexyl) phthalate, heptachlor, and TPH in surface water were considered in the human health and ecological risk assessments according to the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for Mountain Lake are summarized in the following sections.

10.7.6.2.1 Human Health

Mountain Lake is assessed under the open space recreational scenario, as identified by the GMPA. Exposures to surface water and sediment are possible by visitors to the PSF while engaging in recreational activities, such as wading in the lake or playing along the banks. Incidental ingestion and dermal contact were the exposure routes evaluated for surface water and sediment. Therefore, exposures to these media were evaluated only for older children (ages 9 to 18) in the recreational scenario, as they represent the most likely age group that might participate in this type of activity. Additionally, there would not be a significant difference in the risk results if a younger child was assessed for exposure to the same surface water COCs. Surface water is not expected to be a significant pathway of exposure for workers, because these water bodies do not support any industrial or commercial activities that may result in incidental ingestion of water.

In addition to the risk assessments that are based on the potential future scenarios for Mountain Lake, a residential PRG ratio screening assessment for sediment and surface water was performed as a preliminary assessment of a residential scenario. The residential PRG

ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A $1E-06$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with Mountain Lake are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

10.7.6.2.1.1 *Quantification of Cancer Risks*

There were no analytes determined as COCs following the COPC screening in Mountain Lake sediment. Cyanide, lead, chloride, sulfate, and TDS were COCs determined in the surface water at Mountain Lake following COPC screening. None of these COC are considered to be carcinogenic. Therefore, it is unlikely that exposure of these COCs to the recreational older child while playing in Mountain Lake will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk equal to 1E-06.

10.7.6.2.1.2 *Quantification of Noncarcinogenic Effects*

No hazard index is greater than 1E+00, which indicates that exposure at Mountain Lake to the respective receptors is unlikely to result in noncarcinogenic adverse health. The residential PRG ratio screening assessment resulted in a total hazard index greater than 1E+00.

10.7.6.2.2 Ecological

Potential exposure pathways evaluated in the ecological risk assessment included exposure of aquatic and terrestrial receptors to sediment and soil in Mountain Lake. Aquatic plants and invertebrates, fish, and amphibians were evaluated for direct contact. The mallard duck, sandpiper, and raccoon were evaluated for surface water, sediment, and dietary ingestion and also for dermal contact. The American robin, mourning dove, raptors, and western harvest mouse were also evaluated as they may ingest surface water.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Aldrin and lindane were the only sediment COPCs identified for the ecological risk assessment. Several inorganics, miscellaneous parameters, bis(2-ethylhexyl) phthalate, heptachlor, and TPH were surface water COPCs. Results of the risk assessment indicate the following:

- TPH (gas and diesel), barium, cyanide, manganese, and lead in surface water are of potential concern to aquatic life for chronic exposures based on comparison of exposure point concentrations in surface water to the TBVs for aquatic life, which are the chronic AWQC. HQs for these analytes exceed 1 based on the TBV_{Low} and the TBV_{High} .
- Barium and manganese are similar to concentrations observed in ground water, and are therefore likely to be naturally occurring.
- Pesticides in sediments do not exceed the sediment quality criteria for the protection of aquatic life.
- The petroleum hydrocarbons and lead are most likely due to runoff from the road next to the lake.
- The HQ for lead for the dietary ingestion pathway for waterfowl and wading birds exceeds 1 based on comparison to the TBV_{Low} , although surface water ingestion does not contribute to risk. HQ values for the dietary ingestion pathway for mallard, but not sandpiper, exceed 1 based on the TBV_{High} .
- There are no risks to avian or mammalian receptors for ingestion of surface water or sediment.

There was no risk identified for the remaining receptors and pathways that were evaluated. Conservative methods were used for the HQ screen for aquatic life in that only the chronic criteria were used for screening. In addition, the samples used in the evaluation consisted of both filtered and unfiltered data; chemicals bound to particulates (i.e., the unfiltered data) are not readily bioavailable to aquatic life. However, the risk assessment was conservative in utilizing all available data. Because there are no army sources for inorganics, and HQs due to organics that may be related to army activities (i.e., pesticides) do not exceed 1, this site should not be evaluated further from the perspective of ecological risk.

11. GOLDEN GATE BRIDGE HIGHWAY AND TRANSPORTATION DISTRICT

This section describes the area description, sample location rationale, geologic setting, analytical results, results evaluation, and conclusions and recommendations for the GGBHTD Study Area. The GGBHTD is a portion of the land at the southern end of the Golden Gate Bridge which was permitted to the GGBHTD by the U.S. Army in the 1930s. The GGBHTD uses the area for bridge operation and maintenance facilities. A PA conducted for the area assessed the potential for releases of waste materials to groundwater, surface water, soil and air (RLSA, 1992a). The results of the PA do not suggest either releases of wastes from the site to the groundwater, or air or soil exposure pathways. However, the PA indicated that a release to the surface water may have occurred in the paint equipment wash rack area. The Supplemental RI was conducted to confirm the results of the PA.

11.1 AREA DESCRIPTION

The following sections describe the location and physical features, site history and land use, and previous investigations performed at the GGBHTD Study Area. Four areas investigated at the GGBHTD Study Area include the Transformer, UST, Paint Operations, and Bone Yard Storage Areas. The site history and land use of these areas is also included.

11.1.1 Location and Physical Features

The GGBHTD Study Area is located on approximately 11.5 ac in the northwestern corner of the PSF (Figure 1.2-1). The area is bounded by the Baker Beach study area to the south and the Fort Point National Historic Site to the north. The central portion of the study area is situated on a relatively flat portion of a northwest trending ridge crest. Topography slopes steeply away from the study area to the north, east, and west. Elevation at the site ranges from approximately 185 ft to approximately 135 ft (Figure 11.1-1).

The area is located on the surface-water drainage divide between the Pacific Ocean and San Francisco Bay. The Pacific Ocean is approximately 500 ft downslope to the west and San Francisco Bay is approximately 600 ft downslope to the north-northeast. The outfall for the site's storm sewer system is San Francisco Bay. There are no creeks or ponded water bodies

in the GGBHTD Study Area. Most of the central portion of the study area is paved or covered by sidewalks; the remaining portions are either landscaped or covered by natural vegetation.

11.1.2 Site History and Land Use

Batteries Lancaster and Cranston, located on the western portion of the GGBHTD Study Area, were constructed in the 1890s. Guns at the batteries were removed before World War II (Thompson, 1979). The entire study area was permitted to the GGBHTD by the U.S. Army in the early 1930s and currently serves as headquarters for the GGBHTD. Administration buildings, vehicle maintenance facilities, bridge operation and maintenance facilities, the bridge toll plaza and storage areas were built in 1935 with additional construction over the years. The GGBHTD has refurbished portions of the batteries for storage and office space. An evaluation of current and historical waste management practices at the GGBHTD Study Area identified four main areas to be evaluated: the Transformer, UST, Paint Operations, and Bone Yard Storage Areas.

11.1.2.1 Transformer Area

One transformer containing PCBs was located inside the powerhouse building in the Transformer Area (Figure 11.1-1), but was removed in 1982 or 1983. The building that housed this transformer has a concrete floor with no visible cracks. No evidence of previous spills or leaks was noted during the PA visit. No PCB containing transformers are currently used or stored in the GGBHTD Study Area.

11.1.2.2 Underground Storage Tank Area

Five active USTs are present at the GGBHTD Study Area. Two of the tanks, approximately 5,000 gal each, are located near the northwest corner of the maintenance building. The remaining three tanks are located west of the administration building and have capacities ranging from approximately 1,500 to 10,000 gal. The area surrounding all of the tanks is paved with asphalt or concrete. The tanks contain gasoline or diesel fuel and inventory reconciliation is performed daily. Although no loss of product has been noted by reconciliation of fuel withdrawals and additions, GGBHTD personnel noted evidence of fuel on the surface near the active USTs, probably due to poor filling practices and lack of

overflow protection. Overflow protection and inventory control procedures meet current CRWQCB requirements. All of the tanks passed integrity tests in July and September, 1992. Permits for replacement of all tanks are pending with San Francisco County. A single-bunker oil tank, which provided fuel to heat the main administration building, was removed in the summer of 1992. This tank was located west of the administration building.

11.1.2.3 Paint Operations Area

The Paint Operations Area is located adjacent to the vehicle maintenance building and includes a paint equipment washing area and an underground storage tunnel where paint and paint solvents for bridge painting are stored. The underground tunnel is located adjacent to Battery Lancaster. This area has both paved and unpaved surfaces.

The paint equipment washing area includes a wash rack and a connected concrete settling basin system, located adjacent to the vehicle maintenance building. The paint is water-based zinc primer. Approximately 150 gal of wastewater are generated weekly by the paint equipment washing operations. In the past, the wastewater drained from the wash rack to a two-stage concrete settling basin. A flocculent was added and the sludge removed. The remaining liquid flowed from the two-stage settling basin through a PVC pipe to a third settling basin where additional sludge was removed. The sludge generated from this process was primarily composed of zinc powder that was dried and disposed of off site as hazardous waste. The clarified liquid from the third settling basin formerly drained to a storm sewer that terminates in San Francisco Bay.

The settling basin system has been redesigned so that only stormwater is allowed to enter the final settling basin and storm drain. This storm drain is permitted under the SWRCB's General National Pollutant Discharge Elimination System (NPDES) Stormwater Permit for Industrial Facilities and is operated in conformance with the conditions of that permit. Wastewaters from the equipment washing area and the paint equipment wash rack are directed to pretreatment systems that discharge to the sanitary sewer after treatment.

Several 5-gal cans of gasoline, and containers of antifreeze and waste oil are stored near the paint equipment rinsing area. The containers of gasoline are stored in a metal flammable materials storage cabinet and are used for refueling small equipment. Waste antifreeze is

temporarily stored in a 55-gal drum. Full drums are transported to the hazardous waste storage area in the Bone Yard Storage Area pending disposal off-site. Waste oils from the maintenance building are contained in an aboveground steel tank located southeast of the paint equipment washing area. A concrete pad is beneath the tank, but bare soil is downslope of the pad. A small surface oil stain was noted near the aboveground tank during the PA (RLSA, 1992a). Soil Boring GGSB03 is located in the stained area. At the time of sampling, it was noted that the stained soil had been removed.

The remainder of the paint operations area is a concrete tunnel under the toll plaza in Battery Lancaster, where paint and paint solvents are stored in 55-gal drums. All flammable paints and solvents and all 55-gal drums are stored in secondarily contained flammable liquid storage rooms adjacent to the tunnel. Only pelletized, shrink wrapped water based paint is stored in 1-gal cans and these are stored in the main tunnel. A drainage trough extends along the length of the tunnel and discharges to a storm drain at the northeast tunnel entrance.

11.1.2.4 Bone Yard Storage Area

The Bone Yard Storage Area is used for equipment storage and bridge maintenance operations and is located in the eastern portion of the GGBHTD Study Area. The area is partially surrounded by a fence and is restricted to pedestrian traffic by gates and "No Trespassing" signs. An asphalt-covered area for spray painting small fabricated parts, is located in the northern one-third of the Bone Yard Storage Area. Sand and bridge sandblasting facilities, old equipment, scrap metal, asphalt and hazardous-waste storage buildings are located in the southern two-thirds of the Bone Yard Storage Area of which portions are paved.

A locked hazardous-waste building houses waste-paint materials from the paint equipment area prior to their disposal off-site. The building is a 10 ft by 15 ft concrete block-and-slab foundation structure. A 1-ft high concrete berm surrounds the floor to contain spills. A floor drain on the inside of the building, controlled by a gate valve, would contain any liquids spilled in the building. Asphalt and street patching compounds in 55-gal drums are located outside the western wall.

A locked metal roll-off trailer is also used for storage. It holds a few containers of pesticide, fertilizer, and less than 2 gal of over-the-counter herbicides used for groundskeeping. No evidence of spills was noted inside the trailer and no stains were visible on the soils surrounding it.

11.1.3 Previous Investigations

A bunker oil tank used to heat the administration building was removed in the Summer of 1992. Soil samples taken from the tank excavation were tested for TPH and BTEX. The samples had detections of TPH ranging from 630 ppm to 4,000 ppm, and detections of xylene ranging from 0.14 ppm to 0.34 ppm (Chew, 1992).

Four previous investigations provided information regarding the geology at the site. Two of these (Lawson, 1935; Curtis, 1972) focused on the large-scale structures and stratigraphy near the northern and southern bridge foundations. Serpentinite and shaley sandstone underlie the southern footing of the Golden Gate Bridge. These rocks are members or facies of the Franciscan Formation. The shearing and folding in these rocks resulted from deformation prior to the current movement along the San Andreas Fault System.

Two geotechnical investigations also provided information about the site (D&M, 1958; Trans Pacific, 1986). These investigations were conducted to determine the cause of damage to portions of the concrete surface of the Golden Gate Bridge Toll Plaza and to select a site for a public restroom. Soil borings drilled to maximum depths of 20 ft revealed fill, sand and weathered serpentinite. The information from these investigations is used in the following section.

11.2 SAMPLE LOCATION RATIONALE

The four areas investigated at the GGBHTD Study Area, the Transformer, UST, paint operations, and Bone Yard Storage Areas, are associated with vehicle maintenance and bridge operation and maintenance activities. The following sections describe the sample location rationale for these areas. Sampling criteria were determined by evaluating the potential contaminant sources, and their release mechanisms in each of these four areas, according to the site conceptual model (Section 3.1). The potential primary and secondary

release mechanisms include surface-water runoff, infiltration/percolation, leaks/spills and particulate transport.

11.2.1 Transformer Area

PCB containing transformers were formerly located in the powerhouse on a concrete floor with no visible cracks. The potential release mechanisms are spills or leaks from the transformers. Although no evidence of spills or leaks was present, four wipe samples were taken from the floor to evaluate the presence of PCB residue. GGW01, GGW02, and GGW04 are investigative samples. Sample GGW03 was a media blank and is not shown on the figure.

11.2.2 Underground Storage Tank Area

Several USTs containing gasoline or diesel fuel are located at the GGBHTD Study Area. Spills are more likely to drain off the concrete or asphalt pavement that covers the tanks than to infiltrate to the subsurface. No surface soil samples were taken because of the pavement cover. The potential release mechanisms are leaks from the tanks and filling lines. These would affect the subsurface soil and groundwater. The investigation focused on the integrity of the USTs. All active tanks passed previous integrity tests, but subsurface soil and groundwater samples were taken near each tank to characterize the nature and degree of possible gasoline or diesel fuel leakage. TPH and xylene were detected in soil samples from the area of a former oil tank (Chew, 1992). Additional soil and groundwater samples were taken near the former site of the oil tank to evaluate the effect of potential leaks on these media.

11.2.3 Paint Operations Area

Several potential contaminant sources are present in the Paint Operations Area. A wash rack and a connected concrete settling basin system were used for cleaning paint equipment. The paint is a water-based zinc primer. Any solids generated by this system are disposed off-site as hazardous waste, but the clarified liquids formerly flowed to a storm drain. This system is located in an area with both paved and unpaved surfaces. The objectives of the sampling were to characterize possible soil contamination from leaks or spills and determine the effects

of the clarified liquids on the storm drain. Surface and subsurface soil samples were taken from the embankment below the wash rack and below the concrete settling basin system adjacent to the storm drain. One storm drain sediment sample was obtained to evaluate contamination due to the liquids from the clarified wash water.

An aboveground waste oil tank from the maintenance shop is located southeast of the paint equipment cleaning system. The tank rests on a concrete pad, but bare soil is downgradient of the pad. The potential release mechanisms are spills or leaks from the tank that are not contained by the pad. A surface and a subsurface soil sample were obtained to characterize soil quality.

Paint and paint solvents are stored in the concrete tunnel below the bridge toll plaza in Battery Lancaster. Any leaks would discharge to a storm drain a few feet to the northeast. One sediment sample was obtained from this drain to characterize possible releases from leaks or spills.

11.2.4 Bone Yard Storage Area

Several potential contaminant sources exist within the Bone Yard Storage Area. Spray painting is conducted in an asphalt-covered area in the northern portion of the Bone Yard Storage Area. Potential release mechanisms include surface-water runoff and particulate transport. To characterize the nature and degree of possible contamination, the soil beneath the pavement within the spray area was sampled. Samples were also taken from downgradient surface and subsurface soil in an unpaved area near an oil stain.

Old equipment, scrap metal, bridge sandblasting materials, piles of asphalt and drums containing various materials are stored in the southern portion of the Bone Yard Storage Area. This area has both paved and unpaved surfaces. Potential release mechanisms include leaks/spills, infiltration/percolation, surface-water runoff and particulate transport. Surface and subsurface soil samples were taken near the scrap metal, asphalt, and sandblast storage piles to characterize the soil quality. Surface and subsurface soils were also sampled outside the hazardous waste storage building below the drums containing asphalt materials. Sediments from storm drains were also sampled to evaluate possible contamination resulting from surface runoff in this area.

11.3 GEOLOGIC SETTING

The following sections describe the soils, geology, and hydrogeology of the GGBHTD Study Area.

11.3.1 Soils and Geology

The soils in the GGBHTD Study Area were classified as Urban Land by the San Francisco County Soil Survey (Kashiwagi and Hokholt, 1985). Schlocker (1974) identified artificial fill and slope debris and ravine fill as surficial deposits. Serpentine bedrock was encountered below the surficial deposits. Thirteen soil borings, three of which were converted to monitoring wells, and one surface soil sample taken during the Supplemental RI field program corroborate Schlocker's information. The lithologic logs for these borings are in Appendix I. Five soil borings drilled during previous investigations encountered similar deposits (Dames & Moore, 1958; Trans Pacific, 1986). A cross section was constructed to show the variation in unconsolidated deposits throughout the area. The cross section location is shown on Figure 11.1-1. Cross section A-A ϕ (Figure 11.3-1) shows the geology in the Underground Storage Tank Area.

Most borings in the area encountered artificial fill at the surface. The composition of the artificial fill varies and includes sand, silt, and gravel with pieces of charcoal and nails. The fill was found to depths ranging from 0.5 to 2.0 ft bgs in the Bone Yard Storage Area in the eastern portion of the site. Thicker artificial fill was found west of the Bone Yard Storage Area, with depths ranging from 3 to 13 ft bgs.

Native deposits of sands, silts, and clays found in most borings in the area, sometimes occur at the surface but most often below the artificial fill. These sediments range in color from gray to varying shades of brown and are probably part of the Quaternary slope debris and ravine fill deposit mapped by Schlocker (1974). A layer of brown, well-rounded sand with silt was found only to the west of the Bone Yard Storage Area (Figure 11.3-1). This is probably also part of the Quaternary slope debris and ravine fill deposit.

Serpentine bedrock of the Franciscan Formation was found in the Bone Yard Storage Area at depths ranging from approximately 2.0 to 7.0 ft bgs, and in the western portion of the

study area at depths ranging from 6.5 to 24.0 ft bgs. Weathered serpentinite is sometimes found above the hard bedrock. This zone ranges in thickness from 0.5 to 4.5 ft.

11.3.2 Area Hydrogeology

The GGBHTD Study Area is located on a surface-water drainage divide between the Pacific Ocean and San Francisco Bay. Runoff would flow to the north-northeast or west, or into on-site storm sewers. The outfall for the storm sewer system is San Francisco Bay.

Groundwater is present in limited locations across the site. Five borings were drilled during previous geotechnical investigations, two of which reached serpentinite bedrock (Dames & Moore, 1958; Trans Pacific, 1986). No groundwater was encountered in any of these borings during the field exploration. Of the 13 borings drilled during the Supplemental RI, nine reached serpentinite bedrock. Saturated sediments were encountered in one boring, GGGW02, and a well was installed. Two other soil borings encountered only low-moisture sediments, but wells were installed due to the proximity of the borings to USTs and the potential for seasonal variation in groundwater (GGGW01, GGGW03). The remainder of the borings did not encounter groundwater.

Water level measurements are provided on disk in Appendix O. The water measured in the monitoring wells was contained in the upper weathered portion of the serpentinite zone (Figure 11.3-1). This zone was not saturated across the site; water was retained only in a bedrock low. This groundwater would not be considered a potable water supply because of insufficient well yield according to RWQCB resolution 88-63. Also, the dune sand and sandy silt fill found above the weathered serpentinite in the monitoring wells did not contain water. Thus, the saturated zone appears to be limited in both vertical and areal extent. Figure 11.3-2 shows that groundwater near the USTs flows to the north-northwest, as well as the approximate boundary between the saturated and unsaturated zones.

Pavement covers the area where the monitoring wells are located, limiting groundwater recharge from infiltration. Pavement also covers most of the unsaturated upgradient area. Some precipitation may infiltrate directly into fractures in a bedrock outcrop upgradient of the site near Lincoln Boulevard. This water may then migrate along fractures in the weathered zone of the serpentinite to the wells at the GGBHTD Study Area. Because the

bedrock outcrop area is partially covered by a road, some precipitation flows to storm drains that outfall at San Francisco Bay, rather than infiltrating to the subsurface. Leaky water or sewer lines may be an additional source of the water in the monitoring wells.

11.4 ANALYTICAL RESULTS

This section summarizes sample locations, requested analyses, and the analytical results for samples collected from the four areas investigated at the GGBHTD Study Area. Sample locations are shown on Figure 11.1-1. The detection tables in this section show only the analytes detected above the CRLs or RLs. A complete list of target analytes is in Section 3.3 and the diskette containing data are in Appendix O. The concentration of inorganics in soil samples is compared to ambient levels for the particular soil type. Most of the soil, groundwater, and surface-water samples and all of the sediment samples contained common elements found in the environment, including calcium, potassium, magnesium, and sodium. These compounds are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for humans; however, it may be an ecological COPC. Greater-than values for analytes were observed in several samples. Dilutions were not performed on these samples. An estimate of the actual value was provided by the laboratory.

11.4.1 Transformer Area

Three investigative wipe samples were collected from the concrete floor in the Transformer Area where transformers containing PCBs were formerly used and stored. One media blank wipe sample was also collected. The potential release mechanisms are spills or leaks from the transformers. Aroclor 1260 was the only isomer detected (Table 11.4-1); it was found in two of the investigative samples. PCBs were not detected in the media blank wipe sample.

11.4.2 Underground Storage Tank Area

Soil and groundwater samples were collected near several USTs to assess the potential for chemical release by leaks from the tanks and filling lines. Only the subsurface soil was

sampled because the area is covered by pavement. Six soil samples were taken from four soil borings and analyzed for inorganics, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH. The samples were in artificial fill material, native sands, and serpentinite. Numerous inorganics were detected in all the soil samples (Table 11.4-2) and several exceeded ambient levels. These include aluminum, antimony, barium, beryllium, cadmium, chromium, cobalt, manganese, nickel, and vanadium. One or more of the BTEX compounds were detected in three of the samples. The only other VOC detections were of methylethyl ketone. The SVOCs were PAHs found in three of the samples. Alpha-BHC was the only pesticide detected in the soils, and it was found in only one sample. TPH-D was detected in every soil sample except Boring GGGW04. TPH-G was detected in all but the soil samples from Borings GGGW04 and GGGW01.

Volatile and semivolatile unknowns, most naturally occurring or related to UST products, were identified in Borings GGGW01 and GGGW03. Volatile unknowns totaled 10,600 $\mu\text{g/g}$ and semivolatile unknowns totaled 3.0 $\mu\text{g/g}$. Several known volatiles and semivolatiles were detected in the sample.

A WET was performed on the 13.6 ft bgs sample from Well GGGW02. Chromium and nickel were detected at concentrations of 1 and 7.40 mg/L. Lead was not detected. The data are in Appendix O.

A full groundwater suite was obtained from only one well, GGGW02 (Table 11.4-3). The water from this well was analyzed for inorganics, miscellaneous parameters, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH. Due to dewatering during purging, no sample was obtained from Well GGGW01 and only a partial suite was sampled from Well GGGW03. The partial suite was analyzed for VOCs and TPH-G. Several inorganics were detected above the CRLs. The same VOCs detected in the soils were also found in the groundwater, but no SVOCs were detected in the water samples. Alpha-BHC, beta-BHC, and delta-BHC were the only pesticides detected in groundwater samples. TPH-D and TPH-G were also detected in the samples at concentrations ranging from 50 $\mu\text{g/L}$ to 89,000 $\mu\text{g/L}$.

Volatile unknowns were identified in the water samples at Wells GGGW02 and GGGW03 and totaled 1,700 $\mu\text{g/L}$.

Readings from a PID and explosimeter at Well GGGW03 made it necessary during drilling to vent the borehole and use nitrogen to decrease the exposure hazard.

11.4.3 Paint Operations Area

Sediment samples from storm drains were collected to assess the potential for chemical migration by surface runoff or sediment transport from the paint equipment washing system and the paint storage area. Two storm drains were sampled, one downgradient from the paint equipment wash rack, and one downgradient from the paint storage area, and analyzed for inorganics, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH (Table 11.4-4). BTEX, acetone, and methylethyl ketone were found only in Sample GGSD01 downgradient of the paint equipment washing area. No other VOCs were detected in the sediment samples. Various PAHs, bis(2-ethylhexyl)phthalate, and butylbenzylphthalate were detected in both sediment samples. Pesticides were found only in Sample GGSD02, which is also downgradient of the landscaped gardens at the site. Aroclor 1260 and TPH-D were found in both samples. TPH-G was found only in sample GGSD01.

Several volatile unknowns totaling approximately 48,000 $\mu\text{g/g}$, were identified in the sediment samples. Known volatiles were also detected in the sediment.

Six soil samples were taken from three borings downgradient of the paint equipment washing area and an aboveground oil storage tank. The samples were analyzed for inorganics, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH. The samples were taken in artificial fill material and serpentinite. Inorganics detected above ambient values include aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, chromium, iron, mercury, nickel, vanadium, and zinc (Table 11.4-5). No VOCs, PCBs, or herbicides were detected. Several PAHs were detected in a sample from Boring GGSB02 and di-n-butylphthalate was found in the two samples from Boring GGSB03. No other SVOCs were found in the soil samples. Three of the soil samples had detections of at least one of the following pesticides: gamma-BHC, ppDDE, ppDDT, or endrin. TPH-D was found in all of the samples.

Semivolatile unknowns were observed at concentrations totaling 3.6 $\mu\text{g/g}$.

A WET conducted on a sample from Boring GGSB01 at a depth of 7.5 ft bgs detected chromium and nickel at concentrations of 1.2 and 19.0 mg/L, respectively (Appendix O). Lead was not detected using this method.

11.4.4 Bone Yard Storage Area

Sediment samples from storm drains and soil samples were taken in the Bone Yard Storage Area to characterize potential chemicals released from the spray painting and sand blasting areas and from the storage of scrap metal and asphalt. Three sediment samples were analyzed for inorganics, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH. Numerous inorganics were detected in the samples (Table 11.4-6). Acetone and toluene were the only VOCs found. Several PAHs were detected, mainly in sample GGSD04. Bis(2-ethylhexyl)phthalate and butylbenzylphthalate were the only other SVOCs detected. Dieldrin and ppDDD were each detected in one sample. Aroclor 1260 was found in two of the samples and TPH-D was found in all three of the samples.

Several semivolatile unknowns, most related to UST products or naturally occurring compounds, were identified in the sediments. The total concentration of these was approximately 7 µg/g.

Twelve soil samples were taken from seven locations (Table 11.4-7). All but one was analyzed for inorganics, VOCs, SVOCs, pesticides, PCBs, herbicides, and TPH. Sample GGSB08 from 3 ft bgs was not analyzed for inorganics or PCBs, but was analyzed for the remainder of the suite. The samples were taken in artificial fill material, clay, sand, and serpentinite. Numerous inorganics were detected above ambient values, including aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, vanadium, and zinc (Table 11.4-7). Methylene chloride was the only VOC detected, and it was found only in a sample from Boring GGSB07. Several SVOCs, mainly PAHs, were found in samples from Borings GGSB06 and GGSB08. No other SVOCs were detected. The sample from Boring GGSB09 - containing aldrin, ppDDD, and ppDDE - had the only detections of pesticides. TPH-D was found in all but the sample from Boring GGSB05 and the deep sample from Boring GGSB08.

Volatile unknowns totaled 105 µg/g in the surface soil samples at Boring GGSB07.

A WET was conducted on the 1 ft bgs sample from Boring GGSB08. Chromium, nickel, and lead concentrations were 0.870, 2.70 and 17.0 mg/L, respectively.

11.4.5 RESULTS EVALUATION

The following sections briefly summarize the RI findings for each of the four areas investigated at GGBHTD Study Area. Any further evaluation of the site will be addressed by the GGBHTD. A risk assessment of the site will not be performed, therefore, a determination of COPCs is not performed. The site will not be addressed in the FS.

11.4.6 Transformer Area

A concrete-floored powerhouse building in the Transformer Area formerly housed a transformer that contained PCBs. Spills or leaks are potential release mechanisms. Two of the three wipe samples taken on the floor of the building had a detection of Aroclor 1260 (Table 11.4-1). The concrete floor of the building has no visible cracks or staining. It is unlikely that this compound will impact underlying soils or groundwater.

11.4.7 Underground Storage Tank Area

Inorganics, VOCs, SVOCs, TPH, and pesticides were detected in soil and groundwater samples adjacent to the USTs. Inorganics were detected above ambient values in all of the subsurface soil samples near the USTs. Elevated inorganics concentrations may be related to bridge painting activities and emissions from automobiles in this high traffic area.

Manganese and total dissolved solids were detected above the MCLs in groundwater. The inorganics detected in the soils in the UST area show no consistent patterns of increasing or decreasing concentration with depth, or of migration to groundwater. This is also supported by a metals mobility study for PSF soils that shows lead, nickel, and chromium have high potential for retardation in soil and a low tendency to migrate (Appendix Q).

Benzene was detected in the upper sample from Boring GGGW03. BTEX was found in the deeper samples from Borings GGGW01 and GGGW03. No VOCs were found in Boring GGGW02. However, benzene was found in groundwater at Well GGGW02, and BTEX was

found in groundwater at Well GGGW03. All BTEX compounds in groundwater were detected at levels about 10 times or greater above the MCLs. TPH-D and TPH-G were detected in most of the soil samples taken adjacent to the USTs and the concentrations increased with depth. TPH-D and TPH-G were also detected in groundwater in the wells. PAHs were the only SVOCs detected in the soil samples directly adjacent to the USTs. These were found in the upper and lower sample from Boring GGGW03 and only in the deeper sample from Boring GGGW01. No SVOCs were detected in Boring GGGW02 or in the groundwater at the site. BTEX compounds are volatile and soluble and do not strongly sorb to soils. These compounds have migrated from the soils to the water at the site. TPH-G and TPH-D also migrated from soils to groundwater. PAHs tend to sorb to soil and not leach into the groundwater. The PAHs were found in the subsurface soils at the site, but have not been detected in groundwater. All of these compounds are related to gasoline or diesel fuel leaks, and were detected at higher concentrations in the deeper borehole samples. This may indicate they originate from a leak in the tank rather than a leak in the filling lines. However, the tanks passed integrity tests and the source may be overfilling or spills at the surface of the tank before overflow protection was installed. The product may have flowed along the outside of the tank to the soils below.

Methylethyl ketone was detected in the upper and lower sample from Boring GGGW01. Methylethyl ketone was also found in groundwater at Wells GGGW02 and GGGW03. This compound tends to be mobile and volatile and may be derived from paint solvents or degreasers. There is no MCL for methylethyl ketone.

Alpha-BHC, the only pesticide detected in soil samples, was found in only one sample. Groundwater from Well GGGW02 had estimated detections of alpha-, beta-, and delta-BHC. Pesticides tend to sorb to soil and do not readily leach into the groundwater; detections in the groundwater are estimated values below the MDL. There are no MCLs for these pesticides.

11.4.8 Paint Operations Area

Paint operations occur in two sections at the GGBHTD Study Area. One section includes paint equipment washing and storage of antifreeze and waste oil, and the second area is for paint storage. Most of the area is paved. Leaks and spills and surface-water runoff are the

potential release and transport mechanisms. Storm drain sediment, and surface and subsurface soils were sampled in the first area downgradient of the paint equipment washing site and the waste oil storage site. The soil samples were in fill, sand, clay and serpentinite. Inorganics were detected above ambient in all of the samples (Tables 11.4-4 and 11.4-5). There is no consistent pattern of change with depth and the detections are not related to soil type. Zinc and lead in soil may be related to painting operations conducted at the site. Lead may also be related to emission from automobiles in this high traffic area. A metals mobility study (Appendix Q) indicates lead and nickel have a high potential for retardation in the soil and a low tendency to migrate from the site.

BTEX and TPH-G were found only in the sediment sample. These are moderately mobile and readily volatilize. PAHs and TPH-D were also detected; these compounds are less mobile and tend to sorb to soil. The PAHs were detected in the sediment and in one surface soil sample; none were found at depth. TPH-D was detected in the sediment sample and in all soils samples; concentrations decreased with depth in two of the three soil borings. These compounds appear to be related to spills or leaks from gasoline or diesel fuel and transported by surface-water flow to storm sewers, but are not accumulating in the soils.

Acetone and methylethyl ketone, the only other VOCs detected, were found in the storm drain sample. These compounds are mobile and tend to volatilize. They may be derived from paint strippers or degreasers.

Bis(2-ethylhexyl)phthalate and butylbenzylphthalate are SVOCs found in the sediment sample at concentrations similar to or below those naturally found in soils (Dragun, 1988). Di-n-butylphthalate, the only other SVOC detected, was found in both the surface and subsurface sample from Boring GGSB03 at concentrations that increased with depth. This compound has multiple uses, and can be a microcontaminant in paints.

Pesticide detections occur only in the soil samples and are found at values near the or below the RLs. No spacial patterns of the detections are apparent and their existence may be related to former groundskeeping practices. Aroclor 1260 was the only PCB detected in this portion of the site; it was found in the sediment sample (GGSD01) at a concentration of 0.424 $\mu\text{g/g}$. These compounds have a strong affinity for soil and tend to be persistent in the environment.

A sediment sample (GGSD02) was taken from the storm drain downgradient of the paint storage tunnel adjacent to Battery Lancaster. Numerous inorganics were detected in the sample. A metals mobility study (Appendix Q) indicates lead has a high potential for retardation in the soil at PSF and a low tendency to migrate. The zinc may be related to the ongoing paint operations at the site. TPH-G, TPH-D, and PAHs were found in the sample. TPH-G is the most mobile of the three. All are probably derived from surface-water runoff from the parking lot near the site. Bis(2-ethylhexyl)phthalate and butylbenzylphthalate, the other SVOCs detected, were at levels similar to natural concentrations in soils (Dragun, 1988). The pesticides detected in this sample tend to adhere to the sediments: ppDDD and ppDDE are breakdown products of ppDDT. All of the pesticides are most likely related to former groundskeeping practices. Aroclor 1260 was also found in this sediment sample. PCBs tend to remain stable and adsorb to sediment and therefore are not mobile in soils.

11.4.9 Bone Yard Storage Area

The Bone Yard Storage Area is used for equipment storage and various maintenance duties. Spray painting is conducted in a paved area in the northern portion of the Bone Yard Storage Area. Old equipment, scrap metal, sandblasting materials, and piles of asphalt are stored in the partially paved southern portion of the site. Potential release and transport mechanisms include leaks/spills, infiltration/percolation, surface-water runoff, and particulate transport.

A subsurface sample was taken below the asphalt (GGSB05) and a surface and subsurface sample (GGSB04) were taken downgradient in an unpaved area in the northern portion of the Bone Yard Storage Area. The samples were in fill, clay, and serpentinite. Inorganics were detected above ambient in all of the samples (Table 11.4-7). The concentrations do not vary according to the sample material type, and do not show a consistent pattern of change with depth. The zinc values may be related to painting operations. Lead was detected at 17.0 mg/L using a Waste Extraction Test. The lead was found mainly in the upper soil boring samples and may be related to painting of the bridge and emissions from extensive automobile traffic. A metals mobility study (Appendix Q) performed for PSF data indicates lead has a high potential for retardation in the soil and a low tendency to migrate. TPH-D was the only other compound detected in these samples. It was found at the same concentration (8.0 µg/g) in both samples from the downslope boring, Boring GGSB04.

In the southern portion of the Bone Yard Storage Area, sediment from storm drains and surface and subsurface soils were sampled. The soil samples were in fill, sand, clay, and serpentinite. Several inorganics were detected above ambient in the samples (Tables 11.4-6 and 11.4-7). There is no consistent pattern of change with depth and the concentrations are not related to material type.

The VOCs detected were limited in extent. The sole detection of a VOC in the soils at the site was methylene chloride. Acetone and toluene were detected once each in the sediment samples at the site. These may be related to solvents, degreasers, and gasoline.

Only two soil samples had detections of PAHs. Boring GGSB06 had detections of PAHs in the subsurface soils but not in the surface soils. The other PAH detections were in Boring GGSB08 located near an asphalt pile. PAHs tend to adhere to soils and are not mobile, as seen at this site: the PAHs were found in the surface soil but not in the subsurface soil. PAHs were also found in two sediment samples. TPH-D was detected in all but one sample, the deep sample from Boring GGSB08. These TPH-D concentrations generally decrease with depth and may be related to gasoline or diesel fuel used at the site.

Bis(2-ethylhexyl) phthalate and butylbenzylphthalate, the only other SVOCs detected, in soils were found in all of the sediment samples at concentrations similar to or below ambient levels (Dragun, 1988).

Pesticides were detected in the surface soil sample from Boring GGSB09 and in two of the sediment samples, but show no consistent patterns. The ppDDD and ppDDE may be derived from ppDDT, and the aldrin detected may be derived from the dieldrin detected at the site. These pesticides tend to adhere to soils and do not migrate. These tendencies are consistent with the data at this site. These pesticides are probably from former groundskeeping practices. Aroclor 1260 was detected in two of the sediment samples at concentrations of 0.220 and 3.200 $\mu\text{g/g}$. PCB compounds are persistent and tend to adhere to sediment.

11.5 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the results of RI activities at the four areas of investigation at the GGBHTD Study Area. Any further evaluation of the site will be addressed by the

GGBHTD. A risk assessment of the site is not included in this RI report, and the site will not be addressed in the Main Installation FS.

11.5.1 Transformer Area

A concrete-floored powerhouse building in the Transformer Area formerly housed a transformer that contained PCBs. Spills or leaks are potential release mechanisms. Two of the three wipe samples taken on the floor of the building had a detection of Aroclor 1260. The concrete floor of the building has no visible cracks or staining. It is unlikely that this compound will impact underlying soils or groundwater.

11.5.2 Underground Storage Tank Area

Compounds associated with fuel leaks, solvents, and pesticides from groundskeeping were detected near the USTs and some have migrated to the water-bearing zone. There are no drinking water MCLs for the solvents or pesticides detected here. The BTEX concentrations detected in the groundwater are above the MCLs. The groundwater is limited in vertical and aerial extent. The production rates, as determined from recharge rates, for Wells GGGW02 and GGGW03 are 96 gpd and 5 gpd, respectively. These rates are less than the production rate of 200 gpd for a designated drinking water aquifer as specified in State Water Resources Control Board Resolution 88-63. Also the TDS, 887,000 $\mu\text{g/L}$, measured at the site exceeds the California recommended secondary MCL for a drinking water aquifer. Overfill protection and inventory control procedures meet current CRWQCB requirements.

11.5.3 Paint Operations Area

The compounds detected in the Paint Operations Area are related primarily to spills or leaks from fuel or waste oil storage, solvents used during cleaning of paint equipment and former groundskeeping practices. These compounds are limited in extent, with some found only in the sediments or upper soil samples. Concentrations of di-n-butylphthalate, which was found in only one boring, increased with depth. TPH-D increased with depth in only one boring. Surface-water runoff has transported some compounds to sewers, but there is very little migration to the subsurface soils. Wastewaters from the equipment washing area are now directed to pre-treatment systems which discharge to the sanitary sewer after treatment. The

storm drain is permitted under the SWRCB's general NPDES stormwater permit for industrial facilities.

11.5.4 Bone Yard Storage Area

The compounds detected in the Bone Yard Storage Area are limited in extent and are possibly related to isolated fuel spills, the storage of asphalt, painting operations, and former groundskeeping practices. Surface-water runoff has transported some compounds to sewers, but there is very little migration to the subsurface.

12. BAKER BEACH STUDY AREA

The Baker Beach Study Area was included in the PA (RLSA, 1992a) to assess disturbed areas and coastal fortifications, and identify areas requiring further investigation. Although the PA determined that Baker Beach was not an area of concern, chemical sampling was conducted during the RI at various locations in the study area to confirm the PA's findings. The sites in the Baker Beach Study Area that are evaluated as part of this RI include Disturbed Areas 1, 2, 3, and 4. Samples were also collected from an area north of Disturbed Area 1 (referred to as Disturbed Area 1a), where materials used to cover the coastal fortifications are present. The boundaries of the disturbed areas delineated in Figures 12.0-1 and 12.0-2 are approximate limits of observed debris. The distribution of visible debris within the areas is sporadic and at most sites random.

The abandoned coastal fortifications in the Baker Beach Study Area include Battery Lancaster, Battery Cranston, Battery Marcus Miller, Battery Boutelle, Battery Godfrey, Battery Crosby, Battery Chamberlain, Old Mine Casemate, New Mine Casemate, and several underground magazines. Results of inspections and sampling for explosives and propellants in these structures will be presented in a separate report .

12.1 AREA DESCRIPTION

This section describes the location and physical features and history and land use of the Baker Beach Study Area.

12.1.1 Location and Physical Features

The Baker Beach Study Area is located along the western edge of the PSF on property that was irrevocably permitted to the GGNRA prior to transfer of the entire PSF to the NPS. The site encompasses approximately 100 ac and is bounded by the GGBHTD Study Area to the north, the PSF property boundary to the south, Lincoln Boulevard to the east, and the Pacific Ocean to the west (Figure 1.2-1).

Much of the study area is a steeply sloping bluff with a narrow beach at its base (Figures 12.0-1 and 12.0-2). The steepness of the bluff tends to decrease toward the south, yielding a

broader, more developed beach and dune field in the area south of Battery Crosby (Figure 12.0-2). The study area has a western aspect and surface drainage is to the west, toward the Pacific Ocean. Vegetation in the Baker Beach Study Area is generally well-developed except on the steeper cliff and beach areas, and consists of grasses, shrubs, and trees. Also, an endangered plant, Raven's manzanita, grows in the outcrops of serpentinite east of Battery Crosby (Jones and Stokes Associates, Inc., 1990).

12.1.2 History and Land Use

There have been coastal fortifications along the length of Baker Beach since the late 1800s. Many of these fortifications were abandoned and sealed after World War II. However, some are still used for storage, or have been restored for tourist visitation and are currently operated by the NPS. Several of the coastal fortifications in the Baker Beach Study Area contained USTs and will be addressed by the USCOE in a separate base-wide UST management program.

Fill material has been deposited in the Baker Beach Study Area at four disturbed areas that were identified in the PA (RLSA, 1992a). The fill material found in the disturbed areas contains varying amounts of artificial fill, debris fill, and landfill material. Artificial fill consists primarily of non-native rock such as chert and serpentinite fragments. Debris fill consists of building debris such as brick, concrete, glass, and wood. Landfill material at the site contained glass, ceramics, automotive parts, and metal containers. Aerial photographs indicate that the four disturbed areas received fill material intermittently from 1946 to 1973. Aerial photographs prior to 1946 were unavailable.

The material found at the surface in Disturbed Area 1 consists of debris fill, artificial fill, and some landfill material. Near the center of the study area is a mounded area of landfill material consisting mainly of pieces of glass and ceramics. The southern edge of the mounded area is bounded by a shallow ravine which runs east- west through the center of the disturbed area. A small seep is located within the ravine. A topographic map from 1918 (U.S. Engineer's Office, 1918) suggests that filling may have occurred in Disturbed Area 1 as early as 1918. Activity at the site is also visible on the aerial photograph from 1946 (Rindgen and Sitton, 1990). Much of the fill material in Disturbed Area 1 appears to have

been used to control erosion or to level the ground between Battery Marcus Miller and Battery Boutelle.

The presence of fill material in Disturbed Area 2 is apparent in aerial photos from 1955, and is a result of road grading activities that pushed material over the cliff edge during the construction of Battery West which is located southeast of Disturbed Area 2 (Pacific Aerial Surveys, 1955). Field observations indicate that debris such as concrete and asphalt from other sources may have been deposited after the completion of this coastal fortification. However, the additional debris fill is not identifiable on aerial photographs.

The material in Disturbed Area 3 is composed primarily of artificial fill and debris fill containing concrete, asphalt, and metal parts. Disturbed Area 3 received fill material intermittently between 1948 and 1973 as evidenced by aerial photographs (Rindgen and Sitton, 1990; Pacific Aerial Surveys, 1948, 1955, 1958, and 1968). Initially, fill material in Disturbed Area 3 was placed for erosion control along Lincoln Boulevard and the access road to Battery Crosby. The aerial photographs indicate that this area was used for additional dumping of debris until approximately 1973.

Disturbed Area 4 is composed of artificial fill and some debris fill that was used to stabilize a portion of Lincoln Boulevard. Fill material in Disturbed Area 4 is identifiable on the 1955 aerial photographs (Pacific Aerial Surveys, 1955). Aerial photographs after 1955 do not show evidence of any additional fill material. The headward erosion of the drainage channel in this area has distributed some of the debris fill down slope, and does not indicate of the extent of fill material.

12.2 SAMPLE LOCATION RATIONALE

The sampling location rationale for Disturbed Areas 1, 2, 3, and 4 is presented in this section in the context of the conceptual model presented in Section 3.1. The sampling program for the disturbed areas in Baker Beach was designed to identify and evaluate chemicals that may be present in the fill materials. The composition of fill material was assessed through the use of soil borings and field observations of each disturbed area. The areal and vertical extent of

fill materials were estimated using aerial photographs, topographic maps, and soil boring and site reconnaissance information.

Potential target compounds can be transported in surface-water runoff from storm events, groundwater seepage, and releases through infiltration and percolation. Soil samples from the ground surface were obtained from soil borings to evaluate the potential for analyte transport by surface-water runoff. Subsurface soils were collected to determine if the potential for analyte transport through infiltration and percolation exists. A surface-water sample was collected to determine if any target compounds have been released from fill material through infiltration and percolation. Sediments from the seep area were obtained to evaluate this medium as a potential secondary source. Concentrations of target analytes in the soil samples were used to determine the importance of airborne particulate transport.

12.3 GEOLOGIC SETTING

The surficial deposits in the Baker Beach Study Area vary widely between the northern and southern portions. The northern portion is predominantly Franciscan Formation overlain by landslide deposits. The Franciscan Formation in this area consists primarily of Cretaceous serpentinite and minor amounts of Jurassic to Cretaceous sandstones, shales, and cherts (Schlocker, 1974). The overlying landslide deposits are of Quaternary age and generally consist of unstratified mixtures of bedrock fragments, sand, silt and clay (Schlocker, 1974). The southern portion of Baker Beach is covered almost entirely by Quaternary dune sand (Schlocker, 1974). Modern beach deposits are found at the base of the bluff area for the entire length of the study area.

Geologic data were obtained from 20 hand-augered borings in the Baker Beach area during the supplemental RI and an additional 13 hand-augered borings during the Follow-on RI (Appendix J). The soil borings varied in depth from 0.5 to 4.5 ft bgs. The thickness of artificial and debris fill material was not determined in some of the borings in the disturbed areas because of recurring auger refusal or borehole caving. The thickness of artificial fill varies in each disturbed area and is estimated to range from 20 ft to <1 ft, based upon information from soil borings, aerial photographs, topographic maps, and site reconnaissance.

Total volumes of fill were estimated for each disturbed area. The volume of fill in Disturbed Area 1 is estimated to be 16,700 yd³. Disturbed Area 2 is estimated to contain 2,200 yd³ of fill material. Disturbed Area 3 contains the largest amount of fill of the four disturbed areas, with an estimated volume of 33,200 yd³. The fill volume for Disturbed Area 4 is estimated to be 4,000 yd³. The area north of Disturbed Area 1, where two additional soil samples were obtained, is not identified as a disturbed area; therefore, no fill volume was estimated. Debris in this additional area consists of broken pieces of the tar sand roofing material used on either Battery Cranston or Battery Marcus Miller.

Based upon hydrogeologic information from the GGBHTD Study Area, groundwater may be present in limited areas of the landslide deposits, dune sands, and the weathered serpentinite bedrock formations of the Baker Beach Study Area. However, no groundwater was encountered in any of the 33 borings completed in this area. A groundwater seep, originating at approximately mid-slope, was observed and sampled in Disturbed Area 1 (Figure 12.0-1). Other seeps may exist in the northern portion of Baker Beach depending on the season and regional precipitation. However, as indicated on the water table elevation map of the PSF (Figure 2.3-2), the Baker Beach Study Area is largely unsaturated.

12.4 ANALYTICAL RESULTS

This section presents the analytical results for samples collected from the four disturbed areas in the Baker Beach Study Area. Two additional samples were collected in the northern portion of the study area (Disturbed Area 1a), and are discussed with the Disturbed Area 1 data (Figure 2.1-1).

Section 3.3 includes a complete list of target analytes, and the tables presented in Section 12 show the compounds detected at concentrations exceeding the CRLs/RLs. Inorganics data for samples collected are compared to appropriate ambient concentrations as presented in Section 3.6.2. Most of the soil and sediment samples contained elements commonly found in the environment, including calcium, potassium, magnesium, and sodium. These compounds are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is

also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. The Supplemental RI sampling design plan outlined collection of three soil samples from each boring. However, due to difficulties such as borehole caving and auger refusal, two samples and sometimes only one sample were obtainable from each borehole. The discussion of unknowns is based on criteria established in Section 3.5. Unknowns meeting the criteria are presented at the end of Section 12.4.4.

12.4.1 Disturbed Area 1

Sampling at Disturbed Area 1 first occurred during the Supplemental RI and consisted of collecting 8 soil samples from four borings (BBSB01 through BBSB04) throughout the disturbed area and collecting an additional sample from a boring (BBSB05) located downslope of the disturbed area. In addition, a surface water (BBSW01) and sediment sample (BBSD01) were collected from a seep located near the center of the disturbed area (Figure 12.0-1). All soil and sediment samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Analytes in soils with concentrations above the CRLs/RLs are shown in Table 12.4-1. Analytes in sediment with concentrations above the CRLs/RLs are shown in Table 12.4-4. The surface water sample was analyzed for inorganics and general chemical parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Detections above the CRLs/RLs are shown in Table 12.4-3.

Numerous inorganics were detected in all soil samples collected as part of the investigation at Disturbed Area 1 (Table 12.4-1). All samples were comprised of either landfill, debris fill, or artificial fill material, with the exception of the samples from Borings BBSB02 and BBSB05. The shallow sample from Boring BBSB02 was classified as consisting of beach/dune sand and the deep sample was classified as serpentinite. The sample from Boring BBSB05 was classified as serpentinite.

For samples consisting of fill material, regardless of the type of fill, inorganics are compared to ambient fill values. For these samples antimony, beryllium, chromium, cobalt, iron, nickel, and selenium were detected above ambient fill values in at least one sample. The majority of ambient exceedences occurred in the samples from Boring BBSB01. The only ambient

exceedence in samples from Borings BBSB03 and BBSB04 was beryllium, which was detected at a concentration only slightly above the ambient value in the shallow samples. The deep samples from these borings contained no ambient exceedences. The beach/dune sand sample collected at 0.0 ft bgs from Boring BBSB02 contained numerous inorganic analytes at concentrations above beach/dune sand ambient values including aluminum, antimony, barium, beryllium, cadmium, chromium, cobalt, copper, iron, manganese, nickel, selenium, silver, and vanadium. Although this sample is classified as beach/dune sand, the boring log indicates the presence of fill material as well as serpentinite in the interval sampled. When compared to ambient values for these two types of lithologies only aluminum, antimony, barium, beryllium, and selenium were detected at concentrations higher than ambient values. The serpentinite sample collected at 2.5 ft bgs from Boring BBSB02 contained antimony, mercury, nickel, and selenium at concentrations higher than serpentinite ambient levels. For the sample from Boring BBSB05, which consisted of weathered serpentinite, antimony, mercury, nickel, and selenium were detected above ambient serpentinite values.

VOCs detected in the soil samples collected during the Supplemental RI include methylene chloride and trichlorofluoromethane. Methylene chloride was detected above the CRL in the 0.0 and 2.0 ft bgs samples from Boring BBSB01, and the 0.0 and 1.5 ft bgs samples from Boring BBSB04. Trichlorofluoromethane was above the CRL in the 0.0 ft bgs sample from Boring BBSB01, and the 0.0 and 2.5 ft bgs samples from Boring BBSB02. Six SVOCs were detected at concentrations above the CRL: bis(2-ethylhexyl)phthalate in Boring BBSB01, di-n-butylphthalate in Boring BBSB03 and Boring BBSB05, fluorene in Boring BBSB05, 2-methylnaphthalene in Boring BBSB04, phenanthrene in Boring BBSB03, and pyrene in Borings BBSB01, BBSB03, and BBSB04. All of these SVOC detections were in the surface soil samples with the exception of pyrene, which was detected in both the surface and subsurface sample of Boring BBSB03. Eight OCPs were detected at concentrations above the RL: delta-BHC, gamma-BHC, ppDDD, ppDDE, ppDDT, dieldrin, endrin, and endrin aldehyde. The PCB Aroclor 1254 was detected at a concentration of 0.394 µg/g in the 1.5 ft bgs sample from Boring BBSB04. No chlorinated herbicides were detected above the RL. TPH-D detections ranged from 9.0 to 28.0 µg/g.

The surface water sample, BBSW01, was collected during the Supplemental RI, from the outfall of a seep located in a ravine near the center of the disturbed area. Several inorganics and general chemical parameters were detected at concentrations above the CRL. No VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, or TPH were detected at concentrations above the CRLs/RLs.

The sediment sample, BBSD01, was collected at the same location as the surface water sample during the Supplemental RI. Because the sediment could potentially be comprised of all soil types in the area, inorganic detections are considered above ambient values only if the concentration was above the ambient value in all four soil types. Inorganics meeting this criteria include arsenic, barium, cadmium, copper, lead, mercury, silver, and zinc. Barium, lead and zinc were detected at concentrations an order of magnitude higher than the maximum ambient values. No VOCs or SVOCs were detected at concentrations above the CRL. One OCP, ppDDE, was detected at the RL of 0.006 $\mu\text{g/g}$. The PCB Aroclor 1260 was detected at a concentration of 0.126 $\mu\text{g/g}$. No chlorinated herbicides were detected above the RL. TPH-D was detected at a concentration of 6.00 $\mu\text{g/g}$.

To delineate the vertical and lateral distribution of lead and zinc in soil surrounding BBSD01, Borings BBSB23 through BBSB26 were drilled during the Follow-on RI. At each boring, samples were collected from two depths (0.0 and 1.7 ft bgs). An additional sample was collected immediately above bedrock (4.0 ft bgs) from Borings BBSB24 and BBSB26. All samples were analyzed for lead and zinc, and consisted of either debris fill, landfill, or artificial fill material except for the 4.0 ft bgs sample from Boring BBSB26 which contained serpentinite. Lead and zinc were detected above ambient fill values in all samples from Borings BBSB24 and the 0.0 and 1.7 ft bgs samples from Boring BBSB26. Lead and zinc were also detected above ambient serpentinite levels in the 4.0 ft bgs sample from Boring BBSB26. Lead and zinc were detected in the other samples, however, the concentrations were below ambient values. Based on the lack of lead and zinc detections above SDCs in samples collected from the south slope of the ravine (BBSB23 and BBSB25), the lateral extent of zinc and lead is limited to the north slope of the ravine, in particular to a mounded area of landfill material just north of BBSD01 (Figure 12.0-1). The vertical extent of lead

and zinc surrounding BBSD01 is limited by bedrock, which is encountered at approximately 4 ft bgs.

Boring BBSB34 was drilled during the Follow-on RI to confirm that the lead and zinc detections in excess of SDCs are associated with the mounded landfill material on the north slope of the ravine. The boring is located within the mounded landfill material area, approximately 45 ft uphill of BBSD01. Samples consisted of landfill material at 0.0 ft bgs and weathered serpentinite above bedrock at 5.0 ft bgs. Lead and zinc were detected in both samples at concentrations above ambient levels. Based on the results, lead and zinc are present at elevated concentrations within the mounded landfill material on the north slope of the ravine. The vertical distribution is limited by bedrock at 5.0 ft bgs.

To define the northern extent of the mounded landfill material area, Borings BBSB31, BBSB32, and BBSB33 were drilled during the Follow-on RI. Samples were collected from the surface and immediately above bedrock, and consisted of serpentinite. Lead and zinc exceeded ambient serpentinite levels in both samples from Boring BBSB31. This boring is located along the edge of the visible extent of the landfill material area. Ambient levels were not exceeded in either sample from Boring BBSB32, and only lead in the shallow sample was above ambient levels in Boring BBSB33. Borings BBSB32 and BBSB33 are located outside the visible extent of the landfill material area. The results from these samples confirm the presence of elevated lead and zinc associated with the landfill material, and define the extent as shown on Figure 12.0-1.

To define the lateral extent of lead and zinc to the west of the mounded landfill material, Boring BBSB35 was drilled approximately 120 ft down slope of BBSD01 during the Follow-on RI. Samples from this boring consisted of debris fill in the shallow sample (0.0 ft bgs) and serpentinite in the deep sample (8.0 ft bgs). Lead was detected at concentrations below ambient levels in both samples, thus defining the lateral extent of lead to within approximately 120 ft down slope and west of BBSD01. Zinc was detected at a concentration of 290 $\mu\text{g/g}$ in the 0.0 ft bgs sample, which is close to the fill ambient value of 280 $\mu\text{g/g}$. Thus the lateral extent of zinc in soil to the west and downslope of the seep is defined to be within 120 of the seep. The vertical extent of zinc at BBSB35 is limited to within 8.0 ft bgs due to the lack of detectable zinc in the 8.0 ft bgs sample.

12.4.1.1 Disturbed Area 1a

Two additional borings, Borings BBSB21 and BBSB22, were drilled 500 ft north of Disturbed Area 1 because debris fill was noted on the hillside. The debris fill consists of asphalt mixed with sand and most likely came from the roof of the nearby coastal fortification. Boring BBSB21 was drilled within the visible debris, and BBSB22 was drilled down slope of the farthest extent of visible debris. Samples were collected from each boring at depths of 0.0 and 2.0 ft bgs and consisted of beach/dune sand and minor amounts of artificial fill. Several inorganics were detected above the CRL in all four samples, however, only aluminum, chromium, and nickel were detected above ambient beach/dune sand levels. No VOCs were detected above the CRL. Ten SVOCs were detected, predominantly in the shallow sample from Boring BBSB21. Delta-BHC, gamma-BHC, and heptachlor epoxide were the OCPs detected above the RL; all of these detections were in the samples from Boring BBSB21. Two of these detections, gamma-BHC and heptachlor epoxide, were detected in the subsurface sample. No PCBs or chlorinated herbicides were detected above the CRLs/RLs. TPH-D detections ranged from 5.00 to 48.0 µg/g.

12.4.2 Disturbed Area 2

Disturbed Area 2 is the result of road grading during the construction of Battery West. Five borings were initially scheduled in the area during the Supplemental RI, but the extent of fill was smaller than anticipated and the number was reduced to three. Two borings, BBSB06 and BBSB08, were drilled within the disturbed area, and two samples were collected from each. Samples from these borings consisted of debris fill material. An additional boring, BBSB07, was drilled in native material down slope of the farthest extent of fill. One sample was collected from this boring, and consisted of weathered serpentinite. All five samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Analytes detected above the CRLs/RLs are shown in Table 12.4-5.

All four soil samples collected from both borings within the disturbed area (Borings BBSB06 and BBSB08) contained several inorganics above the CRL. The only inorganics detected above ambient fill values was beryllium in all four samples, copper in the 2.0 ft bgs sample from Boring BBSB08, zinc in both samples from BBSB06, and selenium in the 0.0 ft bgs sample from Boring BBSB

07. Beryllium concentrations ranged from 1.07 to 1.31 $\mu\text{g/g}$. The ambient value for beryllium in fill is 0.986 $\mu\text{g/g}$. Copper was detected at a concentration of 118 $\mu\text{g/g}$ in the 2.0 ft bgs sample from Boring BBSB08, which is only slightly above the ambient fill value of 98 $\mu\text{g/g}$. Zinc was detected above the ambient fill value of 280 $\mu\text{g/g}$ at concentrations of 307 and 292 $\mu\text{g/g}$ in the 0.0 and 1.5 ft bgs samples from Boring BBSB06 respectively. Selenium, which was detected at a concentration of 1.29 $\mu\text{g/g}$ in the 0.0 ft bgs sample from BBSB07, exceeded the ambient fill level of 0.819 $\mu\text{g/g}$.

Samples collected from both borings within the disturbed area (BBSB06 and BBSB08) also contained detections of several organic compounds. Two VOCs, benzene and trichlorofluoromethane, were detected above the CRL in the 0.0 ft bgs sample from Boring BBSB08, and xylenes were detected above the CRL in the 2.0 ft bgs sample from the same boring. Thirteen SVOCs were detected in the two borings, and concentrations decreased with depth. Two OCPs, alpha-BHC and endrin, were detected above or at the RL in the shallow sample from Boring BBSB06. Two others, ppDDE and ppDDT, were detected above the RL in the 2.0 ft bgs sample from Boring BBSB08. No PCBs or chlorinated herbicides were detected above the CRLs/RLs, and TPH-D detections ranged from 13.0 to 58.0 $\mu\text{g/g}$, with the lower detections occurring in the deeper samples.

Boring BBSB07 was drilled beyond the extent of the disturbed area, in soil created by the weathering of serpentinite bedrock. Inorganics detected at concentrations above ambient serpentinite values include antimony and selenium. No VOCs, SVOCs, OCPs, PCBs, or chlorinated herbicides were detected above the CRLs/RLs in this sample. TPH-D was detected at a concentration of 11.0 $\mu\text{g/g}$.

12.4.3 Disturbed Area 3

Disturbed Area 3 was initially an erosion control measure along Lincoln Boulevard and was later used as a debris fill site. Four borings (BBSB12 through BBSB15) were drilled within the disturbed area and another (BBSB11) was drilled down slope of the farthest extent of fill during the Supplemental RI. Two samples, at 0.0 and 2.0 ft bgs, were collected from each boring, and analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Analytes detected above the CRLs/RLs are shown in Table 12.4-6. During the

Follow-on RI, four additional borings (BBSB27 through BBSB30) were drilled along the southern extent of the disturbed area in order to define the extent of elevated lead and zinc detected in during the Supplemental RI. Two samples, at 0.0 ft bgs and 2.7 ft bgs, were collected from each boring, and analyzed for lead and zinc. Both samples from Boring BBSB30 were also analyzed for TOC. Analytes detected above the RLs for the Follow-on RI samples are shown on Table 12.4-7.

Borings BBSB12, BBSB13, BBSB14, and BBSB15 were drilled in the disturbed area. All samples collected from these borings consisted of debris fill material, and inorganic detections are compared to ambient fill values. Inorganics detected above ambient fill values in at least one sample include: antimony, beryllium, cadmium, chromium, cobalt, iron, lead, mercury, nickel, and zinc. Of these, antimony, chromium, cobalt, lead, nickel, and zinc are at least one order of magnitude above ambient values. Inorganics were not detected above ambient values in either of the samples from Boring BBSB15.

Because of the elevated detections of lead and zinc in samples from Boring BBSB14, four additional borings (BBSB27 through BBSB30) were drilled during the Follow-on RI surrounding BBSB14 to delineate the vertical and lateral extent of lead and zinc in soil. Two samples were collected from each boring at depths of 0.0 ft bgs and 2.7 ft bgs, and analyzed for lead and zinc. The samples from BBSB30 were also analyzed for TOC. The shallow and deep samples from Borings BBSB27 and BBSB28 respectively were comprised of either artificial fill or debris fill, and inorganic concentrations for these samples are compared to ambient fill values. The shallow and deep samples from Borings BBSB28 and BBSB27 respectively were comprised of fill material made up of sand, and inorganic detections in these samples are compared to beach/dune sand ambient values. Borings BBSB29 and BBSB30 were drilled in native material and inorganic concentrations in these samples are compared to ambient beach/dune sand values. Lead was detected above ambient values in the shallow samples from Borings BBSB27, BBSB28, and BBSB29, as well as the deep sample from Boring BBSB29. Zinc was detected above ambient values in both samples from Borings BBSB28 and BBSB29. TOC concentrations in the 0.0 and 2.7 ft bgs samples were 5,500 µg/L and 5,300 µg/L respectively.

Organic analyses were conducted only on the samples collected under the Supplemental RI. No VOCs were detected above the CRL. Six SVOCs were detected above the CRL: benzo[a]anthracene, benzo[k]fluoranthene, bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene. Six OCPs were detected above the RL. Three samples contained detectable concentrations of ppDDD. The method blank for samples BBSB12 (0.0 ft bgs) and BBSB13 (0.0 and 2.0 ft bgs) contained 0.005 µg/g ppDDE, which may account for the detections of that compound. The method blank also contained 0.007 µg/g ppDDT, which may account for detections in Boring BBSB12 (0.0 ft bgs) and Boring BBSB13 (2.0 ft bgs), but the ppDDT detections in Boring BBSB12 (2.0 ft bgs) and Boring BBSB13 (0.0 ft bgs) can not be accounted for in this manner. Dieldrin was detected in both samples from Borings BBSB12 and BBSB13. Endrin was detected at the RL of 0.006 µg/g in the 2.0 ft bgs sample from Boring BBSB12, and heptachlor epoxide was detected at 0.004 µg/g in the 0.0 ft bgs sample from Boring BBSB13. The PCB Aroclor 1254 was detected above the CRL in the 2.0 ft bgs sample from Boring BBSB14. No chlorinated herbicides were detected above the RL, and TPH-D detections ranged from 5.00 to 50.0 µg/g.

Boring BBSB11 was drilled down slope of the disturbed material during the supplemental RI, and samples were collected at 0.0 and 2.0 ft bgs. The samples were collected from native sand, and the data are compared to ambient beach/dune sand values. No inorganics were detected above ambient values in either sample. No VOCs, SVOCs, OCPs, PCBs, or chlorinated herbicides were detected. TPH-D values were 6.00 µg/g in the 0.0 ft bgs sample, and 5.00 µg/g in the 2.0 ft bgs sample.

12.4.4 Disturbed Area 4

Disturbed Area 4 is the result of an effort to stabilize Lincoln Boulevard. The fill material was deposited close to the road, but with time some has eroded down hill into the drainage channel. Borings BBSB16, BBSB17, and BBSB18 were drilled within the main body of the fill material. Borings BBSB19 and BBSB20 were drilled among the material scattered along the drainage channel. Two samples, at 0.0 and 2.0 ft bgs, were collected from each boring. All 10 samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. Analytes detected above the CRLs/RLs are shown in Table 12.4-8.

All samples consisted of native sand, except for the shallow samples from Borings BBSB16 and BBSB19, which contained artificial and debris fill respectively. Although numerous inorganics were detected in every sample, only cadmium, lead, and silver were detected at concentrations above ambient levels. Both cadmium and silver were detected at concentrations slightly above beach/dune sand ambient levels in the 0.0 ft bgs sample from Boring BBSB18. Lead was detected above ambient levels in three samples including both samples from Boring BBSB16 and the 0.0 ft bgs sample from Boring BBSB20. No VOCs or SVOCs were detected. The OCPs chlordane and ppDDT were detected above the RL in both samples from Boring BBSB16, and ppDDT was also detected at the RL in the 0.0 ft bgs sample from Boring BBSB20. No PCBs or chlorinated herbicides were detected above the CRLs/RLs. TPH-D detections ranged from 3.00 to 140 $\mu\text{g/g}$.

Three unknown SVOC hydrocarbons were tentatively identified in at least 19 soil samples in the Baker Beach Study Area. Additionally, seven unknown SVOC hydrocarbons were tentatively identified in BBSD01.

12.5 RESULTS EVALUATION

The following sections evaluate the results of sampling performed during the RI at the Baker Beach Study Area. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds are considered COPCs. Inorganic analytes are naturally occurring and their presence at a site may or may not be anthropogenic. In determining which inorganic analytes are COPCs, several factors are considered. These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources must be evaluated. For disturbed areas such as those investigated at the Baker Beach Study Area, identification of sources is difficult due to the random distribution of source material within the fill.

12.5.1 Disturbed Area 1

The fill material at Disturbed Area 1 is the result of ground leveling or erosion control. Visual inspection of surface conditions along with observations made during sample collection indicate that the fill material at Disturbed Area 1 contains blocks of concrete, glass, ceramics, building refuse, automotive parts, and metal containers. The distribution of these items within the fill is sporadic and random, with the highest concentration located near the top of the slope, thinning down the ravine in steeper portions of the slope. A mounded area of landfill material consisting mainly of pieces of glass and ceramics is located in the central portion of the disturbed area.

In order to characterize the nature and extent of fill material at Disturbed Area 1, twenty-nine soil samples were collected from within and around the disturbed area. Numerous inorganics were detected above ambient values in at least one soil sample, including: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc. Figures 12.5-1 through 12.5-15 are posting maps which show analyte concentrations for samples collected within Disturbed Area 1. In addition, the figures show the sample lithologies used in comparing inorganic concentrations to ambient values.

Although numerous ambient exceedences occurred in soil at Disturbed Area 1, not all inorganics exceeding ambient levels are considered COPCs. Several of these analytes including: aluminum, arsenic, barium, mercury, and silver were detected at concentrations only slightly above ambient values in a limited number of samples. In addition, although above ambient values, most concentrations are typical for other soils in the region (Table 3.7-1). Aluminum, arsenic, barium, mercury, and silver will not be considered as COPCs in soils at Disturbed Area 1.

Of the remaining analytes detected above ambient values, several have naturally high concentrations in serpentinite. These include beryllium, cobalt, chromium, iron, manganese, and nickel. Because weathered serpentinite is found throughout the fill material (see boring logs in Appendix J), the elevated concentrations of these metals is likely related to serpentinite. Therefore, although these analytes were detected above ambient levels in some samples at the site, they will not be considered COPCs in soil.

Cadmium, copper, and vanadium were also detected above ambient values in one sample at Disturbed Area 1. The 0.0 ft bgs sample from Boring BBSB02 contained the only ambient exceedences for these analytes. The boring log for this sample indicated that it was fill material containing beach/dune sand. When compared to ambient values for beach/dune sand, all three analytes exceed ambient levels. However, when compared to ambient values for fill material all three analytes are below ambient levels. Cadmium, copper, and vanadium are not considered COPCs in soil at Disturbed Area 1.

Sampling results from in and around the mounded landfill material area at the center of the disturbed area confirm the presence of lead and zinc at concentrations above ambient levels in this area. Samples collected from the mounded area contain abundant pieces of glass and ceramic. Dates stamped into several ceramic pieces identify them as being produced in the 1940s. An archaeologist who examined the glass and ceramic pieces, indicated that the ceramics were typical household items and that lead and zinc were not commonly used in glass or ceramics from this period (Bente, 1994). Concentrations of lead and zinc in samples collected outside the mounded landfill area are below ambient values, thus limiting the lateral extent to be within the area shown on Figure 12.0-1. The vertical distribution of lead and zinc in the mounded landfill area varies with depth, but is limited by bedrock, which varies from 2 to 7 ft bgs. Lead and zinc are COPCs in soil at Disturbed Area 1.

The distributions of the remaining inorganic analytes detected above ambient levels (antimony and selenium) are laterally discontinuous and are likely associated with landfill and debris fill located throughout the site. Antimony is commonly used in alloys and metals, both of which have been observed scattered throughout fill material at Disturbed Area 1. The source of selenium is not clear, however, ambient exceedences of selenium are observed to occur in the same samples containing antimony exceedences (samples from Borings BBSB01, BBSB02, and BBSB05). The distribution of antimony and selenium does not appear to be associated with the lead and zinc detections in the mounded landfill material area. The lateral extent of these two analytes is not well defined, but does appear to be limited to the portions of the disturbed area north and west of the seep zone. Antimony and selenium were not detected above ambient levels in samples from Borings BBSB04 and BBSB03 which are located to the south and east of the seep zone respectively. Boring

BBSB05 which is located downslope of the seep at the western edge of the disturbed area contained ambient exceedences of both antimony and selenium. The vertical distribution of these analytes varies, but is limited by shallow serpentinite bedrock, which is present at depths of 2 to 7 ft bgs. Antimony and selenium will be considered soil COPCs for Disturbed Area 1.

Detections of VOCs, SVOCs, OCPs, and PCBs in soil are less extensive than those of the inorganics. Distribution patterns of these compounds are sporadic as would be expected in a fill site due to the random distribution of sources within the fill. Detected phthalates and PAHs all decreased in concentration with depth, with detections occurring in four of five borings. Eight OCPs were detected, with concentrations varying with depth. A PCB was detected in one boring at a depth of 1.5 ft bgs. All detected organic compounds are considered COPCs at Disturbed Area 1.

TPH-D was detected throughout Disturbed Area 1 in both surface and subsurface soil samples, and is considered a soil COPC. TPH chromatograms for the soil samples indicate that the detected constituents of the TPH-D fraction are mixtures other than diesel fuel. The exact makeup of the TPH in the soil is unclear, but it is likely related to some type of waste oil or naturally occurring organic compounds with chain lengths between C₈ and C₃₁. The chromatograms can be used to evaluate whether the detected constituents vary between samples. Close correlations do exist between samples from the same boring, and some similarities are apparent between borings. Some mixtures are present both upslope and down slope while others are present in only one boring. A general conclusion is that the hydrocarbons present are less volatile and less mobile than diesel. This is based on assessment of the chromatograms and data packages from the lab which show that the hydrocarbon chains present have lengths greater than C₈.

Results of the surface water sample collected at the seep near the center of the site indicate that contaminants within fill material result in little impact on water as it passes through the shallow subsurface soils. Eight inorganics and five general chemical parameters were detected above the CRL in the surface-water sample, but the only concentrations exceeding California MCLs are those for barium and TDS, which exceed Secondary MCLs of 1,000 µg/L and 500,000 µg/L, respectively. Barium, as well as manganese, also exceed freshwater

criteria for protection of aquatic life. Freshwater criteria are shown on Table 3.8-7. None of the inorganic or organic soil COPCs identified above were detected in the surface-water sample. Although several MCLs were exceeded in the surface water sample, they are used for comparison purposes only. Groundwater at the Baker Beach Study Area would not be considered a drinking water source due to low volume and accessibility, however, exposure to surface water will be evaluated in the human health and ecological risk assessment. All detected analytes in the surface water sample are considered COPCs.

Analysis of sediment sample results indicate that the soil COPCs lead and zinc are also present in sediment near the seep. The fact that these metals were not above MCLs in the surface water sample confirms the fact that inorganic metals are generally not soluble and tend to sorb to solids. The presence of these analytes in the sediment at the seep indicates that while lead and zinc are not highly mobile in the environment, they can be transported on sediment. Several other analytes were detected above ambient levels in the sediment sample including: arsenic, barium, cadmium, copper, iron, mercury, and silver. Of these, only barium, copper, and silver were detected at concentrations which would warrant their inclusion as sediment COPCs. Copper was also detected at a concentration exceeding sediment criteria for protection of aquatic life (Table 3.8-7). The remaining inorganics were at levels which approximated concentrations found in other regional soils (Table 3.7-1). Barium, copper, lead, silver, zinc, and all detected organics are considered COPCs in sediment.

12.5.1.1 Disturbed Area 1a

Two borings (BBSB21 and BBSB22) were drilled down slope of Battery Marcus Miller to evaluate potential chemical releases from tar-covered sand found in the area. This sand appears to be roofing material removed from the coastal fortification. One boring (BBSB21) was drilled within the extent of the scattered debris, and the other (BBSB22) was drilled within down slope of visible debris. Samples were collected from each boring at depths of 0.0 and 2.0 ft bgs and consisted of sand. Notes taken at the time of sampling indicated the presence of tar covered sand along the slope where the samples were collected.

Several inorganics were detected above the CRL in all four samples, however, only aluminum, chromium, and nickel were detected above ambient beach/dune sand levels. All

ambient exceedences occurred in samples from Boring BBSB21 and were only slightly above ambient levels. Chromium and nickel were above ambient beach/dune sand levels in the 0.0 ft bgs sample, and aluminum was above ambient levels in the 2.0 ft bgs sample. Boring BBSB22 did not contain detections of inorganics above ambient values. Boring logs for both Borings BBSB21 and BBSB22 indicate the presence of fill material throughout the area. In addition, serpentinite bedrock outcrops throughout the hillside where the samples were collected. When compared to ambient values for these two lithologies, all detections in samples from both Borings BBSB21 and BBSB22 are below ambient levels. Based on this analysis, inorganics are not considered soil COPCs at Disturbed Area 1a.

Ten PAHs were detected above the CRL in the upslope boring. In each case, the concentration decreased with depth. Two PAHs, phenanthrene and pyrene, detected at the surface down slope, are known to occur in nature. OCP detections were also limited to the upslope boring, primarily at the surface. TPH-D was detected above the CRL in all four samples, with concentrations decreasing from 48.0 $\mu\text{g/g}$ at the surface upslope to 5.00 $\mu\text{g/g}$ at the surface down slope. PAHs and TPH-D would be expected constituents of tar-covered sand. These compounds also have a fairly limited mobility due to high soil affinity, and decreasing concentrations with depth and distance from the source are as anticipated. Detected PAHs, OCPs, and TPH-D are considered COPCs in soil at Disturbed Area 1a.

Detections of OCPs are not likely to be directly related to a tar-and-sand mixture. Pesticides may have been applied to the upslope area or a nearby area, and concentrations have not had time to attenuate.

All detected organic compounds will be considered COPCs in soil.

12.5.2 Disturbed Area 2

Fill material in Disturbed Area 2 was identified as a potential source of contamination. The fill material is identifiable in aerial photographs from 1955, and is a result of road grading activities. Items identified within the debris fill material include pieces of wood, brick, concrete, gravel, and asphalt. Surface soil and subsurface soil samples were collected within the disturbed area and outside the farthest extent of visible debris to assess impacts from

potential releases of analytes in the fill material. Soil samples collected in Disturbed Area 2 contained inorganics, VOCs, PAHs, OCPs, and TPH-D.

All surface soil and subsurface soil samples in Disturbed Area 2 contained inorganics. The only inorganics detected above ambient fill values were beryllium, which was detected slightly above ambient values in all four samples, copper which was slightly above ambient values in one sample, and zinc which was slightly above ambient values in two samples. Beryllium concentrations ranged from 1.07 to 1.31 $\mu\text{g/g}$. The ambient value for beryllium in fill is 0.986 $\mu\text{g/g}$. The ambient value for beryllium in serpentinite is higher, at 1.54 $\mu\text{g/g}$. serpentinite is present throughout the Baker Beach Study Area (see boring logs, Appendix J). When compared to serpentinite, beryllium detected in these samples is below ambient values. In addition, debris on the surface in the area consisted of concrete fragments and some metal objects, indicating limited anthropogenic sources for beryllium. This, along with the relatively consistent concentration of beryllium throughout the debris fill both laterally and vertically suggests a natural source. Beryllium will not be considered a COPC in soil at Disturbed Area 2.

Copper was also detected in one sample from the disturbed area at a concentration slightly above ambient values. However, because the detection is only slightly higher than ambient, copper will not be considered a COPC in soil. Zinc was also detected at concentrations slightly above ambient levels in both samples from Boring BBSB06. Because the detections of zinc are only slightly above ambient levels and the number of exceedences is limited, zinc will not be considered a COPC in soil.

Several inorganics were detected in the soil sample collected from native material downslope of the disturbed area (Boring BBSB07). The only inorganics detected above ambient serpentinite levels in this sample were antimony and selenium. Beryllium, copper, and zinc, which exceeded ambient levels in the samples collected from the disturbed area, were not detected above ambient levels in the downslope sample. Fill material was not identified in the log for Boring BBSB07 thus limiting potential sources for the elevated antimony and selenium. In addition, the ambient levels for these analytes was chosen to be the detection limit, resulting in a very low ambient level. Because these analytes were not above ambient

in the nearby fill samples, and there is no clearly identifiable source these antimony and selenium are not considered soil COPCs for Disturbed Area 2.

The following VOCs: benzene, trichlorofluoromethane, and xylenes were detected in the upslope sample from Boring BBSB08, which is closest to the parking area near Battery Godfrey. The detections of benzene and trichlorofluoromethane were reported only in the surface soil sample. Benzene and trichlorofluoromethane are relatively volatile and soluble; therefore, volatilization to the atmosphere and leaching through the soil are possible. The xylenes detected at this location were in the subsurface soil sample. Xylene is not highly volatile or soluble, and tends to sorb to soil. Migration of xylene through the unsaturated soils is expected to be minimal. VOCs were not detected in the sample collected below the farthest extent of visible debris (BBSB07). All detected VOCs in soil at Disturbed Area 2 are considered COPCs.

Three of the four samples collected within the disturbed area contained SVOCs, consisting entirely of PAHs, with most detections in the upslope sample. Thirteen different PAHs were detected above the CRL in the two Borings (BBSB06 and BBSB08). Concentrations of these compounds, except for benzo(a)pyrene and pyrene in one sample, decreased with depth in all samples. PAHs were not detected in Boring BBSB07 which is located below the farthest extent of visible debris. The PAHs have low solubilities and tend to sorb to soil; therefore, leaching of these compounds through subsurface soils is not likely. All detected SVOCs in soil at Disturbed Area 2 are considered soil COPCs.

Both borings within the disturbed area contained detections of OCPs at concentrations at or above the RL. OCPs were not detected in the sample collected below the farthest extent of visible debris (BBSB07). The detections were in the surface soil sample at the down slope location (BBSB06) and in the subsurface soil in the upslope sample location (BBSB08). Because pesticides tend to strongly sorb to soils, migration of these compounds through subsurface soils is limited. The presence of OCPs in a subsurface sample at this location may indicate that the chemicals were present on the material before deposition in the fill area. All detected OCPs in soil at Disturbed Area 2 are COPCs.

PCBs and chlorinated herbicides were not detected above the CRLs/RLs in any of the samples.

TPH-D fraction was detected in all of the samples, with concentrations decreasing with depth. The TPH-D method detects C₈ through C₃₁; compounds which can occur naturally in the environment. The detections are considered to represent organic compounds related to waste oil or naturally occurring organic compounds between C₈ to C₃₁. The variability of TPH composition in these samples indicates that a specific source may not be identifiable. Although these detections are reported as TPH-D, specific fuel types cannot be identified because sample chromatograms do not resemble the diesel and kerosene standard chromatograms. TPH-D in soil at Disturbed Area 2 is considered a COPC.

12.5.3 Disturbed Area 3

Fill material in Disturbed Area 3 was identified as a potential source of contamination. As identified in aerial photographs, Disturbed Area 3 has received material intermittently from 1948 to 1973. Artificial and debris fill identified in the boring logs include: concrete, wood, brick, asphalt, glass, and tile. Surface and subsurface soil samples were collected within the disturbed area and downslope of the farthest extent of visible debris to assess impacts from potential releases of analytes in the fill material. Soil samples collected in Disturbed Area 3 contained inorganics, PAHs and a phthalate, OCPs, a PCB, and TPH-D.

Inorganics were detected in all surface soil and subsurface soil samples in Disturbed Area 3. The following inorganics were detected above ambient levels in at least one sample: antimony, beryllium, cadmium, chromium, cobalt, iron, lead, mercury, nickel, and zinc. Of these, antimony, chromium, cobalt, lead, nickel, and zinc were detected at concentrations an order of magnitude above ambient levels and are considered COPCs in soil. Iron, was also detected at elevated levels and will be considered a soil COPC. Beryllium, cadmium, and mercury were detected at concentrations only slightly above ambient levels in only one sample each. Concentrations of these analytes likely represent ambient conditions and therefore, beryllium, cadmium, and mercury are not considered COPCs in soil at Disturbed Area 3.

Because of the random nature of potential source material distributed throughout the fill material at Disturbed Area 1 it is difficult to define the nature and extent of inorganic COPCs in soil. Potential sources identified in the fill material include wood, concrete, brick, tile, glass, metal, and asphalt. While none of the inorganic COPCs can be directly associated with any of these sources, the distribution of elevated concentrations of inorganic COPCs follows a random pattern similar to the random distribution of these items in the fill. Concentrations vary both laterally and vertically throughout the site, with all ambient exceedences occurring in samples from within the disturbed area. Inorganics were not detected above ambient values in either of the samples from Boring BBSB11 which was collected in native material outside the extent of the disturbed area at the base of the hill. This is as expected since inorganics tend to sorb to soils, with minimal migration away from the source. Migration potentials of inorganics are discussed in the metals mobility model (Appendix Q).

The inorganic soil COPCs lead and zinc, which were detected at elevated concentrations during the Supplemental RI, were targeted for further investigation during the Follow-on RI. Results of the Supplemental RI sampling indicated the presence of lead at 1,000 $\mu\text{g/g}$ and zinc at 2,900 $\mu\text{g/g}$ in the 2.0 ft bgs sample from boring BBSB14. At the time of the Follow-on field program sampling to define the extent of an analyte was based on SDCs. The SDC for lead was 300 $\mu\text{g/g}$, and the SDC for zinc was 610 $\mu\text{g/g}$ (Table 3.8-1). Because the lead and zinc detected in Boring BBSB14 were an order of magnitude above SDCs, four additional borings (BBSB27 through BBSB30) were installed surrounding BBSB14 during the Follow-on RI. Results of the Follow-on sampling contained lead and zinc at concentrations below SDCs, thus defining the lateral extent of these analytes to be within a 10 ft radius of BBSB14. The vertical extent is defined by bedrock at approximately 4.0 ft bgs.

No VOCs were detected above the CRL in any of the samples.

SVOCs, including PAHs and bis(2-ethylhexyl)phthalate, were detected above the CRL in all of the samples that were obtained within the disturbed area. Like the distribution of inorganics, concentrations of SVOCs did not follow any pattern either laterally or vertically. Five PAHs were detected above the CRL in samples collected within the disturbed area, but

none were detected in the sample below the farthest extent of visible debris. The PAHs and bis(2-ethylhexyl) phthalate have low solubilities and tend to sorb to soil; therefore, leaching of these compounds through subsurface soils is not likely. All detected SVOCs are considered COPCs in soil.

OCPs were detected at or above the RL in all of the samples within the disturbed area; most of these detections occurred in the central portion of the disturbed area. Concentrations of OCPs decreased with depth in all but one sample, Boring BBSB15, which had a detection in the deeper sample equal to the RL. Because pesticides tend to strongly sorb to soils, migration of these compounds through subsurface soils is limited. No detections of chlorinated herbicides were reported above the RL at this site. All detected OCPs are considered COPCs in soil.

One PCB was detected above the CRL in a sample from near the southern boundary of the disturbed area; Aroclor 1254 was reported in the subsurface soil sample from BBSB14. Aroclor 1254 has a low solubility and a strong affinity to soil; therefore, potential migration of the compound is unlikely. All detected PCBs will be considered COPCs in soil.

Detections of TPH-D were reported above the CRL in all of the samples. Concentrations decreased with depth in all but one of the sample locations. Although these detections are reported as TPH-D, specific fuel types cannot be identified because sample chromatograms do not compare to the diesel and kerosene standard chromatograms. The TPH detected in surface and subsurface soils may be related to waste oil or naturally occurring organic compounds between C_8 through C_{31} . However, the composition of the TPH varies between samples and may indicate the lack of a specific source. TPH-D will be considered a COPC in soil.

12.5.4 Disturbed Area 4

Fill material in Disturbed Area 4 was identified as a potential source of contamination. The artificial and debris fill in Disturbed Area 4 was used to stabilize a portion of Lincoln Boulevard. Aerial photographs from 1955 do not show evidence of any additional fill material. Surface and subsurface soil samples were collected both within the disturbed area and downslope of the farthest extent of visible fill material to assess impacts from potential

releases of analytes in the fill material. Soil samples collected in Disturbed Area 4 contained inorganics, OCPs, and TPH-D.

Inorganics were detected in all soil samples collected at Disturbed Area 4, however, only cadmium, lead, and silver were detected above ambient values. Cadmium and silver were each detected at concentrations slightly above ambient values in only one sample. Because the concentrations of these analytes in these samples are close to ambient levels and fall within the range of concentrations for other regional soils, cadmium and silver are not considered COPCs in soil.

VOCs and SVOCs were not detected in any samples.

The pesticides chlordane and ppDDT were detected in both samples from Boring BBSB16, with chlordane also detected at the RL in the shallow sample from Boring BBSB20. Concentrations of these compounds decrease with depth. Because pesticides tend to strongly sorb to soils, migration of these compounds through subsurface soils is limited. All detected pesticides are considered COPCs.

PCBs and chlorinated herbicides were not detected in any samples.

TPH-D was detected in all samples, with the highest concentrations again occurring in samples from Boring BBSB16. Concentrations of TPH-D in this boring increase with depth, while concentrations in all other borings decrease with depth. Samples collected downhill from the fill area contain concentrations of TPH-D similar to those collected from within the fill area. Interpretation of the chromatograms for these samples indicates that specific fuel types cannot be identified because the sample chromatograms do not resemble the diesel and kerosene standard chromatograms. The TPH-D method detects C₈ through C₃₁; compounds which can occur naturally in the environment or be related to waste oil. Potential sources for these compounds are difficult to identify because of the variability of the detected constituents between samples. TPH-D is considered a COPC.

12.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY

This section summarizes the evaluation of results for the Baker Beach Study Area, including the risk assessment results, as presented in detail in Section 15.

12.6.1 Conclusions

The potential source(s) of contamination evaluated in the Baker Beach Study Area are debris fill and/or landfill materials deposited at the sites. Due to geographical separation, each of four disturbed areas was evaluated individually within the study area.

At all four disturbed areas, target analytes appear to be confined to the disturbed area. Samples collected downhill of the disturbed areas generally had either no detections or lower concentrations of target analytes than those detected in the fill material. The vertical extent of chemicals is limited due to shallow bedrock throughout the Baker Beach Study Area. Groundwater was only observed at a small seep in Disturbed Area 1, and was not detected in any borings at any of the disturbed areas.

COPCs identified in Disturbed Area 1 fill material include inorganics, VOCs, SVOCs, OCPs, PCBs, and TPH-D. Detections of these compounds were discontinuous, both laterally and vertically. Laterally, several inorganics including lead, appear to be defined by a mounded area of landfill material located in the center of the disturbed area. Inorganics and TPH-D were detected in groundwater from a seep near the center of the disturbed area. Sediment collected at the seep contained inorganics, OCPs, PCBs, and TPH-D. At Disturbed Area 2, the identified COPCs included the inorganic beryllium, several VOCs, SVOCs, OCPs, and TPH-D. These analytes were detected in both fill and underlying native material samples, but detections were both laterally and vertically discontinuous at the site. Inorganics, SVOCs, OCPs, and TPH-D were identified as COPCs in Disturbed Area 3. Only OCPs, and TPH-D were considered COPCs in Disturbed Area 4.

12.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. The detected inorganics

and miscellaneous parameters in the seep water sample and the inorganic COPCs and detected organics in the sediment sample are also considered in both the human health and ecological risk assessments.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against EPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Baker Beach Study Area are summarized in the following sections.

12.6.2.1 Human Health

Baker Beach Study Area was assessed as distinct disturbed areas in the human health risk assessment because of the variation in source material and associated COPCs. In addition, the mounded area at Disturbed Area 1 was evaluated separately because of the apparent difference in fill composition. The GMPA identified open space (recreational) use for all four areas, and only exposure to surface soil from 0.0 to less than 0.5 ft bgs is assumed. The surface water and sediments at the seep in Disturbed Area 1 were also evaluated under the open space scenario.

A residential PRG ratio screening assessment for surface soil, sediment, and surface water was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for

informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by EPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with each of the disturbed areas are presented in the following subsections. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to the PSF lead screening value of 840 $\mu\text{g/g}$ for industrial and recreational use, are identified.

12.6.2.1.1 Quantification of Cancer Risks

Table 15.1-114 presents RME lifetime cancer risk estimates for site visitors (recreational open space land use) at the disturbed area sites within the Baker Beach Study Area. At Baker Beach Disturbed Area 1a, PAHs and a pesticide, delta-BHC, were determined to be COCs in surface soil samples following COPC screening. A recreational visitor scenario with incidental ingestion of and dermal contact with surface soil was assessed and resulted in a total cancer risk of $2E-05$, mostly from exposure to benzo(a)pyrene and dermal exposure to benzo(b)fluoranthene and indeno(1,2,3-cd)pyrene. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Inorganics, PAHs and pesticides were determined to be COCs in surface soil at Disturbed Area 1 following COPC screening. The seep on Disturbed Area 1 had lead and PCB 1260 in the sediment samples and manganese and TDS in the surface water samples as COC following the COPC screening. None of these COCs in any of the media resulted in an increased risk to either the recreational visitor exposed via ingestion of or dermal contact with surface soil or the recreational older child (age 9 through 18) exposed to the seeps surface water or sediments. Therefore, it is unlikely that exposure to surface soil, sediment, and surface water at Disturbed Area 1 will result in an excess cancer. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Three PAHs (acenaphthylene, benzo(a)pyrene and phenanthrene) were determined as the COCs for surface soil at Disturbed Area 2 following COPC screening. A recreational visitor scenario with incidental ingestion of and dermal contact with surface soil resulted in a total risk of $5E-06$, all from benzo(a)pyrene. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

At Disturbed Area 3, antimony, chromium, nickel, and phenanthrene were the COCs determined in surface soil samples following COPC screening. The carcinogenic risk is $2E-08$ in the recreational visitor scenario with ingestion of and dermal contact with surface soil. Therefore, exposure to the recreational visitor at Disturbed Area 3 is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Chlordane in surface soil samples at Disturbed Area 4 was the only COC determined following COPC screening. The total risk is $4E-07$, indicating that exposure to the recreational visitor at Disturbed Area 4 via ingestion of or dermal contact with surface soil is unlikely to result in excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk equal to $1E-06$.

12.6.2.1.2 Quantification of Noncarcinogenic Effects

Table 15.1-115 presents the hazard indices calculated for sites at the Baker Beach Study Area. Antimony has a total hazard index of $1E+00$ at Disturbed Area 3. All other sites and COCs have hazard indices less than $1E+00$. Therefore, exposure at these sites is unlikely to result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ for Disturbed Areas 1a and 3 and less than $1E+00$ for Disturbed Areas 1, 2, and 4.

The maximum detected lead value in surface soil at Disturbed Area 1 is 2050 mg/kg , which is greater than the lead soil screening value of 840 mg/kg .

12.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

In addition, surface water data from the seep were evaluated as a source of drinking water for all terrestrial receptors, with the exception of pocket gophers. Exposure by aquatic receptors (e.g., aquatic plants, invertebrates, or amphibians) was considered for both sediment and surface water data.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals was also evaluated. Direct contact for plants, invertebrates and amphibians was evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in

Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

For Disturbed Area 1 outside of the mounded landfill material area, soil COPCs evaluated in the ecological risk assessment include antimony, selenium, VOCs, PAHs and other SVOCs, pesticides, PCB 1254, and TPH-D. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher and plants and soil fauna exceeded 1 when comparisons were made based on the conservative TBV_{Low} and TBV_{High} .
- The dietary ingestion pathway was responsible for most of the ecological risk identified for birds and mammals. Dieldrin, ppDDT, PCB, and selenium dietary HQs exceeded 1 based on a comparison of projected dietary exposure to the TBV_{Low} . Only selenium HQs exceeded 1 based on a comparison of projected dietary exposure to the TBV_{High} .
- Antimony and selenium HQs exceeded TBV_{Low} values for plants and soil fauna. Only antimony HQs exceeded the TBV_{High} values for plants and soil fauna.

Because some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted given the TBV_{High}), the ecological risk assessment for Disturbed Area 1 outside the mounded landfill material area will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

For the mounded landfill material area within Disturbed Area 1, soil COPCs evaluated in the ecological risk assessment include lead and zinc. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs for the American robin, mourning dove, and western harvest mouse exceeded 1 when comparisons were made based on the TBV_{High} .

- The soil and dietary ingestion pathways contributed to risk for terrestrial receptors for both lead and zinc HQs.
- Lead HQs exceeded 100, and zinc HQs exceeded 50, for the American robin for soil or dietary ingestion exposure pathways for exposure relative to the TBV_{Low} . HQs for lead were above 5, and HQs for zinc were 1 and higher, when the TBV_{High} was used as the basis of the risk comparison.
- Lead and zinc HQs exceeded TBV_{Low} and TBV_{High} values for plants and soil fauna.

Because some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted given the TBV_{High}), and several receptors are potentially affected, the ecological risk assessment for mounded landfill material area within Disturbed Area 1 will be further evaluated to determine whether the assessment warrants inclusion of this site into the FS.

For the seep at Disturbed Area 1, COPCs identified in the surface water for the ecological risk assessment include several inorganics and miscellaneous parameters. Sediment COPCs include barium, copper, lead, silver, zinc, TPH-D, PCB 1260, and ppDDE. Results of the risk assessment indicate the following:

- HIs for aquatic life and amphibians exceeded 1 based on comparison to the chronic AWQC which are the TBVs for aquatic life.
- Barium and manganese HQs for surface water exceeded 1 for aquatic life based on the minimum and maximum AWQC identified.
- TPH-D, PCB 1260, ppDDE, copper, and lead HQs exceeded sediment quality criteria, which were the TBVs for invertebrate exposure to sediments.
- HQs for sediment ingestion by the raccoon exceeded 1 for lead when exposure estimates were compared to the conservative TBV_{Low} , but did not exceed 1 when the basis of the comparison was the TBV_{High} .
- Ingestion of surface water by either birds or mammals does not present a risk.

Although there are exceedences between 10 to 1000, because the area is small, and also could be seasonal, the habitat is too limited to support populations of receptors. Only isolated individuals may be affected. Therefore, further evaluation at this location is not warranted from the perspective of ecological risk.

Soil COPCs evaluated in the ecological risk assessment for Disturbed Area 1a include several PAHs, OCPs, and TPH-D. All HQs and HIs were less than 1. Therefore, there is no risk attributable to this site, and further evaluation is not warranted.

Soil COPCs identified for the ecological risk assessment for Disturbed Area 2 include several PAHs, VOCs, OCPs, and TPH-D. Results of the risk assessment indicate the following:

- The only receptor with an HI greater than 1 was the American robin, when comparisons were made to the TBV_{Low} values. ppDDT was identified as the only risk driver to the HI of 6 for this receptor.
- The only risk was due to the dietary ingestion pathway.
- All HIs were less than 1 when the basis of the risk evaluation was the TBV_{High} .

Given the minimal number of risk drivers identified for the pathways evaluated, it appears that the ecological risk attributable to the site is minimal and does not warrant further evaluation. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, further

Soil COPCs identified for the ecological risk assessment for Disturbed Area 3 include several inorganics, bis(2-ethylhexyl)phthalate, PAHs, OCPs, PCB 1254, and TPH-D.

Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs for the American robin, mourning dove, and western harvest mouse exceeded 1 when comparisons were made based on the TBV_{High} .
- The soil and dietary ingestion pathways contributed to risk for terrestrial receptors.
- Antimony, cobalt, chromium, iron, nickel, lead, and zinc HQs exceeded TBV_{Low} values for plants and soil fauna.
- Antimony, cobalt, chromium, iron, and nickel HQs exceeded TBV_{High} values for plants and soil fauna.
- Lead HQs based on the TBV_{Low} exceeded 1 for the peregrine falcon; however, no HQs exceeded 1 based on the TBV_{High} .

Given the TBV exceedences for multiple pathways and receptors evaluated, the ecological risk assessment for Disturbed Area 3 will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

Soil COPCs identified for the ecological risk assessment for Disturbed Area 4 include chlordane, ppDDT, and TPH-D. Results of the risk assessment indicate the following:

- HIs for the American robin exceeded 1 when comparisons were made based on the TBV_{Low} .
- The dietary ingestion pathway was the largest contributor to risk for the robin.

Ecological risk attributable to the site is minimal. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, it appears that the ecological risk attributable to the site is minimal and does not warrant further evaluation.

13. BATTERY HOWE/WAGNER

This section summarizes the RI activities performed at Battery Howe/Wagner. Battery Howe, constructed in 1893, was San Francisco's first modern 12-in mortar fortification. Battery Howe was later divided into two separate fortifications to be used as artillery emplacements and was renamed Battery Howe/Wagner. The site consists a concrete structure covered by fill material, and several other small buildings. A PA of the site conducted in 1992 indicated that the fill material used to cover the battery potentially contained building debris mixed in with the artificial fill (RLSA, 1992a). Battery Howe/Wagner was added to the RI to confirm the results of the PA and define the nature and extent of potential contamination source areas.

13.1 AREA DESCRIPTION

The following sections describe the location and physical features, and history and land use of the Battery Howe/Wagner area.

13.1.1 Location and Physical Features

Battery Howe/Wagner is located in the northwestern portion of the PSF. It encompasses approximately 5 ac and is bounded by Battery Wagner Road to the north, Ruckman Avenue to the south, Upton Avenue to the west, and Storey Avenue to the east (Figure 13.1-1). The study area contains four small buildings, a shed, and an underground concrete battery.

Topography at the site slopes gently to the east except near the eastern end of the fortification, where there is a steep east-northeast facing slope with approximately 20 ft of relief. Surface elevation of the study area ranges from approximately 220 ft PLL along the western boundary to 175 ft PLL in the southeast corner. The only portions of the battery currently exposed are the northeastern walls near Building 1285 (Figure 13.1-1), where the main door is located.

Residences are located north, northeast, and south of the study area. To the west are office buildings formerly used by the Sixth Army and maintenance personnel. Immediately

northwest of the battery is a fenced storage area which was most recently used for storing firewood.

In most areas, the surface of the site is covered with grasses and trees. A small area in the western portion of the site is paved with asphalt (Figure 13.1-1). There are no surface water bodies in the study area. Surface drainage is over vegetated ground or is intercepted by the storm drainage system. Storm drains collect water in the west and north portion of the site, transport it east-southeast, and eventually drain to San Francisco Bay in the vicinity of the FPCGS.

13.1.2 History and Land Use

Construction of Battery Howe, San Francisco's first modern 12-in mortar fortification, began in April 1893. Battery Howe was later divided into two separate fortifications to be used as artillery emplacements and was renamed Battery Howe/Wagner. An undated map from the Post Engineering office shows a proposed enlargement to Battery Howe/Wagner which includes a 2,000-gal underground oil tank, kitchen, and mess hall. Based on an inspection of the battery, the plans were never implemented. In 1915, it was determined that the battery would retain its armament, but would no longer be manned (RLSA, 1992a).

It is not clear from the review of available documents exactly when Battery Howe/Wagner was decommissioned, or when the battery was covered with fill material. In aerial photographs spanning 1946 to 1963 (Rindgen and Sitton, 1990) the battery's cross-shaped outline is visible beneath a mounded covering. In a 1968 aerial photo, most of the study area appears to have been recently graded and the southern outline of the battery is no longer recognizable, indicating that fill material was placed over the southern side of the battery between 1963 and 1968. The current topography of the study area is similar to that shown in the 1968 aerial photo.

The battery's interior is still intact and has been used periodically since 1980 by LAIR for a ballistic weapons testing program. It was once used by the U.S. Treasury Department to store silver ingots during construction of the San Francisco Mint (RLSA, 1992a).

13.2 SAMPLE LOCATION RATIONALE

This section describes the sample location rationale for Battery Howe/Wagner which was designed within context of the site conceptual model described in Section 3.1. The potential sources of contamination investigated during the RI include a reported UST inside the battery and the fill material that covers the site.

Historical documents from the Post Engineers Office were reviewed to determine if a proposed UST was ever installed near the battery. An undated map showed a proposed enlargement to Battery Howe/Wagner that included a 2,000-gal underground oil tank. A visual inspection of the site indicated that there was no visible evidence of a tank or stained areas, and the existing structure of the battery did not match the proposed floor plans. These observations indicate that the battery enlargement plans were never implemented and the 2000-gal UST was not installed.

The fill material that covers the site was investigated as a potential contamination source. Possible release mechanisms associated with the fill include stormwater runoff in contact with the fill, and infiltration of potential contaminants from the fill material to the underlying soil. A potential secondary release mechanism includes the leaching of potential contaminants from the soil into the groundwater. Review of historical documents and assessment of surface conditions at the site did not indicate that any spills had occurred at the site.

The pathways of potential contaminant migration were investigated during the RI by first determining the nature and extent of the fill material. Borings and geophysical surveys were used to delineate the vertical and lateral boundaries. The results of the geophysical surveys were inconclusive because there was not enough difference in the physical properties of the fill material and native soils. Also, buried utility lines and pavement interfered with the operation of the geophysical equipment. Soil samples were collected from the surface of the fill to characterize potential contamination transported by stormwater runoff. Subsurface soil samples were collected in fill material and underlying soil to characterize potential contamination below ground surface and to determine if potential contaminants had migrated beyond the fill boundaries into native soil.

Monitoring wells were installed, and discrete groundwater samples were collected from locations down gradient from potential source areas to characterize the quality of the groundwater. An up gradient well was installed to monitor groundwater entering the site. Groundwater levels in the wells were measured to evaluate hydraulic gradients. Analytical results from groundwater samples were used to characterize the potential for migration of chemicals from the unsaturated zone into groundwater.

13.3 GEOLOGIC SETTING

This section describes the soils, geology, and hydrogeology in the Battery Howe/Wagner area. Soils and geologic data were collected from 20 borings and three monitoring wells (Figure 13.1-1). Additional information was obtained from a geologic investigation of the San Francisco North Quadrangle (Schlocker, 1974). Geologic units in the study area were identified as artificial fill, debris fill, unconsolidated sediments, and serpentinite bedrock of the Franciscan Formation. Results of field investigations in the Battery Howe/Wagner were used to prepare the geologic cross sections in Figures 13.3-1 and 13.3-2.

13.3.1 Soil and Geology

Surficial deposits in the study area are composed of artificial fill and debris fill. The artificial fill in the southern portion of the site consists of varying mixtures of clay, silt, sand, gravel, and clasts of chert and serpentinite. Artificial fill in the northern portion of the study area is primarily composed of weathered serpentinite. The measured thickness of artificial fill ranges from 2.5 ft at Boring HWGW02 to 22.8 ft at Boring HWSB05.

Debris fill was encountered in all areas of the site except the northern portion. The debris fill contains building material, which includes concrete, brick, wood, wire, glass, porcelain, and metal straps in a matrix of mainly clay and silt. The thickest deposits of debris fill are south of the battery in the southeastern portion of the study area (Figure 13.3-3). The measured thickness of debris fill ranges from 3.9 ft at Monitoring Well HWGW01 to 25.5 ft at Boring HWSB01. In general, the accumulation of both artificial fill and debris fill is thickest near the battery and thins near the study area boundary.

The unconsolidated native sediment underlying the fill is comprised of silty and sandy clay of the Colma Formation. The measured thickness of the Colma Formation at this site ranges from 0.0 ft at HWSB02 to 15.7 ft at HWSB05. The geologic investigation of the San Francisco North Quadrangle (Schlocker, 1974) describes the unconsolidated sediments as slope debris and ravine fill deposits.

The bedrock underlying the unconsolidated sediments is identified as serpentinite of the Franciscan Formation. This unit is highly fractured with an upper weathered zone that varies throughout the site in thickness, hardness, and moisture content. The weathered serpentinite is soft and moist in all portions of the study area except in the northern area where the upper bedrock is harder and moisture is mainly confined to the fractured surfaces. Beneath the weathered zone lies solid bedrock that was impenetrable with the finger-type drill bit used during the Supplemental RI. The bedrock displays a characteristic olive-green color with various amounts of manganese and iron coatings on fracture surfaces.

To create a level building surface for construction of the battery, a large portion of the natural hillside was excavated. In some areas, this resulted in excavating through the unconsolidated sediments and into the underlying serpentinite bedrock (Figures 13.3-1 and 13.3-2). After the construction of the battery structure was complete, it was buried, most likely using the same soil that was excavated during construction.

During drilling operations at Battery Howe/Wagner, a PID was used to monitor for the presence of volatile organic vapors. Likewise, a CGI was used to monitor for combustible gas conditions in and around the borehole. Volatile gases were not detected by the PID, and combustible gases were not detected by the CGI.

13.3.2 Hydrogeology

Groundwater was encountered in a portion of Battery Howe/Wagner. Planned well installations to the north (HWGW02) and west (HWGW03) of the battery were left as soil borings because the open holes failed to recharge with groundwater when left overnight. Borings in the southeastern portion of the study area recharged with groundwater within several hours after drilling; hence three monitoring wells, HWGW01, HWGW04, and HWGW05 were installed (Figure 13.1-1). Water level data, lithology and well construction

field logs for Battery Howe/Wagner are in Appendix K. All three well screens are in weathered serpentinite and overlying unconsolidated materials.

Water level measurements were collected from the three wells in July, August, and September 1992, and in March 1995 to assess the hydraulic gradient and potential groundwater flow direction at Battery Howe/Wagner. The measured depth to groundwater ranged from 13.5 to 28.8 ft bgs. Water table elevations from September 1992 and March 1995 were used to construct potentiometric surface maps of the unconfined aquifer (Figures 13.3-4 and 13.3-5). Both maps show that groundwater flow is to the northeast. In September 1992, the hydraulic gradient between Wells HWGW05 and HWGW01 is approximately 0.12 ft/ft. In March 1995, the hydraulic gradient between the same wells was 0.08 ft/ft. The decrease in gradient between 1992 and 1995 is due to higher water levels in 1995. The corresponding increases in water levels for Wells HWGW01, HWGW04, and HWGW05 were 9.45, 6.08, and 3.8 ft respectively. These water level increases are attributed to the heavy rains in the winter of 1995. In March 1995, the saturated thickness of the water bearing zone varied from 7 ft in the upgradient Well HWGW04, to 10 ft in the downgradient Well HWGW01. The thicknesses of the saturated zone in the same two wells in September 1992 were 2.0 and 0.5 ft respectively. The saturated thicknesses measured in 1992 are more typical of the water bearing zone in this area.

Each well in the Battery Howe/Wagner area dewatered before three casing volumes were purged during both development and sampling procedures. Estimated well yields for Battery Howe/Wagner are included in Section 2.3.5.3. Results of individual well yield calculations are shown on Table 2.3-2. The results indicate an average estimated yield of 165 gpd (Table 2.3-3). Although these results are approximate relative to more comprehensive testing techniques, the results indicate that the saturated zone at Battery Howe/Wagner can not sustain an average yield of 200 gpd to a well. Therefore, groundwater at Battery Howe/Wagner likely does not meet the requirements to be considered a drinking water resource as specified in California Resolution 89-39.

13.4 ANALYTICAL RESULTS

This section includes a summary of sample locations, requested analyses, and the analytical results from the RI field programs. The target analytes for each sampling suite are listed in Section 3.3.

Soil inorganic analytical results are compared to ambient soil concentrations for the corresponding sample lithology as described in Section 3.7. Calcium, magnesium, sodium, and potassium are not compared to ambient concentrations. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients. Although groundwater in Battery Howe/Wagner is not considered a potential drinking water supply, results are compared to California Primary and Secondary MCLs for informational purposes. A wipe-sampling survey was conducted inside the fortification to assess the structural surfaces of Battery Howe/Wagner for potential chemical residues associated with explosives. The results of the wipe-sampling survey will be presented in a separate report. The discussion of unknowns is based on criteria established in Section 3.5.

During the Supplemental RI, soil samples were collected from five soil borings (HWSB01 through HWSB05), shown on Figure 13.1-1. Three samples were collected from each boring. All soil samples were analyzed for inorganics, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH. A summary of soil boring sample detections is shown on Table 13.4-1.

Inorganics were detected in samples from all five soil borings. At Boring HWSB01, the shallow sample (0.2 ft bgs) was collected from fill material. Beryllium was detected above the ambient value for fill in this sample. The intermediate sample from 2.2 ft bgs was collected within the fill material and consisted mainly of beach/dune sand. Compared to ambient concentrations in beach/dune sand, beryllium and cobalt exceeded ambient levels. However, neither result exceeded ambient fill values. The deep sample from Boring HWSB01 was collected from a depth of 23.5 ft bgs. This depth corresponds to the contact between native Colma soil and the base of the fill material. Inorganics detected at concentrations exceeding Colma ambient levels include aluminum, arsenic, barium,

beryllium, chromium, cobalt, mercury, silver, and vanadium. Compared to fill ambient levels, only beryllium exceeded ambient levels.

Samples from Boring HWSB02 also contained numerous inorganics. In the shallow 0.5 ft bgs sample from fill material consisting of Colma Formation soil, arsenic, beryllium, cobalt, silver, and vanadium were at concentrations above ambient Colma values. Compared to fill ambient levels, only beryllium exceeded ambient conditions. The intermediate depth sample (13.0 ft bgs) from fill material containing Colma Formation soil contained arsenic, cobalt, lead, mercury, and zinc at concentrations above Colma ambient levels. However, none of these analytes were at concentrations exceeding fill ambient levels. In the deep sample (28.0 ft bgs) collected from weathered serpentinite, antimony, chromium, cobalt, nickel, and silver exceeded ambient serpentinite levels.

The three samples from Boring HWSB03 were all comprised of Colma Formation soil. The shallow and intermediate samples (0.2 and 2.2 ft bgs) were actually collected from within the fill material, but the soil appeared to be similar to Colma Formation soil. The deep sample (14.6 ft bgs) was collected from native Colma soil immediately below the base of fill. In the shallow sample, arsenic, beryllium, cobalt, and vanadium were above Colma ambient levels, however, only beryllium exceeded fill ambient levels. In the intermediate sample, arsenic, cobalt, lead, mercury, and zinc concentrations exceeded the ambient levels in Colma soil, but did not exceed ambient levels for fill material. Barium, beryllium, cobalt, and vanadium concentrations in the deep sample exceeded Colma ambient levels, and were higher than the concentrations found in the shallower fill samples.

At Boring HWSB04, the shallow sample (0.5 ft bgs) was collected from within the fill material, and was comprised primarily of Colma soil. The intermediate sample (7.0 ft bgs) was also collected from within the fill material, but contained an abundance of serpentinite gravel. The deep sample (22.0 ft bgs) was collected from native material below the base of fill. Barium, beryllium, cobalt, and silver, exceeded ambient Colma concentrations in the shallow sample, however, only beryllium was above ambient fill concentrations. In the intermediate sample, antimony, chromium, cobalt, nickel, and silver were at concentrations above ambient serpentinite values. Of these, antimony, chromium, cobalt, and nickel were

also above fill ambient levels. The deep sample from native beach/dune sand did not contain any inorganics at concentrations above ambient levels.

The three samples from Boring HWSB05 all consisted of Colma Formation soils. The shallow and intermediate (0.5 and 2.0 ft bgs) samples were collected from within the fill material, but contained soil which resembled the Colma Formation. The deep sample was collected from the contact between native Colma Formation soil and the base of the fill material. In the shallow sample, antimony, cadmium, chromium, cobalt, iron, manganese, and nickel were detected at concentrations exceeding ambient Colma values. Of these, antimony, chromium, cobalt, and nickel were also above ambient fill values. In the intermediate sample ambient levels were not exceeded by any analyte. In the deep sample, aluminum, barium, beryllium, chromium, cobalt, manganese, nickel, and vanadium were above ambient Colma levels, but only aluminum exceeded ambient fill values.

VOCs were detected in three of the five soil borings, with acetone in two samples and methyl ethyl ketone in three samples. SVOCs were detected in two soil borings; phenanthrene and pyrene were detected at one location, bis(2-ethylhexyl) phthalate and di-N-butyl phthalate were detected at another location. OCPs, PCBs, and chlorinated herbicides were not detected in any of the soil borings. TPH-D was detected in all soil borings.

Unknown organic compounds were tentatively identified as hydrocarbons in all 15 soil samples collected in the Battery Howe/Wagner area. Unknown VOCs were detected in seven samples totaling 196 $\mu\text{g/g}$. Unknown SVOCs were detected in all 15 samples.

Because antimony detections in samples from Borings HWSB04 and HWSB05 were above SDCs, additional borings were drilled during the Follow-on RI to define the extent of antimony in soil surrounding Borings HWSB04 and HWSB05. Antimony concentrations in samples from HWSB04 and HWSB05 were 125 and 107 $\mu\text{g/g}$ respectively. At HWSB04, the antimony detection occurred in the sample collected from 7 ft bgs. At HWSB05, the antimony detection occurred in the sample from 0.5 ft bgs. During the Follow-on RI, four additional borings (HWSB06 through HWSB09) were drilled on 10-ft centers surrounding HWSB04. Samples were collected from three depths (4.5, 7.0, and 14.5 ft bgs), and analyzed for antimony. All three samples from Boring HWSB06 were also analyzed for

TOC. There were no antimony detections in any of the samples collected from borings surrounding HWSB04 (Table 13.4-2). TOC detections ranged from 521 to 3,200 $\mu\text{g/g}$. Four borings (HWSB10 through HWSB13) were also drilled on 10-ft centers surrounding Boring HWSB05. Samples from these borings were collected at two depths (0.5 and 6.5 ft bgs), and analyzed for antimony. As with the borings around HWSB04, there were no detections of antimony in any of the Follow-on RI samples from borings surrounding HWSB05 (Table 13.4-3).

Three monitoring wells, HWGW01, HWGW04, and HWGW05, were installed in the Battery Howe/Wagner area during the Supplemental RI. Groundwater samples collected from the wells were analyzed for filtered and unfiltered inorganics, miscellaneous parameters, VOCs, SVOCs, OCPs, PCBs, chlorinated herbicides, and TPH-D. A summary of Supplemental RI groundwater sample detections is in Table 13.4-4. Numerous inorganics and miscellaneous parameters were detected in all groundwater samples, with aluminum, chromium, iron, manganese, and nickel detected above either the Primary or Secondary MCLs in at least one unfiltered sample. The concentrations of these same inorganics were below MCLs in the associated filtered samples with the exception of chromium and manganese in samples from HWGW01 and HWGW05. The highest inorganics concentrations were typically found in the unfiltered sample collected from the downgradient Well HWGW01. The VOCs acetone (50 $\mu\text{g/L}$) and methyl ethyl ketone (8.8 $\mu\text{g/L}$) were detected in the sample from Well HWGW05, and carbon tetrachloride (0.870 $\mu\text{g/L}$) was detected in Well HWGW01. Of these detections, only carbon tetrachloride was above the Primary MCL. TPH-D (60 $\mu\text{g/L}$) was detected in the groundwater only at the most upgradient well, HWGW04. SVOCs, OCPs, PCBs, and chlorinated herbicides were not detected in the groundwater in the Battery Howe/Wagner area.

Groundwater from all three wells at Battery Howe/Wagner was resampled during the Follow-on RI. The sample suite was the same as is was in the Supplemental RI. Numerous inorganics were detected in each well, with aluminum, antimony, beryllium, cadmium, and chromium detected above either the Primary or Secondary MCLs in at least one unfiltered sample (Table 13.4-5). For each of these inorganics, the concentration in the corresponding filtered sample was below the MCL with the exception of antimony, chromium, and

chromium VI. Detected concentrations were generally lower in the filtered samples. Elevated concentrations of chromium and chromium VI were confirmed in samples from Well HWGW01. The VOC, 1,2-dichloroethane, was detected in all three wells at concentrations slightly above the Primary MCL of 0.5 µg/L. The highest concentration of 1.85 µg/L occurred in the sample from Well HWGW05. Chloroform (0.68 µg/L) in Well HWGW01 was the only other VOC detected, however, the detection likely represents laboratory contamination. Bis(2-ethylhexyl) phthalate (3.79 µg/L in Well HWGW01) was the only SVOC detected, however, the result is affected by blank contamination. No OCPs, PCBs, herbicides, or TPH were detected in any of the samples.

Discrete groundwater samples were also collected during the Follow-on RI. The purpose of the discrete groundwater sampling was to define the lateral and vertical extent of chromium and carbon tetrachloride detected in Well HWGW01 during the Supplemental RI. Chromium VI in the same well was also identified as a COC based on preliminary data from the Follow-on RI sampling.

To define the extent of chromium, chromium VI, and carbon tetrachloride in groundwater near Well HWGW01, discrete groundwater samples were to be collected from four borings surrounding Well HWGW01 (Figure 13.3-1). At two of these locations (HWSB15 and HWSB16), groundwater was not encountered in the unconsolidated deposits above bedrock, and samples were not collected. Groundwater was encountered at the other two locations, HWSB14 and HWSB17, and discrete groundwater samples were collected. Samples were analyzed for filtered and unfiltered chromium and chromium VI, carbon tetrachloride and the carbon tetrachloride degradation products, chloroform, and methylene chloride. Results for these samples are presented in Table 13.4-6. Filtered chromium (710 µg/L) and unfiltered hexavalent chromium (60 µg/L) were detected at concentrations above the SDC (50 µg/L) in the discrete groundwater sample from HWSB14. No other analytes were detected in this sample. Chromium (1,100 µg/L) was detected in the unfiltered sample from HWSB17 at an order of magnitude above the SDC, but was not detected in the filtered sample. To further define the extent of chromium in groundwater, an additional boring was drilled downgradient at HWSB18. Groundwater was collected from this boring at two depths (20 and 24 ft bgs) and analyzed for filtered and unfiltered chromium and hexavalent chromium. Chromium

(510 µg/L) was detected in the unfiltered sample at a concentration above the SDC. The detections of chromium described above were all above the California Primary MCL. However, as is the case in most of the groundwater samples collected at the site, concentrations in the filtered sample were generally below the MCL.

Following the Follow-on RI field program, wells at Battery Howe/Wagner were sampled by Montgomery Watson on a quarterly basis (Montgomery Watson, 1996c). Results of the quarterly sampling are generally consistent with those of the RI. Numerous inorganics were detected in each sample, with aluminum, chromium, iron, manganese, nickel, and thallium detected at concentrations exceeding MCLs in at least one sample from at least one quarter. All of these analytes were above MCLs in samples from Well HWGW01. At Well HWGW04, MCLs have not been exceeded during the quarterly sampling events. At Well HWGW05, only manganese and thallium have exceeded MCLs. Quarterly sampling has also confirmed the presence of the VOCs carbon tetrachloride and chloroform in groundwater at the site. Concentrations of carbon tetrachloride have consistently been at approximately 1.0 µg/L during the four sampling rounds. Chloroform was detected during the two most recent sampling events at Well HWGW01, but was not detected during the first two sampling rounds. Chloroform concentrations during the two most recent sampling events (January and April 1996) were 0.5 and 0.9 µg/L respectively.

13.5 RESULTS EVALUATION

The following sections present an evaluation of the results of sampling performed during the RI at Battery Howe/Wagner. The first step in evaluating the results involves determining which analytes are COPCs as described in Section 3.7. If an analyte is considered a COPC, the nature and extent and fate and transport of the analyte is evaluated. Analytes that are not considered COPCs are not evaluated further.

For soils, the COPC screening process involves several steps depending on the type of analyte being evaluated. The RI assumes that all organic constituents are anthropogenic, and therefore, all detected organic compounds in soil are considered COPCs. Inorganic analytes are naturally occurring and their presence in soil at a site may or may not be anthropogenic. In determining which inorganic analytes are soil COPCs, several factors are considered.

These include: the magnitude and number of detections above ambient values, the spatial distribution, the type of soil comprising the sample, and comparison with concentrations typical for other regional soils. In addition, potential sources are evaluated. For sites containing fill material, the identification of contaminant sources is difficult due to the erratic distribution of fill materials of different origins.

For groundwater, all detected analytes are considered COPCs. In the following discussions, analytical results are compared with California Primary and Secondary MCLs (Tables 3.8-2 and 3.8-5) to provide a frame of reference. If an analyte is present in surface or groundwater at concentrations above MCLs, the source, nature and extent, and fate and transport of the analyte are evaluated.

Numerous inorganics were detected in soil samples at concentrations exceeding ambient values at Battery Howe/Wagner, including aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, iron, lead, manganese, mercury, nickel, silver, vanadium, and zinc. Posting maps displaying the concentrations of several of these analytes are included as Figures 13.5-1 through 13.5-11. Aluminum, cadmium, iron, lead, manganese, mercury, and zinc are not considered soil COPCs due to the limited number of ambient exceedences of these analytes. Each was detected above ambient levels in only one or two of the 15 soil samples collected at the site. In addition, most of these analytes were at concentrations only slightly above ambient levels, suggesting that their presence is likely representative of ambient conditions rather than an anthropogenic source.

Arsenic, barium, beryllium, cobalt, silver, and vanadium were detected above ambient levels in several Colma samples. However, as stated in Section 13.4, many samples from fill material were classified as Colma samples because the soil matrix was similar to the Colma Formation. When compared to fill ambient levels, there are no exceedences of arsenic, barium, silver, or vanadium. Beryllium and cobalt exceed Colma and fill ambient levels in several samples, however, the boring logs for these samples indicate the presence of serpentinite gravel, which is known to have high concentrations of these two analytes. When compared to serpentinite, both beryllium and cobalt are below ambient levels. Therefore, the elevated concentrations of these analytes is likely due to the presence of serpentinite.

Of the inorganics exceeding ambient levels, antimony, chromium, and nickel are considered soil COPCs due to the frequency and magnitude of detections of these analytes above ambient levels. These analytes will be discussed in detail in the following paragraphs.

The nature and extent of the inorganic soil COPCs antimony, chromium, and nickel are erratic. All three were detected in several samples throughout the site at concentrations several orders of magnitude above ambient levels. Antimony was detected at concentrations an order of magnitude above ambient values in the shallow and intermediate fill samples from Borings HWSB05 and HWSB04. Antimony was not detected in the underlying samples from these same borings, indicating that the vertical extent is confined to the fill material. Soil samples from borings surrounding Borings HWSB04 and HWSB05 resulted in no detections of antimony, limiting the lateral extent to be within 10 ft of each boring. Antimony was also detected above ambient values in the 28.0 ft bgs sample of native material beneath the fill in Boring HWSB02. It was not detected in either of the two shallower samples from the same boring.

Like antimony, the distribution of chromium and nickel is also erratic. Both were detected at elevated concentrations in two samples. At Boring HWSB02, chromium and nickel were detected at concentrations above serpentinite ambient levels in the native material sampled at 28.0 ft bgs. Neither was detected above ambient values in the two overlying samples from the same boring. At Boring HWSB04, both chromium and nickel were detected at concentrations exceeding ambient fill levels in the 7.0 ft bgs sample collected from the fill material, but not in the shallow or deep samples from the same boring.

The source of inorganic COPCs in soil is not clear. Debris fill material encountered during drilling were not identified as a clearly identifiable source of these analytes. In addition, all three analytes had the highest concentrations in the native serpentinite sample below the base of fill in Boring HWSB02. Since these analytes have naturally high concentrations in serpentinite, it is possible that their presence at the site is representative of the very high end of ambient conditions. However, since the concentrations of these analytes in the fill material is also significantly elevated, and since a potential source in the fill cannot be entirely ruled out, these analytes are considered soil COPCs.

Detections of organic compounds in soils were not common, and like the distribution of inorganic compounds, the lateral and vertical extent are discontinuous. The VOCs acetone and methyl ethyl ketone were detected in the 13.0 ft bgs sample from Boring HWSB02 which was collected from within the debris fill in the southern portion of the site. The SVOCs phenanthrene and pyrene were detected in the 2.2 ft bgs sample from Boring HWSB03, collected from debris fill in the southern portion of the site. The organics described in these two samples are likely related to debris material within the artificial fill in the southern portions of the site. The distribution of these compounds is discontinuous, both laterally and vertically. With the exception of acetone, none of the compounds were detected in any other samples at the site, and were not detected in groundwater. Metals concentrations in these samples were generally below ambient values. Acetone was detected in one other sample, at a concentration slightly above the CRL. The detection occurred in the 14.6 ft bgs sample from Boring HWSB03. Debris fill was not noted in this boring, and the source of the detection is not clear. TPH-D was detected in all soil samples collected during the Supplemental RI, with the highest concentration of 19.0 $\mu\text{g/g}$ occurring in the 0.5 ft bgs sample from Boring HWSB05. OCPs, PCBs, and chlorinated herbicides were not detected in the fill material.

Groundwater was sampled from three monitoring wells installed during the Supplemental RI. During sampling, all wells dewatered, and showed slow recoveries. The saturated thickness was measured to be only 2 ft, and covered a very limited portion of the site as shown on Figures 13.3-4 and 13.3-5. In addition, well recharge rates are less than 200 gal/day. For these reasons, groundwater in the Battery Howe/Wagner area is not considered to be a potential drinking water resource in accordance with California Resolution 88-63.

Although groundwater at Battery Howe/Wagner is not considered a drinking water resource, sampling results are compared to California Primary and Secondary MCLs to provide a frame of reference. As discussed in Section 13.4, several inorganics were detected above Primary and Secondary MCLs. Most detections were only slightly above the MCLs, and were consistently lower in the filtered samples, indicating that the results are heavily influenced by the presence of sediment in the samples. Chromium, manganese, and nickel in groundwater are most likely related to serpentinite, since serpentinite is present throughout

the site and has been found to have relatively high concentrations of these metals. The distribution of these analytes are shown on Figures 13.5-12 through 13.5-15. The only VOCs detected above MCLs were carbon tetrachloride and 1,2-dichloroethane, which were detected in only one RI sampling round. The presence of carbon tetrachloride was confirmed in the subsequent quarterly sampling performed by Montgomery Watson. However, the extent of this compound appears to be limited to the area near Well HWGW01 since it was not detected in samples from any other wells or in the discrete groundwater samples collected during the Follow-on RI. The presence of 1,2-dichloroethane was not confirmed by the quarterly sampling. The source of these VOC detections is not clear. Both compounds may be associated with either parent or breakdown products, none of which were detected in any samples at the site. Neither compound was detected in soil. 1,2-Dichloroethane was anomalously detected at several other sights during the Follow-on RI, where it had previously not been detected.

13.6 CONCLUSIONS AND RISK ASSESSMENT SUMMARY

This section summarizes the evaluation of results for the Battery Howe/Wagner Study Area including the risk assessment results, as presented in detail in Section 15.

13.6.1 Conclusions

The potential source(s) of contamination investigated at Battery Howe/Wagner are debris/artificial fill materials deposited during construction of the site. In order to evaluate the impact of fill material on the environment, surface and subsurface soils, and groundwater samples were analyzed.

COPCs identified in soil at Battery Howe/Wagner include inorganics, VOCs, SVOCs, and TPH-D. Detections of these compounds were discontinuous, both laterally and vertically. Debris fill material encountered during drilling was not a clearly identifiable source of these analytes. Concentrations of inorganics are elevated in both the fill and underlying native material, possibly due to the presence of serpentinite. VOCs and SVOCs are limited to samples collected from within the fill material. TPH-D was detected in both fill and underlying native material.

Target analytes detected in groundwater include inorganics, VOCs, and TPH-D. Like the soil COPCs, the sources of these compounds is unclear. Several inorganics were detected above Primary and Secondary MCLs. Most detections were only slightly above MCLs, and were consistently lower in the filtered samples, indicating that the results are heavily influenced by the presence of sediment in the samples. VOCs detected above MCLs during the RI include carbon tetrachloride and 1,2-dichloroethane. The presence of carbon tetrachloride was confirmed in the subsequent quarterly sampling performed by Montgomery Watson. However, the extent of this compound appears to be limited to the area near Well HWGW01. The presence of 1,2-dichloroethane was not confirmed by the quarterly sampling. TPH-D was detected in one RI sample.

13.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths in which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed media are first screened against USEPA Region IX residential PRGs, MCLs, the PSF lead screening value (for soil), and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for Battery Howe/Wagner are summarized in the following sections.

13.6.2.1 Human Health

Battery Howe/Wagner was assessed under the open space (recreational) scenario for the purposes of the human health risk assessment because the GMPA identified open space as the future use of the site. Under the recreational scenario, only exposure to surface soil is assumed.

A residential PRG ratio screening assessment for surface and subsurface soil and for site-wide groundwater was performed as a preliminary assessment of a residential scenario. The residential PRG ratio assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC. A separate evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ >1E+00, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very

unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with Battery Howe/Wagner are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects, including a comparison of lead concentrations to PSF lead clean-up values, are identified.

This section describes the results of the HHRA for Battery Howe/Wagner. There were no COCs determined in the surface soil samples for Battery Howe/Wagner following COPC screening. This indicates that ingestion of or dermal exposure to surface soil to recreational visitors to Battery Howe/Wagner is unlikely to result in excess cancer risk or noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$. The residential PRG ratio screening assessment resulted in a total hazard index greater than $1E+00$.

13.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil, sediment, dietary, and water ingestion. Dermal absorption for birds and mammals and direct contact for plants and invertebrates were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified for the ecological risk assessment for Battery Howe/Wagner include antimony, chromium, nickel, di-n-butylphthalate, two PAHs, and TPH-D. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, and western harvest mouse exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs for the American robin and mourning dove exceeded 1 when comparisons were made based on the TBV_{High} .
- Chromium and nickel in soil produced HQs in excess of 1 for the American robin and the mourning dove.
- Concentrations of chromium, nickel and antimony in soil exceed TBV levels for the protection of plants and soil fauna.

Of all the receptor and exposure pathways evaluated, only soil ingestion exposure to the American robin, mourning dove and western harvest mouse indicated a potential for risk. Given the TBV exceedences for multiple pathways and receptors evaluated (i.e., exposure exceeds the upper bound of the gray zone), the ecological risk assessment will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

14. MISCELLANEOUS FOLLOW-ON RI SITES

This section presents area descriptions, sample location rationale, geologic setting, analytical results, evaluation of results, and risk assessment summary and conclusions for the Miscellaneous Follow-on RI Sites. The Miscellaneous Follow-on RI Sites are:

- Building 302
- Building 669
- Building 1245
- Building 1369
- Building 1388
- Building 1750
- East of Mason (EOM)

The Miscellaneous Follow-on RI Sites are sites that were not investigated prior to the Follow-on RI. They are not associated with any of the study areas discussed in previous sections. Sites that were added based on information from the NPS-directed review of PSF historical and current activities include Buildings 669, 1245, 1388, and the EOM site. Buildings 1369 and 1750 were added based on information from this review and from the CERFA research (TETC, 1994). Building 302 was included based on information from the CERFA research.

14.1 BUILDING 302

Building 302, a golf course equipment storage facility, was added to the RI as part of the Follow-on RI in the Spring of 1995. Soil boring samples were collected from below the concrete foundation of Building 302 and outside of the building to evaluate the potential release of COPCs associated with Presidio Golf Course maintenance activities. The following sections describe the Building 302 field program and its results.

14.1.1 Area Description

Building 302 is located on the southern border of the PSF, just north of the Arguello Boulevard entrance at the southeast corner of the Presidio Golf Course. It is the furthest

northwest of a group of buildings constructed to support golf course maintenance. The buildings are situated on a flat area cleared of trees that serves as the eastern boundary of the golf course.

The approximately 36-ft by 75-ft building is constructed of corrugated metal on a concrete slab foundation. Borings drilled inside the building during the Follow-on RI indicated that the concrete slab thickness is irregular; in one of the borings, the 0.3-ft thick floor was underlain by 1.0 ft of gravel, then another 0.7 ft of concrete (Appendix L). The concrete floor was noted to be in good condition.

The terrain surrounding the building slopes gently to the south-southeast. Building 302 is at an elevation of approximately 305 ft-PLL. The surface drainage north of Building 302 is to the east through an unlined minor channel of the storm drainage system. The clearing is bordered on the north by dense trees and on the east and south by trees and shrubs. To the west of Building 302 lies the 9th hole of the golf course. Though surrounded by asphalt pavement on all sides, Building 302 is at the northern edge of the clearing, immediately adjacent to the wooded area to the north.

Building 302 was constructed in 1961. It is used to store golf course maintenance equipment such as lawn mowers (TETC, 1994). The northern portion of the building houses the herbicides, pesticides and fertilizers used at the golf course. As of a 1989 survey, registered fungicides (containing thiram and carbamate) and herbicides (containing 2,4-D and dicamba) were used (ANL, 1989). Materials are delivered and stored on pallets. The access for this section of the building is on the north side, through sliding doors that span an opening of approximately 10 ft.

14.1.2 Sample Location Rationale

The investigation at Building 302 was designed to identify and evaluate possible soil contamination associated with the potential leakage of herbicides, pesticides, and fertilizer. No visible evidence of release of these materials was noted. Minor staining on the concrete floor was interpreted to be oil or other fluid leakage from vehicles parked inside the building. No evidence of staining was noted outside the building.

A total of nine soil samples were collected from four borings at Building 302 (Figure 14.1-1). Soil samples were collected from three borings (302SB01, 302SB02, and 302SB04) inside the north end of the building where the pesticides, herbicides, and fertilizers are stored. One boring (302SB03) was located north of the building, on the asphalt, where the materials are taken in and out of the buildings. Three depths were sampled to evaluate the vertical distribution of potential contamination. Because an obstruction was reached below the first sample collected from Boring 302SB02, the two deeper samples were collected from a second boring (302SB04) offset from Boring 302SB02.

14.1.3 Geologic Setting

The borings drilled at Building 302 penetrated approximately 0.3 ft of concrete or asphalt before reaching sandy gravel that probably represents materials placed during construction of the building. In one boring, the sandy gravel was underlain by another layer of concrete. Dark grayish brown clay was penetrated between 1.5 and 2.0 ft bgs in three borings. This clay is interpreted to be representative of the Typic Argiustolls soil and has probably been derived from underlying weathered bedrock. Surficial sediments in this area are mapped by the USGS as slope debris and ravine fill (Schlocker, 1974). In one of the borings, sandy gravel, possibly construction-related material, was below the clay at 3.5 ft. In the boring north of the building, weathered serpentinite bedrock was reached at 5.5 ft bgs. Perched water, in local zones of saturation, was encountered in two of the borings, at depths of 3.5 and 1.5 ft bgs. Information on the regional water table is not available in this area (Figure 2.3-2).

14.1.4 Analytical Results

A total of nine subsurface soil samples were analyzed for inorganics, OCPs, and chlorinated herbicides. Analytical results of soil sampling at Building 302 are listed in Table 14.1-1. All of the soil samples contained inorganic elements commonly found in the environment, including calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and many are considered essential human nutrients (USEPA, 1989b). Iron is also considered an

essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussions. All other inorganics detected in soil were compared to ambient concentrations for the appropriate type of soil (fill or beach-dune sediments), as described in Section 3.7. Aluminum, chromium, cyanide, manganese, and selenium were detected above ambient concentrations in at least three of the nine soil samples from the Building 302 area. Arsenic, mercury, and nickel were detected above ambient concentrations in one of the nine soil samples. The aluminum, chromium, and manganese, and nickel detections above ambient were generally in the deeper samples collected between 3 and 5 ft bgs.

Two herbicides, Dicamba and 2,4-D (2,4-Dichlorophenoxyacetic acid), were detected at concentrations above the RLs. Dicamba was detected above the RL in the 2.0 ft bgs sample from Boring 302SB03. Detections of 2,4-D were reported above the RL in the 2.0 and 3.5 ft bgs samples from Boring 302SB03, and the 5.0 ft bgs samples from Borings 302SB01 and 302SB04.

14.1.5 Results Evaluation

The potential sources of COPCs at Building 302 are the materials stored in the building, including fungicides, herbicides, and insecticides. Soil samples were collected to assess potential impacts due to possible releases of the stored materials. The primary release mechanism for COPCs in this area is through leaks, spills, surface water runoff, and infiltration.

Several inorganics, aluminum, chromium, cyanide, manganese, arsenic, mercury, nickel, and selenium were detected at concentrations exceeding ambient concentrations. The only sample with arsenic above ambient concentrations was the 3.0-ft bgs sample from Boring 302SB04. This sample contained 5.1 $\mu\text{g/g}$ of arsenic relative to the ambient beach-dune concentration of 5 $\mu\text{g/g}$. It was not detected in association with herbicides. Elevated aluminum concentrations were present in samples composed primarily of clay which could contribute to increased aluminum concentrations. Elevated chromium, manganese, and nickel concentrations are likely related to the presence of serpentinite bedrock at shallow depths

beneath the site. Bedrock was encountered at a depth of 5.5 ft in Boring 302SB03 and the clay encountered in Borings 302SB03 and 302SB04 may have been derived from weathered bedrock. Because all selenium detections were considered to be estimated (Table 14.1-1), no pattern to the detections was observed, selenium is not typically associated with agricultural chemicals potentially present at this site, and selenium is within the potential range of naturally occurring concentrations (Section 3.7), it is considered to be present at ambient levels for this site. Therefore, cyanide and mercury are considered to be the only inorganics or inorganic compounds detected above ambient that are potentially site-derived.

Two herbicides, Dicamba and 2,4-D, were detected in samples from Borings 302SB01, 302SB03, and 302SB04. The highest concentrations were in the 2.0 ft bgs sample from Boring 302SB03; however, concentrations decreased to below the RLs in the 5.0 ft sample from this boring. All concentrations were below the SDCs.

14.1.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 302 area, including the risk assessment results, as presented in detail in Section 15.

14.1.6.1 Conclusions

The northern portion of Building 302 is used to store the herbicides, pesticides and fertilizers used at the golf course. Consequently, the primary suspected contaminants at the Building 302 site were OCPs and chlorinated herbicides. Two herbicides, Dicamba and 2,4-D, were detected at concentrations below the SDCs. No OCPs were detected. The only inorganics detected above ambient that were considered as COPCs for the BRA are cyanide and mercury.

14.1.6.2 Risk Assessment Summary

As presented in Section 3.7, inorganic COPCs (cyanide and mercury) and all detected organics (2,4-D and Dicamba) in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the FPCGS Study Area are summarized in the following sections.

14.1.6.2.1 Human Health

The GMPA identified open space (recreational) uses for the Building 302 area, and only exposure to surface soil from 0.0 to less than 0.5 ft bgs is assumed. Because there were no samples collected from this interval at the site, numerical estimates of health effects based on the future use of the site were not performed. However, a residential PRG ratio screening assessment for subsurface soil was performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment, which are presented for informational purposes, do not indicate an increased health risk at this site.

14.1.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 302 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure

pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified for the ecological risk assessment include cyanide, mercury, 2,4-D, and Dicamba. Results of the risk assessment indicate the following:

- HIs for the American robin and plants and soil fauna exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs were all less than 1 when comparisons were made based on the TBV_{High} .
- Mercury ingestion through the diet was the greatest contributor to risk for the robin
- Mercury in soil was the greatest contributor to risk for plants and soil fauna.

Given the small number of pathways posing a risk potential to ecological receptors, it appears that this site poses a minimal ecological receptor risk. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, this site should not be considered further from the perspective of ecological risk.

14.2 BUILDING 669

Borings were drilled in the vicinity of Building 669 to evaluate the potential release of contaminants associated with incinerator ash. The following sections describe the Building 669 field program and its results.

14.2.1 Area Description

Building 669 is located near the center of the PSF, south of U.S. Highway 101 and northwest of the San Francisco National Cemetery, along Incinerator Road. Building 669 is

a two-story brick building, approximately 35 ft by 40 ft, that is constructed into the hillside. The main (upper floor) of the building houses large paper shredders. The incinerator is in the basement of the building. There are six metal door openings (approximately 2 ft by 2 ft) to the incinerator; ash was present inside at the time of the January 1994 site visit. A chimney is not present at the building.

The terrain surrounding Building 669 slopes to the northwest. Building 669 is at an elevation of approximately 62 ft-PLL. Surface drainage from this area is to the northwest. The area is landscaped with ice plants, grass, and a few trees. A large tree has grown in front of the basement access door.

Building 669 was constructed in 1936 and most recently has been used to house paper shredding machines. The incinerator in the basement apparently was used to dispose of animal carcasses from the nearby veterinary clinic (HLA, 1994). According to NPS personnel, former operators of the facility that were interviewed have stated that ash was periodically removed from the facility and disposed. The disposal site is unknown, but it has been speculated that it was disposed on the hillside surrounding the building (HLA, 1994).

No investigations have been previously conducted to assess releases from the incinerator. However, as part of a CalTrans investigation of contamination from the Presidio Viaduct near Building 669, soil borings were drilled and soil samples were collected and analyzed for lead in October 1994 (California Department of Transportation, 1995). In one of the locations (210S3R), approximately 75 ft down the hillside from Building 669 and approximately 200 ft from the Presidio viaduct, lead concentrations were elevated in the 1.5 and 2 ft bgs samples (2,253 $\mu\text{g/g}$ and 10,530 $\mu\text{g/g}$, respectively). Lead was less than the 300 $\mu\text{g/g}$ SDC in shallower (1 ft bgs) and deeper (3 ft bgs) samples collected by CalTrans at this site. These results were the basis for a portion of the Follow-on RI.

14.2.2 Sample Location Rationale

The investigation at Building 669 was designed to identify possible ash deposits, and, if found, to assess potential COCs. Two areas were investigated. Borings 669SB01, 669SB02, and 669SB03 were drilled around Building 669 to assess the possibility that ash was disposed of outside of the building. Four borings were drilled in the vicinity of the CalTrans

boring (669A, 669B, 669C, and 669d) to investigate whether the lead could be associated with ash from the incinerator. The boring locations are shown on Figure 14.2-1.

14.2.3 Geologic Setting

The general soil classification of the Building 669 area is described by the SCS as Urban Land (fill) (Kashiwagi and Hokholt, 1985). During the field investigation, artificial fill was present in all three soil borings drilled around Building 669 and in all but one of the borings drilled downslope from the building (Appendix H). In the borings surrounding the building, the fill was characterized by sand with pieces of concrete, brick, wood chips, and plastic. Fill in the downslope borings was a mixture of sand, gravel, and sandy clay, with minor amounts of glass, red gravel, and wood.

The surficial sediments in the area have been mapped by the USGS as dune sand (Schlocker, 1974). Dune sand was encountered in one of the borings surrounding the building (669SB03), at a depth of 2.7 ft and in three of the four downslope borings, at depths ranging from 0.5 to 4 ft bgs.

Bedrock is at a depth greater than 12 ft bgs and is estimated to be at an approximate depth of 15 ft bgs in this area (Figure 2.3-4). Groundwater was not reached in the borings, but saturated conditions may be present in unconsolidated sediments below the site (Figure 2.3-2).

14.2.4 Analytical Results

Three borings were drilled to 12 ft bgs to investigate if any ash was present in the Building 669 area. The borings were continuously sampled. The only observation of possible ash was some thin bands (thickness in millimeters) of white and orange-yellow claylike material within a 0.2 ft interval in Boring 669SB02. Because there was not enough of this material to warrant sampling, and no other possible ash layers were observed, no samples were collected for chemical analysis.

Four borings were drilled to 8 ft bgs, approximately 75 ft downslope from Building 669, to investigate if ash was present in the vicinity of the lead detected in CalTrans boring 210S3R.

No ash was observed; therefore, in accordance with the sampling plan, no samples were collected for chemical analysis.

14.2.5 Results Evaluation

The source of potential concern in this area is ash from the incinerator. The possibility of ash disposal in the vicinity of the building and downslope from the building was investigated by drilling and continuously logging soil borings. However, the field investigation indicated that ash was not disposed of in the areas thought most likely to have been used for disposal. Because some very thin (millimeters thick) layers of possible ash were observed in one of the borings within a 0.2 ft interval (0.8 to 1.0 ft bgs), it is possible that ash could have been emitted from the incinerator, deposited on the ground surface outside of the buildings, and buried by anthropogenic or natural processes. However, this did not appear to be a widespread occurrence as no other potential ash was noted.

14.2.6 Conclusions and Risk Assessment Summary

Based on observations made during drilling, little or no ash deposits are present in the shallow subsurface in the vicinity of Building 669. The source of the elevated concentrations of lead detected in the 1.3 to 2 ft bgs interval of the CalTrans boring is unknown. Further investigation of this site may be warranted to assess the source and extent of elevated lead concentrations. The U.S. Army will review available information and contact CalTrans to see if any additional information is available. If warranted, the U.S. Army will consider taking a limited number of samples to assess the source and extent of lead. However, under the future use recreational scenario, there would be no exposure pathway to human receptors because elevated concentrations of lead were in subsurface soil. Potential ecological receptor exposures are possible. Because no analytical data were collected under the RI, Building 669 is not included in the risk assessment except to evaluate the effects of the PSF water supply on the industrial worker in the area.

The COCs in the PSF water supply (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, exposure to the PSF water supply to industrial workers is unlikely to result in an excess cancer risk at Building 669. In addition, the hazard index for the water

supply is less than 1E+00, therefore it is unlikely that ingestion or dermal exposure to the water will result in noncarcinogenic adverse health effects.

14.3 BUILDING 1245

Subsurface soil samples were collected outside of Building 1245 to assess the potential leakage or spillage of materials stored in this building. The following sections describe the Building 1245 field program and its results.

14.3.1 Area Description

Building 1245 is located in the northwestern portion of the PSF, approximately 700 ft southwest of the elevated intersection of State Highway 1 and U.S. Highway 101. It is bordered on the north and east by enlisted family housing and on the south and west by Warehouses 1241 through 1244.

Building 1245 is on an east-facing hillside, at approximately 188 ft-PLL. Appleton Street is on the north side of the building; grass surrounds the building on the other sides (Figure 14.3-1). Surface drainage flows to the east.

Building 1245 was constructed in 1918. It is a flammable material storage building, constructed of concrete and measuring approximately 6 by 8 ft. A wooden drum cradle is located inside the building. In this area, two 2-in diameter holes have been cored through the concrete. Evidence of leakage/spillage was observed. A portable hydraulic crane was stored inside. No historical documentation of materials present at this site has been found.

14.3.2 Sample Location Rationale

The primary sources identified at Building 1245 were associated with the storage of materials and potential releases through spillage or leakage. Release to the soil was most likely to occur through the hole in the concrete floor of the building or from potential transfer or storage of the materials outside of the building. Therefore, two borings were drilled to a depth of 3 ft bgs on the east side of Building 1245 near the drain hole associated with the tank cradle (Figure 14.3-1). Subsurface soil samples were collected from two depths and

analyzed for SVOCs, OCPs, herbicides, and TPH to assess the nature and extent of potential contamination.

14.3.3 Geologic Setting

The general soil classification of the Building 1245 area is described by the SCS as Urban Land (fill) (Kashiwagi and Hokholt, 1985). Clayey sand was penetrated in the two borings at the site (Appendix H). The surficial sediments in the area have been mapped by the USGS as slope debris and ravine fill (Schlocker, 1974). Bedrock is projected to be at 38 ft bgs in this area (Figure 2.3-4). In both borings, saturated soil was reached at 3.0 ft bgs.

14.3.4 Analytical Results

Building 1245 is a flammable material storage shed and potential contamination due to releases by leaks or spills were investigated. Two subsurface samples were collected from each boring and analyzed for SVOCs, OCPs, herbicides, and TPH. Analytical results are listed in Table 14.3-1. Dieldrin, ppDDT, and ppDDE were detected in the 2.7 ft sample from Boring 1245SB01 and in both the 0.7 and 2.7 ft samples from Boring 1245SB02. Each of these compounds were below the RL in the 0.7 ft sample from Boring 1245SB01. None of the concentrations of these compounds were above 1.0 $\mu\text{g/g}$ and the SDCs for dieldrin and ppDDT were not exceeded. In addition, bis(2-ethylhexyl)phthalate and di-n-butylphthalate, two compounds which were present in numerous method blanks, were detected in three or four of the four samples collected from the two borings at concentrations less than 0.2 $\mu\text{g/g}$. Fluoranthene and pyrene were detected in both samples from Boring 1245SB02 at concentrations less than 0.09 $\mu\text{g/g}$. TPH was not detected in any of the four samples.

14.3.5 Results Evaluation

The potential source of contamination at Building 1245 is releases or spills of flammable materials formerly stored at this location. No information on the exact nature of the materials stored in this building is available. In Boring 1245SB02, concentrations of the PAHs and pesticides were slightly higher in the 2.7 ft sample than in the 0.7 ft sample. In Boring 1245SB01, PAHs and pesticides were not detected in the shallow sample, but pesticides were slightly above the RLs in the deeper sample. The concentrations of the compounds

detected above the RLs were all below SDCs for those compounds with SDCs such as ppDDT and dieldrin. Therefore, the data suggest that any leakage here was of a minor nature.

14.3.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1245 area, including the risk assessment results, as presented in detail in Section 15.

14.3.6.1 Conclusions

The analytical data indicate the presence of dieldrin, ppDDT, ppDDE, fluoranthene, and pyrene in low concentrations in subsurface soil adjacent to Building 1245. The primary sources identified at Building 1245 were associated with the storage of materials and potential releases through spillage or leakage. However, the pesticides may be from routine applications, and the PAHs may be associated with ubiquitous urban sources. Phthalates, which are commonly associated with plastics and common laboratory contaminants, were detected at low concentrations and are not likely to be related to activities at the site.

Although the data indicate that SDCs are not exceeded and that concentrations decrease with depth, these compounds are considered COPCs for both the human health and ecological risk assessments.

14.3.6.2 Risk Assessment Summary

As presented in Section 3.7, all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs and MCLs. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also

quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1245 area are summarized in the following sections.

14.3.6.2.1 Human Health

The GMPA identified institutional (industrial) uses for the entire Building 1245 area, and exposures to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are possible. Soil samples within the subsurface soil depth interval were collected from this site. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for subsurface soil was performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions

used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 1245 area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

14.3.6.2.1.1 Quantification of Cancer Risks

COCs were not identified in the subsurface soils collected at Building 1245. The COCs in the PSF water supply (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, exposure to the PSF water supply to industrial workers is unlikely to result in an excess cancer risk at Building 1245. The COPCs for the residential PRG ratio screening assessment are not considered carcinogenic at this site.

14.3.6.2.1.2 Quantification of Noncarcinogenic Effects

The hazard index for this site is less than $1E+00$, therefore it is unlikely that ingestion or dermal exposure to the media and receptors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices less than $1E+00$.

14.3.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 1245 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

Soil COPCs identified for the Building 1245 ecological risk assessment include di-n-butylphthalate, fluoranthene, pyrene, dieldrin, ppDDE, and ppDDT. Results of the risk assessment indicate that all HIs and HQs are much less than 1 for all receptors. This site does not present an ecological risk, and warrants no further evaluation.

14.4 BUILDING 1369

Soil samples were collected next to Building 1369 to evaluate the potential release of lead associated with this indoor firing range. The following sections describe the Building 1369 field program and its results.

14.4.1 Area Description

Building 1369 is located in the northwest portion of the PSF. It is bordered on the north by a parking lot, on the east by Ralston Avenue and the enlisted men's barracks, on the west by Lincoln Boulevard, and on the southwest by Battery Dynamite. Building 1369 has an active firing range inside the building. It has a concrete floor and measures approximately 115 ft by 40 ft.

Building 1369 is located at an elevation of approximately 261 ft-PLL on a northeast sloping surface northeast of Battery Dynamite. Surface drainage in the area is to the northeast. The

building is bordered on the north by a large paved parking area, and by grassy landscaped areas on the other sides. Further to the west are large trees.

Building 1369 was constructed between 1946 and 1948, as indicated by aerial photographs. It was used as an indoor firing range; bullets were fired at paper targets (HLA, 1994). Spent ammunition was collected in a sand pit. A trench extends from the west to the east side of the building, ending at a 2-ft diameter sump/settling basin on the east side. There is a drainage pipe near the top of the basin that extends to the ground surface outside the building. The system has been interpreted as a mechanism for collecting rinsate from washing of the indoor area, with sand collecting in the sump and water draining to the outside (HLA, 1994). During a site visit on January 4, 1994, the U.S. Army representative, Alex Macievich, indicated that the U.S. Army had previously removed solid sheets of lead from the target area and lead-contaminated sand from the sand pits.

14.4.2 Sample Location Rationale

The potential source of contamination that was investigated at Building 1369 is the drainage pipe on the east side of the building. Sample locations were based on the conceptual model presented in Section 3.1. Releases of rinsate from the pipe could potentially infiltrate into the subsurface. Consequently, three surface and three subsurface soil samples were collected in the vicinity of the drain outlet. Sample locations are shown in Figure 14.4-1.

14.4.3 Geologic Setting

The soils in the vicinity of Building 1369 have been classified by the SCS as Urban Land (fill) (Kashiwagi and Hokholt, 1985). The soil boring drilled at the site penetrated sandy clay (Appendix H). The surficial sediments in the area are mapped by the USGS as slope debris and ravine fill (Schlocker, 1974). Bedrock is estimated to be at a depth of 20 ft bgs (Figure 2.3-4). Groundwater was not encountered; the regional water table elevation map indicates an absence of groundwater in shallow unconsolidated sediments (Figure 2.3-2).

14.4.4 Analytical Results

Soil samples were collected at four locations outside of Building 1369. One boring was sampled at three depths and three surface soil samples were collected surrounding this

boring. These six samples were analyzed for lead. Analytical results of soil sampling are shown in Table 14.4-1. Lead was detected in five of the six soil samples collected. All of the samples were categorized as fill. One detection was above both the ambient fill concentration of 221 $\mu\text{g/g}$ and the SDC of 300 $\mu\text{g/g}$. This lead detection of 365 $\mu\text{g/g}$ was reported in the shallow soil sample (0.5 ft bgs) from Boring 1369SB01. Lead was detected above ambient in the 2.0-ft bgs sample from this boring (291 $\mu\text{g/g}$), but was not detected in the 5.0-ft bgs sample. There are no other lead results that exceed the ambient lead value for fill.

14.4.5 Results Evaluation

The potential source of lead at Building 1369 is from the drainage pipe located on the east side of the building. This source was evaluated through collection and analysis of soil samples near the drainage pipe. The primary release mechanism for lead in this area is through surface water runoff and infiltration following discharge from the drainage pipe.

Lead was detected above the SDC only in the shallowest sample closest to the drain outlet (Boring 1369SB01), indicating that lead has not migrated very far from the drain outlet. This is supported by the presence of lead below the SDC and below ambient in the deepest soil sample collected from Boring 1369SB01 and in the surrounding surface soil samples. The potential for migration of lead in PSF soils is discussed in the metal mobility model (Appendix Q).

14.4.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1369 area, including the risk assessment results, as presented in detail in Section 15.

14.4.6.1 Conclusions

The presence of lead above the SDC of 300 $\mu\text{g/g}$ in the vicinity of Building 1369 is limited to a shallow soil sample (0.5-ft bgs) from one boring with a concentration of 365 $\mu\text{g/g}$. The presence of lead above ambient fill concentrations only occurred in this sample and in the 2.0-ft bgs sample from this boring. Surrounding surface soil samples indicate that the elevated lead concentrations are confined to a small area below the end of the drainage pipe.

Lead is evaluated as a subsurface soil COPC in the human health risk assessment and as a soil COPC in the ecological risk assessment.

14.4.6.2 Risk Assessment Summary

As previously described, the only detected target analyte in samples collected from this site was lead. Samples were collected from both surface and subsurface soils, and all samples were considered in the human health and ecological risk assessments according to the depths in which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) is evaluated as a drinking water source for the area.

In the human health risk assessment, lead concentrations are first screened against the PSF screening value for lead in soil. If the screening value is exceeded and the frequency of detection is greater than 5%, lead is considered a COC. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1369 area are summarized in the following sections.

14.4.6.2.1 Human Health

The Building 1369 area was identified in the GMPA for institutional (industrial) uses, under which exposures to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil (0.5 to less than 15 ft bgs) are possible. However, the only COPC, lead, was a COPC for subsurface soil samples, not surface soil samples. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for surface and subsurface soil was performed as a preliminary assessment of a residential scenario. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening

assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, an evaluation based on USEPA and DTSC guidance is performed for lead in soil, as discussed in Section 15.1.4.11. Numerical estimates of health effects are not performed for lead. Instead, lead is identified as a COC at sites where lead concentrations in soil exceed the lead soil screening value of 840 mg/kg (used for both industrial and recreational).

14.4.6.2.1.1 Quantification of Cancer Risks

COCs were not identified in the soils collected at Building 1369. The COCs in the PSF water supply (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, exposure to the PSF water supply to industrial workers is unlikely to result in an excess cancer risk at Building 1369. The COPCs for the residential PRG ratio screening assessment are not considered carcinogenic at this site.

14.4.6.2.1.2 Quantification of Noncarcinogenic Effects

The hazard index for this site is less than 1E+00, therefore it is unlikely that ingestion or dermal exposure to the media and receptors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices greater than 1E+00.

14.4.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 1369 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were

also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

The only soil COPC for the Building 1369 ecological risk assessment is lead. The results of the risk assessment indicate the following:

- HIs for the American robin and mourning dove exceeded 1 when comparisons were made based on the conservative TBV_{Low}.
- HIs were all less than 1 when comparisons were made based on the TBV_{High}.

Given the small number of pathways posing a risk potential to ecological receptors, it appears that this site poses a minimal ecological receptor risk. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, this site should not be considered further.

14.5 BUILDING 1388

Soil borings were drilled and sampled in the vicinity of Building 1388 to evaluate the potential release of petroleum hydrocarbons associated with activities in the area. The following sections describe the Building 1388 field program and its results.

14.5.1 Area Description

The Building 1388 area is in the northwest portion of the PSF. The building is bordered on the northeast by trees, on the south by an asphalt parking lot, and on the west by Building 1387, a bowling alley. The general area slopes to the northeast and is at an approximate elevation of 214 ft-PLL. In the vicinity of the borings, the ground surface slopes to the northwest toward the grassy area between the parking lot and the bowling alley and the grassy area north of Building 1388.

Building 1388 was built in 1960. It is a one story (10 ft by 10 ft) sheet metal and concrete structure. In January 1994, it was being used as living quarters by an on-site worker. The asphalt parking lot south of Building 1388 is being leased by a U.S. Army contractor for storage. The following items were noted in the area in January 1994 (HLA, 1994):

- Two portable 500-gal ASTs (one diesel and one gasoline)
- Several large maintenance vehicles
- Three truck trailers
- Two wooden pallets full of cement bags
- One wooden pallet with eight 5-gal plastic containers of hydraulic fluid.

The pallet of hydraulic fluid and the ASTs were not present at the time of the field investigation. Stained asphalt was observed near the ASTs (Figure 14.5-1).

14.5.2 Sample Location Rationale

Two primary sources were identified in the Building 1388 area: the ASTs and the pallet of hydraulic fluid. Staining, considered to be the result of spills or leaks from the tanks or containers, was noticed on the asphalt near both of these potential sources. The primary release mechanism for the two ASTs is leakage to the asphalt, and subsequent migration to soil below the asphalt or to downslope soil. Four borings were drilled through the pavement in stained areas and two borings were located on the grass, downslope from the stained areas (Figure 14.5-1). Subsurface soil samples were collected to evaluate potential contamination in the soil and the potential extent of contaminant infiltration and percolation.

14.5.3 Geologic Setting

The general soil classification of the Building 1388 area is described by the SCS as Urban Land (fill) (Kashiwagi and Hokholt, 1985). Brown to greenish brown clay was penetrated in the borings drilled at the site (Appendix H). This is interpreted to be slope debris and ravine fill, as mapped by the USGS (Schlocker, 1974). One of the borings penetrated light brown sand at approximately 5.5 ft bgs, which is interpreted to be dune sand. Bedrock is estimated to be at a depth of 15 ft bgs (Figure 2.3-4). Groundwater was not encountered; the regional

water table elevation map (Figure 2.3-2) indicates an absence of groundwater in unconsolidated sediments beneath the site.

14.5.4 Analytical Results

Six borings were drilled to 10 ft bgs to investigate if any petroleum hydrocarbons had been released to the soil. Each boring was sampled and analyzed for TPH (immunoassay) at three depths to assess the vertical distribution of hydrocarbons. In addition, the 0.5 ft sample from Boring 1388SB06 was also analyzed for TPH-D and TPH-G. Analytical results of soil sampling are shown in Table 14.5-1. TPH (immunoassay) was detected in only one of the 18 samples. The TPH (immunoassay) detection ($> 100 \mu\text{g/g}$) was reported in the 0.5 to 1.0 ft sample from Boring 1388SB05. TPH-D and TPH-G were not detected in the 0.5 ft sample from Boring 1388SB06. Total organic carbon ranged from $4750 \mu\text{g/g}$ in the 1.0 ft sample from Boring 1388SB02 to $856 \mu\text{g/g}$ in the 9.5 ft sample from the same boring.

14.5.5 Results Evaluation

The potential sources of TPH at Building 1388 are the ASTs formerly present at the site. These sources were evaluated through collection and analysis of soil samples. The primary release mechanism for TPH in this area is through surface water runoff and infiltration.

TPH was detected in only one of the eighteen soil samples collected. This sample was collected from Boring 1388SB05, directly below stained pavement at a depth of 0.5 to 1.0 ft bgs. TPH was not detected in either of the two deeper samples from the same boring. The results indicate that little or no vertical migration of TPH has occurred at this location and that the single detection of TPH was limited to surface soil, directly below the asphalt.

14.5.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the Building 1388 site, including the risk assessment results, as presented in detail in Section 15.

14.5.6.1 Conclusions

Soil sampling in the Building 1388 area was conducted in the areas with visible staining and where ASTs were formerly located. The results of chemical analysis of these soil samples

indicate that TPH above the SDC is limited to soil directly below the stained asphalt in the immediate vicinity of Boring 1388SB05. The TPH will be assessed in the BRA.

14.5.6.2 Risk Assessment Summary

As presented in Section 3.7, all detected organics in soil (TPH) were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated. In addition, the PSF water supply (Lobos Creek and Well 13) was evaluated as a drinking water source.

In the human health risk assessment, detected TPH concentrations are first screened against TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the Building 1388 area are summarized in the following sections.

14.5.6.2.1 Human Health

The GMPA identified institutional (industrial) uses for the entire Building 1388 area, and exposures to surface soil (0.0 to less than 0.5 ft bgs) and subsurface soil are possible. At this site, soil samples within the subsurface depth interval were collected. Additionally, exposure to the PSF water supply is evaluated for the industrial worker in this area.

A residential PRG ratio screening assessment for subsurface soil was performed as a preliminary assessment of a residential scenario. This assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for

informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health effects for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A $1E-06$ cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the $HQ > 1E+00$, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the Building 1388 area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

14.5.6.2.1.1 Quantification of Cancer Risks

COCs were not identified in the subsurface soils collected at Building 1388. The COCs in the PSF water supply (lead, manganese, and nitrate) are not considered carcinogenic.

Therefore, exposure to the PSF water supply to industrial workers is unlikely to result in an excess cancer risk at Building 1388. The COPCs for the residential PRG ratio screening assessment are not considered carcinogenic at this site.

14.5.6.2.1.2 *Quantification of Noncarcinogenic Effects*

The hazard index for this site is less than 1E+00, therefore it is unlikely that ingestion or dermal exposure to the media and receptors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices less than 1E+00.

14.5.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment for Building 1388 included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds.

Similar to the noncarcinogenic risk estimates for human receptors, risks to ecological receptors are represented by HQs, which can be summed to obtain an HI for each exposure pathway evaluated. Pathways evaluated, as applicable, include soil and dietary ingestion. Dermal absorption for birds and mammals and direct contact for plants and soil fauna were also evaluated. The HQs were estimated using a range of toxicity criteria, or toxicity benchmark values (TBVs), as described in Section 3.9.2. An HQ low is an estimate of ecological hazard based on toxicity criteria (TBV_{High}) that correspond to the lowest levels of exposure that have been shown in published studies to cause adverse effects. An HQ high is more conservative because it is based on lower toxicity criterion (TBV_{Low}) that have been shown in published studies to cause no adverse effects. The range of risks between the HQ low and HQ high represent a grey zone where risks are possible but unlikely.

TPH was the only soil COPC identified for the ecological risk assessment for Building 1388. The results of the risk assessment indicate that HQs and HIs are much less than 1 for all receptors and pathways evaluated.

Given the small number of pathways posing a risk potential to ecological receptors, it appears that this site poses a minimal ecological receptor risk. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, this site should not be considered further from the perspective of ecological risk.

14.6 BUILDING 1750

The Building 1750 site, a former motor pool area, was the focus of a soil-gas survey to evaluate the potential release of contaminants associated with activities in this area. The following sections describe the Building 1750 field program and its results.

14.6.1 Site Description

Building 1750 is in the Golden Gate Army Reserve Unit Complex (GGARUC), located near the southwest corner of the PSF. The area is bordered on the north by a forested area, on the west by Lincoln Boulevard, and on the south by an asphalt parking lot. Howard Road extends along the south side of the parking lot. Lobos Creek is located south of the road. Building 1750 is located on the north side of the GGARUC and Buildings 1752 through 1755 are to the east and southeast, along the edges of the parking lot.

The Building 1750 area is at an approximate elevation of 72 ft-PLL on a southwest trending slope toward Lobos Creek. Surface drainage from the area is to the southwest. Parking lot runoff is captured by a storm drainage system that extends from east to west across the parking lot.

The Building 1750 area was formerly used as a motor pool. Aerial photographs show structures along the north and east ends of the parking lot. In 1946 and 1948 aerial photos, the parking lot is unpaved; 1955 and later photos show the area to be paved.

Building 1750 was constructed in 1970 on the north end of the site after the previous structures were demolished. The building is used for administration (offices and training). The 1983 Installation Assessment Report mentioned a photographic laboratory in this building (ANL, 1989). Other buildings in the vicinity include a garage (Building 1752) which has storage areas for batteries and hazardous waste, a waste POL storage shed (Building 1754), a storage shed for flammable materials (Building 1753A), and an outdoor vehicle service ramp (Building 1755), associated with motor pool activities (TETC, 1994). A 50-gallon AST (Tank 1750.2), used for hydraulic oil, was removed from north of Building 1752 in August 1993 (TETC, 1994). An inactive 300-gallon waste oil/water UST (Tank 1750.1) was reported to be south of Building 1750 (TETC, 1994). This area was also

described to be a concrete sump east of Building 1754 that receives wash water from a recessed vehicle wash area (JMM, 1992b). The April 7, 1995 Tank Status Map indicates this tank was removed in 1993 (Montgomery Watson, 1995e).

The Lobos Creek Protected Range, used in the early 1900s, partially overlaps the Building 1750 site. It is being investigated under the small arms firing range program, conducted under the direction of the Sacramento Corps of Engineers. Under this program, antimony, barium, copper, lead, and zinc were analyzed. The results will be presented in the *Sampling Investigation Report for the Small Arms Firing Ranges* (report in progress by Montgomery Watson).

14.6.2 Sample Location Rationale

The potential sources of contamination that were investigated at the Building 1750 area include leaks and spills from previous and recent maintenance/motor pool activities in the area. Prior to paving of the area, there may have been releases of contaminants to surface soil and infiltration to deeper soils. After the area was paved, releases to the asphalt could infiltrate to underlying soil through cracks in the pavement.

A soil gas sampling survey was performed to identify any specific areas that needed to be further investigated. A multi-depth soil-gas survey was performed at 18 locations in the parking lot. These locations were on a grid spacing of approximately 100 ft (Figure 14.6-1). Two additional sampling locations were near the northeast corner of the parking lot to assess potential releases from recent activities associated with the vehicle service ramp (Building 1755), the waste POL storage shed (Building 1754) and the hazardous materials building (1753). Staining was noted near Building 1754 (a waste POL storage shed), indicating minor release of materials to the asphalt (TETC, 1994). Based on the results of the soil gas sampling, a boring was drilled and sampled at one of the sites.

14.6.3 Geologic Setting

The soil in the vicinity of the Building 1750 is designated by the SCS as Urban Land (fill) (Kashiwagi and Hokholt, 1985). Sand, interpreted to be dune sand, was penetrated in the boring drilled at the site, from below the asphalt and road base (0.7 ft bgs) to total depth (12

ft bgs). This classification corresponds to the USGS map of the surficial sediments in this area (Schlocker, 1974). Bedrock was not encountered during drilling, but is estimated to be at a depth of approximately 50 ft bgs (Figure 2.3-4). Groundwater was not encountered; the regional water table elevation map (Figure 2.3-2) suggests that groundwater is present at a depth of about 25 to 30 ft beneath the site area.

14.6.4 Analytical Results

The multi-depth soil-gas survey included the installation of 20 soil-gas probes to approximately 3.5 ft bgs and 10 ft bgs. Samples were analyzed for total volatile hydrocarbons and aromatic and halogenated hydrocarbons. Details of the soil-gas survey are presented in Appendix S. To summarize, no halogenated or aromatic hydrocarbons were detected above the detection limit of 1 $\mu\text{g/L}$. Total volatile hydrocarbons (as compared to a gasoline standard) were not detected above the detection limit of 50 $\mu\text{g/L}$. However, because an unidentified compound was detected by the total volatile hydrocarbon analysis in the 10 ft bgs sample from soil probe location 1750SB16 (147 to 173 $\mu\text{g/L}$), a soil gas sample was collected for independent laboratory analysis using a Tedlar bag and a vacuum chamber. GC/MS analysis tentatively identified alpha-pinene in this confirmation sample. To provide further confirmation of this analysis, a soil boring was drilled and a soil sample from 10 ft bgs was collected for analysis of alpha-pinene. It was not detected above the RL of 0.3 $\mu\text{g/g}$.

14.6.5 Results Evaluation

Soil-gas sampling and confirmation soil sampling was conducted to evaluate whether hydrocarbons were present as a result of former activities in the Building 1750 Area. No halogenated or aromatic hydrocarbons were detected above the detection limit of 1 $\mu\text{g/L}$. Total volatile hydrocarbons (as compared to a gasoline standard) were not detected above the detection limit of 50 $\mu\text{g/L}$. Therefore, it was not deemed necessary to collect any soil samples for aromatic or halogenated hydrocarbon analysis.

14.6.6 Conclusions and Risk Assessment Summary

Results of soil-gas sampling and confirmation soil sampling indicate that none of the hydrocarbons analyzed were detected. Therefore, no further investigation of the hydrocarbon

sources is recommended for the Building 1750 site and the site is not included in the BRA except to evaluate the effects of the PSF water supply on the industrial worker in the area.

The COCs in the PSF water supply (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, exposure to the PSF water supply to industrial workers is unlikely to result in an excess cancer risk at Building 1750. In addition, the hazard index for the water supply is less than 1E+00, therefore it is unlikely that ingestion or dermal exposure to the water will result in noncarcinogenic adverse health effects.

The investigation of the firing range adjacent to and within the Building 1750 site is being conducted under a separate program; any additional conclusions or remedial actions will be based upon the information presented in the *Sampling Investigation Report for the Small Arms Firing Ranges* (Montgomery Watson, report in progress).

14.7 EAST-OF-MASON

Surface soil, subsurface soil, and discrete groundwater samples were collected at the East-of-Mason (EOM) area to evaluate the physical and chemical characteristics of its soil and groundwater. The following sections describe the EOM field program and its results. Information regarding the history and use of this area was obtained from historical maps, aerial photographs, and the Enhanced PA (ANL, 1989).

14.7.1 Area Description

The EOM area is located between the Crissy Field and DEH Study Areas. It is bordered by San Francisco Bay to the north, the DEH Study Area and Javowitz Street to the east, Mason Street to the south and west, and the Crissy Field Study Area and Mitchell Street also to the west (Figure 14.7-1). The topography in the area is flat with elevations ranging from approximately 10.5 to 12.5 PLL. A 3-ft railing and a popular jogging path run along the northern boundary of the area and a 5-ft fence is located along the western edge. An asphalt pad is located in the northeastern section of the EOM area. The area is planted with grass and eucalyptus trees with the exception of a dirt parking lot in the northwestern portion that is used to access the jogging path. Buildings constructed in the area were used primarily for

administrative activities. Most of these buildings were demolished from 1959 to 1988, and those remaining were demolished by early 1995.

An 1851 U.S. Coast Survey map indicates that the EOM area was part of a marsh system that consisted of 97 ac of salt marsh, 10 ac of mudflats and sandflats, and 20 ac of subtidal channels (D&M, 1995). A map dated August 2, 1882 (U.S. Surveyor General, 1882) showed the area as beach sand and marshland (Figure 5.1-2). Fill material, such as dredged bay sediments, was used to drain the marshland after 1870. It is believed that debris from the 1906 earthquake was used as fill material for the Crissy Field, EOM, and DEH Study Areas.

In February 1995, a feasibility study was completed to evaluate the potential for restoring portions of the Crissy Field, EOM, and DEH Study Areas to the pre-1900s land use as a wetland (D&M, 1995b). The report analyzed the potential for re-introducing native vegetation, such as coastal sagewort and evening primrose, and the viability of creating a 30- to 60-acre wetland or a freshwater backdune marsh without using an intensive land management approach. In addition, it calculated the potential sediment loads and effects of tidal fluctuations on groundwater and surface water quality and elevations.

14.7.2 Sampling Location Rationale

The sampling program at the EOM area was based upon the conceptual model presented in Section 3.1. Debris fill which may have been deposited after the 1906 earthquake and general maintenance activities associated with the administration buildings were considered the potential sources of contamination in this area. The contaminant pathways associated with these sources include stormwater runoff, particulate transport, and infiltration. Surface soil, subsurface soil, and discrete groundwater samples were collected during the Follow-on RI to provide physical and chemical information regarding the fill material, native soil, and groundwater in the EOM area.

14.7.3 Hydrogeologic Setting

The geology at the EOM area, including depth to bedrock, is believed to be similar to that at the Crissy Field and DEH Study Areas because of its location between them and the similarity of the geologic data that have been collected in both of those study areas.

According to Figure 2.3-4, the depth to bedrock in the area is inferred to be more than 100 ft bgs. Site-specific geologic data were obtained from the lithologic logs of four, 10-ft deep, soil borings (lithology was not recorded for EOMSB01). The lithology logs (Appendix L) indicate that the surficial soils are composed of artificial fill, consisting mainly of brown to olive brown silty and clayey sand, with occasional concrete and brick fragments. The artificial fill ranges in thickness from 0.5 to 6 ft. The fill material is consistently underlain by sand deposits which are described as poor- to moderately-sorted and dark grey-brown to olive-brown. A clay layer was encountered at 8.5 ft bgs in Boring EOMSB03. This clay layer was not fully penetrated by the boring. A similar clay layer was encountered from 7 to 7.5 ft bgs in Boring EOMSB05. The absence of clay in Boring EOMSB04 suggests that the clay is discontinuous.

Because of its location and similar depositional environment, the uppermost water-bearing zone in the EOM area is believed to be hydrostratigraphically equivalent to the shallow water-bearing zone beneath both Crissy Field and DEH Study Areas (Figure 2.3-9). During drilling in the area, groundwater was first encountered at approximately 6 to 7 ft bgs. Potential sources of recharge in the EOM area include infiltration and lateral flow from upgradient areas such as the Main Post Study Area. Data from the other coastal study areas at the PSF indicate that a zone of saltwater intrusion exists along the coast (Figure 2.3-12), and this saltwater intrusion is assumed to impact the groundwater beneath EOM in a similar fashion. Deep groundwater samples at the adjacent sites have shown electrical conductivities in excess of the potable water quality standard in California State Water Resources Control Board Resolution 88-63. In addition, the shallow groundwater samples collected at the EOM site exceeded the recommended Secondary MCL for EC, which is equal to 900 $\mu\text{S}/\text{cm}$ (Title 22, CCR Article 16, Section 64449).

Tidal fluctuations in San Francisco Bay are assumed to affect groundwater flow direction in the same manner as they affect the Crissy Field and DEH Study Areas. Monthly water levels taken from October 1993 to March 1994 indicate that net groundwater elevations in the coastal study areas may be minimally affected, i.e. 1 foot, by tidal and seasonal fluctuations (D&M, 1995).

14.7.4 Analytical Results

Soil and groundwater samples were collected from the five borings in the EOM area during the Follow-on RI. Two soil samples and two groundwater samples were collected from each boring, with the exception of EOMSB01, where groundwater from only one depth was sampled. The soil samples were analyzed for inorganics, VOCs, SVOCs, OCPs, herbicides, TPH-G, and TPH-D. Table 14.7-1 lists the concentrations of those analytes which were detected in the soil samples. Posting maps showing the detected concentrations in soil for aluminum, arsenic, chromium, copper, lead, manganese, mercury, nickel, ppDDE, and ppDDT are presented as Figures 14.7-2 through 14.7-11. The groundwater samples were analyzed for inorganics, SVOCs, OCPs, and herbicides. Both filtered and unfiltered groundwater samples were collected from the deepest samples from Borings EOMSB02 through EOMSB05 and analyzed for inorganics. The analytical results for analytes detected in the discrete groundwater samples are presented in Table 14.7-2. Posting maps showing the detected concentrations in groundwater for arsenic, cadmium, chromium, copper, lead, manganese, and nickel are presented as Figures 14.7-12 through 14.7-18.

14.7.4.1 Soil Samples

All of the surface soil samples were collected from fill material. The subsurface soil sample from Boring EOMSB04 was also collected from fill material, but beach-dune sediments were collected in the subsurface samples from the other four borings. All of the samples contained the following inorganic elements commonly found in the environment: calcium, magnesium, potassium, and sodium. These inorganics are not usually evaluated as part of risk assessments because they are ubiquitous in the environment, are not associated with toxicity to humans or the environment under normal circumstances, and are generally considered essential human nutrients (USEPA, 1989b). Iron is also considered an essential human nutrient and is not considered a COPC for the human health risk assessment; however, it may be an ecological COPC. Therefore, calcium, magnesium, potassium, and sodium are excluded from the following discussion.

The detected inorganics concentrations were compared to the appropriate ambient concentrations calculated for samples collected across the PSF as discussed in Section 3.7. Inorganic analytes were detected above ambient concentrations in only two of the 10 soil

samples collected in the EOM area. Mercury and manganese were detected above ambient concentrations for beach/dune sand in the 0.5 ft sample from Boring EOMSB02. Aluminum and mercury were detected above ambient levels for beach/dune sand in the 0.5 ft sample from Boring EOMSB05.

Two VOCs, acetone and methylene chloride, were detected in soil samples. Acetone was detected at a concentration of 0.122 $\mu\text{g/g}$ in the 4.5 ft bgs sample from Boring EOMSB04. Methylene chloride was detected in the 4.5 ft bgs sample from Boring EOMSB04 (0.0254 $\mu\text{g/g}$) and in both the 0.5 and 4.5 ft bgs samples from Boring EOMSB05 (0.0062 and 0.0027 $\mu\text{g/g}$, respectively). Acetone and methylene chloride are common laboratory contaminants.

Several SVOCs were detected in EOM soil samples. Bis(2-chloroethoxy)methane was detected in seven of the 10 soil samples, at concentrations ranging from 0.16 to 0.57 $\mu\text{g/g}$. Bis(2-ethylhexyl)phthalate was detected in the 0.5 ft sample from Boring EOMSB02 at a concentration of 0.40 $\mu\text{g/g}$. Di-n-butylphthalate was detected in both samples from both Borings EOMSB02 and EOMSB04, at concentrations ranging from 0.067 to 0.084 $\mu\text{g/g}$. Fluoranthene and pyrene were detected in the 0.5 ft sample from Boring EOMSB02 at concentrations of 0.087 and 0.118 $\mu\text{g/g}$, respectively.

Organochlorine pesticides ppDDE and ppDDT were detected in the 0.5 ft sample from Boring EOMSB05. The detection of ppDDE was at a concentration of 8.49 $\mu\text{g/g}$, and ppDDT was detected at a concentration of 4.66 $\mu\text{g/g}$.

There were no detections of chlorinated herbicides or TPH fractions in any of the samples.

14.7.4.2 Groundwater Samples

Discrete groundwater samples were collected from each of the five borings. An unfiltered sample was collected from a shallow interval in each well, and filtered samples were collected for inorganic analyses from the deepest sampled interval in Borings EOMSB02 through EOMSB05. In all, nine unfiltered and four filtered samples were collected. The results are listed in Table 14.7-2 for those analytes that were detected above the RLs. Inorganics which exceeded SDCs in one or more unfiltered samples were aluminum, arsenic, beryllium, cadmium, chromium, lead, nickel, and thallium. The beryllium and thallium

detections, however, were affected by blank contamination. Aluminum, chromium, lead, and nickel exceeded SDCs most often. Inorganic concentrations were much lower in the filtered samples. The only inorganics to exceed SDCs in the four filtered samples were beryllium and cadmium, both at concentrations of 7 µg/L in the 10-ft sample from Boring EOMSB02. However, neither of these analytes was detected in the corresponding unfiltered sample.

Bis(2-ethylhexyl) phthalate was the only organic compound detected in the groundwater samples. As indicated on Table 14.7-2, all but the detection reported in the 8.3 ft sample from EOMSB02 (56.2 µg/L) were considered to be affected by blank contamination.

14.7.5 Results Evaluation

This section presents the evaluation of the sampling results for the East of Mason Study Area. RI sampling was conducted in this area during the Follow-on RI investigation to assess the potential impacts of debris within fill material and routine maintenance of the administrative buildings. This assessment involved the collection of soil and groundwater samples, and the intent of the following discussion is to determine which data should be entered into the Risk Assessment as COPCs (see Section 3.7). RI samples were analyzed for inorganic and organic analytes. Inorganic analytes are naturally occurring, and their presence at a site may or may not be anthropogenic. In determining which inorganic analytes are COPCs, several factors are considered. These include the magnitude and number of detections above ambient values, the spatial distribution of these exceedences, the type of soil in the sample, and comparison with concentrations typical of soils in other areas of the region. The RI assumes that all organic analytes are anthropogenic, and all detected organic compounds are, therefore, considered COPCs. Analytes that are not considered COPCs will not be discussed further.

Once COPCs are identified, the nature and extent and fate and transport of these analytes will be discussed. The fate and transport of COPCs are discussed in the context of physical and chemical properties of the analyte, relation to other detected compounds, and the sample media. The potential contaminant migration pathways for the EOM area are infiltration and particulate transport by stormwater runoff. If infiltration is a major pathway for a compound, it can result in migration from the fill material to the native material and shallow

groundwater at the site. Particulate transport via stormwater runoff from the site can affect San Francisco Bay. The transport of chemicals to the bay from EOM soil and groundwater and potential impact on aquatic life also were investigated as part of the ESAP.

In order to provide a frame of reference for the discussion of groundwater, the concentrations of inorganics and organics in groundwater are compared to Primary MCLs and saltwater aquatic standards. The saltwater aquatic standards, which were only used to evaluate filtered samples, may only be applicable to groundwater within 150 ft of the shoreline, in the area that has been designated a Saltwater Ecological Protection Zone by the SCRs (California Regional Water Quality Control Board, 1996). In addition, comparison to MCLs does not imply that groundwater in the EOM Study Area is suitable for domestic or industrial use. In fact, the GMPA for the PSF prepared by the NPS (1994) does not include development of groundwater in the EOM Study Area for either a drinking water source or industrial use. In addition, several of the California secondary MCLs are exceeded in the PSF coastal zone because of saltwater intrusion, as was discussed previously in Section 2.3.6 of this RI report. Because of saltwater intrusion, groundwater in the study area does not meet criteria set forth in California Resolution 88-63 for potential municipal or domestic water supplies.

The only inorganics detected at concentrations greater than ambient levels were aluminum, mercury, and manganese. Manganese was found to exceed ambient beach/dune sand concentration in the 0.5 ft bgs sample from Boring EOMSB02, and aluminum exceeded the ambient beach/dune sand concentration in the 0.5 ft bgs sample from Boring EOMSB05. Mercury exceeded ambient in both of these samples. Each of these samples was originally compared to ambient values for beach/dune sand because the lithologic description was predominantly sand. In each case, however, the sampled interval was determined by the geologist in the field to consist of fill material. Since none of these three analytes was detected above ambient fill concentrations, they are not considered COPCs in soils in the EOM area.

A comparison of filtered and unfiltered groundwater results indicates that most of the inorganics detected in unfiltered samples are associated with particulate matter. Several inorganics were detected above primary MCLs in the unfiltered discrete groundwater samples including aluminum, arsenic, beryllium, cadmium, chromium, lead, and nickel.

None of these inorganics exceeded primary MCLs in the corresponding filtered samples. Beryllium and cadmium were detected above primary MCLs in filtered samples from Boring EOMSB02 (10.0 ft bgs), but they were below the RLs in the corresponding unfiltered sample. Numerous inorganics exceeded criteria for the protection of saltwater aquatic life, but there were no exceedences of these standards in the more relevant filtered samples. Because of the much lower inorganic concentrations in the filtered samples relative to the unfiltered samples, and the high TDS and EC values in this area due to saltwater intrusion, inorganics are not considered to be a major concern in groundwater.

Several of the VOCs and SVOCs that were detected are common laboratory contaminants. These include acetone, methylene chloride, di-n-butylphthalate, and bis(2-ethylhexyl) phthalate. In addition, none of the VOCs or SVOCs was detected in soil at a concentration greater than 1 µg/g, and, other than bis(2-ethylhexyl) phthalate, none of the VOCs and SVOCs detected in soil was detected in groundwater. Bis(2-ethylhexyl) phthalate was the only organic compound detected in the groundwater, and it is a common laboratory contaminant and is not thought to be site-derived.

The detections of ppDDT and ppDDE in Boring EOMSB05 were limited to the sample collected at 0.5 ft bgs. Since neither compound was detected in either the deeper sample from this boring or in groundwater, it appears that they are not migrating downward.

As part of the ESAP, the potential transport of soil and groundwater analytes was assessed by collecting and analyzing stormwater and bay sediment samples associated with storm drains in the EOM site. Sediment sample locations are shown on the posting maps and are identified by the prefix of "OF06" for Outfall 6, followed by the specific sediment sample number from that outfall (i.e., SD01, etc.). Analytical and bioassay testing data for sediments indicated that there was no significant effect on the toxicity of the sediments to the tested species. The analytical and bioassay testing data for stormwater indicated potential low toxicity at Outfall 6 and Outfall 4 (to the east of Outfall 6), potentially associated with the concentrations of metals in the stormwater. However, only small portions of the EOM site are within the drainage areas for these outfalls (<4 percent), and the metals concentrations likely are representative of urban conditions in the surrounding areas (D&M, 1996a, b). Chemicals present in the stormwater do not appear to be incorporated into the

sediments adjacent to the outfalls. Therefore, the transport of soil or groundwater analytes from the EOM site to the bay is not a significant exposure pathway.

14.7.6 Conclusions and Risk Assessment Summary

This section summarizes the evaluation of results for the EOM Study Area, including the risk assessment results, as presented in detail in Section 15.

14.7.6.1 Conclusions

The investigations in the EOM Study Area were designed to assess the chemical impact of U.S. Army activities at the site. The potential source investigated through sampling at this site was artificial fill material. There were no inorganic COPCs identified in soil, and a comparison of filtered and unfiltered groundwater results indicates that most of the inorganics detected in unfiltered samples are associated with particulate matter. There were few organic detections in either soil or groundwater. In fact, the only organic compound detected in any of the nine discrete groundwater samples was bis(2-ethylhexyl)phthalate, which is a common laboratory contaminant. The impact of U.S. Army activities at this site appears to be minimal.

14.7.6.2 Risk Assessment Summary

As presented in Section 3.7, any inorganic COPCs and all detected organics in soil were considered in the human health and ecological risk assessments according to the depths at which they occurred and the exposure scenarios that were evaluated.

In the human health risk assessment, concentrations of the COPCs for each assessed medium are first screened against USEPA Region IX residential PRGs, MCLs, and TPH criteria presented in the FPALDR for surrogate compounds. If any of these values are exceeded and the frequency of detection is greater than 5%, the analyte is considered a COC and quantitatively evaluated. This initial screening is not conducted for the residential PRG ratio screening calculations, which are preliminary, very conservative estimates of risk; all COPCs are evaluated. The ecological risk assessment also quantitatively assesses all COPCs without any initial screening. The human health and ecological evaluations for the FPCGS Study Area are summarized in the following sections.

14.7.6.2.1 Human Health

The EOM Study Area was assessed in two different ways in the human health risk assessment. The GMPA identified open space (recreational) uses for the entire area, and only exposure to surface soil from 0.0 to less than 2.0 ft bgs is assumed under this scenario. In this case, no exposure to groundwater was assumed, and the PSF drinking water supply was not assessed. In addition to the site-wide assessment, soil samples from Borings EOMSB01, EOMSB04, and EOMSB05 and groundwater samples from all borings were included in the assessment of the Proposed Wetlands Restoration Area. The results of this evaluation are detailed in Section 15.1 and summarized in Section 6.6.

A residential PRG ratio screening assessment for surface soil was performed as a preliminary assessment of a residential scenario. Site-wide groundwater was assessed with the proposed wetland restoration area described in Section 5 of this RI report. The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters that was performed in the recreational and industrial risk scenarios assessed in this RI report. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic exposure assumptions based on the future uses actually planned for the sites as identified in the GMPA and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented for informational purposes and do not contribute to risk assessment conclusions made in this RI report.

After the COPC to COC screening is performed, as presented in detail in Section 15.1, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health risk for each COC.

Excess cancer risks are calculated for potential carcinogens and hazard indices are calculated for chemicals with noncarcinogenic effects. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. A target risk range of 1E-04 to 1E-06 is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991). The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions

used to develop the cancer risk estimates; actual risks may be significantly less than predicted values.

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability, but as a ratio termed a hazard quotient (HQ). If the HQ >1E+00, there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a HQ <1E+00 are very unlikely to result in noncarcinogenic adverse health effects. Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI).

Estimates of total cancer risks and HQs associated with the EOM Study Area are presented below. The chemicals and exposure pathways presenting the greatest cancer risks and hazards of noncarcinogenic effects are identified.

14.7.6.2.1.1 Quantification of Cancer Risks

Analytes at EOM determined to be COCs following COPC screening in surface soil to 2 feet included bis(2-chloroethoxy)methane, ppDDE, and ppDDT. The total risk to the recreational visitor from ingestion of and dermal contact exposure to surface soil is 4E-06 from the two pesticides. The residential PRG ratio screening assessment resulted in a total cancer risk greater than 1E-06.

14.7.6.2.1.2 Quantification of Noncarcinogenic Effects

The hazard indices for all media are less than 1E+00, therefore it is unlikely that ingestion or dermal exposure to the media and receptors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in a total hazard index less than 1E+00.

14.7.6.2.2 Ecological

A potential exposure pathway evaluated in the ecological risk assessment included exposure of terrestrial receptors to soil at depths less than 3 ft. Terrestrial receptors selected for evaluation include terrestrial plants and soil fauna (invertebrates), mammals, and birds. Because receptors in this site are expected to also occur in the adjacent Fill Site 7 area, data from this site was assessed with the Fill Site 7 data, as summarized in Section 5.6.2.2. Two

additional scenarios were also evaluated, as described in Section 5.6.2.2. Because a portion of the EOM site is planned to be restored to a wetland, soil and groundwater were included in an assessment of the effects on wetland receptors. An assessment of the soil excavated from the wetland area was performed for receptors that might be exposed to the excavated soils.

15. BASELINE RISK ASSESSMENT

A baseline risk assessment (BRA) was conducted to evaluate potential human health and ecological risks associated with exposure to site-related chemicals in soil, groundwater, sediments, and surface water at the PSF. The BRA for the PSF study areas is divided into two major sections, the human health risk assessment (Section 15.1) and the ecological risk assessment (Section 15.2). Each section identifies chemicals of concern (COCs) from the COPCs for relevant populations, assesses exposure pathways and toxicity of COCs, and quantifies the risks associated with potential exposures to these chemicals. The BRA evaluates site-specific risks for areas within the PSF. The approach to risk assessment is based on the Risk Assessment Guidance for Superfund (RAGS), Volume I Human Health Evaluation Manual (Part A) (USEPA, 1989b).

Sites within each study area were evaluated separately for both the human health and ecological risk assessments. Because of the different habitat requirements and behavior of human and ecological receptors, the sites for each evaluation were not necessarily the same. For the human health risk assessment (HHRA), sites within each study area were evaluated under future industrial or recreational land use scenarios, depending on the land use designated in the NPS General Management Plan Amendment (GMPA) (NPS, 1994). Because the PSF has been transferred to the NPS as of October 1, 1994, only the future land uses were evaluated in the human health risk assessment for this BRA.

Both the human health and the ecological risk assessments for the PSF study areas and sites are organized and discussed in subsections according to the four steps common to most risk assessments:

- Identification of COCs
- Exposure assessment
- Toxicity assessment
- Risk characterization.

Following the human health and ecological risk assessments, a glossary defining common risk assessment terms is included as Section 15.3.

15.1 HUMAN HEALTH RISK ASSESSMENT

This HHRA assesses the potential risks to future receptors associated with on-site exposure to COCs detected in soil, groundwater, sediment, or surface water sampled in the PSF study areas. Sites within each study area were evaluated separately under industrial or recreational land use scenarios, depending on the predominant potential future land use of each site.

Following USEPA Region IX guidance, a residential PRG ratio assessment was performed as a screening-level residential scenario by calculating the ratio of the maximum detected site concentration of each COC to the appropriate USEPA Region IX residential preliminary remediation goal (PRG). This was applied at all RI sites using soil data prepared as defined for the industrial scenario (surface and subsurface soil) in addition to surface water, sediment, and groundwater, when available. If soil data were not prepared for the industrial scenario, soil data sets as defined for the recreational scenario (surface soils down to 2 ft only) were used. For each site, the resulting ratio values were then summed for all ratios in which the PRG was derived based on cancer risk. This total ratio was multiplied by 1E-06 to estimate cumulative risk. A separate total was calculated for ratios in which the PRG was derived based on noncarcinogenic hazard to estimate cumulative hazard. If the USEPA Region IX PRG was not risk-based (i.e., based on the soil saturation equation ["sat"] or ceiling limit concentration ["max"]), the ratios were calculated but not added to the cumulative risk or hazards. California CPA PRGs ("CAL-Modified PRG") were all assumed to have been derived from carcinogenic risk, except for lead, which was assumed to have been derived from noncarcinogenic hazard. COCs in the water from the PSF water supply (Lobos Creek and Well 13) were not included in any PRG ratio site assessment but were assessed separately.

The residential PRG ratio screening assessment is very conservative and does not include the detailed evaluation of exposure parameters as was performed in the recreational and industrial risk scenarios assessed in this RI report. The residential PRG ratio assessment is more conservative because it tends to assume larger exposure concentrations, includes all exposure pathways, sums the risks and hazards from all COCs, includes all exposure media, and assumes a greater exposure duration and frequency. In contrast, the recreational and industrial scenarios assessed in this RI are based on conservative, but more realistic

exposure assumptions based on the future uses actually planned in the GMPA for the sites and site conditions that allow valid modification of exposure parameters. The results of the residential PRG ratio screening assessment are presented in Appendix U following the future land use scenario results and are summarized in Table 15.1-119. The PRG ratio screening results are included for informational purposes such as identifying sites where a more detailed residential risk assessment should be performed in the event that residential use is contemplated. Since residential use is not anticipated at any of the RI sites, the PRG ratio screening results do not contribute to the conclusions in this risk assessment.

The methods used in the HHRA comply with the USEPA's RAGS Volume I Human Health Evaluation Manual (Part A) (USEPA, 1989b) and CEPA guidance (CEPA, 1992). The RAGS document and supplements present the USEPA's most current risk assessment methodology and are the most complete documents of their kind. Therefore, the RAGS documents and supplements are often used as the primary source of risk assessment guidance for all types of site investigations. The CEPA guidance (Supplemental Guidance for Human Health Multimedia Risk Assessment of Hazardous Waste Sites and Permitted Facilities) provides California agencies-specific risk assessment guidance.

The human health risk assessment for the PSF study areas is organized and discussed according to the four steps common to most risk assessments:

- Identification of COCs
- Exposure assessment
- Toxicity assessment
- Risk characterization.

The principal tasks associated with these four steps are summarized in Figure 15.1-1. Each of these steps is described in the following sections. Section 15.1.1 describes the methodology for and identifies the COCs for human health at each of the study areas. Section 15.1.2 presents the exposure assessment for each site within the study areas, including characterization of the exposure settings, identification of exposure pathways, and quantification of exposure for pathways of concern. Section 15.1.3 presents the toxicity assessment, which includes a discussion of toxicity values used to assess risks associated with potential exposures. Section 15.1.4 presents the risk characterization by discussing the

quantification of carcinogenic risk and noncarcinogenic hazard estimates for each site. Also included in Section 15.1.4 is an analysis of uncertainties associated with the identification of COCs, the exposure assessment, the toxicity assessment, and the risk characterization. A summary and conclusions of the human health risk assessment is presented in Section 15.1.5.

15.1.1 Identification of Chemicals of Concern

The objectives of this step are to identify the chemicals that are of concern for human health and are likely to be site-related, and to select a data set of reported concentrations that is of acceptable quality for use in the quantitative risk assessment. A complete description of site investigations at each of the study areas is included in previous sections of the RI including sampling locations and rationale, analytical results, and quality assurance and quality control considerations.

To perform the BRA, specific kinds of site characterization data (e.g., surface soil, subsurface soil, groundwater, sediment, and surface water samples and analyses) were required to ensure complete assessment of health risks. Data collected to date at the PSF study areas were evaluated to ascertain its appropriateness and adequacy for use in the risk assessment. In addition, data were evaluated to ensure its usability for risk assessment per the Guidance for Data Usability in Risk Assessment (USEPA, 1990c). Wipe sample data were collected at some sites to identify the presence of residues on various surfaces; however, these data were considered unsuitable for estimating potential exposures and deriving quantitative risk estimates. Sediment samples collected from storm drains at various sites and water samples collected within the Nike Facility missile silos were also not considered in the risk assessment because, as discussed in Section 15.1.2, exposure to these media is unlikely under land use scenarios.

The following subtasks were performed on the data sets for each site and media during the identification of COCs from COPCs:

- Removal of soil samples greater than 15 ft deep
- Removal of analytes with no detections
- Removal of essential human nutrients (calcium, iron, magnesium, potassium, and sodium)

- Multiplication of the CRL of non-detected analytes by 0.5 as a conservative proxy concentration
- Removal of the lower concentration of filtered and unfiltered samples of groundwater analytes
- Averaging of duplicates and triplicates
- Separation of soil samples by depth into surface and subsurface soil
- Removal of surface and subsurface soil inorganic non-COPCs identified in the ambient analysis
- Removal of analytes with frequency of detections (FODs) less than five percent
- Removal of analytes with maximum detected concentration less than the appropriate USEPA Region IX residential PRG and California primary and secondary MCLs

Analytes retained through the screening process represent the most prevalent, toxic, persistent, or mobile contaminants at each PSF study area or site. These COCs were used in the remaining quantitative and qualitative steps of the risk assessment. The data sets which were used in the quantitative HHRA are provided in electronic form on diskettes in Appendix U.

The COPC to COC screening for each site with the assessed study areas are presented in Tables 15.1-1 through 15.1-49, organized by site and environmental medium. Included in these tables are the number of detected samples, the total number of samples, the frequency of detection (FOD) (i.e., the number of samples in which the analyte was detected divided by the total number of samples), the maximum and minimum detected values, the USEPA Region IX residential soil or tap water PRG, the California MCL (where appropriate), and the decision of whether the COPC remains a COC. COPCs are considered COCs if the FOD is greater than 5 percent and the maximum detected value is greater than the USEPA Region IX residential PRG or the California MCL.

Based on the results of chromium VI analyses conducted on four ambient and two investigative soil samples, 0.1 percent of total chromium is assumed to be chromium VI and 99.9 percent is assumed to chromium III for all soil and sediment samples. For groundwater and surface water samples, 100 percent of chromium is conservatively assumed to be chromium VI, the most toxic oxidation state of chromium.

Lead was assessed differently than the other COPCs in this HHRA. A soil lead screening value of 840 mg/kg was applied to sites with industrial and recreational future land use scenarios. If the maximum lead concentration in soil samples was above the lead soil screening value, lead is considered a COC at that site. However, there are no toxicity values for lead and it was not quantitatively assessed. Maximum concentrations above the lead soil screening value are discussed for each site where appropriate.

Total petroleum hydrocarbons (TPH) were evaluated using surrogates following the assessment of storage tanks methodology presented in the Fuel Product Action Level Development Report (FPALDR) (Montgomery Watson, 1995e). The fuel constituents include both the more toxic or mobile constituents such as BTEX as well as surrogate compounds such as naphthalene, n-hexane, n-nonane, and n-eicosane that would represent the characteristics of bulk petroleum products. If no BTEX was found at a site they were dropped from the list of fuel constituents. Individual components of the complex TPH mixture have not been identified; thus, toxicity criteria cannot be developed to assess exposures to the mixtures and surrogates must be assigned. When TPH-diesel fraction was a detected analyte, the maximum detected concentration was multiplied by and compared against the product action level for the appropriate aliphatic and aromatic surrogate constituents (n-nonane - 65 percent and naphthalene - 35 percent, respectively). This comparison evaluated the effects of the main constituents of diesel fuel. For TPH-gas fraction, the aliphatic (n-hexane - 60 percent) and aromatic (naphthalene - 40 percent) surrogate constituents of gasoline were evaluated in the same way as the TPH-diesel fraction evaluation. The TPH-fuel oil fraction surrogates were n-eicosane (aliphatic - 65 percent) and naphthalene (aromatic - 35 percent). If the COPC for a particular site was listed as just TPH, the site history was further evaluated and a designation of either TPH-diesel fraction or TPH-gas fraction was assigned to the site based on the history and best professional judgment. If a distinction was not possible, the most conservative fraction, TPH-gas fraction, was assumed.

Lobos Creek has been used in the past and is assumed to be used in the future to provide 90 percent of the water supply for the PSF. The remaining 10 percent of water supply is assumed to be from Well 13. Table 15.1-39 provides the analytes and maximum

concentrations found in Lobos Creek and Well 13. The corresponding percentage from both sources was calculated with the resulting PSF water supply concentration provided in Table 15.1-39. The PSF water supply COPC concentrations were compared with USEPA Region IX PRGs for residential tap water (USEPA, 1996) and California Primary and Secondary MCLs as presented in the table. If the PSF water supply concentration for a COPC was less than either the PRG or MCL, it did not remain a COC.

The results of the COPC to COC screening analyses for environmental media of concern at the PSF Study Areas are summarized in Table 15.1-50. The data summary table shows that a variety of inorganic compounds, volatile and semivolatile organic compounds, PAHs, PCBs, pesticides, and/or water quality parameters were determined to be COCs in the environmental media sampled.

Although inorganics were identified as COCs at the study areas, the levels present in soil at each site are not necessarily related to site operations. Because inorganics are natural constituents of the environment, concentrations of inorganics of concern may be within the true range of normal ambient levels, even though they exceeded the site-specific ambient soil concentrations.

Bis(2-ethylhexyl) phthalate was identified as a COC for several sites; however, this chemical may not be site-related because it is frequently detected in the environment as a laboratory contaminant or constituent of many types of plastics. Additionally, bis(2-ethylhexyl) phthalate and related phthalates do not exist as compounds not in a mixture with other chemical in the environment. Phthalates are ubiquitous indicator compounds for common plastics, and their increased concentrations in the present context can be used most reliably in detecting household and other refuse landfilling or similar activities.

At several sites, not all samples were analyzed for all potential analytes. Consequently, the list of COCs may not be complete. This possibility is very small because sampling data were collected and analyzed after careful consideration of likely sources of contamination at the PSF. Thus, the likelihood that chemicals presenting significant risks to receptors at the PSF were not identified in this evaluation is very low.

The concentration term, hereafter referred to as the exposure point concentration, in the exposure equation (discussed in Section 15.1.2.3 -- Quantification of Exposure) is meant to reflect the average concentration, contacted at the exposure point, over the exposure period (USEPA, 1989b, 1992b). The maximum detected value, the 95 percent UCL, and the exposure point concentration for each COC are presented in Tables 15.1-51 through 15.1-85. The exposure point concentration is the lesser of the maximum detected value or the 95 percent UCL.

15.1.2 Exposure Assessment

Exposure assessment is the process of identifying human populations that could potentially come in contact with site-related chemicals and estimating the magnitude, frequency, duration, and route(s) of potential exposure. The exposure assessment phase of the risk assessment includes the following steps: identification and characterization of exposed populations, evaluation of exposure pathways, estimation of contaminant concentrations at exposure points, estimation of human intake rates, and calculation of intake factors. Each of these steps is described below.

15.1.2.1 Identification and Characterization of Exposed Populations

The first step in exposure assessment is to characterize each site in terms of its physical setting, land use, and associated human populations that may be exposed to site-related chemicals. This information is used to identify possible exposure pathways for each potentially exposed population and to determine appropriate exposure intake variables to quantify exposure. A general description of local demographics, land use, and the physical setting of the PSF, including climate, topography, geology, and hydrology, is provided in Section 2. Specific information on each study area, including location, past and current land use, geology, and hydrogeology, is provided under the area descriptions, sample location rationale, and geologic setting sections for each study area.

Based on future land use patterns described in the GMPA at the PSF, the following human populations could potentially be exposed to contaminants found at, or originating from, the site:

- **Workers** - Since the Presidio is currently and will continue to be operational, workers at the site are potential receptors. If complete exposure pathways to these site workers are identified, then the risks to such site workers will be addressed. PSF site workers are categorized in the HHRA under one exposure scenario, the industrial scenario. The industrial scenario includes two different assessments. The first industrial scenario includes the site workers identified in the GMPA as institutional workers, commercial/office workers, or industrial workers. The second industrial scenario includes the construction workers exposed to groundwater at the proposed wetlands restoration area and the Building 900s Series Study Area UST remediation project. These two industrial scenarios have different exposure parameters assumed for exposure to the different workers as discussed in Section 15.1.2.3 Quantification of Exposure.
- **Recreational Visitors** - Recreational site visitors are a potential receptor population at the PSF, which contains numerous trails and roads that are used by the general public for hiking, bicycling, and other forms of recreation.

This HHRA did not include a separate NPS Park Rangers/maintenance staff land use scenario. The conservative exposure scenarios evaluated in the HHRA adequately evaluate potential risks posed by the sites to the NPS workers and an additional separate exposure scenario receptor is not needed. Areas where the NPS maintenance staff would be spending the majority of their time (an average of 80 percent) in direct contact with the soil are not located in contaminated sites and groundskeeping activities in contaminated sites would be intermittent. In addition, when the NPS employees are working in sites assessed under the recreational or industrial scenarios, the conservatism of these scenarios would also include potential exposure to the NPS workers.

As the following discusses, many sites within the study areas are or have been used for light industrial or commercial purposes in which workers may be exposed to chemicals in environmental media (e.g., soil, air, and water). Occupational exposures to chemicals or hazardous wastes generated by on-site use of such chemicals are regulated by the

Occupational Safety and Health Administration (OSHA) and, thus, were not evaluated in this risk assessment.

For each specific site within a study area, the potential for future receptors to be exposed to on-site chemicals was evaluated under a recreational or industrial exposure scenario. These scenarios reflect the differences in potential exposure pathways and intake variables of the receptor populations. Generally, if more than one receptor population was possible at a site (e.g., workers and site visitors), the exposure scenario presenting the highest potential for exposure was selected for inclusion in this evaluation. At some sites, exposures to surface soil were not evaluated because of paving or buildings at the sites. Therefore, data were collected only in deeper (nonaccessible) soil. The exposure pathways and intake variables associated with each exposure scenario are discussed in detail in Sections 15.1.2.2 and 15.1.2.3, respectively.

15.1.2.2 Evaluation of Exposure Pathways

This section identifies exposure pathways applicable to the potentially exposed populations at each site. An exposure pathway is defined as the course a chemical takes from a source to an exposed organism. Exposure pathways include the following four elements:

- A source
- A mechanism of release, retention, or transport of a chemical in a given medium (e.g., air, water, or soil)
- A point of contact with the affected medium (i.e., exposure point)
- An exposure route at the point of contact (e.g., ingestion or dermal contact).

If any of these elements is missing, the pathway is considered "incomplete" (i.e., it does not present a means of exposure). Table 15.1-86 presents the PSF RI study areas and sites with corresponding media, scenarios, and exposure pathways. The exposure pathways associated with each environmental medium of concern are described in the following section. The exposure scenarios and exposure pathways applicable to each site based on future land use are then identified. Table 15.1-87 presents the PSF RI study areas and sites with corresponding media and inorganic COPCs for the residential PRG ratio screening assessment.

15.1.2.2.1 Overview of Exposure Pathways by Environmental Medium

An exposure pathway consists of four elements. Sources of chemicals and actual or potential mechanisms of release and transport are described for each study area in the area description and results evaluation sections. This section discusses the last two elements of exposure pathways (i.e., point of human contact and exposure routes) for the following environmental medium of concern:

- Soil
- Groundwater
- Surface water
- Sediment
- Air

15.1.2.2.1.1 Soil

Receptors are most likely to come in contact with site-related chemicals via dermal contact and incidental ingestion of surface soil. Such exposures are most likely for younger children who may frequently come in contact with soil during outdoor play activities. Adults may also come in contact with surface soil while engaging in recreational activities. For the industrial scenario, workers may be exposed to both surface and subsurface soil chemicals, particularly during construction activities. For this HHRA, surface soil was considered to be soil from surface level to 0.5 ft below surface and subsurface soil was considered to be soil from below 0.5 ft bgs.

For sites located along the San Francisco Bay for which recreational open space scenarios are proposed, as a conservative estimation of children digging in the sand, surface soil was considered to be soil from surface level to 2 ft bgs and subsurface soil was considered to be soil from below 2 ft bgs. These sites are designated with "SS (2)" in the recreational pathways assessed column in Table 15.1-86.

Soil samples within the Crissy Field Study Area and EOM areas designated as within the proposed wetlands footprint might be brought to the surface and spread out along the San Francisco Bay. The soil sample sites within the proposed wetlands restoration area are indicated in Figure 15.1-2. To conservatively assess the exposure to recreational visitors, the

soil from the samples at 0 to 15 ft in the proposed wetlands footprint were separately assessed for incidental ingestion of and dermal contact with for the recreational visitor.

Inhalation of VOCs migrating upward through soil is not expected to be a significant exposure pathway. There are no basements or shower facilities in these areas that could provide a means of exposure. However, two VOCs classified by USEPA as human carcinogens, benzene and vinyl chloride, were detected in groundwater at the Building 900s Series Study Area. To support the supposition that inhalation of VOCs is not a significant pathway for receptors, even if paving in the Building 900s Series Study Area is removed, an evaluation of potential air concentrations of benzene and vinyl chloride resulting from volatilization from groundwater is provided. Although there is high uncertainty in some values used in the calculations, conservative modeling assumptions and parameter values were used consistently.

The concentrations of benzene and vinyl chloride in the air were estimated following release from the soil as discussed in the following paragraphs.

Atmospheric Calculation - A simple box model was used to estimate the concentrations of chemicals in the air following release by soil. The following assumptions were made when using this model:

- The chemicals are uniformly distributed in the box
- There is no lateral dispersion
- There are no degradation processes occurring in the box.

The equation for the box model is:

$$C_{\text{air}} = \frac{J \times L \times W}{U \times H \times W \times k}$$

where:

- C_{air} = the concentration of chemical in the air (mg/m^3)
- J = the average chemical flux to the box ($\text{mg}/\text{m}^2\text{-day}$)
- $L \times W$ = the area of the bottom of the box across which the flux occurs (length x width)
- U = the wind speed through the box (m/s)
- H = the mixing height (box height) (m)
- k = a conversion constant between days and seconds (1 day/86,400 seconds).

The dimensions of the box were determined by the dispersion characteristics of the atmosphere (height), the path length along which the air would be accumulating chemicals (length), and an arbitrary width of 1 m. Width is not an important parameter in this calculation because lateral dispersion is assumed to be zero and all fluxes are assumed to be uniform across the width of the site (both conservative assumptions). Therefore, width drops out of the equation.

The prevailing wind path runs from the Building 979 area toward the Building 937 area, which allows air to accumulate chemicals along the path. The length of the wind path was taken as the distance from the well immediately upwind of the first well with a detectable chemical to the well immediately downwind of the last well with a detectable chemical. Two path lengths were used for benzene and vinyl chloride because these chemicals were distributed differently in groundwater. Vinyl chloride was found in groundwater below both the Buildings 979 and 937 areas, whereas benzene was limited to the Building 937 area. One detectable concentration (0.07 mg/L) of benzene was found at Well 979GW05; however, the path length was not extended into this area. This was done because the concentration was very low and extending the box into this area would decrease the average. The length of the wind path for vinyl chloride, which started at Well 979GW04 and ended at Well 937GW35, was 200 m. The wind path for benzene started at Well 937GW28 and ended at Well 937GW26, a distance of 100 m. The flux at any point along the bottom of the box varied depending on the concentrations in each well. The flux used in the calculation was the average calculated flux for all wells along the path length. For vinyl chloride, fluxes of <0.025, 9.6, 0.06, 1.4, 5.6, and <1.9 mg/m²-day were used to obtain an average flux to the box of 3.1 mg/m²-day. For benzene, fluxes of <5.5E-04, 0.076, 0.0038, 0.55, and <5.5E-04 mg/m²-day were used to obtain an average value of 0.13 mg/m²-day.

Gaussian distributions are commonly used to characterize the distribution of chemicals in the atmosphere following release from a source (Wark and Warner, 1976). In this approach, horizontal and vertical dispersions are quantified by sigmas (analogous to the standard deviation), which are controlled by wind speed, atmospheric stability, and distance from the source. The mixing height for the box was taken as the Gaussian sigma used to quantify vertical dispersion. Based on a wind speed of 4 m/s and moderate solar radiation, the site

was predicted to have a stability class from B to C. A Class C atmosphere is more stable (i.e., less dispersion) than Class B and, therefore, was used for estimating vertical dispersion. Over the short distances encountered in the Buildings 979 and 937 area, vertical dispersion is nearly linearly proportional to distance from the source. Therefore, average box heights were taken as the vertical sigma at the midpoint along the box. Because the source is at ground level, the mixing height was taken to be 1 sigma instead of 2 sigma. For Class C conditions, the values for sigma at 50, 100, and 200 m are 4, 7, and 14 m, respectively (Wark and Warner, 1976). Box heights used for benzene and vinyl chloride were 4 and 7 m, respectively.

The atmospheric concentrations of benzene and vinyl chloride estimated with this model were 0.009 mg/m³ and 0.26 mg/m³, respectively. The corresponding cancer risk estimates for benzene and vinyl chloride were 7E-09 and 5E-07, respectively, assuming a recreational exposure scenario (i.e., exposure occurs 4 hrs/day, 150 days/yr for 30 yr, with an assumed inhalation rate of 20 m³/day for a 70-kg adult) and using the CEPA inhalation cancer slope factors (CSFs) of 0.1 and 0.27 (mg/kg-day)⁻¹, respectively.

15.1.2.2.1.2 Groundwater

Groundwater sources (Wells 6 and 13) near the water treatment plant were previously mixed on an as-needed basis with water from Lobos Creek (and occasionally from the City of San Francisco water system) to supply potable water to the PSF. The source of the water has been from the City of San Francisco since August, 1994. The existing water treatment plant has recently been upgraded but is not currently operating. When operational, the retrofitted treatment plant is assumed to receive water from Lobos Creek and Well 13 only. Well 6 will be capped and not used. On-site workers, may be exposed to the COCs in the PSF water supply (lead, manganese, and nitrate). Workers could be exposed via both oral ingestion and dermal absorption during showers.

Groundwater sampled from sites in several study areas not located along the San Francisco Bay or the Pacific Ocean was considered of sufficient quantity and potentially potable. These sites are the Nike Facility, Building 215, Fill Site 6, and Building 662. These sites were

assessed separately with exposure to groundwater as the water source with the same pathways as described in the previous paragraph for the PSF water supply.

Construction workers of the proposed wetlands restoration area of Crissy Field Study Area may be exposed to contaminants in the groundwater at those sites (a portion of Fill Site 7 and all of EOM) during construction of the wetlands. The groundwater sample locations in the proposed wetlands restoration area are indicated in Figure 15.1-3. In addition, construction workers at the Building 900s Series Study Area might also be exposed to groundwater during UST remediation procedures. As a conservative measure, these construction workers were assessed quantitatively for ingestion of and dermal contact with the groundwater during restoration and remediation activities.

Inhalation of VOCs migrating from groundwater upward through soil is not expected to be a significant exposure pathway. There are no basements or shower facilities in these areas that could provide a means of exposure. However, two VOCs classified by USEPA as human carcinogens, benzene and vinyl chloride, were detected in groundwater at the Building 900s Series Study Area. To support the supposition that inhalation of VOCs is not a significant pathway for receptors, even if paving in the Building 900s Series Study Area is removed, an evaluation of potential air concentrations of benzene and vinyl chloride resulting from volatilization from groundwater is provided. Although there is high uncertainty in some values used in the calculations, conservative modeling assumptions and parameter values were used consistently.

The concentrations of benzene and vinyl chloride in the air were estimated calculating the flux of VOC contaminants from the groundwater across the soil surface as discussed in the following paragraphs.

Flux Calculation - The following assumptions were used in calculating the flux of these chemicals to the atmosphere:

The rate limiting step in transport is diffusion of gaseous chemicals through the vadose zone.

- The concentration in the gas phase (C_g) at the water table is in equilibrium with the concentration in the groundwater (i.e., Henry's Law is applicable).

- The concentration in the gas phase at the soil surface is much less than the concentration in the gas phase at the water table (i.e., the concentration at the soil surface is ~0).
- There are no degradation or attenuation mechanisms occurring in the soil.
- The concentrations of benzene and vinyl chloride in the groundwater are constant with time (i.e., the chemicals are not depleted).
- The system is at steady-state.

To calculate the flux of these chemicals across the soil surface, Fick's Law was used:

$$J = D_g \times F_t \times \frac{dC_g}{dx}$$

where:

- J = the flux (mg/m²-s)
- D_g = the binary gas diffusion coefficient for the chemical (m²/s)
- F_t = a tortuosity factor for diffusion in soil (unitless)
- dC_g = the concentration difference across the boundary layer (mg/m³)
- dx = the distance across which the concentration difference exists (m).

Diffusion coefficients were calculated for each chemical using the method of Fuller et al. (1966, as cited in Lyman et al., 1982). The tortuosity factor was calculated using the equation of Millington and Quirk (1961):

$$F_t = \frac{a^{10/3}}{p^2}$$

where:

- F_t = tortuosity factor
- a = the volumetric air content
- p = the porosity of the soil.

The soil in the vadose zone in the Building 900s Series Study Area is primarily a sandy silt with an estimated porosity of 0.40 (Freeze and Cherry, 1979). The air and water contents by volume were estimated to be 0.13 and 0.27, respectively. These values are midway between typical values used for sand and clay (Jury et al., 1990). The concentrations in the gas phase directly above the water table were calculated from the most recent data on chemical concentrations in the groundwater at the site and Henry's Law constant (Kh). Values of Kh

were compiled from several sources and averaged. The Kh values for benzene from the different references varied by only 10 percent, but those for vinyl chloride varied over two orders of magnitude. A value for dCg was calculated from the estimated concentration in the gas phase at the water table minus zero. This is a conservative approach in that it maximizes the concentration gradient. The boundary layer thickness (dx) is the distance from the water table to the soil surface (about 2 m).

Fluxes were calculated using the most recent data for each well for which groundwater had been analyzed. The calculated fluxes for benzene and vinyl chloride ranged from $<3.3E-05$ to $0.55 \text{ mg/m}^2\text{-day}$, and <0.025 to $9.6 \text{ mg/m}^2\text{-day}$, respectively.

15.1.2.2.1.3 Surface Water

Surface waters that visitors to the PSF may contact while engaging in recreational activities include El Polin spring, Lobos Creek, Mountain Lake, and at the seep on Baker Beach Study Area Disturbed Area 1. Contact with surface water at the Nike Facility is very unlikely. Incidental ingestion and dermal contact were the exposure routes evaluated for the surface water medium.

Incidental ingestion of and dermal contact with surface water at El Polin spring, Lobos Creek, Mountain Lake, and the seep on Baker Beach Study Area Disturbed Area 1 could occur during activities such as wading in the spring, creek, lake, or seep or playing along the banks. Lobos Creek is not easily accessible because of its location in a ravine and the thick vegetation near the creek's bank. The NPS plans to reestablish the natural drainage in the El Polin spring area for which they anticipate little, if any, potential for recreational contact. In addition, the Baker Beach Study Area Disturbed Area 1 on which the seep is located is a steeply-sloped and heavily vegetated area making it also not easily accessible. Therefore, exposures to these surface waters were evaluated only for older children (ages 9 to 18) in the recreational scenario, as they represent the most likely age group that might participate in this type of activity. Because of the difficult access to Lobos Creek and the seep on Disturbed Area 1, younger children and adults will, most likely, not play in these water bodies. Similarly, only older children are likely to ingest or have dermal contact with water from El Polin spring. While Mountain Lake is not a posted source of recreational swimming

water, the older child was also assessed at Mountain Lake as a future potential recreational receptor. When the exposure parameters are compared between an older child (ages 9 to 18) and a younger child (ages 0 to 8), there is an insignificant difference in exposure via ingestion of and dermal contact with surface water. In addition, toxicity values do not differentiate between an older child and a smaller child, resulting in similar risk assessments. Therefore, while an older child is assessed with exposure to surface water at Mountain Lake, there would not be a significant difference than if a younger child were assessed to the same surface water COCs. Surface water is not expected to be a significant pathway of exposure for workers, because these water bodies do not support any industrial or commercial activities that may result in incidental ingestion of water.

Lobos Creek has been used in the past and is assumed to be used in the future to provide 90 percent of the water supply for the PSF. The remaining 10 percent of the PSF water supply is assumed to be from Well 13. Industrial workers at the PSF may be exposed to the PSF water supply via ingestion or dermal contact during showering.

15.1.2.2.1.4 Sediment

Older children may contact sediment in El Polin spring, Lobos Creek, Mountain Lake, or the Baker Beach Study Area Disturbed Area 1 seep while playing in the surface water. As with the exposure to surface water, exposure may be via dermal contact and incidental ingestion and these exposure routes were assessed quantitatively in the risk assessment. Younger children and adults are not likely to contact sediments in these water bodies for the reasons discussed under the surface water discussion. Although some sediment samples were taken from storm drains at other sites to investigate potential transport and migration of chemicals, exposure to these sediments is highly unlikely under any scenario. Therefore, these samples were not evaluated. However, soil beneath pavement, in open ditches, or at the outlets of storm sewers was evaluated for these sites.

15.1.2.2.1.5 Air

Human exposure to chemicals in air may occur from the generation and transport of fugitive dust. This is not likely to be a significant exposure pathway for receptors because most sites are either paved or have significant vegetation that would effectively inhibit the generation of

fugitive dust. Therefore, fugitive dust was not analyzed in this risk assessment. However, because paving is likely to be removed from some sites adjacent to San Francisco Bay (particularly in the Crissy Field Study Area) as part of their conversion to a recreational area, exposures via inhalation of fugitive dust may be of concern. Air monitoring data are not available for any sites at the PSF. An evaluation of the significance of fugitive dust inhalation as a potential exposure pathway is provided in Section 15.1.2.3.11.

15.1.2.2.2 Summary of Exposure Pathways by Study Area

In this section, land use and the corresponding exposure scenario used to evaluate potential exposures under present conditions are summarized for the various sites within each study area

15.1.2.2.2.1 Nike Facility

The Nike Facility is a 6-ac site located on Battery Caulfield Road, bordered by the Building 1400s housing area to the north, the former PHS area to the south, the Presidio Golf Course to the east, and the 1500s housing area to the west. The facility is situated on a terraced, south facing slope with large trees along two of its borders and within its perimeter. The facility contains three abandoned missile silos and Buildings 1450 and 1451. Building 1450 is a two-story poured-concrete structure that was used by U.S. Army Explosive Ordnance Demolition (EOD) personnel for administration purposes. Building 1451 is a single-story concrete garage that was used for facility maintenance. The missile silo area used by the NPS to store trash dumpsters as well as woodchips and gravel for landscaping. The Nike Facility is surrounded by a 6-ft, chain-link and barbed-wire fence, and another fence separates the buildings from the missile silo area. Access to the buildings and missile silo area is also restricted. Because both Buildings 1450 and 1451 are restricted only to workers, potential exposures to site-related chemicals were evaluated in an industrial (institutional) scenario. No COCs were determined following the COPC screening in surface or subsurface soils. Therefore, Buildings 1450 and 1451 were assessed with exposure to the PSF water supply COCs only.

While the silo and storage area is surrounded by a fence, there may be future access to this area by recreational visitors, and exposure to soil contaminants was evaluated in a recreational scenario.

Soil and groundwater samples were collected at the Nike Facility. Samples of water, probably from surface seepage, in the Nike Facility missile silos and sediment samples from storm drains and ground surfaces within the missile silos area were also collected for laboratory analysis. Because the missile silos are covered by steel-plate bay doors that are welded shut, exposure pathways are incomplete for surface water. However, this water may potentially percolate into groundwater via soil. Thus, wells were installed downgradient from the silos to monitor groundwater. Use of groundwater at the Nike Facility for the water source in addition to water from the PSF water supply (Lobos Creek and Well 13) was assessed for the institutional worker although it is not anticipated due to very poor well yield and high TDS values.

Sediment samples collected in the perimeter drainage ditch and from paved surfaces were included in the soil assessment. Other sediment exposure pathways are incomplete because the other samples were collected in storm drains where exposure is highly unlikely.

15.1.2.2.2 Crissy Field Study Area

The Crissy Field Study Area is a relatively flat area situated north of U.S. Highway 101 in the north-central region of the PSF. The study area can be divided into the following five subsections and the proposed wetlands restoration area which includes portions of Fill Site 7 and all of EOM:

- The Consolidated Motor Pool facility, which contains Buildings 634, 640, 642, and 643
- The Petroleum, Oil, and Lubrication (POL) Area, which contains Buildings 637 and 638
- Fill Site 7, which includes the fenced area of the Crissy Field Study Area helipad, the landing strip, and GGNRA land
- Buildings 609, 611, and 633, and
- The Sewer Lift stations.

This section discusses land use, potentially exposed populations, and potential exposure pathways for each site included in the Crissy Field Study Area, organized by building

number and then alphabetically by site. The potential for receptors to be exposed to site-related chemicals was evaluated under a recreational scenario except for Buildings 640 and 643 which were evaluated together under the industrial scenario (institutional). For each of the sites evaluated under the recreational scenario, surface soil samples included those soil samples taken from 0 to 2 ft bgs to protect recreational children digging in the sand.

Building 609, originally built in 1919, was demolished and reconstructed in 1987 and now serves as the PSF commissary. A pesticide spill in the building was reported in the Enhanced Preliminary Assessment (ANL, 1989). Further investigation of the incident indicates that the spill involved a small amount of household pesticide that fell off a shelf at the commissary. No analytes were determined to be COCs following the COPC screening in the surface soil samples to 2 ft bgs for Building 609. Therefore, exposure to soil by receptors at Building 609 is not expected to cause a risk or hazard.

Building 611 no longer exists, but was a transformer storage vault. Documentation of previous transformer inventories and possible spill incidents is not available. PCBs were not detected in surface soil samples collected at this site. Thus, there are no complete exposure pathways associated with Building 611.

An outdoor firing range southwest of Building 633 was used for small arms and rifle target practice. The area is overgrown with vegetation and currently bounded by a concrete backstop on one side and a chain-link fence and an asphalt parking lot on the other. A concrete floor under the backstop contains sand which ranges from 2.5 to 5 ft in depth. Soil samples from 0 to 2 ft sampled during the Follow-on RI did not have any analytes determined as COCs following the COPC screening. Building 633 was not quantitatively assessed in the HHRA.

Building 634, built in 1978, was used to store a variety of materials. Substances most recently stored in the building include motor oil, primers, lubricants, paint thinner, sulfuric acid, chlorine (for pools), hydraulic fluids, insecticides, cleaning compounds, brake fluid, floor waxes, and sodium hydroxide. Hazardous wastes were removed from the building by a commercial contractor. The only samples taken from this site are wipe samples. Because the

area surrounding Building 634 is paved, all exposure pathways appear to be incomplete. Building 634 was not quantitatively evaluated in the risk assessment.

Buildings 637 and 638 are both located in the POL Area, which is surrounded by a fence. Building 637 was a small fuel control building; historical photographs indicate evidence of previous fuel leakage and spillage in the area of the building. However, many of the historically stained areas are now covered by concrete pavement. All tanks, underground piping, fuel islands, and pump control house (Building 637) were removed in September 1993 (Montgomery Watson, 1995e). Building 638 is a storage building for inflammable materials, but data were unavailable on the specific types of materials stored there. There is a spill containment system near the building and some evidence that spills have occurred in this area. The associated USTs, were removed in 1993 (Montgomery Watson, 1996a). Because the source of contamination for both Buildings 637 and 638 is the fuel tanks, the sites are being assessed under the USCOE petroleum cleanup program and not in this risk assessment.

Building 640 was built as an airplane maintenance hangar in 1928, has an unbermed concrete floor, and was recently used for vehicle maintenance. Previous chemical spills in the building have not been reported. Staining outside the building, in areas now covered with cement pavement, is evident in historical photographs. Hazardous waste was removed from Building 640 by a commercial contractor. Building 640 is frequented by workers. The area surrounding the building is paved and groundwater is not used in the area. A sediment sample collected from the storm drain approximately 60 ft north of Building 640 and wipe samples from both buildings 640 and 643 were not assessed in the risk assessment because they do not represent a complete pathway. Building 643, a former aircraft hangar, was recently used as a maintenance shop for electronic equipment. Although solvents have been routinely used during operations, previous spills in the building have not been documented. Because of the close proximity and similar contamination sources, Buildings 640 and 643 were combined and assessed in the risk assessment together. Therefore, potential exposures to site-related chemicals were evaluated in an industrial (institutional) scenario.

Building 642 contains an emergency generator in its cinder block structure. Fuel oil spilled from an aboveground storage tank in October 1993 resulted in a 10 ft by 10 ft stained area

on pavement adjacent to the tank (HLA, 1994). No analytes were determined to be COCs following the COPC screening in the surface soils from 0 to 2 ft containing leaked material. Therefore, it is unlikely that soil at Building 642 will result in excess cancer risk or noncarcinogenic adverse health effects to potential receptors.

Fill Site 7 extends almost the entire length of the old Crissy Field Study Area complex. Reports indicate that the site may have been used as a disposal area for waste oils and solvents. There is some uncertainty as to what materials were used to fill the marsh, but the *Enhanced Preliminary Assessment Report* (ANL, 1989) and *Wetland and Riparian Corridor Restoration Feasibility Study* (Dames & Moore, 1995b) reported that the area was filled with bottom muds and sediments dredged from San Francisco Bay in preparation for the 1915 Panama Exhibit, construction debris resulting from the 1906 earthquake, and sand. Recreational visitors could be exposed to soils from Fill Site 7, including the helipad area. A recreational scenario was assessed with soils from 0 to 2 ft.

Fill Site 7 is included in the proposed wetlands restoration area as it was in the wetlands area prior to 1870. Workers constructing the wetlands on Fill Site 7 and EOM could be exposed to groundwater during construction and an industrial scenario evaluating exposure to groundwater was assessed. In addition, soil samples within the proposed wetlands restoration area footprint from 0 to 15 ft were assessed for the recreational visitor scenario because this soil may be distributed along the bay following construction.

Two Sewer Lift Stations are located near the Crissy Field Study Area and used to pump industrial wastes and sewage over the higher elevations of the PSF. The stations have failed during storms due to intermittent power from the emergency generators, and sewage is believed to have overflowed to the storm drain network. Soil and groundwater samples have been analyzed near the two Sewer Lift Stations. The recreational visitor would not access the groundwater. Therefore, a recreational scenario was evaluated for this site with surface soils from 0 to 2 ft.

15.1.2.2.2.3 Building 900s Series Study Area

The Building 900s Series Study Area, which covers approximately 15 ac and is entirely fenced, is located on the northern boundary of the PSF. This study area is adjacent to the

FPCGS and is bounded by the San Francisco Bay to the east and by a cliff to the west (on top of which Long and Crissy Avenues are built). The topography of the area is relatively flat. Except for the shoreline, which is sand and riprap, most of the ground surface of the area is covered by concrete, asphalt, compacted sandy silt, or one of the 17 buildings in the study area. Most of the buildings in the Building 900s Series Study Area were constructed as maintenance facilities for airplanes using the Crissy Airfield. When airfield support activities were reduced in 1936, many of the buildings were converted to vehicle maintenance shops. On the basis of history and use, the study area has been divided into three parts: the Vehicle Maintenance Area, which contains Buildings 920, and 923 through 937; the Storage Area, which consists of Buildings 949, 950, 973, and 974; and Building 979, in the northern portion of the study area. Buildings in the Building 900s Series Study Area for which soil or groundwater data are available are discussed below numerically by building number. (See Section 6 for a detailed description of all buildings and sampling data available.) Potential exposure pathways for each site in this study area are summarized in the following paragraphs. Although the U.S. Army operations in the Building 900s Series Study Area have recently ceased, industrial scenarios are evaluated for most sites in the risk assessment because the NPS may resume institutional types of industrial activities in the future.

Buildings 920 through 937 are located in the southern portion of the study area and contained most of the PSF vehicle maintenance operations. Building 920 is located along the southern edge of the Building 900s Series Study Area, and was a former motor pool repair shop. During the early 1990s the building was used for parachute packing, inspection, and repair. Since 1993, the building has been used for furniture storage. A 12-in diameter metal cylinder, which may have been part of a hydraulic lift system, is located within the building. Two inactive 50-gal hydraulic oil tanks are believed to be located beneath the concrete slab, however, GPR performed in 1992 failed to locate the tanks (JMM, 1992b). Potential exposure is to contaminants in the soil. There were no analytes determined to be COCs following the COPC screen in the surface and subsurface soil samples for Building 920 and it was assessed in the HHRA only with exposure of the institutional worker to the PSF water supply (Lobos Creek and Well 13).

Building 926 was constructed on a concrete slab foundation in 1921 as an airplane hangar. The structure was used most recently for automotive body work, painting, and recharging and draining batteries. The aerial photograph taken in 1963 shows ground staining adjacent to the west wall of Building 926 (Rindgen and Sitton, 1990). Outside the north wall of the building were several transformers on metal rails. Paints, waste solvents, and old batteries are also stored outside of Building 926. Building 927 is adjacent to 926, in the northwest corner, and was used to store transformers. Materials used in and around this building complex include lead-based paints, waste oils, degreasing solvents, electrolytes, and thinners (including xylene). Subsurface soil samples were taken at Building 927 but no contaminants were detected. Therefore, only exposure of the PSF water supply (Lobos Creek and Well 13) to institutional workers was assessed.

Because of proximity and similar sources of contamination, Buildings 923 through 935 are grouped and assessed together in the HHRA and referred to as the Building 923 Area. Building 923 is a small transformer building located near the northwest corner of Building 924. An abandoned solvent dip tank was temporarily stored behind the building. Building 925 is a fenced transformer pad containing three transformers. The pad is located to the south of Building 923. Building 924 was originally built for support of the Nike-missile anti-aircraft defense program but in recent years was used for servicing large vehicles. Large amounts of lubricating oils and greases were stored and used in the building. Prior to the 1980s, waste drums were temporarily stored in the back of the building. Two active ASTs, containing bulk oil and waste oil, and transformers are located in the back of the building. A waste oil UST is also adjacent to the building. Three surface soil samples were collected behind Building 924. One of these samples was collected adjacent to Building 925, which is a small structure located along a fence behind Building 924. This area is closed from the public by fences.

Buildings 929, 930, 931, 933, 934, and 935 are located in close proximity to each other in the southern portion of the vehicle maintenance area and, thus, were considered a single site for purposes of characterizing potential exposures. This cluster of buildings, referred to as Building 929 Area, was primarily used for storage. Buildings 929, 930, and 931 were used for storage of materials including lead-based paints, waste oils, degreasing solvents,

electrolytes, and thinners. Building 929 also served as a compressed air plant. The area between Buildings 930 and 931 was used for steam cleaning and contains an underground concrete oil-water separator that was periodically drained. Spray painting of vehicles is done behind Building 931. In the past, USTs have been located in the vicinity of this building complex. Today, USTs containing hydraulic and used oils are located in the vicinity of Buildings 929 and 930. Building 933, previously used for aircraft maintenance and as a boiler house, was used for storage of tires, acetylene, and nitrogen tanks and equipment prior to closure of the maintenance area. Building 934 was used for vehicle maintenance, and Building 935 was a storage area. An inactive UST of unknown capacity and contents is thought to exist near the southeast corner of Building 934 (WES, 1990), however, GPR performed in 1992 failed to locate the tank (JMM, 1992b). Data were unavailable on the nature of the materials stored in Building 935. Surface and subsurface soil samples were collected at Buildings 929 through 935. Because Buildings 929, 930, 931, 933, 934, and 935 are surrounded by the fence that encompasses most of the Building 900s Series Study Area, the most likely receptors to be exposed to site-related chemicals are workers in the vehicle maintenance area. Exposures associated with Buildings 923 through 935 were evaluated in an industrial (institutional) scenario with exposures to soil and water from PSF water supply (Lobos Creek and Well 13).

Building 937, constructed on a concrete slab foundation, was the main vehicle maintenance shop at the PSF. Solvents, waste oils, fuels, paints, and thinners were used or generated at this building. Three outdoor vehicle maintenance pads, used for changing oil, are adjacent to the building. On the north side of Building 937 there were two inactive USTs that were removed in 1992 as part of the IRA. One of the USTs was reportedly used for diesel fuel, waste oil, paint and lacquer thinner, carburetor cleaners, and degreasing solvents and the other was reportedly used to store xylenes. There are no surface soil COCs determined following COPC screening. Because Building 937 could be used by the NPS for vehicle maintenance, potential exposures to soil associated with this site and water from the PSF water supply (Lobos Creek and Well 13) were evaluated in an industrial (institutional) scenario.

Centrally located in the Building 900s Series Study Area complex, Buildings 949, 950, 973, and 974 were open structures, on partial concrete slabs, that are used for storage of materials and equipment. These buildings were demolished by the NPS in 1996. POL materials used in Building 937 were stored in Building 950, and equipment used for sandblasting vehicles was stored in Building 973. The area between Buildings 973 and 974 was used for sandblasting. Although Buildings 949, 950, and 973 are surrounded by a fence, they are adjacent to Building 979. Recreational visitors are potentially exposed to site-related chemicals in surface soil. Exposures associated with these sites were evaluated in a recreational scenario. While Building 949 was assessed separately, there are no COCs determined in the soil samples following the COPC screening. Because of close proximity to and similar sources of contamination, Buildings 950, 973, 974, and 979 are assessed together. Building 979, approximately 660 ft northwest of Building 937, was originally constructed as a vehicle maintenance shop and gas station. More recently, the building was used for storage of construction materials, transformers, and paints. In 1982, approximately 50 to 100 gal of waste petroleum, oil, and lubricant materials were spilled at Building 979. The materials were quickly contained; however, no sampling was conducted to assess the effectiveness of the up. Two USTs and surrounding soil were recently excavated from the Building 979 area. At one time, there reportedly were three ASTs at the site. Potential exposure to soil in the recreational scenario, the future land use for these sites, was assessed.

Groundwater samples taken and analyzed for Buildings 937 and 979 were combined and assessed with incidental ingestion and dermal contact for construction workers remediating the USTs for the Building 900s Series Study Area.

15.1.2.2.2.4 DEH Study Area

The DEH Study Area has been used by U.S. Army personnel to provide administrative, storage, and maintenance support for the base and is located in the northeastern corner of the PSF. In addition, it provided a supply route to Fort Mason and San Francisco (Dames & Moore, 1995). It is bounded by the San Francisco Bay to the north, Allen Street to the south, Lyon Street to the east, and the EOM site to the west. During the course of U.S. Army activities, the majority of the ground surface in the DEH Study Area was covered with concrete or asphalt, and stormwater runoff was collected by a storm drain network that

discharged into San Francisco Bay (Figure 7.1-1). Currently, all of the buildings in the area have been demolished by the NPS in accordance with the reuse plan, and surface soils are exposed over the entire site. As part of the building demolition, existing utilities were disconnected and in part removed or abandoned. In addition, the permanent fences which had restricted access to the general DEH Study Area have been replaced with temporary construction fences.

Topographically, the DEH Study Area is relatively flat and was mostly paved. The DEH Study Area encompasses about 4.4 ac. Sampling data for surface or subsurface soils are available for Buildings 268, 269, 283, and 293. Adjacent areas also evaluated are a washrack next to Building 267, a storm drain near Building 286, and a maintenance shed (Building 287). The DEH Study Area's NPS land use classification is for recreational open space use (NPS, 1994) and all soil samples assessed were from 0 to 2 ft bgs to assess the potential situation of a child digging in the sand. Potential pathways of exposure to chemicals at these sites are summarized numerically by building number in the following paragraphs.

A wash rack, located near Buildings 267 and 268 in the northeast section of the DEH Study Area, consisted of a concrete pad and oil/water separator which drained to a storm drain. The storm drain discharged to San Francisco Bay. Subsurface soil (below 2 ft) around the storm drain near Building 267 has the potential to be exposed. A metal storage locker located on the north side of Building 287 contained gasoline containers and some of the containers may have spilled onto the surrounding soil. Building 287 was located in the northeast section of the DEH Study Area. Building 268 was used to store and repair DEH Study Area maintenance vehicles, and the area north of the building was used to store waste prior to offsite disposal. An fuel oil AST located north of Building 268 and another diesel AST, enclosed in a heavily stained concrete barrier was near the building, west of Building 266. In addition, debris, equipment, and raw materials were located north of the building. Interviews with PSF personnel indicated that transformers, which possibly utilized fluids containing PCBs, were stored adjacent to Building 268. Because of the close proximity and similar contamination, Buildings 267, 268, and 287 were assessed together. Exposures associated with this site were evaluated in a recreational scenario with surface soil to 2 ft.

Building 269, located in the eastern section of the DEH Study Area, was used to store and mix pesticide solutions. Waste pesticides (i.e., rinsates) were collected by a floor drain and routed to a subsurface holding tank adjacent to the building. Seven soil samples from four soil boreholes were collected near the underground tank. Because the area around the building was paved, direct contact with soil was not a complete exposure pathway. However, during the site survey for the Enhanced PA (ANL, 1989), the concrete around a drain on the north side of the building appeared to be stained and cracked. Building 293, a metal building set on a concrete slab foundation and situated in a row with other similar buildings, was used for storing pesticides. Although the building entrance was paved, the areas behind Building 293 and between buildings were exposed. Because of the close proximity and similar contamination, Buildings 269 and 293 were evaluated together. Potential exposure to surface soil to a depth of two ft was evaluated for this site under the recreational scenario.

Building 283 was previously used for removal and repair of aircraft engines. The building was more recently used for offices and a vehicle maintenance shop. The floor inside the shop was stained with oil. Wastes and oil were stored in drums in a small shed outside the shop area. Although the shed was surrounded by a berm to contain spills, the asphalt outside of the shed was stained. Because Building 283 is no longer an active workplace, potential exposures associated with this site were evaluated under a recreational scenario with surface soil to 2 ft.

Building 285, which was located in the western section of the DEH Study Area, was used for painting signs, vehicle components, and furniture with enamel and latex paints. Waste paints and thinners were drummed and sent to the DEH Study Area waste storage area prior to disposal offsite. Equipment that was used with latex paint was cleaned in a sink near the southeast corner of the building. Only one sediment sample was collected from the storm drain near Building 285. Therefore, there is no complete pathway to potential recreational visitors and this site was not quantitatively assessed in this risk assessment.

South of Building 286, in the northeast section of the DEH Study Area, there was a storage yard with various waste containers placed either on pavement or in a waste storage area. Stains were observed near the containers and in the storage yard (ANL, 1989). Used lead-acid batteries were stored in the yard in a second shed that was separate from the waste

storage shed. Stormwater runoff discharged to adjacent storm drains. Debris fill in the subsurface north of Building 286 was also sampled. Recreational visitors have a potential to be exposed to contaminants in surface soil to 2 ft and this site was evaluated under a recreational scenario.

15.1.2.2.2.5 Main Post Study Area

The Main Post Study Area has been used to support many U.S. Army functions including administration, maintenance, various services, housing, and entertainment activities. The Main Post Study Area is located in the northeastern portion on the PSF to the south and west of U.S. Highway 101. Approximately 70 to 80 percent of the Main Post Study Area is paved or covered by buildings; the remaining area consists of landscaped lawns and traffic islands. Topographically, the area gently decreases in elevation to the north, toward San Francisco Bay. The RI field programs for the Main Post Study Area included sampling of soil or groundwater at and around Buildings 215, 228/231, 1057, 1065, 1151, and 1167. The Main Post Study Area will probably be used by PSF personnel for industrial purposes due to the nature of the facilities in the study area. Therefore, all were evaluated under industrial potential exposure pathways as summarized in the following paragraphs.

Two leaking USTs and associated contaminated soil were reportedly removed from the vicinity of Building 215 during construction of a nearby Burger King restaurant. However, no documentation was available regarding tank removal or confirmatory sampling of soils in the tank excavation. Buildings within the Building 215 area include 215, 211, 87, and 36. Building 215 is the westernmost of the sites in the Main Post Study Area. Aerial photos from 1946 to 1988 indicate that six buildings in the vicinity of Building 215 were removed some time between April 22, 1973 and May 4, 1988 (Ringden and Sitton, 1990). The area once occupied by these buildings is now a parking lot. No analytes were reported above the CRL in soil samples collected the the site. Groundwater at this site was evaluated under an institutional worker scenario assuming that groundwater would be used for drinking and showering purposes in addition to water from the PSF water supply (Lobos Creek and Well 13).

Building 228, immediately south of Building 231, was constructed in 1909 as a bakery. Based on building use records, the building was used for dry cleaning operations some time after 1950, and prior to 1973. Dry cleaning equipment in the building has not been in service since 1984. Soil contamination was found adjacent to four USTs formerly located between Buildings 228 and 231. These tanks were found to contain petroleum products and not organic solvents when they were removed in 1993. No COC were determined in soil samples following COPC screening and only water from the PSF water supply (Lobos Creek and Well 13) was assessed for institutional workers at this site.

Building 231 was built in 1950 as a service station for privately-owned vehicles but most recently was used as a tire store where automobile repairs were also performed. In 1988, four underground gasoline storage tanks and associated gasoline pumps were removed from north of the building. Because of the fuel storage tank contamination, Building 231 will be further assessed under the USCOE petroleum cleanup program and not in this risk assessment.

Building 1057, added to this investigation as part of the Follow-on RI, is located in the east central portion of the Main Post Study Area to the southeast of Building 1065. Constructed in 1924, Building 1057 was reportedly used as a former maintenance shop, wood shop, and medical research and development (R&D) facility (HLA, 1994). During the NPS site inspection in January 1994, the building was empty. It was thought that Building 1057 may have been used as a storage shed, but unlikely that this building was used as a maintenance shop or R&D facility due to the small size of the building and lack of equipment (HLA, 1994). The concrete vault immediately north of Building 1057 was considered to be a potential source of contamination to the underlying soils and shallow groundwater. Thus a sediment sample was collected above the concrete in the bottom of the vault and a soil sample was collected from below the bottom of vault. No analytes were determined to be COCs in the surface and subsurface soil samples following the COPC screening at Building 1057. Therefore, only water from the PSF water supply (Lobos Creek and Well 13) was assessed to institutional workers at Building 1057.

Located in the central portion of the Main Post Study Area, Building 1065 was added to the Main Post Study Area as part of the Follow-on RI on the basis of the NPS directed review of

the PSF and CERFA research. Building 1065 was constructed in 1919 and has been described as part of the motor pool, as a pathological waste incinerator, and a former service station (HLA, 1994). The Enhanced PA (ANL, 1989) and the CERFA report (TETC, 1994) indicated that a UST, containing oil or various POL products, may have been under or near Building 1065. However, Montgomery Watson's April 7, 1995, Tank Status Map indicates that this is an unsubstantiated, non-existent tank. Other potential sources in the Building 1065 area include a sump immediately northeast of Building 1065, stained areas in the pavement to the south of Building 1065, and the above ground fuel oil tank and associated distribution lines northeast of Building 1040. Hydrocarbon contamination was detected in groundwater north, east, and south of Building 1065. Building 1065 was demolished in the summer of 1996 by NPS contractors. Because of the nature of contamination and its former use as a service station, Building 1065 will be further assessed under the USCOE petroleum cleanup program and not in this risk assessment.

The Building 1151 area includes Buildings 1151 and 1152, as well as a concrete pad (referred to as Building 1153) that held transformers. Buildings 1151 and 1152 are located immediately southwest of U.S. Highway 101 along Gorgas Avenue. Both the building and the transformer pad are separated from pavement on all sides by a narrow strip of grass. Prior to 1987, Building 1153 was used for transformer storage. After a 1987 PCB investigation, the inactive transformers and the building were removed (ECJC, 1990a). The site currently contains a concrete pad with active transformers surrounded by a chain-link fence. There are no surface water bodies or groundwater wells at the site. Releases from transformers by leaks or spills would potentially impact soils in the area. Buildings 1151 and 1152 were assessed in the institutional scenario with exposure to subsurface soil and water from the PSF water supply (Lobos Creek and Well 13).

Building 1167, a former furniture repair and paint shop, was added to the RI as part of the Follow-on RI on the basis of the NPS-directed review and CERFA research. Building 1167 is located in the east-central portion of the Main Post Study Area immediately southwest of Highway 101 and northeast of Gorgas Avenue. Building 1163 adjoins Building 1167 to the southwest. The area around Building 1167 is covered with pavement except for an area to the northwest of Building 1168 which is covered with grass. Constructed in 1919, Building

1167 is described as a former Department of Logistics furniture shop where painting and stripping operations were conducted (HLA, 1994). Stains, paints, lacquers, adhesives, and solvents associated with furniture repair were noted to be stored in drums in Building 1167 and three former paint spray booths are inside the north side of the building. Because the building is used by the NPS to store furniture (TETC, 1994; HLA, 1994), an industrial (institutional) scenario was assessed for Building 1167.

15.1.2.2.2.6 Fill Sites and Landfills

This section characterizes exposure pathways of the Fill Sites and Landfills that are located throughout the upland area of the PSF and includes Fill Sites 1, 5, and 6; Landfills 2, 4, and E; El Polin spring, the Transfer Station; and Graded Area 9. Because the Fill Sites and Landfills are no longer operational, all of the sites except Fill Site 6 (located under a parking lot) are assessed for exposure to the recreational visitor. Potential exposure pathways for these sites are summarized in this section.

Fill Site 1, once used for the disposal of building debris and landscape wastes, is situated at the south end of El Polin Loop and is relatively flat and sparsely covered with grass and annual plants. The Julius Kahn Public Playground and an athletic field are in the vicinity of the fill site. Because the area surrounding the fill site is used for recreation, visitors to these areas could enter the fill site and could be exposed to site-related chemicals. There were no COCs determined in the surface soil for Fill Site 1 following COPC screening. Therefore, this site was not assessed in the risk assessment.

Landfill 2, used in the past for disposal of landfill and building debris, is located upslope and to the southwest of El Polin Loop. El Polin Spring, which is located about 300 ft downhill from Landfill 2, is included as part of this site for the purpose of characterizing potential exposures. Most of the site is hilly and forested with trees and brush; the remaining area is grass. An access road to Landfill 2 is frequently used as a walking trail by local residents. Soil exposure pathways to recreational visitors were evaluated even though exposure is limited by vegetation. Direct contact (incidental ingestion and dermal contact) with water from El Polin spring to an older child (9 to 18 years old) was evaluated under a recreational scenario for this site.

The Transfer Station, located in the west-central portion of the PSF on the southeastern edge of Wright Loop, was used as a solid-waste transfer facility for the PSF. Surface releases may have resulted from hazardous wastes and materials temporarily stored at the facility before transfer offsite. The area is relatively flat, sloping downhill to the northeast. The area includes both forested and cleared areas as well a loading ramp. Access is via a dirt road, and the area is accessible to the public. Because the area may be used for recreation, visitors to this area may potentially be exposed to site-related chemicals. Exposures associated with this site were therefore evaluated in a recreational scenario.

Landfill 4, located to the west of Wright Loop and between Central Magazine Road and Hitchcock Street, is relatively flat, sloping slightly downhill to the north. The landfill, which was once used for disposal of both solid and chemical wastes, is now covered with a 3-ft-thick cap and large trees and brush. Because the landfill area is accessible to the public, visitors to this area may potentially be exposed to site-related chemicals. Exposures at the site were therefore evaluated in a recreational scenario.

Fill Site 5 was used during the same period as Landfill 4, which is located only 300 ft away. Wastes were dumped down a steep ravine and periodically covered with soil, although the main portion of the site is now relatively flat. Most of the surface of the fill site area is composed of graded dirt and pea gravel and is partially covered by grass. The site is bordered by trees at the north and southwest ends. Poured concrete slabs remain at the southern portion of the site, and concrete and tree debris is visible along the western slope of the fill site. Because the fill site is accessible to the public and may be used for recreation, potential exposures to site-related chemicals could be evaluated in a recreational scenario. However, there were no COCs determined in the surface soil for Fill Site 5 following COPC screening. Therefore, this site was not assessed in the risk assessment.

Fill Site 6, which reportedly contains building demolition debris from the previous Letterman Army Hospital, is located underneath a parking lot for the Enlisted Women's Barracks (Building 1028) in the northeastern portion of the PSF. Because this area is covered entirely by pavement, exposures to potential chemicals in Fill Site 6 would be for institutional workers during and after the removal of the pavement. However, there were no analytes determined to be COCs in the subsurface soil samples following the COPC screening at this

site. Groundwater at Fill Site 6 was considered of adequate supply and quality to be considered a water source and an institutional worker was assessed with this pathway.

Graded Area 9, located in the southwestern corner of the PSF, northwest of the U.S. Public Health Service Hospital complex, was reportedly used to dispose of clean fill and rubble. The land surface slopes to the south, and dirt and rock fill, sparsely covered with grass, constitutes the majority of the site. The site is bordered to the north by trees and to the west by enlisted family housing. Only deeper soil samples were collected during the RI. Therefore, there is no exposure pathway for the potential future recreational visitor and no quantitative assessment was performed for this site.

Landfill E is a flat site, primarily covered by a baseball field and parking area, situated in the east-central portion of the PSF to the southeast of Hicks Road. A wooded hillside borders the western and southern edges of the site, while trees and housing are located to the east. A steeply sloping valley wall forms the northern edge of the area. Landfilling activity occurred at the site from at least 1946 to 1965, based on aerial photographs; however, the nature of the fill material was not documented. Because the landfill area may be used for recreation, visitors to this area may potentially be exposed to site-related chemicals. Exposures associated with soil at this site were, therefore, evaluated in a recreational scenario.

15.1.2.2.2.7 Miscellaneous Sites

Miscellaneous sites are buildings and bodies of water not associated with study areas discussed previously. These sites include Buildings 662, 680, 1244, and 1351; the FPCGS; Lobos Creek; Mountain Lake; and from groundwater production Wells 6 and 13. Potential exposure pathways for these sites are summarized in the following paragraphs.

Building 662, located in the northwestern portion of the PSF at the intersection of McDowell Avenue and Cowles Street, was used as an automobile hobby shop for military personnel. The building is situated on a flat area, but the terrain immediately surrounding it slopes east toward McDowell Avenue and downward toward Crissy Field Study Area and San Francisco Bay. An UST and AST located near the building were both used to store waste oil. The AST was used to store waste oil and was removed in April 1994. Both the UST and AST are included in the USCOE site-wide UST and AST management programs. The RI

data associated with the UST and AST locations are not included in this BRA because these areas will be assessed in the USCOE's basewide petroleum cleanup program. Thus, workers in the Building 662 area were considered potentially exposed populations to site-related chemicals in other areas investigated under the RI at Building 662, and exposures are evaluated in an industrial (institutional) scenario. Lead was the only COC determined after the COPC screening in the subsurface soil and in the groundwater samples. Groundwater at Building 662 was assessed as a water source, in addition to water from the PSF water supply (Lobos Creek and Well 13).

Building 680, located in the northwest portion of the PSF at the intersection of Park Boulevard and Schofield Road, was used to store electrical equipment. Leaking or unserviceable transformers were stored in the concrete-bermed shed adjacent to the building. The building is situated on gently sloping terrain and is completely enclosed by a fence. Because workers have access to the Building 680 and associated contaminated soil areas, potential exposure to site-related chemicals was evaluated in an industrial (institutional) scenario.

Building 1244 is located in the northwest portion of the PSF off Appleton Street, adjacent to an unpaved portion of Schofield Road. This building served as a field printing plant and housed lithographic machines and an automatic film processor. Subsurface soil samples were collected during the Follow-on RI but no COCs were determined for this site following the COPC screening. Therefore, Building 1244 was assessed only with exposure to water from the PSF water supply (Lobos Creek and Well 13) to institutional workers.

Building 1351, centrally located on the western side of the PSF at the motor pool off Battery Saffold Road, is used as a vehicle maintenance shop. A concrete berm area for storing petroleum, oil, and other lubricants is adjacent to the building. Building 1351, along with several other structures, is enclosed by a fence. Because employees have access to the Building 1351 area, potential exposure to site-related chemicals was evaluated in an industrial (industrial) scenario.

The FPCGS, located west of Crissy Field Study Area on the shore of San Francisco Bay, consists of nine buildings and a pier that extends into the bay northeast of Building 991.

Seven of the buildings at the FPCGS are located on shore, and the other two, Buildings 998 and 999, are located on the pier. A sea wall runs between the station and the beach, and some areas are enclosed by a fence. Soil samples were collected to evaluate stained areas and current and former tank locations. Although a USCG employee resides on site, this individual is less likely to contact soils in the storage yard area than is a recreational visitor. The UST-associated contamination at this site is the responsibility of the USCG and is not included in this RI risk assessment. All other contamination associated with the FPCGS is assessed in this RI risk assessment under a recreational visitor scenario having contact with surface soils sampled from 0 to 2 ft bgs.

Lobos Creek, a natural stream at the PSF, is about 1.3 mi long, flows westward in a highly vegetated channel along the southern boundary of the PSF, and discharges into the Pacific Ocean. Lobos Creek has been used to supply over 90 percent of the PSF potable water (Nolte and Associates, 1993). When the water plant was in operation, most of the water in the stream was diverted to the water plant at Baker Beach. This resulted in very low flow in the creek downstream of the water plant intake, with the remaining water discharging into the Pacific Ocean. Treated water was pumped to an aboveground reservoir where it was stored for use on the PSF. The water plant recently was upgraded; operations had not resumed as of December 1996. The source of water has been from the City of San Francisco since August, 1994. The existing water treatment plant was recently renovated but is not currently operational. When operational, it is assumed that the retrofitted treatment plant will receive water from Lobos Creek and Well 13 only. Well 6 will be capped and not used. After treatment, the water is pumped to a reservoir on Presidio Hill where it is stored for use. The COCs determined in the PSF water supply were assessed with exposure to industrial workers via ingestion and dermal contact during showering at all sites which had the industrial scenario identified as the future land use.

In addition to the PSF water supply, older children may potentially wade or play in Lobos Creek, recreational exposure scenarios for older children (9 to 18 years old) were evaluated for this body of water and associated sediments.

Mountain Lake is an unlined, spring-fed natural lake located near the southern boundary of the PSF. It covers nearly 4 ac and has a maximum depth of 15 ft. The land surrounding

Mountain Lake is used as a recreational area. It is feasible that older children (9 to 18 years old) may play in the water. Thus, potential exposures of surface water and associated sediment to this age group were evaluated in a recreational scenario.

Two groundwater wells (Wells 6 and 13) located near the water purification plant have been used when necessary to supplement the PSF potable water supply (up to approximately 25 percent of the water supply). Ten percent of Well 13 is assessed as the PSF water supply along with Lobos Creek as described in the paragraph on Lobos Creek. Well 6 will be capped and not used as a water source in the future and was not assessed quantitatively in this risk assessment.

15.1.2.2.2.8 GGBHTD Study Area

The GGBHTD Study Area is an 11.5-ac site located in the northwestern corner of the PSF at the southern end of the Golden Gate Bridge and is bounded by Baker Beach Study Area and the Fort Point National Historical Site. Because the GGBHTD Study Area is under the jurisdiction of the GGBHTD, the site is assessed under the GGBHTD Program and not in this risk assessment.

15.1.2.2.2.9 Baker Beach Study Area

The Baker Beach Study Area encompasses approximately 100 ac of steeply sloping bluffs, a beach, and a dune field, situated on the western edge of the PSF. Several areas of the beach have been associated with former PSF activities, including four primary fill sites (Disturbed Areas 1, 2, 3, and 4) and several abandoned, sealed fortifications (i.e., coastal fortification, casemates, and underground magazines). Samples were also collected from an area north of Disturbed Area 1 (referred to as Disturbed Area 1a), where materials used to cover the coastal fortifications are present. The fill material found in the disturbed areas includes varying amounts of non-native rock, building debris, automotive parts, and metal containers. The fill material found in Disturbed Area 1 includes blocks of concrete, building debris, automotive parts, and a few metal containers. Based on aerial photographs, Disturbed Area 2 appears to be a result of road grading activities, during which material was pushed over the cliff edge; debris from other sources may also have been deposited into the fill. The

additional fill material consists of concrete and asphalt. Disturbed Areas 3 and 4 contain concrete, asphalt, and metal parts.

Vegetation in the Baker Beach Study Area is generally well-developed except on the steeper cliff and beach areas, and consists of grasses, shrubs, and trees. The site is located on property permitted to the GGNRA and is currently used predominantly for recreation. Because the area is popular for recreation and the NPS must consider the public's best interest in determining future use of this area, it is unlikely that the land will ever be used for residential development. Potential exposures via incidental ingestion of and dermal contact with surface soil at the sites within Baker Beach Study Area were evaluated under the recreational scenario. Surface water and sediment from the seep in Disturbed Area 1 were sampled. Because older children (9 to 18 years old) would be able to access surface water and sediment from the seep, these receptors were also evaluated in a recreational scenario.

15.1.2.2.2.10 Battery Howe/Wagner

Battery Howe/Wagner is located on approximately 5 ac in the northwestern portion of the PSF, and contains four small buildings, a shed, and an underground concrete fortification. Surrounding the site are several residences and office buildings formerly used by the Sixth U.S. Army and maintenance personnel, as well as a playground and revegetated grass-covered slope. Battery Howe was built in 1893, later divided into two separate fortifications, and renamed Battery Howe/Wagner. There is no reliable documentation on when the fortifications were decommissioned or covered with fill material. The fortification has been used periodically since 1980 by LAIR for ballistic weapons testing.

The topography of the area is generally gently sloping. The site is mostly covered with grasses and trees, while the remaining area is paved. There is no surface water in the study area. Battery Howe/Wagner is accessible to site visitors and is used occasionally by PSF personnel.

For Battery Howe/Wagner, exposures via incidental ingestion of and dermal contact with soil were evaluated under a recreational scenario because it is an open grassy area. No COCs were determined in surface soil following the COPC screening. Groundwater samples were also collected in Battery Howe/Wagner. Exposure to this medium represents an

incomplete future pathway because the recreational visitors are not expected to drink water from groundwater as a water source. Additionally, water wells do not exist in this area.

15.1.2.2.11 Miscellaneous Follow-on Sites

The Miscellaneous Follow-on Sites are individual areas that are not associated with any of the study areas or sites discussed in previous sections nor were investigated prior to the Follow-on RI. The Miscellaneous Follow-on Sites include Buildings 302, 669, 1245, 1369, 1388, and 1750 and EOM. Buildings 669, 1245, and 1388 were added based on PSF historical and current activities that were identified from the NPS-directed review (HLA, 1994). Buildings 1369 and 1750 were added based on information from this review and from the CERFA research (TETC, 1994) and Building 302 was included based on the CERFA research information. Potential exposure pathways for these sites are summarized in this section.

Located on the southern border of the PSF, Building 302 is a golf course equipment (e.g., lawn mowers) storage facility. It is the furthest northwest of a series of buildings constructed to support golf course maintenance and is constructed of corrugated metal on a concrete slab foundation. Herbicides, pesticides, and fertilizers used at the golf course are stored in the northern portion of the building. No evidence of release of these materials was noted nor was there evidence of staining outside of the building. Minor staining on the concrete floor was interpreted to be oil or other fluid leakage from vehicles parked inside the building. While potential recreational visitors have access to the areas around Building 302, because of paving and buildings, only subsurface soil samples were analyzed and, thus, the recreational scenario is not a complete pathway to subsurface soils.

Building 669, a two-story brick building constructed into the hillside near the center of the PSF along Incinerator Road, was most recently used to house paper shredding machines. An incinerator in the basement of Building 669 apparently was used to dispose of animal carcasses from the nearby veterinary clinic (HLA, 1994). Ash was periodically removed from the facility and disposed to an unknown site. Speculation has been made that it was on the hillside surrounding the building. The field investigation indicated that ash was not disposed of in the areas thought most likely to have been used for disposal. Because no

significant ash layers were observed in any of the soil borings, samples were not collected and it was concluded that ash from the incinerator was not disposed around Building 669. This site was evaluated with exposure of institutional workers to the PSF water supply (Lobos Creek and Well 13) only.

Building 1245, a hazardous material and flammable storage building constructed of concrete with a wooden drum cradle inside, is located in the northeastern portion of the PSF approximately 700 ft southwest of the elevated intersection of State Highway 1 and U.S. Highway 101. The primary sources identified in Building 1245 were associated with the storage of materials and potential releases through spillage or leakage. Release to the soil was most likely to occur through the hole in the concrete of the floor of the building or from potential transfer or storage of materials outside the building. No analytes were determined to be COCs following the COPC screening. Therefore, this site was assessed with exposure of institutional workers to the PSF water supply (Lobos Creek and Well 13) only.

Located on the west side of the PSF, Building 1369 contains an previously active firing range where bullets were fired at paper targets and spent ammunition was collected in a sand pit (HLA, 1994). There is a drainage pipe near the top of the basin that extends the ground surface outside the building. Releases of rinsate from the pipe could be discharged to the ground and infiltrate. During a site visit on January 4, 1994, an U.S. Army representative indicated that the U.S. Army had previously removed solid sheets of lead from the target area and lead-contaminated sand from the sand pits. No analytes were determined to be COCs following the COPC screening in the surface or subsurface soil samples for Building 1369. Therefore, this site was assessed with exposure of institutional workers to the PSF water supply (Lobos Creek and Well 13) only.

The asphalt parking lot south of Building 1388 was leased by a U.S. Army contractor for storage of two portable 500-gal ASTs (one diesel and one gasoline), several maintenance vehicles, three truck trailers, two wooden pallets full of cement bags, and one wooden pallet with eight 5-gal plastic containers of hydraulic fluid. Building 1388 is located in the northwest portion of the PSF and is a sheet metal and concrete structure. In January 1994, Building 1388 was being used as living quarters by an on-site worker. Staining, considered to be the result of spills or leaks from the tanks or containers, was noticed on the asphalt

near both of these potential sources. The primary release mechanism for the sources is leakage to the asphalt, and subsequent migration to the soil below the asphalt or to downslope soil. No analytes were determined to be COCs in the subsurface soil samples for Building 1388 following the COPC screen. Therefore, this site was assessed with exposure of institutional workers to the PSF water supply (Lobos Creek and Well 13) only.

The Building 1750 site is in the Golden Gate Army Reserve Unit Complex, located near the southwest corner of the PSF. The area was formerly used as a motor pool and Building 1750 was used for administration (offices and training). The potential sources of contamination include leaks and spills from previous and recent maintenance/motor pool activities in the area. Prior to paving of the area, there may have been releases of contaminants to surface soil and infiltration to deeper soils. The area was paved after 1955. Releases to the asphalt could infiltrate to underlying soil through cracks in the pavement. There were no petroleum hydrocarbons or BTEX compounds detected in a soil gas survey conducted at Building 1750. Therefore, this site was assessed with exposure of institutional workers to the PSF water supply (Lobos Creek and Well 13) only.

The EOM site is located between the Crissy Field Study Area and DEH Study Areas and was filled with dredged bay sediments. Buildings constructed in the area were used primarily for administrative activities with most of these buildings being demolished from 1959 to 1988 and the remainder of the buildings demolished by early 1995. There is currently a dirt parking lot in the northwestern section and an asphalt pad in the northeastern section of the study area; elsewhere the study area was replanted with grass and eucalyptus trees. The parking lot provides access to a heavily-used jogging path north of the study area. The artificial fill at the study area is considered a potential source of contamination with the contaminant pathways including stormwater runoff, particulate transport, and infiltration. Surface soil, subsurface soil, and discrete groundwater samples were collected during the Follow-on RI. Because this study area is near a heavily-used jogging path and it is in the area of potential wetlands restoration, potential exposures to site-related chemicals in surface soils from 0 to 2 ft were evaluated in a recreational scenario. The soil samples in the proposed wetlands restoration area were assessed separately in a recreational scenario with the soil samples from Crissy Field Study Area Fill Site 7. In addition, groundwater samples

from the proposed wetlands restoration area were combined with the groundwater samples from Crissy Field Study Area Fill Site 7 and assessed for exposure to construction workers building the proposed wetlands restoration area.

15.1.2.3 Quantification of Exposure

In this section, chemical intake rates are estimated for the exposure routes identified in the previous section: ingestion of and dermal contact with surface and subsurface soil, municipal water, surface water, sediment, and groundwater.

Estimates of chemical intake were based on estimates of concentrations at the exposure point (exposure point concentrations) and on the estimated magnitude of exposure to contaminated media. Estimates of chemical intakes were calculated separately for the recreational and industrial scenarios based on different assumptions about exposure conditions for site visitors and workers.

Exposure estimates for ingestion, termed intakes or administered doses, are defined as the mass of a substance taken into the body, per unit of body weight, per unit of time. For dermal contact, calculated exposures are expressed as absorbed dose rather than administered dose. Chemical intakes for chronic exposures, or chronic daily intakes (CDIs), were calculated for the COCs using methods described by USEPA (USEPA, 1989b). Calculations were made for the reasonable maximum exposure (RME) case, which is described by as the highest exposure that is reasonably expected to occur at a site (USEPA, 1989b). Appendix U contains spreadsheet printouts with the CDIs and HHRA risk results.

The exposure algorithms and the associated exposure parameters and assumptions used to calculate CDIs for each of the 11 exposure routes are presented in the subsections that follow. Exposure parameters that apply to all of the exposure algorithms are included. These parameters include exposure concentration, exposure duration, body weight, and averaging time.

The concentration term in the exposure equation is meant to reflect the average concentration, contacted at the exposure point, over the exposure period (USEPA, 1989b, 1992b). In most situations, assuming long-term contact with the maximum concentration in

any exposure medium is not reasonable. RAGS states that although the average concentration does not reflect the maximum concentration that could be contacted at any one time, it is regarded as a reasonable estimate of the concentration likely to be contacted over time (USEPA, 1989b). However, because of the uncertainty associated with estimating the average exposure concentration, the 95-percent upper confidence limit (UCL) of the arithmetic mean assuming lognormal distribution was used in estimating chronic intake in most cases, as recommended in supplemental guidance to RAGS (USEPA, 1992c). The maximum detected concentration was conservatively used as the exposure point concentration in all cases when less than five samples were available to estimate the exposure concentration or when the maximum concentration was lower than the 95-percent UCL. The maximum detected concentration, 95 percent UCL, and the exposure point concentration for each COC are presented in Tables 15.1-51 through 15.1-85.

Distribution testing of 148 data sets with five or more samples from the DEH site for ecological and human receptors was performed to test for normal and lognormal distribution in each data set. The number of data sets was related to the COPCs in ecological soil (depth of 0 to less than 3 ft), surface soil, subsurface soil, and groundwater. Additionally, nonparametric data sets were assessed for completeness. The distribution testing indicated that the distribution of 71% of the data sets could not be determined; 16% of the data sets had a lognormal distribution; and 13% of the data sets had a normal distribution. Exposure point concentrations (the lower of the 95 percent UCL and maximum detected value) were compared assuming lognormally-distributed data and also based on distribution testing data. In all cases, the exposure point concentration assuming lognormally-distributed data is slightly higher or the same as the exposure point concentration based on distribution data. For the nonparametric data sets, the exposure point concentration is the maximum detected value 51% of the time and the 95 percent UCL 49% of the time. Because there was no significant difference in these tests, the 95 percent UCL was calculated assuming lognormal distribution of the data sets.

Assumptions concerning exposure duration and body weights of adults and young children used in the exposure algorithms are standard default exposure assumptions provided in the latest supplemental guidance to RAGS (USEPA, 1991d). The USEPA default value for

average adult body weight is 70 kg; 15 kg is the default value for average body weight for children 1 to 7 yr old. The exposure duration used in these calculations for the recreational scenarios is 30 yr, which is the 90th percentile for the United States population for the amount of time spent in one residence. The exposure duration of 25 yr for the industrial scenario is based on the 95th percentile for the amount of time workers spend at the same work location.

The averaging time used to determine a CDI is dependent on the type of toxic effect being assessed. For assessing carcinogenic effects, CDIs are calculated by prorating the total cumulative dose over a lifetime. The estimate of the average lifespan has been revised upward from 70 to 75 yr based on new data for the United States population (USEPA, 1989b). For assessing noncarcinogenic effects, CDIs are calculated by averaging intakes only over the period of exposure. The distinction between these two approaches is based on the currently held scientific opinion that the mechanisms of action are different for carcinogenic and noncarcinogenic processes (USEPA, 1989b).

Exposure point concentrations and CDI estimates for future land-use conditions are presented along with the risk calculation spreadsheets in Appendix U, organized by study area and receptor. CDIs were calculated using the pathway-specific exposure algorithms and assumptions described in the following subsections and Tables 15.1-88 through 15.1-97. The spreadsheets in Appendix U indicate the exposure pathway and exposure scenario evaluated.

15.1.2.3.1 Ingestion of Soil

The exposure algorithm for ingestion of soil is presented in Table 15.1-88. This algorithm was based on incidental ingestion of surface or subsurface (industrial worker only) soil as a result of direct contact with contaminated soil on hands, followed by hand-to-mouth activity (either inadvertent or associated with eating or smoking). Estimates of soil ingestion rates recommended in USEPA (1991d) are 100 mg/day for older children (>7 yr old) and adult receptors, 50 mg/day for workers, and 200 mg/day for younger children (1 to 7 yr old) who are assumed to have more frequent hand-to-mouth activity. These rates are believed to represent most reasonable estimates of soil ingestion. The USEPA recommends a soil ingestion rate of 480 mg/day for short-term soil-intrusive activities such as those that might be encountered in construction. However, only two of the sites where the future land use is

assessed under the industrial scenario have the industrial workers as construction workers. These are the proposed wetlands restoration area and the Building 900s Series Study Area UST remediation. Therefore, the use of 480 mg/day soil intake is not appropriate at the other PSF sites where the future land use is assessed under the industrial scenario.

Soil at the proposed wetlands restoration area and the Building 900s Series Study Area UST remediation site was assessed under the recreational and institutional scenarios, respectively. A comparison of the non-carcinogenic exposure parameters for the institutional worker, recreational visitor, and construction worker indicates that the intake for the institutional worker would be approximately twice that of the construction worker, even ingesting 480 mg soil/day. Similarly, intake for the recreational visitor would be approximately 200 times higher than that of the construction worker. Therefore, while the soil at these two sites was not assessed for exposure to the construction worker, it was conservatively assessed under the two other scenarios.

For the recreational scenario, CDIs for cancer effects were based on an exposure duration of 30 yr; 6 yr as a child and 24 yr as an adult. For noncarcinogenic effects, CDIs were conservatively based on the 6-yr child exposure duration only. Exposure was conservatively assumed to occur 3 days/week for 50 weeks (52 weeks of the year minus 2 weeks typically spent away from home on vacation) for the entire exposure period. The fraction of soil ingested per day that was assumed to originate from the site is 50 percent.

For the industrial scenario, all workers were assumed to be adults (i.e., 70 kg body weight). The exposure frequency recommended in USEPA (1991d) for workers is 250 days/yr, based on the assumption that a worker is on site 5 days/week, 50 weeks/yr, for 25 years. Because all of the soil ingested for an industrial or institutional worker would most likely be while they work, all soil ingested was assumed to originate from the site.

15.1.2.3.2 Dermal Contact with Soil

The algorithm for exposure via direct contact with surface soil is presented in Table 15.1-89. Dermal exposures are expressed as absorbed dose by incorporating a chemical-specific absorption factor into the exposure equation. Chemical-specific soil absorption (ABS) values are provided for arsenic, cadmium, pentachlorophenol, PCBs, and dioxin as recommended

by USEPA's Office of Research and Development (USEPA, 1994a) for the evaluation of chemical absorption through the skin. Default skin absorption fractions are assumed to be 0.01 and 0.1 for inorganics or organics, respectively (USEPA, 1996).

In the recreational scenarios, a skin surface area equivalent to the arms and hands of an average adult (3,000 cm²) or child from 1 to 9 years old (1,300 cm²) was assumed to be completely covered with soil (USEPA, 1989b). In the industrial scenario, workers may contact soil over approximately 2,000 cm² of exposed skin. This scenario assumed that a worker will wear a long-sleeved shirt, pants, and shoes (USEPA, 1989b). The soil-to-skin adherence factor refers to the amount of soil that remains deposited on the skin after contact. The adherence factor of 0.5 mg soil/cm² of skin is an estimate used by CEPA DTSC (Sedman, 1989). Exposure frequency and duration assumptions were the same as those described for the soil ingestion pathway.

15.1.2.3.3 Ingestion of Drinking Water

Table 15.1-90 presents the exposure algorithm for ingestion of drinking water. Workers were assumed to ingest only 1 L of water/day from the site (i.e., one-half of their daily water intake) (USEPA, 1991d). The other assumptions for exposure frequency and duration and body weight were the same as those discussed previously.

15.1.2.3.4 Dermal Contact with Drinking Water

The algorithm for calculating the absorbed dose from dermal contact with drinking water is presented in Table 15.1-91. This pathway was evaluated for workers who may have extensive dermal contact with drinking water while showering or bathing at work.

In the industrial scenario, a worker was assumed to take a daily shower or bath of 15 minutes duration, based on best professional judgment. The body surface area assumed to be in continuous contact with water while showering or bathing was equivalent to the total body surface area except the head of the average adult (USEPA, 1989b). The permeability constant reflects the rate of movement of the chemical across the skin. The permeability constants used in the algorithm (see Table 15.1-98) are either measured (if available) or estimated values for chemicals from Table 5-8 of the Dermal Exposure Assessment: Principles and Applications (USEPA, 1992b). Dermal absorption of metals is negligible. The

other assumptions for exposure frequency and duration and body weight were the same as those discussed previously.

15.1.2.3.5 Ingestion of Surface Water

Older children may contact surface water while playing in El Polin spring, Lobos Creek, Mountain Lake, or the Baker Beach Study Area Disturbed Area 1 seep. The exposure algorithm for incidental ingestion of surface water under the recreational scenario is shown in Table 15.1-92. The USEPA currently recommends using an ingestion rate of 50 mL/hr for estimating incidental ingestion of water while swimming (USEPA, 1989b). Exposure was assumed to occur 30 times/yr (equivalent to 10 days/month for 3 months of summer) and for 1 hr for each event, based on best professional judgment. The exposure duration of the older child swimming is 9 yrs, based on the age of the child (9 to 18 yrs old). The body weight of the older child is the USEPA default value for an average child aged 9 to 18. These intake parameters were believed to be reasonably conservative, given that the average American swims only 7 days/yr (USEPA, 1989b) and that El Polin Spring, Lobos Creek, Mountain Lake, or the Baker Beach Study Area Disturbed Area 1 seep are unauthorized swimming areas.

15.1.2.3.6 Dermal Contact with Surface Water

Older children playing in the surface water of El Polin spring, Lobos Creek, Mountain Lake, or the Baker Beach Study Area Disturbed Area 1 seep are likely to have dermal contact with the surface water in these water bodies. The exposure algorithm for dermal contact with surface water under the recreational scenario is shown in Table 15.1-93. The surface area except for the head for the average male and female older child of 4,205 cm² was estimated (USEPA, 1989b). The remaining exposure factors of exposure time, frequency, and duration, and body weight as used in the estimation of ingestion of surface water were assumed to be the same.

15.1.2.3.7 Ingestion of Sediment

Older children playing in El Polin spring, Lobos Creek, Mountain Lake, or the Baker Beach Study Area Disturbed Area 1 seep may also incidentally ingest sediment. The exposure algorithm for this pathway is shown in Table 15.1-94. Contact with sediment was assumed

to occur with the same frequency and duration as contact with surface water. Because current studies on soil ingestion do not distinguish between soil and sediment intake, the ingestion rate and the fraction of intake from the site are the same as those assumed in the soil ingestion exposure algorithm.

15.1.2.3.8 Dermal Contact with Sediments

Older children playing in the surface water of El Polin spring, Lobos Creek, Mountain Lake, or the Baker Beach Study Area Disturbed Area 1 seep are likely to also come in dermal contact with the associated sediments in these water bodies. The exposure algorithm for dermal contact with surface water under the recreational scenario is shown in Table 15.1-95. Contact with sediment was assumed to occur with the same frequency and duration as contact with surface water. Because current studies on soil dermal contact do not distinguish between soil and sediment contact rates, the adherence factor from the site are the same as those assumed in the soil dermal exposure algorithm.

15.1.2.3.9 Ingestion of Groundwater

As discussed in Section 15.1.2.2.1.2, construction workers may contact groundwater while developing the proposed wetlands restoration area in portions of the Crissy Field Study Area and EOM site and the remediation practices of UST removal in the Building 900's Study Area. The exposure algorithm for incidental ingestion of groundwater under the industrial/construction scenario is shown in Table 15.1-96. The USEPA currently recommends using an ingestion rate of 50 milliliters/hour (mL/hr) for estimating incidental ingestion of water while swimming (USEPA, 1989b). There is no further guidance for incidental ingestion of groundwater during construction activities so this value is conservatively used in this exposure estimation. Exposure was assumed to occur only during 3 months in a period of one year. This equates to 60 two-hour periods of contact per year, which is equivalent to five days per week, 12 weeks per year, based on best professional judgment. The body weight of the adult (70 kg) is used.

In addition, for the sites with groundwater assessed as a water source, the drinking water scenario was applied to the exposure point concentrations for the industrial receptors at inland sites of Building 215, Fill Site 6, and Building 662.

15.1.2.3.10 Dermal Contact with Groundwater

Construction workers developing the proposed wetlands restoration area of Crissy Field Study Area and EOM are likely to have dermal contact with the groundwater found during construction activities. The exposure algorithm for dermal contact with groundwater under the industrial scenario is shown in Table 15.1-97. As with industrial dermal exposure of soils, the surface area is approximately 2,000 cm² assuming the construction worker will be wearing long-sleeved shirt, pants, and shoes. Exposure time, frequency, and duration and body weight is the same as used in the estimation of ingestion of groundwater.

At sites with groundwater assessed as the water source, the dermal contact with drinking water for the industrial scenario is assessed.

15.1.2.3.11 Inhalation of Dust

As discussed in Section 15.1.2.2.1.5, inhalation of fugitive dust is not likely to be a significant exposure pathway for receptors because most sites are either paved or have significant vegetation. However, some sites adjacent to San Francisco Bay (particularly the Crissy Field Study Area) are likely to have paving removed in the future as part of renovations for recreational use. An analysis is provided in this section indicating that the inhalation pathway would also be a negligible contributor to risks for site visitors.

For chemicals where oral and inhalation routes of exposure produce similar dose-response, risk estimates are directly proportional to chemical intake. Chemical intake from soil for a site visitor (recreational scenario) is estimated to be 0.00000031 mg/kg-day for every mg chemical/kg soil. Conservatively assuming that outdoor air contains 50 mg of respirable fugitive dust/m³ (CEPA, 1992a), the corresponding chemical intake from inhalation of fugitive dust for a site visitor is only 3.9E-10 mg/kg-day, or 3 orders of magnitude lower than for soil, based on comparable exposure assumptions (i.e., exposure occurs 4 hours/day, 150 days/yr for 30 yrs, and assuming an inhalation rate of 20 m³/day for a 70-kg adult). Thus, the inhalation pathway is negligible compared to the soil ingestion pathway for chemicals with similar dose-response for both pathways.

Cadmium and chromium (VI) are the two COCs in soil that demonstrate significantly greater toxicity via inhalation than via oral pathways. These two metals are classified by USEPA as

probable and known human carcinogens via inhalation, respectively. The inhalation CSFs for cadmium and chromium (VI) are 15 and 510 (mg/kg-day)⁻¹, respectively versus the oral CSF for chromium VI of 0.42 (mg/kg-day)⁻¹ (CEPA, 1992b). There is no oral CSF derived for cadmium. Using these toxicity values and the maximum exposure point concentrations calculated for cadmium and chromium at any site at the PSF [79.5 mg/kg cadmium and 0.37 mg/kg chromium VI, at Buildings 929, 930, 931, 933, and 939], the maximum risk estimates for cadmium and chromium at the PSF are 5E-07 and 2E-09, respectively. These values are below the target risk range of 1E-04 to 1E-06 considered by USEPA to be safe and protective of public health (Federal Register 56(20):3535, Wednesday, January 30, 1991).

15.1.3 Toxicity Assessment

The purpose of a toxicity assessment is to evaluate the potential for COCs to cause adverse health effects in exposed persons and to define, as thoroughly as possible, the relationship between the extent of exposure to a hazardous chemical and the likelihood and severity of any adverse health effects. Standard procedures for toxicity assessment include identifying toxicity values for carcinogenic and noncarcinogenic effects and summarizing other relevant toxicity information.

USEPA-derived toxicity values used in risk assessments are termed CSFs and reference doses (RfDs). CSFs are used to estimate the incremental lifetime risk of developing cancer corresponding to CDIs calculated in the exposure assessment. The potential for noncarcinogenic health effects is typically evaluated by comparing estimated daily intakes with RfDs, which represent daily intakes at which no adverse effects are expected to occur over a lifetime of exposure. Both CSFs and RfDs are specific to the route of exposure. For example, ingestion is specific to oral exposure. Currently there are no CSFs or RfDs for dermal exposure; therefore, route-to-route extrapolation is necessary to assess dermal exposure.

In assessing the carcinogenicity potential of a chemical, USEPA classifies the chemical into one of the following groups, according to the weight of evidence from epidemiologic and animals studies:

- Group A - human carcinogen (sufficient evidence of carcinogenicity in humans)

- Group B - probable human carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
- Group C - possible human carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
- Group D - not classifiable as to human carcinogenicity (inadequate or no evidence).

As indicated in RAGS (USEPA, 1989b), the primary source for USEPA-derived toxicity values is the USEPA's Integrated Risk Information System (IRIS) (USEPA, 1996). This computerized database contains verified toxicity values in addition to up-to-date health risk and USEPA regulatory information for many chemicals commonly detected at hazardous waste sites. The *EPA Health Effects Assessment Summary Tables and Supplements* (HEAST) (USEPA, 1994a), which are updated quarterly, also provide USEPA-derived toxicity values that may or may not be verified at the time of publication. The CSFs and RfDs used to assess oral exposures for the COCs are summarized in Table 15.1-98. Table 15.1-98 also includes soil absorption factors and dermal permeability constants, USEPA's weight-of-evidence groups for carcinogenic COCs, and target organs for noncarcinogenic COCs.

As presented in Table 15.1-98, there are several COCs which do not have CSF or RfD toxicity values derived by USEPA and, therefore, it is not possible to characterize quantitative risk or hazard from these chemicals. These chemicals are: total chromium, lead, bis(2-chloromethyl)methane, acenaphthylene, benzo(g,h,i)perylene, 2-methylnaphthalene, phenanthrene, delta-BHC, isodrin, MCP, chloride, sulfate, and total dissolved solids.

Toxicity profiles, which summarize toxicity information and the derivation of oral toxicity values for the COCs, are presented in Appendix U before the HHRA intakes and risk results. The following is a discussion on the use of route-to-route extrapolations to derive dermal toxicity values for several COCs.

15.1.3.1 Toxicity Assessment for Exposure Routes With No USEPA-Derived Toxicity Values

Neither USEPA nor CEPA have developed any toxicity values for dermal exposure. USEPA suggests, however, that dermal toxicity values may be derived from oral toxicity values for

chemicals with systemic effects that are not dependent on route of administration (USEPA, 1989b). In deriving such values, consistency is required between the type of dose that forms the basis of the oral toxicity and the type of dose that will be calculated by the dermal exposure models. Specifically, a distinction must be made between an administered dose or intake (i.e., the amount of chemical taken into the body) and the absorbed dose (i.e., the amount of chemical that crosses the body membranes and enters the blood-stream).

Oral toxicity values and CDIs for oral exposure are based on administered doses (or intakes). Usually no adjustments are necessary to calculate risk estimates for oral exposures. Because dermal exposures are usually expressed in terms of absorbed doses, dermal toxicity values must also be based on absorbed, rather than administered, doses (USEPA, 1989b). To derive a dermal toxicity value for absorbed dose from an oral toxicity value based on administered dose, the oral toxicity value must be adjusted by the fractional oral absorption. RfDs are multiplied by the fractional oral absorption, while CSFs are divided by the fractional oral absorption because CSFs are expressed in units of $(\text{mg}/\text{kg}\text{-day})^{-1}$. For example, if the oral absorption of the chemical in question is 80 percent, the oral RfD should be multiplied by 0.8 to determine the dermal toxicity value. For this derivation, the most conservative approach is to use the lowest expected oral absorption (i.e., to assume that the toxic effects observed following oral exposures were produced by the lowest expected absorbed dose.) If oral absorption is thought to be in the range of 80 to 100 percent, use of the 80-percent absorption factor will yield the lowest, or most conservative, dermal toxicity value.

Table 15.1-99 presents the dermal toxicity values derived for chemicals that are of concern via the dermal absorption pathway. Most of the oral absorption factors used to derive these toxicity values are based on experimental data described in the toxicity profiles. The extent of oral absorption of endrin and endrin aldehyde from the gastrointestinal tract has not been quantified. Because endrin and dieldrin are stereoisomers (Hayes and Laws, 1991), it was assumed that the extent of oral absorption for both are similar. The oral absorption factor for dieldrin (90 percent) was used as the default value for endrin aldehyde.

The derivation of dermal toxicity values from oral toxicity factors was assumed to be valid when systemic toxicity is induced by the absorbed chemical. USEPA states in RAGS,

however, that such derivation is inappropriate when substances, such as benzo(a)pyrene, produce "skin cancer through a direct action at the point of application." As a result, "generally only a qualitative assessment of risks from dermal exposure to these chemicals is possible" (USEPA, 1989b). Thus, although skin painting studies with laboratory animals indicate that benzo(a)pyrene and other high-molecular-weight PAHs are carcinogenic via dermal exposure, risks associated with dermal exposure to carcinogenic PAHs were not quantitatively evaluated in this assessment.

15.1.4 Risk Characterization

In risk characterization, quantitative exposure estimates and toxicity factors are combined in the human health BRA to calculate numerical estimates of health risk. In this section, estimates of cancer and noncarcinogenic health risks were calculated for all study areas based on long-term exposure to COCs in surface or subsurface soil, drinking water, surface water, sediment, or groundwater. The risk characterization methods described in RAGS (USEPA, 1989b) were used to calculate excess cancer risks for potential carcinogens and hazard indices for chemicals with noncarcinogenic effects. These methods and the results of the risk characterization for the aforementioned study areas are described in this section.

Quantifying total excess cancer risk requires calculating risks associated with exposure to individual carcinogens and aggregating risks associated with simultaneous exposure to several carcinogenic substances. Cancer risks for a single carcinogen are calculated by multiplying the carcinogenic CDI of the chemical by its CSF. A 1E-06 cancer risk represents a one in one million additional probability that an individual may develop cancer over a 75-yr lifetime as a result of the exposure conditions evaluated. Because cancer risks are assumed to be additive, risks associated with simultaneous exposure to more than one carcinogen in a given medium are aggregated to determine a total pathway cancer risk. For each exposure scenario (recreational and industrial), total cancer risks for each pathway are then summed to determine the total cancer risk for the populations of concern (recreational visitors and workers).

A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health for known or suspected carcinogens (FR 56(20):3535, Wednesday, January 30, 1991).

The likelihood that actual risks are higher than these risk estimates is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values. USEPA's Guidelines for Carcinogen Risk Assessment states that "... the linearized multistage procedure leads to a plausible upper limit to the risk that is consistent with proposed mechanisms of carcinogenesis... The true value of the risk is unknown, and may be as low as zero." (Fed. Reg. 51, 185:33992-34054, 1986).

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as a probability. Instead, these effects are expressed as the ratio of the estimated exposure over a specified time period to the RfD derived for a similar exposure period (e.g., CDI/chronic RfD). This ratio is termed a hazard quotient (HQ). If the CDI exceeds the RfD (i.e., $HQ > 1E+00$), there may be concern for noncarcinogenic adverse health effects. Exposures resulting in a $HQ < 1E+00$ are very unlikely to result in noncarcinogenic adverse health effects.

Typically, chemical-specific HQs are summed for each chemical to determine a chemical hazard index (HI). Chemical HIs can then be summed to determine the total HI for each population of concern. Simple additivity is typically assumed if similar target organs or mechanisms of toxicity were in effect for all noncarcinogenic COCs. However, there is no well-accepted body of information about the possible additive, synergistic, or antagonistic effects of simultaneous exposure to multiple chemicals. If the target organ or effect is different, then cumulative hazard indices are likely to overestimate the magnitude of the estimated noncarcinogenic adverse effects. Therefore, the results of the noncarcinogenic hazards are discussed as HQs and chemical HIs but not pathway and total HIs. The tables in Appendix U present total HIs for pathways, COCs and receptors for completeness only.

Estimates of total cancer risks and HQs associated with recreational or industrial scenarios for individual sites within the study areas are presented in the following subsections. In addition, the chemicals and exposure pathways presenting the greatest cancer risks and

hazards of noncarcinogenic effects for each site are identified. Chemical-specific cancer risks and HQs for each exposure pathway evaluated for each site are presented in the spreadsheets of Appendix U, organized by study area. Following the discussion of cancer and noncarcinogenic risk estimates, a separate evaluation is presented for lead (Section 15.1.4.12). Risks associated with potential exposure to lead were evaluated differently than for other chemicals because neither a CSF or RfD is currently available for this metal. The discussion for lead is then followed by an uncertainty analysis (Section 15.1.4.13), which identifies the major sources of uncertainty associated with the risk estimates presented in this section.

15.1.4.1 Nike Facility

This section describes the results of the HHRA for the Nike Facility.

15.1.4.1.1 Quantification of Cancer Risks

Table 15.1-100 presents RME lifetime cancer risk estimates for institutional workers at Buildings 1450 and 1451 and Nike Facility groundwater as a water source. For the Silo/Storage Area, Table 15.1-100 also presents cancer risk estimates for the open space recreational visitor.

No COCs were determined after COPC screening in the soil for the Buildings 1450 and 1451 area. Therefore, only the PSF water supply was assessed for Building 1450 and 1451. Lead, manganese, and nitrate are not considered carcinogenic so it is unlikely that there is an excess cancer risk for this site. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$.

COCs in surface and subsurface soil determined for the Silo/Storage Area included arsenic, lead, several PAHs, and PCB 1260. The future land use recreational scenario was assessed with ingestion of and dermal exposure to surface soil for the Nike silo/storage site. The individual carcinogenic risks are all above $1E-06$ for all COCs except PCB 1260. The total risk for the Nike Silo/Storage Area is $1E-04$. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

The groundwater at the Nike Facility was assessed as a water source for institutional workers in addition to the PSF water supply (Lobos Creek and Well 13). COCs in the Nike Facility groundwater include several inorganics, chloroform, nitrate, nitrite, and TDS. The total risk is $3E-04$, mostly from ingestion of chromium (assumed to be 100% hexvalent chromium). The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

15.1.4.1.2 Quantification of Noncarcinogenic Effects

Table 15.1-101 presents the hazard indices above $1E+00$ calculated for the buildings, silo/storage area, and groundwater of the Nike Facility. Hazard indices for the COCs in PSF water supply at the Buildings 1450 and 1451 area are all less than $1E+00$ and therefore, it is unlikely that exposure to COCs at the site will result in noncarcinogenic health effects in the industrial scenario. The total noncarcinogenic index for arsenic, the only noncarcinogenic COC at the Silo/Storage Area, for the recreational scenario is $1E+00$, mostly from ingestion of surface soil. Manganese in the groundwater as a water source has a noncarcinogenic index of $2E+00$. The residential PRG ratio screening assessment resulted in total hazard indices above $1E+00$ for the Nike Facility Silo/Storage Area and was below $1E+00$ for groundwater assessed at Buildings 1450 and 1451.

The maximum detected value of lead in surface soil at the Nike Facility Silo/Storage Area is 2143 mg/kg, which is greater than the lead soil screening value of 840 mg/kg for recreational use.

15.1.4.2 Crissy Field Study Area

This section describes the results of the HHRA for the Crissy Field Study Area.

15.1.4.2.1 Quantification of Cancer Risks

Table 15.1-102 presents RME lifetime cancer risk estimates for workers (institutional use and construction) and site visitors (recreational land use) at sites within the Crissy Field Study Area. Buildings 609, 633, and 642 had all analytes in the surface and subsurface soils screened out during the COPC screening and none remained as COCs. Therefore, these sites within the Crissy Field Study Area are unlikely to pose potential excess cancer risk to recreational visitors.

Buildings 640 and 643 were assessed together with an institutional worker exposed via ingestion of and dermal contact with COCs in surface and subsurface soil and the PSF water supply. Three inorganics, chromium, lead, and nickel; and one inorganic, phenanthrene were COCs in surface or subsurface soil samples. A total risk of $2E-09$ was determined, which is less than $1E-06$ and, therefore, it is unlikely that exposure to COCs at this site will result in an increased cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Surface soil and subsurface soil COCs at Fill Site 7 included beryllium and several PAHs and pesticides. Ingestion of and dermal contact with surface soil to 2 feet was assessed for recreational visitors at this site. A total carcinogenic risk of $1E-05$ was determined, mostly from incidental ingestion of and dermal contact with benzo(a)pyrene, and ingestion of beryllium in the surface soil. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

In addition to the recreational visitor scenario, a wetlands construction worker scenario was also assessed for the proposed wetlands restoration area. The COCs in groundwater within the proposed wetlands restoration area included several inorganics, VOCs, SVOCs, PAHs, pesticides, and water quality parameters. The total risk is $6E-07$, indicating that it is unlikely that this site will result in an excess cancer risk potential to the wetlands construction worker when exposed to the groundwater via ingestion or dermal contact to at the proposed wetlands restoration area.

The COCs in the soil from 0 to 15 ft which may be removed from the proposed wetlands restoration area and distributed elsewhere at the PSF included beryllium, bis(2-ethylhexyl) phthalate, benzo(a)pyrene, phenanthrene, ppDDE, and ppDDT. The total risk is $2E-06$, mostly from ingestion of beryllium in the soil. The residential PRG ratio screening assessment resulted in a total cancer risk for the proposed wetlands restoration area greater than $1E-06$.

Cyanide in surface soil to 2 feet was the only COC for the Sewer Lift Stations on the Crissy Field Study Area. Cyanide is not considered a carcinogen so it is unlikely that there is an excess cancer risk from exposure to this site to the recreational visitor. The COCs for the

Sewer Lift Station are not considered carcinogenic in the residential PRG ratio screening assessment.

15.1.4.2.2 Quantification of Noncarcinogenic Effects

Table 15.1-103 presents the chemical-specific hazard indices calculated for sites at the Crissy Field Study Area. All noncarcinogenic hazard indices are less than 1E+00 and, therefore, it is unlikely that exposure to surface or subsurface soil to recreational visitors, construction workers, or institutional workers at the Crissy Field Study Area will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazards greater than 1E+00 for Buildings 633 and 640/643, Fill Site 7, Crissy Field groundwater, the proposed wetlands restoration area, and the Sewer Lift Station.

The maximum detected value for lead in surface soil at the Building 640/643 area is 1420 mg/kg, which is greater than the lead soil screening value of 840 mg/kg.

15.1.4.3 Building 900s Series Study Area

This section describes the results of the HHRA for the Building 900 Series Study Area.

15.1.4.3.1 Quantification of Cancer Risks

Table 15.1-104 presents the RME lifetime cancer risk estimates for institutional workers (industrial land use) and site visitors (recreational open space land use) for the Building 900s Series Study Area. Buildings 920 and 926/927 had no analytes which were COCs in the media sampled. Therefore, these sites were assessed for the institutional worker exposed to the PSF water supply only. The COCs in the PSF water supply are not considered carcinogenic and it is unlikely that there is an excess cancer risk from exposure to them.

PCB 1254, PCB 1260, arsenic, cadmium, lead, mercury, methylene chloride, 1,4-dichlorobenzene, and phenanthrene were the COCs in surface soil for the Building 923 Area (Buildings 923 through 935) which also assessed PSF water supply exposure to the institutional workers. The total risk for the industrial/institutional worker exposed via ingestion of and dermal contact with surface soil and PSF water supply is 2E-05, mostly from PCB 1254 and arsenic. PCB 1254, PCB 1260, and arsenic have total risks by chemical

greater than $1E-06$. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Building 937 had methylene chloride, 2-methylnaphthalene, TPH-diesel fraction, TPH-gas fraction, and phenanthrene as the COCs in subsurface soil for assessment of exposure to institutional workers as well as the COCs in PSF water supply. Methylene chloride, the only carcinogenic COC has a total risk of $7E-08$, which is less than $1E-06$ and, therefore, it is unlikely that exposure to these COCs at this site will result in excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Buildings 950 and 973/974 Area had inorganics (arsenic, cadmium, lead, and thallium as the COCs in surface soil samples. A recreational visitor scenario with exposure via incidental ingestion of and dermal contact with surface soil has an excess carcinogenic risk of $5E-06$ from arsenic, the only carcinogenic COC. The residential PRG ratio assessment resulted in a total cancer risk greater than $1E-06$.

COCs in the Building 900s Series Study Area groundwater included several inorganics, VOCs, SVOCs, and water quality parameters. Construction workers during the remediation of the USTs at the study area have a total cancer risk of $7E-08$, which is less than $1E-06$ and, therefore, they are unlikely to have excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

15.1.4.3.2 Quantification of Noncarcinogenic Effects

Table 15.1-105 presents the hazard indices calculated for sites at the Building 900s Series Study Area. All the noncarcinogenic COCs have hazard indices less than $1E+00$ and, therefore, it is unlikely that exposure to the COCs at these sites will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ for Buildings 923 area, 937, 950, and the Building 900s Series Study Area groundwater.

Maximum detected values of lead in surface soil for the Buildings 923 and 950 areas are 4700 and 4000 mg/kg, respectively. These are greater than their respective soil lead screening values for industrial and recreational use (840 mg/kg).

15.1.4.4 DEH Study Area

This section describes the results of the HHRA for the DEH Study Area.

15.1.4.4.1 Quantification of Cancer Risks

Table 15.1-106 presents cancer risk estimates for site visitors (open space recreational land use) exposed to surface soil from 0 to 2 ft via ingestion and dermal contact at Buildings 267/268/287, 269/293, 283, and 286 in the DEH Study Area. Several PAHs and pesticides were determined as COCs in surface soil samples at Buildings 267/268/287. Exposure to recreational visitors via ingestion of or dermal contact with surface soil to 2 feet resulted in a total carcinogenic risk of $5E-05$, mostly from exposure to the pesticides chlordane and dieldrin. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Seven pesticides were determined to be COCs in surface soil for Building 269/293. A total carcinogenic risk of $1E-04$ resulted from ingestion of and dermal exposure to surface soil to 2 feet to recreational visitors, mostly from exposure to the pesticides chlordane and dieldrin. All carcinogenic COCs have a total risk by chemical of greater than $1E-06$ with a total cancer risk of $1E-04$ for the site. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Building 283 had lead, several PAHs, and ppDDD determined as COCs in surface soil samples. A total carcinogenic risk of $2E-06$ was calculated for ingestion of and dermal contact with surface soil to 2 feet for the recreational visitor to Building 283. The main contributor to this risk was dermal contact with benzo(a)anthracene. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Only manganese was determined as a COC in surface soil to 2 feet at Building 286 to assess an exposure to the recreational visitor. Manganese is not considered carcinogenic and therefore, exposure to the surface soil at this site is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$.

15.1.4.4.2 Quantification of Noncarcinogenic Effects

Table 15.1-107 presents the hazard indices calculated for sites at the DEH Study Area. No hazard indices are greater than $1E+00$ at Buildings 267/268/287, 283, and 286, and, therefore, exposure to surface soil to the recreational visitor at these sites is unlikely to result in noncarcinogenic adverse health effects. Chlordane in surface soil resulted in a hazard index of $7E+00$ at Building 269/293, with hazard quotients greater than $1E+00$ for both the ingestion and dermal pathways. All the other pesticide COCs in the soil at this site have hazard indices less than $1E+00$. Residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ for Buildings 283, 286, and the DEH groundwater.

The maximum detected lead value in surface soil at DEH Building 283 is 1200 mg/kg, which is greater than the lead soil screening value of 840 mg/kg for recreational use.

15.1.4.5 Main Post Study Area

Results of the HHRA for the Main Post Study Area are described in this section. The Building 231 Area and Building 1065 are being assessed under the USCOE petroleum cleanup program and not in this HHRA.

15.1.4.5.1 Quantification of Cancer Risks

Table 15.1-108 presents cancer risk estimates for institutional or commercial/office workers (industrial use) at the Main Post Study Area. The total cancer risk is $7E-05$ for the institutional worker, mostly from ingestion of the inorganics arsenic, beryllium, and chromium from the groundwater. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Buildings 228 and 1057 had the PSF water supply (Lobos Creek and Well 13) only assessed with ingestion and dermal contact to commercial/office workers. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$ for Building 228 and equal to $1E-06$ for Building 1057.

PCB 1260 was the only COC determined for surface soil samples to 2 feet at Buildings 1151/1152. Incidental ingestion of and dermal contact with PCB 1260 to the recreational visitor resulted in a total cancer risk of $3E-05$, indicating an excess risk of cancer from

exposure to PCB 1260 in surface soil. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Subsurface soil samples from Building 1167 had lead determined as the only COC and this was assessed along with the COCs in the PSF water supply (Lobos Creek and Well 13) for the institutional worker at this site. These COCs are not considered carcinogenic and therefore, it is unlikely that exposure to the institutional worker to them will result in an excess cancer risk. The COCs for Buildings 1167 are not considered carcinogenic in the residential PRG ratio screening assessment.

15.1.4.5.2 Quantification of Noncarcinogenic Effects

Several inorganics, chloroform, 1,2-dichloroethane, chloride, and TDS were the COCs in groundwater as a water source at Building 215. COCs in the PSF water supply (lead, manganese, and nitrate) were also assessed for ingestion and dermal exposure. The hazard indices calculated for sites at the Main Post Study Area are shown in Table 15.1-109. No hazard indices are greater than $1E+00$, indicating that it is unlikely that exposure to the COCs in the media at these sites will result in noncarcinogenic adverse health. Residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ at Buildings 215, 1057, and 1167.

The maximum detected lead value in subsurface soil at Building 1167 is 586 mg/kg which is less than the lead soil screening value of 840 mg/kg.

15.1.4.6 Fill Sites and Landfills

This section describes the results of the HHRA for the Fill Sites and Landfills.

15.1.4.6.1 Quantification of Cancer Risks

The cancer risk estimates for Landfill 2, El Polin spring, the Transfer Station Site, Landfill 4, Fill Site 6, and Landfill E are presented in Table 15.1-110. At Fill Sites 1 and 5, no analytes remained COCs following the COC screening. Therefore, it is unlikely that exposure to surface soil to recreational visitors at these sites will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in total cancer risks greater than $1E-06$ for both Fill Site 1 and Fill Site 5.

Landfill 2 had phenanthrene, ppDDT, and MCPD as the COCs in surface soil samples. The future recreational visitor scenario with ingestion of and dermal contact with surface soil resulted in a total cancer risk of $1E-06$ from ppDDT, the only carcinogenic COC. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Antimony, beryllium, chromium, cyanide, lead, and manganese were the COCs in surface water samples for El Polin spring, which is part of the Landfill 2 site. The total carcinogenic risk is $2E-07$, indicating that incidental ingestion of or dermal contact with the COCs in surface water to the recreational teen (age 9 through 18) is unlikely to result in excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Several PAHs, bis(2-ethylhexyl) phthalate, and isodrin were determined as COCs in surface soil samples at the Transfer Station following COPC screening. A future recreational scenario was assessed with incidental ingestion of and dermal contact with surface soil COCs. A total cancer risk of $3E-06$ was calculated, mostly from ingestion of and dermal contact with bis(2-ethylhexyl) phthalate. The residential PRG ratio screening assessment resulted in total cancer risk greater than $1E-06$.

Delta-BHC and isodrin were the COCs determined following the COPC screening in the surface soil at Landfill 4. A recreational visitor scenario with exposure to surface soil via ingestion and dermal contact resulted in a total risk of $4E-08$, which indicates that exposure to the COCs is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in total cancer risk greater than $1E-06$.

Fill Site 6 had no analytes determined as COCs following the COPC screening in the subsurface soil samples. Therefore, it is unlikely that exposure to soil to institutional workers at Fill Site 6 will result in an excess cancer risk. When groundwater was assumed to be the water source, nine inorganics were determined to be COCs. An institutional worker scenario with ingestion of groundwater as water in addition to the PSF water supply resulted in a total cancer risk of $3E-03$ from ingestion of the inorganics chromium (assumed to be 100% hexvalent chromium), arsenic, and beryllium from the groundwater. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Only subsurface soil was sampled at Graded Area 9. There is no complete pathway to these samples for the recreational visitors at Graded Area 9 and, therefore, no quantitative HHRA assessment was performed for the future land use scenario. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Silver and several pesticides were determined as COCs in surface soil samples for Landfill E following the COPC screening. The future land use recreational scenario with oral and dermal exposure to surface soil has a total cancer risk of $8E-07$, indicating that it is unlikely that exposure to COCs in surface soil to recreational visitors will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

15.1.4.6.2 Quantification of Noncarcinogenic Effects

Table 15.1-111 presents hazard indices for noncarcinogenic health risks at the Fill Sites and Landfills. At Landfill 2, El Polin spring, the Transfer Station, and Landfill 4, all the hazard indices are less than $1E+00$ and, therefore, it is unlikely that exposure to media at these sites to the future recreational visitors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices for Fill Site 5 and Graded Area 9 that are less than $1E+00$, and greater than $1E+00$ for all other Fill Sites and Landfills sites.

At Fill Site 6, all inorganic COCs except barium, beryllium, and silver resulted in hazard indices greater than $1E+00$ for the industrial worker from ingestion of groundwater as a water source. This indicates that the groundwater is not a good source for municipal water at Fill Site 6. For the recreational scenario, Landfill E has hazard indices greater than $1E+00$ for silver ($2E+00$). All other hazard indices at the Fill Sites and Landfill sites are less than $1E+00$, indicating that exposure to COCs in the media for the future land use scenarios at these sites is unlikely to result in noncarcinogenic adverse health effects.

15.1.4.7 Miscellaneous Sites

This section describes the results of the HHRA for the Miscellaneous Sites.

15.1.4.7.1 Quantification of Cancer Risks

The cancer risk estimates for Miscellaneous Sites (Buildings 662, 680, 1244, and 1351; FPCGS; Lobos Creek; and Mountain Lake) are presented in Table 15.1-112. Lead in groundwater was the only COC for Building 662. In addition, the PSF water supply COCs (lead, manganese, and nitrate) are assessed with ingestion and dermal contact to institutional workers at Building 662. No analytes were determined to be COCs in surface soil. The COCs are not considered carcinogenic so it is unlikely that exposure to COCs in the subsurface and the PSF water supply will result in an excess cancer risk to the institutional worker at Building 662. The residential PRG ratio screening assessment resulted in a total cancer risk less than $1E-06$.

For Building 680, the only COC in both surface and subsurface soil is PCB 1260. In addition, the PSF water supply COCs (lead, manganese, and nitrate) were assessed. The future land use institutional worker scenario with ingestion of and dermal exposure to surface and subsurface soil and the PSF water supply resulted in a total risk of $6E-05$, mostly from both ingestion of and dermal exposure to PCB 1260 in surface soil. The residential PRG ratio screening assessment resulted in total cancer risk greater than $1E-06$.

Building 1244 had only the PSF water supply (Lobos Creek and Well 13) assessed with ingestion and dermal contact to commercial/office workers as there were no COCs determined in the subsurface soil following COPC screening. The PSF water supply COCs (lead, manganese, and nitrate) are not considered carcinogenic and, therefore, it is unlikely that exposure of these COCs to commercial/office workers at Building 1244 will result in an excess cancer risk. The COPCs for the residential PRG ratio screening assessment are not considered carcinogenic for Building 1244.

COCs in the soil samples for Building 1351 are lead (surface soil), cadmium and bis(2-ethylhexyl) phthalate (subsurface soil). A future land use industrial worker scenario with ingestion of and dermal contact with surface and subsurface soil and the PSF water supply was assessed. The industrial worker scenario resulted in a total risk of $4E-07$, indicating that exposure to the COCs at this site is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

TPH-gas fraction and several PAHs were the COCs determined in surface soil samples at the FPCGS. The recreational visitor scenario with ingestion of and dermal contact with surface soil to 2 feet was assessed and resulted in a total carcinogenic risk of $8E-05$, mostly from ingestion and dermal exposure of the PAHs. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Lobos Creek had surface water and sediment COCs of arsenic (sediment only) and lead, manganese and nitrite (surface water only) to assess for the older child (age 9 through 18) playing in the creek. The total cancer risk from ingestion and dermal contact with sediment in Lobos Creek is $5E-07$, indicating that exposure to the COCs at this site is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Lobos Creek is also a source for the PSF water supply and conservatively is assumed to provide 90 percent of the PSF water supply in the industrial scenarios but PSF water supply COCs (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, it is unlikely that exposure to industrial workers to the PSF water supply will result in an excess cancer risk.

There were no analytes determined as COCs following the COPC screening in Mountain Lake sediment. Cyanide, lead, chloride, sulfate, and TDS were COCs determined in the surface water at Mountain Lake following COPC screening. None of these COC are considered to be carcinogenic. Therefore, it is unlikely that exposure of these COCs to the recreational older child while playing in Mountain Lake will result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk equal to $1E-06$.

15.1.4.7.2 Quantification of Noncarcinogenic Effects

Table 15.1-113 presents hazard indices calculated for the Miscellaneous Sites. At FPCGS, n-hexane and naphthalene (both TPH-gas fractions) were the only COCs with a hazard indices greater than $1E+00$ with values of $1E+00$ each from ingestion of and dermal contact with TPH-gas fraction in the surface soil samples to the recreational visitor. At all other Miscellaneous Sites, no hazard index is greater than $1E+00$, which indicates that exposure at these sites to the respective receptors is unlikely to result in noncarcinogenic adverse health.

The residential PRG ratio screening assessment resulted in total hazard indices at each of the Miscellaneous Sites greater than $1E+00$.

The maximum detected lead value at Building 1351 surface soil is 473 mg/kg. This value is less than the lead soil screening value of 840 mg/kg.

15.1.4.8 Baker Beach Study Area

This section describes the results of the HHRA for the Baker Beach Study Area.

15.1.4.8.1 Quantification of Cancer Risks

Table 15.1-114 presents RME lifetime cancer risk estimates for site visitors (recreational open space land use) at the disturbed area sites within the Baker Beach Study Area. At Baker Beach Disturbed Area 1a, PAHs and a pesticide, delta-BHC, were determined to be COCs in surface soil samples following COPC screening. A recreational visitor scenario with incidental ingestion of and dermal contact with surface soil was assessed and resulted in a total cancer risk of $2E-05$, mostly from exposure to benzo(a)pyrene and dermal exposure to benzo(b)fluoranthene and indeno(1,2,3-cd)pyrene. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Inorganics, PAHs and pesticides were determined to be COCs in surface soil at Disturbed Area 1 following COPC screening. The seep on Disturbed Area 1 had lead and PCB 1260 in the sediment samples and manganese and TDS in the surface water samples as COC following the COPC screening. None of these COCs in any of the media resulted in an increased risk to either the recreational visitor exposed via ingestion of or dermal contact with surface soil or the recreational older child (age 9 through 18) exposed to the seeps surface water or sediments. Therefore, it is unlikely that exposure to surface soil, sediment, and surface water at Disturbed Area 1 will result in an excess cancer. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Three PAHs (acenaphthylene, benzo(a)pyrene and phenanthrene) were determined as the COCs for surface soil at Disturbed Area 2 following COPC screening. A recreational visitor scenario with incidental ingestion of and dermal contact with surface soil resulted in a total

risk of $5E-06$, all from benzo(a)pyrene. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

At Disturbed Area 3, antimony, chromium, nickel, and phenanthrene were the COCs determined in surface soil samples following COPC screening. The carcinogenic risk is $2E-08$ in the recreational visitor scenario with ingestion of and dermal contact with surface soil. Therefore, exposure to the recreational visitor at Disturbed Area 3 is unlikely to result in an excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

Chlordane in surface soil samples at Disturbed Area 4 was the only COC determined following COPC screening. The total risk is $4E-07$, indicating that exposure to the recreational visitor at Disturbed Area 4 via ingestion of or dermal contact with surface soil is unlikely to result in excess cancer risk. The residential PRG ratio screening assessment resulted in a total cancer risk equal to $1E-06$.

15.1.4.8.2 Quantification of Noncarcinogenic Effects

Table 15.1-115 presents the hazard indices calculated for sites at the Baker Beach Study Area. Antimony has a total hazard index of $1E+00$ at Disturbed Area 3. All other sites and COCs have hazard indices less than $1E+00$. Therefore, exposure at these sites is unlikely to result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices greater than $1E+00$ for Disturbed Areas 1a and 3 and less than $1E+00$ for Disturbed Areas 1, 2, and 4.

The maximum detected lead value in surface soil at Disturbed Area 1 is 2050 mg/kg , which is greater than the lead soil screening value of 840 mg/kg for recreational use.

15.1.4.9 Battery Howe/Wagner

This section describes the results of the HHRA for Battery Howe/Wagner. There were no COCs determined in the surface soil samples for Battery Howe/Wagner following COPC screening. This indicates that ingestion of or dermal exposure to surface soil to recreational visitors to Battery Howe/Wagner is unlikely to result in excess cancer risk or noncarcinogenic adverse health effects. The residential PRG ratio screening assessment

resulted in a total cancer risk greater than $1E-06$. The residential PRG ratio screening assessment resulted in a total hazard index greater than $1E+00$.

15.1.4.10 Miscellaneous Follow-On Sites

This section describes the results of the HHRA for the Miscellaneous Follow-on Sites. Miscellaneous Follow-on Sites Buildings 669, 1245, 1369, 1388, and 1750 all had no analytes determined to be COCs in their respective surface or subsurface soil samples following COPC screening. Therefore, only the PSF water supply (Lobos Creek and Well 13) was assessed for institutional workers at these sites. Building 302 had no complete pathway to sampled media. Therefore, no quantitative assessment was performed for the future land use scenario at Building 302.

15.1.4.10.1 Quantification of Cancer Risks

The cancer risk estimates for the Miscellaneous Follow-on Sites are presented in Table 15.1-116. The COCs in the PSF water supply (lead, manganese, and nitrate) are not considered carcinogenic. Therefore, exposure to the PSF water supply to industrial workers is unlikely to result in an excess cancer risk at Buildings 669, 1245, 1369, and 1750. The COCs for the residential PRG ratio screening assessment are not considered carcinogenic at these sites.

Analytes at EOM determined to be COCs following COPC screening in surface soil to 2 feet included bis(2-chloroethoxy)methane, ppDDE, and ppDDT. The total risk to the recreational visitor from ingestion of and dermal contact exposure to surface soil is $4E-06$ from the two pesticides. The residential PRG ratio screening assessment resulted in a total cancer risk greater than $1E-06$.

15.1.4.10.2 Quantification of Noncarcinogenic Effects

Table 15.1-117 presents hazard indices calculated for the Miscellaneous Follow-on Sites. The hazard indices for all sites and media are less than $1E+00$, therefore it is unlikely that ingestion or dermal exposure to the media and receptors will result in noncarcinogenic adverse health effects. The residential PRG ratio screening assessment resulted in total hazard indices less than $1E+00$ except for Building 1369, where it is greater than $1E+00$.

15.1.4.11 Risk Characterization for Lead

In risk assessment, the potential for noncarcinogenic effects associated with exposure to lead is evaluated differently from that of other chemicals for two primary reasons. First, although many studies have evaluated the effects of low-level exposure to lead, the USEPA study groups have not reached a consensus on a threshold level for lead exposure. It appears that some of lead's effects, particularly those associated with certain blood enzymes and neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. As a result, no RfD has been established for lead, even though adverse effects are well known. Second, lead is ubiquitous in the environment, coming from a variety of sources including air pollution, diet, water pipes, soils, and paints. Because exposure is rarely limited to one pathway, hazards associated with lead cannot be fully evaluated without regard to other environmental contributors. In light of these issues, the USEPA has developed the integrated exposure uptake biokinetic (IEUBK) model for lead in children, which integrates the various exposure pathways for a child population in a specific area.

The CEPA DTSC has developed their own tool for evaluating exposure to the potential for adverse health effects resulting from lead in the environment, referred to as the DTSC Lead Risk Assessment Spreadsheet, or the "Pb6 Model" (CEPA, 1996). The Pb6 model, designed following the USEPA IEUBK model, assesses human health effects from lead based on blood lead concentrations. Toxicological data indicate that 10 mg/dL is the residential blood lead concentration of concern of the protection of human health. The Pb6 model uses an algorithm for estimating blood lead concentrations in children and adults based on a multi-pathway analysis.

The DTSC Pb6 Model was used with various tap water lead concentrations of 3, 5, 9, 11, and 15 ppb; with and without plant uptake of lead from the soil; bioavailability of lead from the soil of 3, 20, and 44 percent; and using residential and recreational scenarios. Input exposure factors were the same as those used in the RI risk assessment or model default values. The results are presented in Table 15.1-118. Pb6 modeling resulting in 10 mg/dL blood levels in the 95th percentile of residential and recreational children using the variety of input parameters listed above resulted in soil lead concentrations of 125 to 2,981 and 230 to

7,330 mg/kg, respectively. These results corroborate the use of the lead soil screening values presented in the next paragraph.

In this RI HHRA, lead soil screening values were developed for use in screening lead concentrations in the soil for residential, industrial, and recreational exposure scenarios. There are two lead soil screening values developed, a residential and recreational, the later of which was used for both the recreational and industrial scenarios. The residential lead soil screening value is 400 mg/kg and the recreational lead soil screening value is 840 mg/kg. These values are maximum concentrations interpreted to be protective of human health under these scenarios at the PSF. The residential lead soil screening value is identical to both the national and Region IX USEPA residential PRG for lead in soil. The recreational soil lead screening value is the same as federally mandated allowable lead concentrations in soil amendments sold to the public for use in home gardens and is supported by the Pb6 model results developed under this RI.

As mentioned in the previous paragraph, the recreational soil lead screening value of 840 mg/kg is used in this HHRA for both the recreational and industrial scenarios. The recreational screening value was selected as the most appropriate value for use in the industrial scenario because exposure to soils is less under industrial scenario than under the recreational scenario in this HHRA. Thus, the recreational screening value is conservative for use in the industrial scenario. The residential screening value is not appropriate for the industrial scenario because residential soil exposure is greater than that for both the recreational and the industrial scenarios. Additionally, the USEPA Region IX industrial PRG for lead is 1000 mg/kg, which is closer to 840 mg/kg, while the residential PRG is 400 mg/kg.

15.1.4.12 Uncertainties

There are uncertainties associated with each step in the risk assessment process that may influence the results of the risk assessment. Many uncertainties are generic to the risk assessment process, while others are site-specific. The major sources of uncertainties in this risk assessment are identified below for each of the four risk assessment steps.

15.1.4.12.1 Uncertainties Associated with Identification of COCs

Uncertainties associated with identifying COCs include:

- Potential risks associated with chemicals intentionally excluded from the risk assessment
- Potential risks associated with chemicals unintentionally excluded from the risk assessment.

As discussed in Section 15.1.1, not all chemicals detected at each site were selected as COCs.

Potential risks associated with chemicals unintentionally excluded from the risk assessment also constitute a source of uncertainty in the risk assessment. Although the RI included an assessment of all areas where site-related chemicals were suspected because of past activities at the PSF, some chemicals could potentially be present in environmental media not sampled in the RI field program. Also, not all samples were analyzed for the full list of analytes. Thus, chemicals that may be present on site, but not identified in the RI, could cause underestimation of total site risks. However, it is very unlikely that chemicals presenting significant risks to receptors at the PSF were not identified in this evaluation. As discussed in Section 1.2, the results of an enhanced preliminary assessment were used to develop the sampling rationale in the RI work plan, and specific analytes for each sample were selected based on operational history of the site.

Several soil samples from the Building 900s Series Study Area, Crissy Field Study Area, and the DEH Study Area were collected near or within the saturation zone of these sites. These samples may be considered either groundwater or soil samples but were assessed as soil samples. This may over- or underestimate the concentrations in the soil samples.

While there are COCs determined in the PSF water supply following COPC screening (lead, manganese, and nitrate), the upgraded water treatment plant is likely to remove these contaminants during treatment. The estimation of noncarcinogenic adverse health effects from these three COCs might overestimate the risk at site with institutional, industrial, or commercial/office worker future land use scenarios.

15.1.4.12.2 Uncertainties Associated with Exposure Assessment

Most site-specific uncertainties are associated with the exposure assessment. The most significant uncertainties associated with this step that may influence the results of the risk assessment include:

- Assumptions used to estimate exposure point concentrations and intake variables
- Difficulties in accurately characterizing exposure under land use conditions and in predicting future land uses
- Risks associated with potential exposure pathways excluded from the risk assessment.

As discussed in Section 15.1.2.3, the 95-percent UCL of the arithmetic mean assuming lognormal distribution or the maximum detected concentration was conservatively used to represent the exposure point concentration. These values are likely to overestimate true concentrations at the site over the exposure periods evaluated, because samples at each site were generally collected in areas most likely to contain analytes (e.g., where visible staining was present) and chemical concentrations were assumed to remain constant over the entire exposure period (i.e., up to 30 yr). However, in a few cases an analyte in a sample was qualified by the laboratory as greater than the reported concentration, indicating that the actual concentration in the sample was unknown. Exposure point concentrations based on this subset of samples are therefore likely to be underestimated, although risks may still be either overestimated or underestimated, depending on the influence of other uncertainties. Additional uncertainty is introduced by the use of data that are qualified as estimated. These data may be biased high or low, resulting in risks that may be overestimated or underestimated.

Although it is current USEPA policy to calculate CDIs for carcinogenic effects by prorating the total cumulative dose over a lifetime, this approach becomes problematic as the exposures in question become less frequent or shorter in duration (USEPA, 1989b). Also, this approach does not account for the age at onset of exposure and, therefore, assumes that exposure to a carcinogen for a given period poses the same carcinogenic risk to all individuals regardless of age. However, for some genotoxic carcinogens, experimental data suggest that a dose applied early in life can have a different effect than the same dose applied later in life. Thus, uncertainty associated with exposure assessment of carcinogens, particularly genotoxic carcinogens, increases as exposure duration decreases.

A comparison of the USEPA approach with an alternative approach provides one measure of the magnitude of uncertainty associated with the exposure assessment method. Crump and Howe (1984) present an alternative model for calculating risks associated with exposure to carcinogens that adjusts for age at onset of exposure. In comparison to the USEPA approach for calculating the CDI and risk associated with a 30-yr exposure duration, which was used in this risk assessment, this alternative model estimates greater risks to individuals whose exposure begins before about age 16 and lower risks to individuals whose exposure begins after age 16. Specifically, the Crump and Howe model predicts risks that are about two-fold higher than risks predicted by the USEPA approach if exposure begins at birth, but less than one-fifth the risk if exposure begins at age 45. Thus, the difference in risk estimates developed using the USEPA approach versus the Crump and Howe model may span as much as one-half an order of magnitude; however, for the large majority of individuals (i.e., those over age 16), the USEPA method provides a higher (i.e., more conservative) estimate of risk.

The degree to which the available sampling data accurately reflect levels of chemicals at each site is another important source of uncertainty. Risk estimates at sites where limited sampling was conducted may be overestimated or underestimated. This uncertainty is especially critical for risk estimates based on the results of one sample. Also, there is significant uncertainty associated with all risk estimates for chromium, because sampling data for chromium do not distinguish between chromium III and chromium VI. As indicated previously, risk estimates for soil exposure pathways were based on the assumption that 0.1 percent of total chromium would be present as the more toxic form chromium VI (see Section 15.1.1). This assumption may overestimate or underestimate actual site risks from ingestion or inhalation of chromium in soil.

As noted previously, other uncertainties associated with exposure assessment include the assumptions used to estimate intake variables for individual exposure pathways, the likelihood of exposure pathways and land uses occurring, and the risks associated with exposure pathways not quantitatively evaluated. As discussed in Section 15.1.2.3, the exposure variables used in this risk assessment were selected to represent the RME for the populations of potential concern. Some potential exposure pathways were not fully quantified, including inhalation of chemicals in fugitive dust and inhalation of vapors

generated during showering or other activities using hot water. As noted in Section 15.1.2.3.11, exposures via inhalation of fugitive dust are not likely to be significant because chemical intake via inhalation of fugitive dust is 3 orders of magnitude less than intake via ingestion of soil. Inhalation exposures to VOCs in municipal water are difficult to estimate; however, interim guidance from the USEPA's Risk Assessment Forum indicates that exposure via inhalation of VOCs in municipal water is roughly comparable to that resulting from ingestion of 2 liters of water/day (Wood, 1988). Therefore, the use of ingestion of drinking water from the PSF water source and groundwater to industrial workers at certain PSF sites is an adequate estimate of exposure to VOCs in municipal water. The use of the PSF water source and groundwater as municipal water sources potentially overestimating the exposure to industrial, institutional, or commercial/office workers as discussed previously in this section and in the following paragraph.

The use of groundwater as the municipal water source is assumed in the BRA at several RI sites where an industrial, institutional, or commercial/office use is projected. However, groundwater is not currently used as a source of water at any of these sites and this is an overestimation of potential risk. As discussed in section 2.3.6 of this RI report, the use of groundwater as the municipal water source at many of the RI sites is impractical or inadvisable because of low well yields, the shallowness of the water table, and the presence of sanitary sewers. Low well yields would prevent wells from providing useful quantities of water. Shallow groundwater is unlikely to provide the appropriate water quality because of the infiltration of ubiquitous chemical and biological contamination from the ground surface. In urbanized areas, even small amounts of leakage from sanitary sewer systems can contaminate shallow groundwater. For example, average estimated well yield at the Nike Facility is insufficient to support useful water supply wells. Groundwater at the Nike Facility eventually flows to Lobos Creek which has been used as a municipal water source, but at a distance of nearly 2,000 ft, any contaminants at the Nike Facility are unlikely to have a significant impact on Lobos Creek as evidenced by sample results from Lobos Creek. Fill Site 6 and Buildings 215 and 662 are located in urbanized areas with shallow groundwater.

Several sources of uncertainty in the exposure assessment affect the estimates of exposure and the final estimates of risk. In all exposure assessments, uncertainties are associated with

the representativeness of the sampling data and the inadequacy of the exposure assumptions. Because of these uncertainties, chemical intakes were calculated for individual exposure pathways using conservative intake variables (frequently 90th-percentile estimates), which were likely to overestimate true exposure. However, total intakes may be underestimated when all potential exposure pathways are not evaluated.

15.1.4.12.3 Uncertainties Associated with Toxicity Assessment

Most of the major uncertainties associated with toxicity assessment are ubiquitous to risk assessment process and include uncertainties related to:

- The quality of studies used as the basis for toxicity factors
- Potential differences in toxicity and absorption efficiency between humans and laboratory animals
- Derivation of dermal toxicity values from oral toxicity values
- Applicability of studies conducted in experimental animals dosed at high levels to human exposures at lower concentrations
- Validity of the critical underlying assumption in the dose-response model for carcinogens (linearized multistage model) that there is no threshold for carcinogenesis (i.e., there is no dose of a carcinogen that is not associated with a risk of cancer)
- Calculation of lifetime cancer risks on the basis of less-than-lifetime exposures
- Potential synergistic or antagonistic interactions of chemicals to which the same individual may be exposed.

Because of these uncertainties associated with toxicity assessment, risk assessment methods are designed to be highly conservative. For example, estimates of cancer risk are likely to be overestimations of actual cancer risks because USEPA- and CEPA-derived CSFs are based on the upper 95th-percentile risk estimates in the carcinogenesis dose-response model. The use of uncertainty factors in the derivation of RfDs is also devised to be health protective and may tend to overestimate risks for some chemicals. For example, the magnitude of the uncertainty factor for antimony (1,000) is large in comparison to the hazard indices calculated for this metal and, therefore, may overestimate true site risks.

Chromium was identified as a COC at several sites. A high degree of uncertainty is associated with the evaluation of chromium VI as a carcinogen via oral exposure. USEPA

considers the weight of evidence to be insufficient to evaluate chromium VI as an oral carcinogen. However, CEPA has taken a more conservative approach and derived an oral CSF from a single study in which a significant increase in malignant and benign stomach tumors (combined) was observed in female mice, but not male mice, fed chromium VI in the regular diet. Although the oral CSF derived by CEPA was used in this risk assessment, the high degree of uncertainty associated with this value should be considered when interpreting the results of this evaluation.

There are several COCs that could not be quantitatively evaluated in the risk assessments (i.e., no USEPA-derived toxicity values or alternative approaches were available to quantify potential risks). The toxicity profiles provide a qualitative discussion of the noncarcinogenic effects associated with exposures to these COCs. Because of the lack of toxicity values for these COCs, the risk and hazard indices can not be calculated and evaluated. Therefore, there is a tendency to underestimate the potential exposure from the media to receptors.

Uncertainties associated with quantifying the dermal exposure pathway include all of the points noted above and are important to this risk assessment. Neither the USEPA nor CEPA have developed dermal toxicity values, in large part because quantitative data regarding dose-response relationships following dermal exposure are very limited. To account for the additional uncertainties associated with the dermal exposure pathway, conservative assumptions concerning oral and dermal absorption were used to derive intakes and dermal toxicity values. However, as discussed in Section 15.1.3.1, risks associated with dermal exposure to PAHs were not quantified and, therefore, remain a source of uncertainty in the risk assessment.

15.1.4.12.4 Uncertainties Associated with Risk Characterization

Uncertainties associated with risk characterization include:

- The validity of adding risks or HQs for multiple chemicals
- The validity of adding risks or HQs across pathways.

Instances where it may be inappropriate to sum HQs (e.g., the COCs affect different target organs) are noted in the previous sections on quantification of noncarcinogenic effects.

Again, risk assessment methods are designed to be highly conservative to address the uncertainties associated with each step in the risk assessment process. Thus, where sufficient sampling data are available to characterize the environmental setting, "true" risks are very unlikely to be greater than (and may be significantly less than) risks estimated by using standard risk assessment methods.

15.1.5 Summary and Conclusions

This risk assessment was conducted to evaluate potential human health risks associated with exposure to site-related chemicals in soil, groundwater, sediments, and surface water at the PSF. For the RI, the PSF was divided into 11 study areas: Nike Facility, Crissy Field Study Area, Building 900s Series Study Area, DEH Study Area, Main Post Study Area, Fill Sites and Landfills, Miscellaneous Sites (Buildings 662, 680, 1244, 1351, FPCGS, Lobos Creek, and Mountain Lake), GGBHTD, Baker Beach Study Area, Battery Howe/Wagner, and Miscellaneous Follow-On Sites (Buildings 302, 669, 1245, 1369, 1388, 1750, and EOM). Area designations were based on future site land uses and on analytes identified by available sampling data. The risk assessment included identification of COCs, exposure assessment, toxicity assessment, and risk characterization.

COCs were identified on the basis of several nature and extent characteristics. Substances were selected for inclusion in the risk evaluations for each site when the maximum detected value was greater than the respective residential USEPA Region IX PRG or California MCL, was not an essential nutrient, and was detected above the CRL at a frequency greater than 5 percent. A variety of inorganics, VOCs, SVOCs, PAHs, PCBs, pesticides, and water quality parameters were subjected to the COC screening process for soil, sediment, surface water, and groundwater at all RI sites where COCs were identified.

No air sampling was conducted in this investigation. However, the air pathway may be expected to contribute a relatively minor amount to total site risks as most of the study sites are either paved or heavily covered with vegetation, thus reducing the potential for dusts to become airborne (see Section 15.1.2.3.11 for an example calculation).

Two land-use scenarios were considered in the risk assessment. Sites within each study area were evaluated separately under industrial or recreational land use scenarios, depending on the predominant potential future land use of each site from the GMPA (NPS, 1994).

Where appropriate, the following exposure pathways were considered:

- Ingestion of and dermal contact with soil
- Ingestion of and dermal contact with drinking water
- Ingestion of and dermal contact with surface water
- Ingestion of and dermal contact with sediment
- Ingestion of and dermal contact with groundwater.

RME estimates of lifetime cancer risk were calculated for each of the land-use scenarios described above. A target risk range of $1E-04$ to $1E-06$ is considered by USEPA to be safe and protective of public health (Federal Register 56(20):3535, Wednesday, January 30, 1991). This risk range was used as a basis for comparison of risk estimates calculated for carcinogens identified at the PSF. Noncarcinogenic effects were compared to a hazard index of $1E+00$, which indicates that the exposure is below a level that is likely to cause adverse health effects even in the most sensitive members of the population. Lead was compared with the lead soil screening value of 840 mg/kg for industrial and recreational land use scenarios.

Maximum detected lead values in surface soil was greater than the lead soil screening value of 840 mg/kg for the following sites:

- Nike Facility silo/storage area (2143 mg/kg)
- Crissy Field Study Area Building 640/643 (1430 mg/kg)
- Building 900s Series Study Area Building 923 Area (4700 mg/kg) and Buildings 950/973/974 (4000 mg/kg)
- DEH Study Area Building 283 (1200 mg/kg)
- Baker Beach Study Area Disturbed Area 1 (2050 mg/kg).

A summary of the risks and hazards for the HHRA is presented in Table 15.1-119. Sites assessed for carcinogenic risk with estimated total cancer risks less than $1E-06$ are listed below by study area.

Crissy Field Study Area

- Building 640/643
- Proposed wetlands restoration area.

Building 900s Series Study Area

- Groundwater
- Building 937.

Fill Sites and Landfills

- El Polin Spring
- Landfill 4
- Landfill E.

Miscellaneous Sites

- Lobos Creek.

Baker Beach Study Area

- Disturbed Area 1
- Disturbed Area 3
- Disturbed Area 4.

There were several sites with COCs not considered carcinogenic which indicates that exposure to the COCs at these sites is unlikely to result in excess cancer risk. Four sites, the Nike Facility silo/storage area and groundwater; DEH Study Area Buildings 269/293, and Fill Site 6 have estimated total carcinogenic risks greater than or equal to $1E-04$.

Ingestion of the PSF water supply and dermal contact during showering was possible in all industrial, institutional, and commercial/office land use scenarios. Three COCs (lead, manganese, and nitrate) were identified in the COPC screening. These COCs are not considered carcinogenic and result in a total hazard index of $5E-01$. This indicates that it is unlikely that exposure to the PSF water supply to industrial worker will result in an excess cancer risk or noncarcinogenic adverse health effects.

The likelihood that actual risks are underestimated is very low because of the conservative assumptions used to develop the cancer risk estimates; actual risks may be significantly less than predicted values. USEPA's Guidelines for Carcinogen Risk Assessment states that "...the linearized multistage procedure leads to a plausible upper limit to the risk that is consistent with proposed mechanisms of carcinogenesis..." The true value of the risk is unknown, and may be as low as zero." (Fed. Reg. 51, 185:33992-34054, 1986).

Estimated chemical-specific HIs exceed or are equal to 1E+00 for the future land use scenarios for the sites listed below.

- Nike Facility silo/storage area (arsenic 1E+00)
- Nike Facility Groundwater (manganese - 2E+00)
- Building 269/293 in the DEH Study Area(chlordane - 7E+00)
- Fill Site 6 (several inorganics ranging from 1E+00 to 1E+01)
- Landfill E (silver 2E+00)
- FPCGS [n-hexane and naphthalene (TPH-gas fractions) both 1E+00].

15.2 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment for the PSF follows guidance in USEPA (1992e), and includes the following components:

- Problem Formulation
- Exposure Analysis
- Stress Response Analysis (characterization of ecological effects and toxicity assessment)
- Risk Characterization.

Each of these components is discussed in this section. The ecological risk assessment data are available on diskette in Appendix U.

15.2.1 Problem Formulation

The Problem Formulation section summarizes existing information pertinent to the assessment of ecological risk at the PSF. The PSF is a 1,400 acre facility managed by the NPS, with areas within the PSF managed by other federal and state agencies. The area is

highly disturbed, and most of the vegetation is non-native. The forest that covers the PSF is largely comprised of non-native species, and the only native trees are the coast live oak and the arroyo willow, which are limited to the riparian forests near Lobos Creek and Mountain Lake (Jones and Stokes, 1994). Historically, trees were not a dominant feature of the landscape.

The climate is moderate, and characterized by few frosts, fog, winter rains, and onshore marine winds. The winds have affected the PSF vegetative communities, as the slopes facing the ocean historically were dominated by low shrubs and grasses. Trees only occurred in sheltered valleys. The forests were planted by the U.S Army in the late 1800's, and included acacia, pine, eucalyptus, and cypress trees; native redwood, spruce and madrone were also planted (Jones and Stokes, 1994). The 1935 distribution of the forest is now termed the "Cultural Forest". The trees have aged, and according to Jones and Stokes (1994) many have exceeded their normal life span.

The geologic units at the PSF include modern beach deposits, dune deposits, the Colma Formation, serpentinite-rich Franciscan Formation. The geologic units are described in detail in Section 2.3.4. The surface water hydrology is detailed in Section 2.3.3. Ground water hydrology is discussed in Section 2.3.5, and geology in Section 2.3.4.

There is wildlife habitat of high value at the PSF, especially considering that the rest of the San Francisco Bay Area is so highly urbanized. The habitats that have the highest bird diversity are the native coast live oak and willow, followed by eucalyptus, and Monterey pine and Monterey cypress (Jones and Stokes, 1994). Forest habitat in large unbroken portions, with multi-storied vegetation and a shrub or herbaceous understory, are considered to have the highest value. High value habitat occurs at Mountain Lake and Lobos Creek. The central and southern parts of PSF also contain high value habitat (Jones and Stokes, 1994).

The U.S. Army managed the forests primarily by maintaining the introduced forest by removing down material, mowing ground cover, removing fuel, suppressing fire, and pruning or removing trees to avoid imminent hazards (Jones and Stokes, 1994). Other Army activities at the PSF included disposal of residential wastes, the Nike facility operations, and

maintenance of hospitals, officer housing, and the golf course. Currently, much of the PSF is used for hiking.

The types of contaminants that potentially occur at the PSF are metals, solvents, and pesticides. Pesticides were not stored in many areas, and so some of the pesticide occurrence is likely the result of registered use of the compounds to control insect pests. Sections 4 through 14 describe the historical use of chemicals at the PSF, and document the likely sources at PSF.

The assessment and measurement endpoints, which structure the risk assessment, are presented in Table 15.2-1. An endpoint is a characteristic of an ecosystem that can be related to exposure to one or more of the COPCs (USEPA, 1992e). An assessment endpoint is a value of the ecosystem for which protection is desired (USEPA, 1989e). Assessment endpoints have some or all of the following characteristics (USEPA, 1989e):

- social relevance,
- biological relevance,
- susceptibility to the hazard,
- logically related to the decision,
- unambiguous operational definition, and
- are measurable or predictable.

Measurement endpoints are quantifiable responses to one or more of the COPCs that are related to or predictive of the assessment endpoint. Measurement endpoints were selected that were readily measurable as well as appropriate to the scale of the site and the exposure pathways. The assessment endpoint for Crissy Field is obviously specific to this one location (Table 15.2-1). The assessment endpoints for aquatic life applied only where surface water was present or potentially present, which are Lobos Creek, Mountain Lake, the Baker Beach seep, Crissy Field, and El Polin Spring. Although El Polin Spring contains surface water, the aquatic habitat is limited. The other assessment endpoints apply to all locations, as indicated in Table 15.2-1.

The biota that occur at the PSF, as well as a short description of each of the study areas, are discussed in the following sections. Table 15.2-2 lists the sites within the PSF for which

ecological risk was addressed. Figure 3.1-1 presents the Conceptual Site Model for the PSF. The major habitat types were identified and summarized from the Forest Management Plan 1995 (Jones and Stokes, 1994). Habitat maps from the Forest Management Plan (Jones and Stokes, 1994) were used as the basis for the summary (Appendix U).

15.2.1.1 Description of Biota

This section provides an overview of the taxa present at the PSF. The key receptors (Section 15.2.1.2) were selected from this overall review of species and taxa. Further detail on species and habitats present at the PSF can be found in Jones and Stokes (1994).

Special Status Species. Special status species are those species that are listed or proposed for listing as threatened or endangered according the Federal Endangered Species Act (ESA), 50 CFR 1711-12, or those species that are listed by the State of California under the California ESA (14 California Administration Code 670.5). Other species included as special status species are those listed in 54 FR 544, January 6, 1989 as Category 1 or 2 candidates for possible future listing under the Federal ESA, and those animal species of special concern to DFG (Jones and Stokes, 1994). In addition, animals fully protected under the California Fish and Game Code, Sections 3511 (birds), 4700 (mammals), 5050 (reptiles and amphibians), as well as 3503.5 (active and recently active raptor nests) are included as species of special status (Jones and Stokes, 1994).

A table of habitat types and potentially occurring species of special Federal or State status (i.e., threatened, endangered, or other classification) associated with these habitat types was compiled from data obtained from Jones and Stokes, 1994. Table 15.2-2 summarizes this information relative to the sites investigated at the PSF. The sites and study areas at the PSF are highly impacted by human activity. Most of the sites are physically disturbed to a great extent, planted in non-native vegetation, and often mowed. However, other habitat types occur within the immediate vicinity of these sites, which could provide habitat to species of special status.

Species expected to frequent open marine or bay waters were excluded from Table 15.2-2 because they are not directly associated with the sites or study areas; the ESAP report (Dames and Moore, 1995) addresses potential impacts to the San Francisco Bay due to

transport of contaminants from the PSF into the Bay. Special status species that are included in Table 15.2-2 as potentially occurring at PSF are those that have been reported at various locations in the PSF (i.e., Raven's manzanita), or that frequent habitats common on the PSF (i.e., Cooper's hawk, which forages in forested areas). Many of the avian species listed as special status species potentially occurring at the PSF are considered rare or uncommon visitors to the PSF, or migrants (Jones and Stokes, 1994).

The tree lupine moth (*Grapholita edwardsiana*) is a Federal C3 species, occurs in coastal sand dunes typically in association with its larval food plant *Lupinus arboreus*, and is common throughout the PSF wherever its food source is found. Other listed invertebrate species have not been detected in recent surveys, and suitable habitat is generally lacking for these species (Table 15.2-2) (Jones and Stokes, 1994).

No amphibian or reptile special status species were observed (Jones and Stokes, 1994). Suitable habitat for the California red-legged frog (*Rana aurora draytoni*) exists only at Mountain Lake and Lobos Creek, but individuals were not observed, perhaps due to the presence of bullfrogs (*Rana catesbiana*). Pond turtles probably historically occurred at Mountain Lake, but are not present now, possibly because of the presence of an introduced species, the red-eared slider.

There are several avian species of special status that occur at the PSF. Of the avian species that have recently been noted or likely may occur at the PSF, the double-crested cormorant (*Phalacrocorax auritus*) is a species of special concern to the State of California, and occurs at Mountain Lake. Other special status avian species that may occur are the western snowy plover (*Charadrius alexandrius nivosus*), loggerhead shrike (*Lanius ludovicianus*), and long-billed curlew (*Numenius americanus*), which are uncommon winter visitors; the plover and curlew frequent sandy coastal areas or mudflats, while the shrike frequents open habitats. The California gull (*Larus californicus*) is a common nonbreeding visitor that occurs along shorelines and at Mountain Lake. The saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*) is an uncommon resident and possible breeder at Mountain Lake. The elegant tern (*Sterna elegans*) and the California least tern (*Sterna antillarum browni*) are rare or uncommon nonbreeding visitors. The Vaux's swift (*Chaetura vauxi*), California yellow warbler (*Dendroica petechia brewsteri*), and the willow flycatcher

(*Empidonax traillii*) are uncommon spring and/or fall migrants, and the flycatcher frequents Mountain Lake and Lobos Creek.

Numerous raptor species are rare or uncommon migrants over the Marin Headlands, and possibly the PSF; these are the white-tailed kite (*Elanus caeruleus*), bald eagle (*Haliaeetus leucocephalus*), northern harrier (*Circus cyaneus*), sharp-shinned hawk (*Accipiter striatus*), northern goshawk (*Accipiter gentilis*), Swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), golden eagle (*Aquila chrysaetos*), and prairie falcon (*Falco mexicanus*) (Jones and Stokes, 1994). The Cooper's hawk (*Accipiter cooperi*) and merlin (*Falco columbarius*) are rare or uncommon nonbreeding visitors to the forested areas. The peregrine falcon (*Falco peregrinus anatum*) is an uncommon nonbreeding resident.

The saltmarsh vagrant shrew (*Sorex vagrans halicoetes*) is not likely to occur at this time at the PSF due to the absence of its preferred habitat. It is unknown if the Townsend's western big-eared bat (*Plecotus townsendii townsendii*) occurs at the PSF at this time (Jones and Stokes, 1994). Table 15.2-2 summarizes the findings of Jones and Stokes (1994) and provides a list of the special status species potentially occurring at the PSF.

Aquatic Life. Freshwater aquatic habitat capable of supporting populations of aquatic life at the PSF is limited to Lobos Creek and Mountain Lake. In addition, there is a seep at Baker Beach that likely supports aquatic plants, invertebrates, and possibly amphibians. Mountain Lake is expected to support typical lentic species, whereas lotic species are to be expected in Lobos Creek. El Polin Spring supports limited numbers of freshwater aquatic invertebrates and possibly amphibians, but not fish, due to its small size and limited flow. The ESAP report (Dames and Moore, 1995) describes marine life and potential impacts to the Bay from the PSF in detail. This ecological risk assessment focuses on potential impacts to terrestrial life, freshwater aquatic life, and the future wetland at Crissy Field.

Plants. Native woodlands at PSF were historically limited to Lobos Creek, and the northern and northeastern sides of the hills where they were sheltered from saline marine winds (Jones and Stokes, 1994). The current forest consists of introduced species. Open space on the PSF has vegetation that includes native species, landscaping species, shrubs, lawns, and weeds.

The native vegetation and soils have been highly disturbed due to human settlement; native soil has been moved or lost to erosion, and soils have been compacted by vehicle and foot traffic. The growth of the cultural forest altered the organic matter content, soil fertility, water-holding capacity, and soil pH of the PSF soils (Jones and Stokes, 1994). The planted forests have displaced nearly all of the native vegetation at the PSF. The remaining patches have been subjected to invasion by non-native species.

The following native vegetative communities were listed by Jones and Stokes (1994), who used the classification system of Holland (1986):

- Northern foredunes
- Central dune scrub
- Northern coastal bluff scrub
- Northern coastal scrub
- Mixed serpentine chaparral
- Coastal terrace prairie
- Serpentine bunchgrass
- Coastal and valley freshwater marsh
- Freshwater seep
- Central coast live oak riparian forest
- Central coast riparian scrub
- Coast live oak woodland

Non-native communities include:

- Non-native grassland
- Ice plant mats
- Cultural forest

The native plant communities remaining at PSF occur along the west- and north-facing coastal bluffs, from the Crissy Field area to Baker Beach, and as scattered fragments of habitat in the southwestern and southeastern part of PSF (Jones and Stokes, 1994).

Invertebrates. Invertebrates are animals without backbones. There are numerous terrestrial invertebrates that inhabit the PSF, including coleopterans (beetles), lepidopterans (butterflies

and moths), and arachnids (spiders). Invertebrates are often referred to as "soil fauna" in the ecological risk assessment.

Amphibians. There are several amphibian species expected to occur at the PSF. Among these are tree frog species, bullfrogs (*Rana catesbeiana*), leopard frogs (*Rana pipiens*), and salamander species. Amphibians are poikilothermic vertebrates with smooth, moist, hairless skins; they include caecilians, sirens, newts, salamanders, toads, and frogs. Toads and frogs form the order Anura or Salintia. Toads are typically considered members of the genus *Bufo*, and frogs are typically in the genus *Rana*; generally speaking, toads have dry warty skins whereas frogs are slippery. Some amphibian species tolerate saline waters; the crab eating frog (*Rana cancrivora*), green toad (*Bufo viridis*) and some members of the salamander genus *Ambystoma* and *Batrachoseps* live in saline aquatic habitats, including saline lakes and ocean beaches (Feder and Burggren, 1992). However, no amphibians are truly marine. It is doubtful that the future wetland at Crissy Field would ever support populations of amphibians due to its salinity.

Amphibians may contact surface soils, but toxicity information relating direct contact with soil to adverse effects in populations is generally lacking. Likewise, dietary toxicity studies that would allow relating intake to adverse effects are also lacking for this class of animals. It is assumed in the ecological risk assessment that birds, which have dietary intakes an order of magnitude or more higher than amphibians, will drive (i.e., be the most sensitive taxa) in the risk assessment, and that risks due to exposure to soils derived from intake estimates for birds will be protective of amphibians.

Toxicity information for amphibians is available for direct contact with water; however, because chemical uptake rates from soil relative to those from water are likely to be quite different, toxicity due to exposure to a soil medium is not comparable to toxicity due to exposure to water. In addition, many of the studies available for review were performed with amphibian early life stages (Devillers and Exbrayat, 1992). The larval life stage of amphibians, which is aquatic, is often more sensitive than the adult terrestrial life stage. The special status amphibians listed by Jones and Stokes (1994) have not been observed in recent times. Risk to amphibians will be addressed for exposure to surface water in Mountain Lake, Lobos Creek, a naturally occurring seep at Baker Beach, and El Polin Spring.

Birds. Many bird species, including those with special status, occur or may occur because appropriate habitat is available at the PSF. Species of special status include the snowy plover (*Charadrius alexandrinus*), long-billed curlew (*Numenius americanus*), California gull (*Larus californicus*), Cooper's hawk (*Accipiter cooperii*), and merlin (*Falco columbarius*). Osprey (*Pandion haliaetus*) occur, but as consumers of fish, are not expected to be exposed to soil or terrestrial biota. As true freshwater aquatic habitat is extremely limited, osprey are expected to forage widely in the San Francisco Bay area, and thus contact with the PSF is expected to be minimal. Raptors are assumed to avoid areas of human disturbance, and are predicted to forage primarily in the more remote areas of PSF. Other bird species are more tolerant of human disturbance, such as the mourning dove (*Zenaidura macroura*). Many passerines occur at the PSF, and of these species, those that feed on the ground are expected to be the most highly exposed.

Mammals. Mammals at PSF are expected to be exposed to soils and surface water, as well as to other biota by ingestion of potentially contaminated prey items. Many small mammals burrow, and may ingest greater quantities of soil than non-burrowing animals. Different species occur at different sites within the PSF. Valley pocket gopher (*Thomomys bottae*) mounds were observed at many sites. Western harvest mice (*Reithrodontomys megalotis*) are expected to occur. They are omnivorous small mammals predicted to consume 50 percent vegetation and 50 percent animal matter. Raccoon (*Procyon lotor*) and skunk tracks were also observed at many locations. Large grazing mammals are not present at the PSF.

15.2.1.2 Key Receptors

The ecological receptors selected as indicator species for the ecological risk assessment met the following criteria:

- Species or group of species occurs at the PSF
- If species is a special status species, its habitat occurs at the PSF and makes its occurrence a possibility
- Species has a likelihood of exposure to chemical sources at the PSF
- Species is a component of assessment endpoints

- Species has a likelihood of high exposure due to natural history such that it represents a "worst-case" for exposure parameters, and risk estimates will be protective of lesser exposed species
- Species is socially or biologically significant
- Toxicological literature is available for this or similar species.

The purpose for selecting a subset of potentially occurring species as key receptors to represent risk at a site is to:

- Reduce the complete list of species known or suspected to occur at a site to a few representatives
- To make the assessment comprehensible and manageable
- Avoid redundancy and repetition with respect to the analysis.

There are two primary factors that introduce redundancy into the ecological risk assessment. These are the toxicity benchmark values (TBVs), and the media specific ingestion rates. For example, there are many species of passerine birds at the PSF. However, there is only one avian TBV for most of the COPCs; i.e., toxicological information is not available for all species of sparrows or other small bird that may occur. Dietary ingestion information for passerine birds is limited to very few values. Therefore, all estimates of avian risk based on the same TBVs and the same exposure parameters will be equal.

Use of key receptors to represent all species that potentially occur at a site is not intended to avoid making the assessment less site specific or less conservative. Use of key receptors merely reflects the lack of species specific information available and uses the data to address those types of receptors most likely to be exposed to source media. The assumption behind these estimates is that if there is no risk to highly exposed species, then all species will be protected.

Raptors and other avifauna contact various exposure media including soil, surface water, and biota. Waders and waterfowl may ingest sediments and surface water along the shoreline during feeding activities. Raptors and upland birds are not expected to contact sediments, but may ingest surface water. Raptors and upland birds are exposed to soils during feeding and preening activities, although soil ingestion by raptors is expected to be lower than that of

ground feeding birds. Because of their relatively high metabolic rates, which lead to increased dietary ingestion rates, and their potential to contact many source media, various species of avifauna predominate as key receptors at the PSF.

A site tour with the U.S. Army and its subcontractors, NPS, USEPA, and representatives of the State of California was conducted in the fall of 1994. The purpose of this tour was to view the PSF from an ecological perspective, select appropriate receptors for which to quantify risks at the PSF, and to identify potential exposure pathways at each site. Most of the sites identified for investigation on the PSF were visited, and the habitat and likely ecological receptors at each site identified. The Forest Management Plan (Jones and Stokes, 1994) was reviewed for the occurrence of special status species and habitats at the PSF. In addition, species of special or social interest were considered as ecological receptors.

Based on efforts by the above agencies, the following list of key species was compiled to represent major feeding guilds and taxa:

Terrestrial

Plants	Special interest to NPS, contact soils, important food base
Soil fauna	High rate of soil contact, common prey item
American robin	Ground feeding with high soil contact, insectivore
Mourning dove	Ground feeding with high soil contact, granivore/herbivore
Western harvest mouse	Burrowing omnivore with high soil contact, common prey item
Valley pocket gopher	Burrowing herbivore with high soil contact
Raccoon	May burrow, contacts sediments, surface water and soils
Peregrine falcon	Preys predominantly on birds
Red-tailed hawk	Preys predominantly on small mammals

Wetland/Aquatic

Aquatic life	High rate of contact with sediments and surface water (includes fish, benthic invertebrates, and aquatic plants)
Amphibians	Common at PSF, contact water and sediments
Mallard duck	Ubiquitous, dabbling duck contacts sediments, feeds on invertebrates and plants
Western sandpiper	Ubiquitous, contacts sediments, feeds on invertebrates

Table 15.2-2 presents the key receptors expected at each study area or site. Invertebrates and plants were selected as the primary receptors in direct contact with soils.

Red-tailed hawks (*Buteo jamaicensis*) were selected to represent raptors that feed predominantly on small mammals. Peregrine falcons (*Falco peregrinus*) were selected to represent raptors that feed predominantly on birds.

Mourning doves were selected to represent birds that feed primarily on plant material, and American robins (*Turdus migratorius*) were selected to represent birds that consume invertebrates, although this species actually is omnivorous and consumes equal amounts of animal and plant material. As ground-feeding birds, these species exposure rates are likely to be higher than any arboreal species.

Valley pocket gopher mounds were observed at many sites, so this species was selected to represent herbivorous small mammals. Western harvest mice were selected as small omnivores because they are likely to occur and be a major component of PSF food chains. Raccoons were selected to represent larger carnivore/omnivores.

Mallard ducks (*Anas platyrhynchos*) were selected to represent waterfowl. These are dabbling ducks and are likely to be exposed to sediments and surface water, as well as to invertebrates. Food habits and toxicological information are available for this species, which makes the mallard a good key receptor as risk estimates are less uncertain.

Western sandpipers (*Calidris mauri*), a common representative of the family *Scolopacidae*, which includes sandpipers, tattlers, godwits, curlews, and dowitchers, were selected to represent shorebirds. Shorebirds have higher sediment ingestion rates than waterfowl based on the available data (Beyer et al., 1994).

Amphibians were listed as key receptors at the Baker Beach seep, Mountain Lake, El Polin Spring, and Lobos Creek.

15.2.1.3 Description of Study Area and Site Conditions

This section provides a brief overview of the sites and study areas evaluated from an ecological perspective. Some of the areas that are currently developed are scheduled to be returned to the natural state. For example, a portion of the Crissy Field Study Area and a portion of the EOM site, for which soil and groundwater data are available, will eventually become a wetland under the current management plan.

The Ecological Risk Assessment is not intended to stand alone without the supporting background information contained in the RI report, or in the tables or figures that accompany Section 15.2. Further information regarding the geology, hydrology, and physical characteristics of the sites and study areas is found in Section 15.1.2.2 of this report.

Large surface water resources are limited to Lobos Creek and Mountain Lake. Isolated seeps occur, which are very small and have minimal flow rates; these seeps do not flow into Lobos Creek or Mountain Lake. Table 15.2-2 presents an overview of the habitat, special status species expected, key receptors, and potential exposure pathways for each of the study areas and sites within the PSF.

Nike Facility. No special status species were reported within the site (Jones and Stokes, 1994); however, the site is relatively isolated and could therefore be attractive to raptors. The Nike facility is an open disturbed area where landscaping materials are stored. Broken pavement covers a large portion of the surface area. The area is surrounded by upland forest. There are no surface water features, although the site drains towards a swale in the ground surface which was observed to be met in the spring of 1996. All terrestrial key receptors were evaluated for contact with potentially contaminated soils and sediments from open ditches (Table 15.2-2). Overland flow of contaminants towards the swale was estimated, and potential impacts to receptors predicted.

Crissy Field Study Area. Crissy Field Study Area is a flat, open area that lies next to the San Francisco Bay and which includes Fill Site 7, as well as Buildings 609, 611, 633, 637, 640/643, 642, and the Sewer Lift Stations. Building 637 is assessed in the basewide petroleum cleanup program; therefore, no ecological assessment is presented for this site. Several assessments were performed for the potential future scenarios in this study area.

All key terrestrial receptors were evaluated for the sites listed above. The Fill Site 7 area was assessed in combination with the EOM site because of the similar characteristics of the area. In addition, because a portion of the area is scheduled to be returned to a wetland state, three additional assessments were performed as described below.

Key terrestrial receptors were evaluated for contact with soils in the future wetland footprint because of the possibility of the soil (to a depth of 15 feet) being extracted and spread on the

surface. As the current soil/sediments within the wetland footprint would require extraction in order to form the future wetland, these soils/sediments are unlikely to be a source of exposure for future aquatic life. However, all soils within 15 feet of the surface also were evaluated as if they were sediments under the future wetland scenario.

Aquatic receptors were evaluated for future contact with surface water as estimated by current groundwater data for the future land use conditions in the wetland area. The wells used for the evaluation of future risk to the wetland were in or near the Crissy Field Study Area.

Influx of saltwater from the Bay will determine the physical and biological character of the wetland as predominantly marine or estuarine. Aquatic life adapted for saline conditions will predominate in the wetland; benthic invertebrates, marine or estuarine fish and vegetation are the key receptors.

Building 900s Series Study Area. There were many buildings, parking lots and roads within this flat and highly disturbed study area during the U.S. Army's activities. Many of the buildings have since been demolished by the NPS. Special status water birds may occur in the vicinity of this study area due to the proximity to the Bay. Special status plant species may occur nearby. The special status plants are not within the 900s area, since this is mowed and disturbed, but may occur on the serpentinite cliff behind the 900s area (Table 15.2-2). The cliff has not been disturbed by army activities, and so was not evaluated. All terrestrial key species were evaluated at this site. In addition, quantitative risk estimates were made for the mallard duck and sandpiper. There are no freshwater features at this location to attract amphibians, or provide habitat for true aquatic life. During the comment response period for the Draft RI, the regulatory agencies suggested examining waterfowl and wading birds at the Building 900s area. Therefore, these receptors in the aquatic food web were also evaluated here.

DEH Study Area. This is a disturbed area near the Bay, which used to be mostly covered with pavement and buildings. The pavement and buildings were demolished in 1996. There are no freshwater features. Although the study area is in close proximity to the Bay, it is bordered on one side by residential/commercial property, and avian feeding and nesting

habitat is all but non-existent. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are most likely to occur.

Main Post Study Area. This study area is disturbed and is comprised of non-native vegetation. It includes data for Buildings 215, 228, 231, 1057, 1065, 1167, and 1151. There were no chemicals detected at Building 215, and all COPCs at Building 1057 occurred only within a metal covered vault, for which there are no ecological exposure pathways. Both Buildings 231 and 1065 are assessed under the basewide petroleum cleanup program. Therefore, these four sites do not appear in the ecological risk assessment results. All key receptors may occur except water birds, aquatic life, and amphibians. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are most likely to occur.

Fill Site 1. This site is disturbed and is comprised of non-native vegetation and forest. Special status raptors may occur (Jones and Stokes, 1994). All key receptors may occur except water birds and amphibians. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur.

Landfill 2. Special status raptors and plants may occur at this site in this mature eucalyptus forest. All key terrestrial receptors were evaluated.

El Polin Spring. Surface water data from El Polin Spring were evaluated as a source of drinking water for terrestrial animals, although true aquatic habitat is not currently present at El Polin Spring. Data for El Polin Spring, which is downgradient of Landfill 2, were evaluated. El Polin Spring is a small spring approximately two feet in diameter and less than six inches deep. A slight trickle of water emerges from the spring, is funneled into an artificial rock-lined channel, which then flows through a residential area. The NPS has discussed plans to return this area to a natural riparian state; however, with the new redevelopment plans for the PSF, this area may continue to remain disturbed. Amphibians may utilize this spring, although its significance to populations of amphibians at PSF is

likely to be small due to its small size. Freshwater snails and invertebrates were observed under debris in El Polin Spring during January, 1996 by the U.S. Army. All key receptors except water birds were evaluated (Table 15.2-2).

Transfer Station. The habitat around this area is forest and mixed non-native vegetation. It is relatively remote, and sits at the end of a cul-de-sac. It is possible that any of the terrestrial ecological receptors selected for the analysis could occur in this area. In addition, several special status species may occur (i.e., Coopers hawk and merlin). Historic activities at the site were the transfer of household garbage. The area is fairly small (1.01 ac), which means that the possibility of the site affecting populations of ecological receptors is small. All key receptors except aquatic life, amphibians, and water birds were evaluated (Table 15.2-2).

Landfill 4. Special status raptor species may occur at this site. The site consists of mixed grass/forested habitat. All key receptors except water birds, aquatic life, and amphibians are predicted to occur here (Table 15.2-2).

Fill Site 5. This site is disturbed and is comprised of non-native and native vegetation, and includes a sensitive plant community. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are most likely to occur. All key receptors were evaluated, water birds, aquatic life, and amphibians.

Fill Site 6. This site is disturbed and is comprised of non-native vegetation. All key receptors may occur except water birds, aquatic life, and amphibians. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Graded Area 9. This site is disturbed and is comprised of non-native vegetation. All key receptors may occur except water birds, aquatic life, and amphibians. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Landfill E. This site is disturbed and is comprised of non-native vegetation. All key receptors may occur except water birds, aquatic life, and amphibians. Water birds, aquatic

life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 662. This is a small site consisting of 0.056 ac. The habitat at the site is disturbed and consists of non-native grasses. No special status species are expected to use the site. All key receptors may occur except water birds, aquatic life, and amphibians. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 680. Special status raptor species may occur in the forested habitat near this site. All key terrestrial receptors were evaluated at this location. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are the types of animals most likely to occur (Table 15.2-2). The area west of the building was the former site of a UST and an AST. The area is included in the basewide petroleum cleanup program, and therefore, samples collected in the tank area are not assessed in this report.

Building 1244. No assessment is presented for this site because samples were collected only from inside the building and there are no exposure pathways for ecological receptors.

Building 1351. This site includes the building and surrounding vicinity. Data collected within the building were not used in the analysis as there is little chance of complete exposure pathways for the ecological receptors. Raptors are unlikely to occur due to the high level of human activity immediately at the site, but were included as potential receptors due to the open area nearby. No special status species occur at the site. The area is small (0.034 ac) and physically disturbed. All key receptors may occur except water birds, aquatic life, and amphibians. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

FPCGS. The habitat at this site is disturbed, and the area is almost entirely paved. All key receptors may occur except aquatic life and amphibians. Due to the buildings, there is a high level of human disturbance likely to drive raptors away. Aquatic life and amphibians lack

appropriate feeding or breeding habitat; the ESAP addresses impacts to the Bay waters from PSF source areas. The former UST area north of Building 991 is not assessed in this risk assessment. It will be included under the USCG program.

Lobos Creek. This creek is the major lotic surface water feature on the PSF. It lies within a steep gully, and flows westward to the Pacific Ocean. The creek is shallow (less than one foot depth) and narrow (less than three feet wide) in most places. For further information on the flow, refer to Section 2.3.3. Birds, amphibians, and mammals may frequent the riparian habitat. This site includes sensitive habitat and native vegetation communities. Special status species may occur. All key receptors, both terrestrial and aquatic, were evaluated for this site (Table 15.2-2).

Mountain Lake. Mountain Lake is the only large ponded site occurring on the PSF. This lake receives surface runoff from the highway, the golf course, and residential areas south of the PSF during periods of heavy precipitation. Amphibians, benthic invertebrates, fish, and emergent and submergent aquatic vegetation are present. Birds and wildlife associated with open water and wetland areas are expected to occur at the site. Native vegetation communities occur, as well as the potential for many special status species. All key receptors, both terrestrial and aquatic, were evaluated for this site (Table 15.2-2).

GGBHTD. This area was permitted to the GGBHTD by the U.S. Army in the 1930's. No assessment is presented for this site because any further evaluation will be conducted by the GGBHTD.

Baker Beach Study Area. There are several small subareas within the Baker Beach Study Area, and these were evaluated independently. Special status species are expected to occur within the Baker Beach Study Area. At one site, Disturbed Area 1, a seep occurred and provided an opportunity to evaluate potential risk due to surface water ingestion by terrestrial species, as well as direct contact by amphibians or other aquatic life. Exposure to a sediment sample collected from the seep was also assessed. At all Baker Beach sites, soil is the contaminated media. The area of Disturbed Area 1 is small, consisting of 1.315 ac. A portion of Disturbed Area 1 (0.10 ac) is characterized as a mounded landfill material area and is evaluated separately. Disturbed Area 1a, north of Disturbed Area 1, is 0.059 ac.

Disturbed Area 2 is a small area that consists of 0.39 ac. Disturbed Area 3 consists of 3.49 ac. Disturbed Area 4 consists of 0.52 ac. The habitat and species occurrence are expected to be similar for the other Baker Beach sites. The total area that is potentially affected by U.S. Army related activities is approximately 6 ac (Table 15.2-2). All key receptors except waterfowl and wading birds were evaluated for the Baker Beach sites.

Battery Howe/Wagner. Special status raptors have the potential to occur in this study area, where the habitat is composed of mixed grasses and forest. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 302. No special status species are expected to occur in this site. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 669. No special status species are expected to occur in this site. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 1245. Special status raptors have the potential to occur at this site, where the habitat is composed of mixed grasses and forest. All other key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 1369. No special status species are expected to occur at this site. Raptors are not expected to frequent this vicinity due to high levels of human disturbance, although quantitative risk estimates were made in order to be conservative. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 1388. No special status species are expected to occur at this site. Raptors are not expected to frequent this vicinity due to high levels of human disturbance. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

Building 1750. The investigation of this site resulted in the identification of no chemicals of concern. Therefore, this site was not evaluated in the ecological risk assessment.

Fill Site 7/East of Mason Shoreline. No special status species are expected to occur at this site. All key receptors except water birds, aquatic life, and amphibians were evaluated. Water birds, aquatic life, and amphibians lack appropriate feeding or breeding habitat. Small birds tolerant of human disturbance, and mammals (rodents, raccoons) are likely to occur (Table 15.2-2).

15.2.1.4 Selection of COPCs

COPCs were selected on a site by site basis. The total list of analytes at each site or study area was reviewed. Inorganic analytes were compared to ambient soil concentrations as discussed in Section 3.7. Summary statistics for the COPCs are reported in Tables 15.2-4 through 15.2-44. The methodology used to select the COPCs is presented in Section 3.7. The application of the methodology used to select the COPCs is presented by location in Sections 4-14.

Analytes typically considered non-toxic, as well as those that do not occur as a free ion in the environment, were not evaluated in the ecological risk assessment. These included calcium, magnesium, nitrate/nitrite, potassium, sodium, sulfate, and chloride.

When the analyte was detected in one sample of a duplicate pair, but not the other, the nondetected value was divided by two and the resulting value averaged with the detected value. The analyte was considered to have been detected.

The maximum detected value was then compared to the lognormal UCL95 for each analyte, and the lower of the two values selected as the Exposure Point Concentration (EPC). In all cases, when the sample size was less than five, the maximum was used and not the UCL95

in all cases. The methodology used to determine the lognormal UCL95 was presented in Section 15.1.2.3.

Soil data used in the ecological risk assessment to obtain exposure point concentrations included those samples collected from depths less than three ft (91.44 cm). Jorgensen et al. (1991) reports information that 63 percent of plant roots for over 20 plant species, including grasses, occur at depths ranging from 0.09 to 4.7 ft (2.8 to 144 cm). The mean was 0.85 ft (25.98 cm), with a standard deviation of 0.79 ft (24.2 cm) for a total of 103 data points. This indicates that 63 percent of root system can occur 0.85 ft from the surface. Therefore, using the top 3 ft of soil does include the majority of the root system. Observations of fallen eucalyptus trees indicated a shallow root system as well. The route of exposure for plants is direct contact with soil.

15.2.2 Exposure Analysis

This section evaluates which of the exposure pathways presented in the site conceptual model (Figure 3.1-2) are actually complete, and are quantifiable for the media investigated. In some instances, exposure pathways that may be complete cannot be quantified due to lack of appropriate information. In other cases, the pathway is qualitatively evaluated and is found to be an unlikely source of significant exposure, and is not quantified. Because of the large variety of ecological receptors present at the PSF, a subset (termed key receptors) was selected for quantitative analysis. The criteria used to select this subset were described in Section 15.2.1.2.

The types of ecological receptors include aquatic life, vegetation, invertebrates, amphibians, birds, and mammals. There are several major habitats at PSF which include terrestrial uplands and aquatic habitats. The habitats and the physical description for each study area or site were provided in Table 15.2-2 and Section 15.2.1.3. Some urban areas are scheduled to be converted back to natural habitat, so that future use exposure scenarios were considered. In addition, the presence of sensitive plant communities on serpentinite outcrops is also important to consider.

This section of the report describes how exposure was predicted for the various receptors. Exposure intakes for ingestion of soils, surface water, sediment, and diet were quantitatively

evaluated for birds and mammals. Exposure for aquatic life and amphibians was addressed with the exposure point concentrations for surface water, or in the case of Crissy Field, the exposure point concentrations for ground water. The exposure rates for plants and soil fauna were addressed by utilizing the exposure point concentrations for soil.

15.2.2.1 Exposure Pathways

An exposure pathway is the process in which plants, animals, or birds are exposed to site-related contaminants. A complete exposure pathway consists of a COPC, a source media (i.e., soil, surface water, or sediment), a receptor, release and transport mechanism(s), and a route of exposure (e.g., ingestion of source media).

The major exposure pathways identified in the Ecological Conceptual Site Model (Figure 3.1-2) were evaluated to the extent that data allow. Table 15.2-2 and 15.2-3 indicate the exposure media and exposure routes, both of which form the exposure pathways, that were quantitatively addressed for each of the key receptors at each location.

All vertebrate receptors except amphibians were assumed to contact soils or sediments in some manner on a regular basis. Amphibians also may contact soils, but the toxicological data are inadequate to address adverse effects by this exposure pathway. Because ingestion rates are higher for birds and small mammals, as are surface areas, any exposure intakes due to ingestion or dermal contact with soils or sediments are presumed to be conservatively indicative of exposures for amphibians as well.

Plants and soil invertebrates are considered to be exposed by being in direct contact with soils. Ingestion is difficult to quantitate for invertebrates; therefore, only direct soil contact was evaluated.

Dermal contact by birds and mammals may occur, although this pathway is insignificant for most of the contaminants at the PSF relative to ingestion of soils or dietary ingestion. However, exposure to sediments or soils by dermal contact was quantified in order to be conservative. (Figure 3.1-2).

Surface water resources at the PSF are very limited. The USEPA ambient water quality criteria (AWQC), which are protective of most species of aquatic life, were used as

benchmarks for the evaluation of toxicity to aquatic life (i.e., plants, aquatic invertebrates, or fish) and amphibians for surface water at Mountain Lake and Lobos Creek, as well as the future wetland at Crissy Field. Amphibians have a permeable dermal membrane compared to birds or mammals, and therefore direct contact with chemicals in water was considered to be the major route of exposure. Frogs, however, do not ingest drinking water, so ingestion of water is not a route of exposure for amphibians. Amphibians were evaluated for exposure to surface water or sediments at El Polin Spring.

Birds and mammals ingest surface water; therefore, drinking surface water was a complete pathway for avian and mammalian key receptors. Dermal contact with surface water by birds and mammals was not quantitatively addressed because it is expected to be a very minor source of exposure relative to ingestion. Small mammals (e.g., western harvest mouse, pocket gopher) are unlikely to ingest surface water due to their fossorial nature, and likely meet most of their metabolic water requirements by dietary consumption (Table 15.2-3). Palmer and Fowler (1975) indicate that pocket gophers do not drink surface water; therefore, surface water ingestion was only evaluated for the western harvest mouse, all bird species, and raccoons. Terrestrial plants and invertebrates were considered to not contact surface water.

Small upland burrowing mammals typically do not burrow in sediments, because the burrows flood. Therefore, small upland mammals were not considered to be exposed to sediments under most conditions. One exception occurred at the Nike site, where sediment data were combined with soil data.

Sediment ingestion by waterfowl, waders, and mammals was evaluated wherever sediment data occurred in conjunction with aquatic or riparian habitat. Amphibians and fish also contact sediments, but in general, toxicology information relating exposure to adverse effects was not available. Thus, this pathway, although indicated as a potential exposure pathway in Figure 3.1-2, was not quantified. Terrestrial plants and invertebrates are not expected to contact sediments; however, risk to aquatic plants and invertebrates is addressed with the ambient water quality criteria and sediment quality criteria, as available.

Upland surface soils are likely to be ingested by any of the terrestrial receptors, including passerines, raptors, and small birds. Raptors are unlikely to ingest large quantities of soil, because often they do not ingest the gastrointestinal contents of their prey. Predators of small birds, insects and mammals, such as the fox, have low soil ingestion rates. Therefore, it was assumed that raptors also have low soil ingestion rates as they feed on the same prey items as do the fox. Small ground-feeding birds and shorebirds are more likely to contact soils or sediments, respectively, than are raptors.

Plants and invertebrates are exposed directly to chemicals by contact with soil or sediment. Therefore, intakes were not calculated for these groups. Soil data used in the ecological risk assessment to obtain exposure point concentrations included those samples collected for the top 3 ft (91.44 cm) of soil depth.

Frogs and other amphibians are exposed to water by direct contact; frogs, however, do not drink water (Feder and Bruggeren, 1994). Therefore, there are no surface water intakes for amphibians. Risk to amphibians is predicted by comparing the abiotic media concentrations to the AWQC for water or the sediment quality criteria (SQC) for sediment exposure.

Dietary ingestion is a potential pathway for all receptors except plants. However, the dietary ingestion pathway was only quantitatively addressed for birds and mammals. Dietary ingestion data for invertebrates is limited, as is toxicity information for invertebrates, fish, and amphibians relating dietary chemical concentrations to adverse effects.

Ingestion pathways (i.e., ingestion of surface water, sediment, or soil by birds and mammals) were quantitatively evaluated by predicting intakes of chemicals from ingestion of these media; intakes were then compared to TBVs from studies based on oral ingestion. Direct contact pathways (e.g., plant or invertebrate contact with soil or amphibian contact with surface water) were evaluated by comparing chemical concentrations in abiotic media to TBVs for these media. Not all receptors are necessarily exposed to all media, as indicated in Figure 3.1-2.

15.2.2.2 Exposure Point Concentrations

Those inorganic analytes for which soil concentrations exceeded ambient values, and were assessed to be potentially associated with army activities, were considered COPCs. Analytes that occurred at concentrations less than the ambient soil concentration at all samples within a site were excluded from further evaluation as being unrelated to army activities. Analytes typically considered nutrients were not evaluated; these included calcium, potassium, sodium, and magnesium. These analytes would not be expected to be a major component of risk outside of situations such as pure deposits. Other analytes considered nutrients, but which are toxic at high concentrations and associated with industrial or human activities, such as zinc, were evaluated. Additional inorganics in water that were not evaluated included nitrate, nitrite, sulfate, and chloride, as discussed in Section 15.2.1.4. All organic analytes in all media were evaluated as COPCs in the ecological risk assessment.

The maximum detected value was used as the Exposure Point Concentration (EPC) when there were less than five samples. When there were five or more samples, the lower of the values for the maximum compared to the UCL95 based on a lognormal data distribution was used as the EPC. For all locations except the Crissy Field future wetland, soil depths within three feet of the surface were evaluated. At the Crissy Field future wetland, it was assumed that disturbance and removal of surface soils would occur during wetland construction; therefore, soils within 15 feet of the surface were evaluated. Summary statistics for each site evaluated in the ERA are presented in Tables 15.2-4 through 15.2-44.

15.2.2.3 Exposure Intakes

Exposure intakes are the quantities of chemicals ingested by birds or mammals as a result of receptors inadvertently ingesting contaminated soil or sediment, as a result of drinking contaminated water, or as a result of ingesting contaminated prey items. This section describes how estimates daily intakes for the ecological receptors were made for the complete exposure pathways identified in Table 15.2-3. These intakes are represented in units of milligram chemical/kilogram body weight/day (mg/kg bw/d).

An exposure intake is the amount of chemical in the source media multiplied by the receptor-specific ingestion rate for that source. The exposure intakes are determined by the exposure parameters of body weight, home range, percent soil in diet, dietary ingestion rate, surface

area, and water ingestion rate (Table 15.2-45). The 95th percentile of the available data was used as the exposure parameter statistic in the exposure intake equations, except for home range, for which a mean value was used to be conservative. This is conservative because the mean home range is smaller than the 95th percentile estimate, and so results in a more conservative AUF.

To realistically predict exposure of animals that are mobile in their environment, both areal extent of contamination (Table 15.2-2) and home range estimates (Table 15.2-45) for the ecological receptors were utilized. The size of the home range, or the entire area that the animal lives and feeds in, was used in conjunction with the areal extent or site area to derive area use factors (AUFs). These factors were then applied to exposure intake equations to more accurately reflect chemical intake. In some instances, use of feeding territory was deemed more appropriate as a representation of an animal's foraging space. These instances were when a species had a large home range and /or was migratory, so that during the time it was expected to remain at the PSF, its feeding territory would define exposure better than the entire home range.

The AUF is the ratio of the site area to home range area for each of the ecological receptors, and adjusts the exposure intakes to reflect that the animal is mobile in the environment. When the site area exceeded the receptor's home range, an AUF of one was applied to the exposure intake estimates. The AUF does not ever exceed one, as this would artificially inflate exposure estimates. However, when the site area was small relative to the home range, the exposure intakes were proportionally reduced to reflect that the receptor obtains part of its daily soil, surface water, or dietary ingestion from areas outside of the site.

Home range data for each of the receptors were obtained from several sources. Home range data for passerine birds were available for robin and marsh wren (USEPA, 1993d). The robin data were used to represent the robin at the PSF, whereas data for both species were used to represent the mourning dove. As the goal is to assess all species by evaluating risks to the key receptors, it is appropriate to consider exposure parameter data for different species. Territory estimates are often used in lieu of home range; territory is space that is actively defended, and as such, the size is smaller and more conservative. Home range data were available for both the red-tailed hawk and the mallard duck (USEPA, 1993d). Data for the

American kestrel were used to represent the peregrine falcon. Data for the spotted sandpiper were used to represent the western sandpiper.

Home range data were available for the raccoon (USEPA, 1993d). Palmer and Fowler (1975) provided an estimate of home range for the pocket gopher. Data for the deer mouse from USEPA (1993d) were used to represent home range for the western harvest mouse.

15.2.2.3.1 Chemical Intake due to Ingestion of Soil or Sediment

Daily soil or sediment ingestion as a percent of dietary ingestion was based on information obtained from Beyer et al. (1994).

Dietary and soil ingestion rates are unavailable for all of the ecological receptors identified at the site. Therefore, data for species not considered key species were used to develop the exposure parameters in Table 15.2-45 for the key species. Dietary ingestion data were available for the robin, mallard duck, and the red-tailed hawk (USEPA, 1993d), and dietary ingestion data were unavailable for the mourning dove. Therefore, the dietary ingestion rate (DIR) was estimated from the minimum and maximum body weights with the following allometric equation for mourning dove (USEPA, 1993d):

$$DIR = \frac{0.398 * BW^{0.85}}{BW}$$

where:

DIR = Dietary Ingestion Rate
BW = Body Weight

Dietary ingestion rates for the American kestrel were applied to the peregrine falcon. Data were unavailable for the western sandpiper, so dietary ingestion was estimated from minimum and maximum body weights for the spotted sandpiper (USEPA, 1993d) and the following allometric equation (USEPA, 1993d):

$$DIR = \frac{0.302 * BW^{0.751}}{BW}$$

Dietary ingestion rates for the deer mouse were applied to the western harvest mouse.

Dietary ingestion was estimated from minimum and maximum body weights for the pocket

gopher (Palmer and Fowler, 1975), and the raccoon (USEPA, 1993d), with the following allometric equation (USEPA, 1993d):

$$DIR = \frac{0.621 * BW^{0.564}}{BW}$$

Upland receptors were assumed to ingest soils, whereas shorebirds or waterfowl were assumed to ingest sediments. Soil or sediment ingestion was estimated for birds and mammals from the 95th percentile for dietary ingestion rates and the 95th percentile for fraction of soil in diet with the following equation:

$$IR_{soil} = DIR * FSD * AUF * C_s$$

where: IR_{soil} = Chemical Intake Due to Ingestion of Soil or Sediment (mg/kg bw/d)
 C_s = Concentration in Soil or Sediment (mg/kg)
 DIR = Receptor-specific Dietary Ingestion Rate (kg/kg bw/d)
 FSD = Fraction Soil in Diet (unitless)
 AUF = Area Use Factor (unitless)

Data concerning the fraction of soil in the diet (Beyer et al., 1994) was available for the mallard duck, and four sandpiper species (stilt, least, western, and spotted). The values for the sandpipers were averaged to obtain a conservative overall value for western sandpiper. Sediment ingestion rates were lower for the waterfowl than for the shorebirds (Table 15.2-45).

Beyer et al. (1994) cite a fraction of soil in the diet for turkey and woodcocks, but not robins or doves. These values were considered appropriate for both passerine birds, as turkeys and woodcocks are ground-feeding upland birds that are likely to have high soil ingestion rates. This is appropriately conservative. There were no data on the fraction of soil in the diet of raptors available in the literature reviewed. However, a value was cited for red fox (Beyer et al., 1994). Because fox and raptors are in similar feeding guilds (i.e., they are predators), and consume many of the same food items, the value for the fox was considered appropriate to represent the fraction of soil in the diet of raptors.

Beyer et al. (1994) cite soil fraction in diet of meadow vole (*Microtus pennsylvanicus*) of 2.4%, and a value of <2% for white-footed mice (*Peromyscus leucopus*). Both values are

similar and fairly low relative to those for avian species. These data were used to estimate the fraction of soil in the diet of small mammal key receptors. A value of 9.4 percent was cited for raccoon (Beyer et al., 1994).

15.2.2.3.2 Chemical Intake due to Ingestion of Water

Table 15.2-45 presents water ingestion rates for the categories of ecological receptors. As discussed for soil ingestion, data were unavailable for every species listed as an ecological receptor. Data for similar species are reported, when available. Water ingestion rates were available for robin, red-tailed hawk, and mallards (USEPA, 1993d). Data for the American kestrel were used to represent water ingestion by the peregrine falcon. Ingestion rates were estimated for the mourning dove and western sandpiper by the following allometric equation for birds (USEPA, 1993d):

$$WIR = \frac{0.059 * BW^{0.67}}{BW}$$

where: WIR = Water Ingestion Rate (L/kg bw/d)

Water ingestion rates for robin were also estimated with the above allometric equation and the minimum and maximum body weight for robins to include in the exposure parameter estimates since only one robin value was available. Water ingestion data were available for the kestrel and ranged from 0.11 to 0.12 L/kg bw/d for males and females (USEPA, 1993d); these data were used to represent water ingestion by peregrines. Preston and Beane (1993) cited a range of 0.055 to 0.059 L/kg bw/d for red-tailed hawk. A range of 0.126 to 0.34 L/kg bw/d for the deer mouse was obtained from USEPA (1993d), and used to represent the western harvest mouse. Pocket gophers were assumed to not ingest surface water as they live nearly totally beneath the surface; Palmer and Fowler (1975) also indicate that pocket gophers do not ingest surface water. Data were available from USEPA (1993d) for the raccoon and provided a range of 0.082 to 0.083 L/kg bw/d.

The daily chemical intake resulting from ingestion of surface water for birds and mammals was calculated with the following equation. AUFs are not applicable to ingestion of surface

water, since many animals will congregate or utilize the same surface water resources, even if outside their immediate territory. The equation is:

$$IR_{water} = C_w * WIR$$

where: IR_{water} = Chemical Intake Due to Water Ingestion (mg/kg bw/d)
 C_w = Concentration in water (mg/L)

15.2.2.3.3 Chemical Intake Due to Dermal Exposure

Animals can absorb chemicals across the skin when contact with contaminated soil occurs. In order to predict dermal absorption of chemicals, the following equation was used for birds and mammals:

$$IR_{dermal} = \frac{C_s * SA * AF * ABS * AUF}{BW}$$

where: IR_{dermal} = Chemical Intake due to Dermal Absorption (mg/kg bw/d)
 C_s = Concentration in Soil (mg/kg)
 SA = Receptor-specific Surface Area (cm²)
 AF = Soil Adherence Factor (0.2 mg/cm²) (USEPA, 1995a)
 ABS = Absorption Factor, unitless (0.1 for organics, 0.01 for inorganics)(USEPA, 1995a)
 BW = Body Weight (kg)
 AUF = Area Use Factor (unitless)

Receptor-specific surface areas were obtained from USEPA (1993d). In some cases, data for a receptor at the PSF were lacking, and data for a similar species were substituted. Data for the meadow and prairie vole were used to represent the valley pocket gopher. Data for the woodcock were used to estimate the surface area of a mourning dove. Data for the American kestrel were used to predict surface area and body weight of the peregrine falcon.

The values for AF and ABS are based on human health guidance (USEPA, 1995a); however, they are applicable to evaluating ecological risk as most of the human health data are ultimately extrapolated from laboratory animal studies.

15.2.2.3.4 Chemical Intake Due to Ingestion of Dietary Items

Dietary intakes were estimated by use of a food web bioaccumulation model for the terrestrial and aquatic food webs (Figures 15.2-1 and 15.2-2). Bioaccumulation is defined as

the uptake of contaminant from all sources, including soil ingestion, water ingestion, and dietary ingestion. The bioaccumulation factor (BAF) is the ratio of chemical concentration in tissue to chemical concentration in the exposure media (i.e., soil, diet, and water). In contrast, a bioconcentration factor (BCF) is defined as the ratio of chemical concentration in tissue to concentration in water. For bioaccumulation to occur, the chemical must be both contacted and absorbed at a rate that exceeds metabolism and excretion.

Certain chemicals are very slowly metabolized or excreted. These include the OCPs, which are highly lipophilic and very stable. Some metals, including those that are also nutrients, will bioaccumulate if exposure rates are high and exceed the excretion ability of metabolic pathways. Dietary ingestion of the following COPCs was quantitatively addressed. The dietary ingestion pathway was quantified for the following analytes:

- Cadmium
- Copper
- Chlordane
- Heptachlor
- Heptachlor Epoxide
- Lead
- Mercury
- PAHs
- PCBs
- ppDDD
- ppDDE
- ppDDT
- Selenium
- Zinc

All literature-derived BAFs and BCFs were converted to a wet weight basis prior to predicting bioaccumulation or bioconcentration, and the values used in the ecological risk assessment are summarized in Tables 15.2-46 and 15.2-47. The data used to derive the BAFs and BCFs used in the risk assessment appear in Appendix U. Conversion of dry weight BAFs for plants and invertebrates was accomplished by dividing the dry weight BAF

by the wet/dry weight ratio. If data were available in the cited paper, they were used. However, in most cases an assumed value was applied since the appropriate data for conversion were absent. The ratio used for invertebrates was six (Jorgensen et al., 1991). The wet/dry weight ratio for plants was estimated from data for 15 macrophyte species, which indicated dry weight is 15 percent of the wet weight (Jorgensen et al., 1991). A 100 g plant sample when dried would therefore weigh 15 g due to water loss. The wet to dry weight ratio (100/15) for plants is thus 6.7.

15.2.2.3.5 Terrestrial Food Web

The equations used to estimate prey or forage concentrations in the terrestrial food web (Figure 15.2-1) are as follows:

$$C_{plant} = BAF_{plant} * C_{soil}$$

$$C_{invertebrate} = BAF_{invertebrate} * C_{soil}$$

Tissue concentrations were also predicted for birds and mammals that feed on plants and soil invertebrates:

$$C_{robin} = BAF_{bird} * C_{invertebrate} * 1$$

$$C_{dove} = BAF_{bird} * C_{plants} * 1$$

$$C_{mouse} = BAF_{mammal} * 0.5 * (C_{invertebrate} + C_{plant})$$

$$C_{gopher} = BAF_{mammal} * C_{plant} * 1$$

where: $C_{receptor}$ = receptor species tissue concentration (mg/kg)
 $BAF_{receptor}$ = bioaccumulation factor for receptor species (unitless)

The fractions refer to the fraction of the dietary item in the receptor species diet (Figure 15.2-1); for example, mourning doves are modeled as consuming 100% vegetation in their diet, whereas the western harvest mouse is modeled as consuming 50% plants and 50% invertebrates.

The predicted tissue concentrations (mg/kg) were used to estimate dietary intakes (mg/kg bw/d) for each receptor according to the following general equation:

$$IR_{diet} = DIR * C_{diet}$$

where: IR_{diet} = chemical intake due to dietary ingestion (mg/kg bw/d)
 DIR = dietary ingestion rate (kg/kg bw/d)
 C_{diet} = estimated tissue concentration from food web model (mg/kg)

For each receptor in the terrestrial food web, the equations are:

$$IR_{robin} = DIR_{robin} * C_{invertebrate}$$

$$IR_{dove} = DIR_{dove} * C_{plant}$$

$$IR_{mouse} = DIR_{mouse} * 0.5 * (C_{plant} + C_{invertebrate})$$

$$IR_{gopher} = DIR_{gopher} * C_{plant}$$

$$IR_{peregrine} = DIR_{peregrine} * 0.5 * (C_{robin} + C_{dove})$$

$$IR_{redtail} = DIR_{redtail} * 0.5 * (C_{mouse} + C_{gopher})$$

$$IR_{raccoon} = DIR_{raccoon} * 0.5 * (C_{dove} + C_{invertebrate})$$

Table 15.2-46 presents the BAFs used in the ERA. Appendix U presents the supporting background data used to derive these BAFs.

15.2.2.3.6 Aquatic Food Web

The equations used to estimate prey concentrations in lower trophic levels the aquatic food web (Figure 15.2.2) are as follows:

$$C_{plant} = BCF_{plant} * C_{water}$$

$$C_{invertebrate} = BCF_{invertebrate} * C_{water}$$

$$C_{fish, amphibian} = BCF_{fish, amphibian} * C_{water}$$

where: $BCF_{(receptor)}$ = Bioconcentration factor for the receptor group indicated (L/kg)
 C_{water} = Water concentration (mg/L)

The above equations relate tissue concentrations directly to water concentrations. Tissue concentrations are not directly related to sediment concentrations. Bioconcentration factors are available from the literature, whereas sediment concentration factors are less available. Therefore, this approach is justified because there is more supporting information. Bioconcentration factors for fish were used to represent chemical uptake by either fish or amphibians. The data used to derive bioconcentration factors are presented in Appendix U. These data are summarized in Table 15.2-47.

The chemical exposure due to dietary ingestion for the mallard consuming 100% plants, sandpipers consuming 100% invertebrates, and raccoons consuming 50% invertebrates and 50% fish or amphibians (Figure 15.2-2), are given by the following equations:

$$IR_{mallard} = DIR_{mallard} * C_{plant}$$

$$IR_{sandpiper} = DIR_{sandpiper} * C_{invertebrate}$$

$$IR_{raccoon} = DIR_{raccoon} * 0.5 * (C_{fish} + C_{invertebrate})$$

When sediment data were available, but water data were lacking, for an organic COPC, the concentration in surface water was predicted with the following equation:

$$C_{water} = C_{sed} / K_{oc} * f_{oc}$$

where: C_{sed} = Sediment concentration (mg/kg)
 K_{oc} = Soil-water partition coefficient normalized for organic carbon
 f_{oc} = fraction of organic carbon

A value of 1.1% (0.011) was used for f_{oc} ; this is the average value for sediments at PSF.

The Log K_{oc} values were obtained from Lyman (1995) and are as follows:

- Aldrin/Dieldrin = 3.82
- PCBs = 6.25
- Benzo(a)anthracene = 6.24
- Benzo(a)pyrene = 6.74
- Chrysene = 5.77
- ppDDE = 5.17
- ppDDT = 5.48

Log K_{oc} must be antilogged prior to use in the above equation. In addition, several inorganics appeared on the COPC list for which Log K_{oc} values were unavailable. For these COPCs, a value of Log K_{oc} was assigned based on K_{oc} for similar compounds from the above list of Log K_{oc} from Lyman (1995). The chemicals and the Log K_{oc} assigned to them were:

- PAHs = 6.0
- TPH = 6.0

Use of the equilibrium partitioning approach is inaccurate for metals or other inorganics because the chemical fate is more influenced by sediment physical characteristics (Lyman, 1994). Therefore, if metal concentrations appeared in sediment but not surface water, they were not evaluated for the dietary ingestion pathway.

15.2.3 Stress Response Assessment

The stress response assessment quantifies the potential toxicological effects related to the COPCs. There are no biological data available for the site except that documented in the environmental assessment documents compiled by the NPS (Jones and Stokes, 1994). This text is not intended to represent a complete toxicity analysis. All specific studies and their associated endpoints are presented in Table 15.2-48 and 15.2-49. This text is merely a general description of the overall adverse effects that might be expected from exposure to any of the types of COPCs.

15.2.3.1 Ecotoxicological Data

The COPCs include metals, pesticides, and organics. The toxicity of these chemicals to terrestrial plants, birds and wildlife is discussed below in general. When data were unavailable for birds and wildlife, data for laboratory animals were reported. Screening criteria were termed Toxicity Benchmark Values, or TBVs, and were selected from the literature reviewed. These values represent concentrations at the site that if exceeded, would indicate a likely risk to ecological receptors.

The literature was reviewed for data regarding NOAELs (no observed adverse effects levels). Chronic studies were considered preferable to studies of shorter duration, because ecological receptors are exposed for entire lifetimes. If NOAELs were unavailable, the lowest concentration or dose reported to have an effect, such as the lowest observed adverse

effects level (LOAEL), lowest lethal dose (LDLo), or lowest toxic dose (TDLo), were considered. Values corresponding to lethal doses to 50% of test populations (LD50) and lethal concentrations to 50 % of test populations (LC50) are reported in Table 15.2-48 and 15.2-49; however, these data are considered more uncertain for the assessment of ecological risk because they involve exposure scenarios unlike those expected for ecological receptors. Data from the literature reviewed are summarized in Table 15.2-48 and 15.2-49. When data were available, toxicity values for wildlife species likely to be found at PSF were used. Where possible, data from short-term studies (i.e., single dose or less than at least a week) and dose levels or dietary intakes that resulted in mortality were avoided.

Many values were reported as dietary concentrations (i.e., mg/kg diet or ppm). Dietary concentrations were converted to intakes (mg/kg bw/d) using dietary ingestion rates. The conversion factors applied to each toxicity value are described in Table 15.2-48.

In the toxicity assessment, toxicological data pertinent to the evaluation of ecological risk were reviewed and summarized. The following data sources were evaluated for toxicity information:

- Toxline (an online database specializing in peer reviewed toxicological studies available through the National Library of Medicine)
- USEPA documents
- Other sources.

Following comments on the Draft ERA (Dames & Moore, 1995), additional literature review was performed. The additional sources reviewed included:

- All Environmental Toxicology and Chemistry Journals from 1/93 to current for any pertinent articles for any of the COPCs.
- RTECS was searched for aluminum, nickel, anthracene, vanadium, and chromium information.
- TOXLINE was searched for zinc toxicity information.
- Great Lakes Water Quality Initiative Report (USEPA, 1995b) was reviewed for ppDDT, PCBs, and mercury data.
- Ecotoxicology of Invertebrates, Chapter 19 (Donker et al., 1993), was reviewed for information on metal toxicity to soil invertebrates.

- Consultation with the regulatory agencies and review of documents provided by the agencies.

The search resulted in adding additional references to the toxicity tables. The toxicity assessment focused on endpoints or health effects that were likely to adversely affect populations of ecological receptors at the site, as opposed to health effects such as cancer that occur on an individual basis. This is consistent with current ecological risk assessment guidance (USEPA, 1992e). Health effects that impact populations include increased mortality, morbidity, and reproductive effects (Barnhouse, 1993). For the purposes of the risk assessment, reproductive effects include developmental effects (i.e., fetotoxicity, embryotoxicity) as well as indices of reproductive success such as litter size. Carcinogenicity and mutagenicity were not used as endpoints for the risk assessment. There are many other ecotoxicological endpoints that may be of importance to the success of populations at the PSF, such as indirect effects such as loss of prey, and changes in vegetation communities and thus habitat. Direct effects on small mammals (e.g. mortality and/or reproductive effects attributable to direct exposure) are evaluated as assessment endpoints in order to address indirect effects.

Habitat changes are virtually impossible to correlate with chemical concentrations due to the large amount of physical disturbance and urbanization at the PSF. The risk assessment focuses on those toxicological endpoints that are most likely to be linked with chemical concentration in literature studies.

The assessment of toxicity to plants is complicated by the effects that site-related soil factors have on bioavailability and thus toxicity of both organic and inorganic chemical to plants (Bodek et al., 1988). For example, soil pH has effects on nickel and aluminum toxicity, and probably the toxicity of most metals, to plants (Bodek et al., 1988). Metals in acidic soils are more toxic by factors of two or more to plants (see Table 15.2-90, nickel) (Bodek et al., 1988). Organic matter provides negatively charged sites on the soil particles that tend to adsorb metals, making the metals less bioavailable. Organic matter also tends to sorb organic compounds. Furthermore, the presence of multiple nutrients (i.e., iron, copper, nickel, zinc) in soils affects toxicity because the nutrients compete with receptors on the plant roots, further complicating the assessment of toxicity (Bodek et al., 1988).

The presence of large amounts of calcium and magnesium tend to ameliorate toxicity to plants (Bodek et al., 1988). In addition, laboratory toxicity tests may overestimate toxicity in the field because the tests are typically run with a water-soluble form of metal compound; in the field, water-soluble species tend to be leached from soils, leaving behind species that are more tightly bound to clays and iron oxides (Will and Suter, 1995). The analytical methods used to extract metals provide the total metal in soil; this is usually higher than the metal actually available to the plant. The preferred method of addressing plant toxicity would through the use of equations relating toxicity to various site-related factors. However, in most instances, equations of this type were unavailable in the literature reviewed. The soil pH at the PSF ranges between 6.4 and 7.9; the majority the pH values were approximately 7.0. The average and geometric mean of pH was 7.1 and 7.0, respectively. (Montgomery Watson, 1995e), and therefore metals are likely to be less available than those in many of the studies used to obtain TBVs (Will and Suter, 1995).

15.2.3.1.1 Metals

A number of metals are essential in small amounts for animal nutrition (Amdur et al., 1991). These include, but are not limited to, cobalt, copper, iron, magnesium, manganese, molybdenum, selenium and zinc (Amdur et al., 1991). Animals have developed a variety of homeostatic mechanisms for metabolism of the essential metals, so they are less likely to produce toxic effects than are the nonessential elements such as barium, cadmium and lead. Nevertheless, physiological control mechanisms can be overwhelmed or circumvented and some essential elements can produce toxic effects when exposure occurs to concentrations greater than the optimum levels (Amdur et al., 1991). Calcium and magnesium are not expected to present a hazard regardless of concentration, and because of their valence, which may actually inhibit uptake of other divalent metals, (i.e., lead and cadmium), by plants and aquatic organisms, that predominantly occur at a +2 valence (i.e., lead and cadmium) (Bodek et al., 1988; Eisler 1985a).

The toxicity of many elements is influenced by the chemical speciation in which they occur (Eisler, 1988; Bodek et al., 1988). Exposure via diet (inclusive of soil ingestion) and water are often the most important pathways as opposed to exposure via dermal absorption or inhalation since many chemicals do not readily absorb across ecological receptor integument.

Because potentially toxic trace elements occur in many different chemical forms that have varying toxicity, total concentration of some elements in the exposure media may not be a good predictor of toxicity. The Stress-Response Assessment section attempts to identify both highly toxic and environmentally predominant forms of each chemical of concern in abiotic media in order to provide insight into potential health risks.

The toxicity of inorganic elements varies so widely that it was not practical to list specific concentrations that cause adverse effects under conditions of acute or chronic exposure for all species. The Toxicity Assessment identified potentially toxic levels and adverse health effects for species similar to those that may be found at the PSF. When information was unavailable for closely related species, data for distantly related species in the same class were cited. Data were not extrapolated between classes unless there was evidence to suggest that doing so would be technically justified (e.g., the literature reported that all species tested exhibited a certain sublethal effect at the same dose). Lack of toxicity information increases uncertainty in assessing ecological risk. The following provides a summary of relevant toxicological information for each chemical addressed within the risk assessment.

There is no evidence that aluminum is an essential element in animal nutrition. Intestinal absorption is generally very poor, and toxicity is low in comparison to many other metals (Amdur et al., 1991).

Both antimony and arsenic can have multiple valance states and are metalloids (Bodek et al., 1988). In general, inorganic arsenic compounds are more toxic than organic arsenic compounds (Eisler, 1988). Organic arsenicals are used as feed additives in agriculture, and their biological fate and toxicity differs from the inorganic forms. Trivalent inorganic arsenicals (arsenites) are often more toxic than pentavalent compounds (arsenates), but trivalent arsenic is often less prevalent in the environment than the pentavalent form (Eisler, 1988). Arsenic does not tend to biomagnify into upper trophic level animals as it is readily metabolized and excreted. Arsenic is bound to iron oxides and clays in soil, reducing its bioavailability to plants (Eisler, 1988). Antimony has not been studied to the extent that arsenic has been studied. Antimony has been reported to produce toxicity in species of aquatic life (Rand, 1995), but studies with terrestrial wildlife and birds are lacking.

Cadmium is nonessential for biota (Amdur et al., 1991). Cadmium is highly toxic at relatively low levels to most species and is bioaccumulative (Eisler 1985a). Cadmium is not controlled by homeostasis (Amdur et al., 1991). Cadmium is retained in tissues, and body burdens may increase with age and exposure duration. Freshwater biota tend to be sensitive (i.e., exhibit adverse health effects at low cadmium concentrations to cadmium (Eisler 1985a). Cadmium is one of the hardness dependent metals for which AWQC are available; this means that as water hardness increases, toxicity decreases according to an exponential equation.

Chromium is an essential trace metal for mammals (CEPA, 1994b). Chromium is toxic at high doses, and certain chemical species of chromium are highly toxic. Hexavalent chromium is the most biologically active form, although little data are available for the toxicological properties of organic chromium compounds, water-soluble chemical species, or interactions of different chromium compounds in complex mixtures (CEPA, 1994b). Hexavalent chromium is chemically reduced to trivalent chromium in the acid fluid of the mammalian stomach. Chromium concentrations are usually highest at the lowest trophic levels, which may be in more direct contact with the abiotic source media. Biomagnification has not been observed in food chains (CEPA, 1994b). Female turkeys fed 10 ppm (approximately 0.97 mg/kg bw/d based on ingestion rates for chickens) chromium (III) in diet exhibited some reproductive effects (Frobish, 1980); and juvenile ducks had decreased survival and growth at this dietary concentration (approximately 1.27 mg/kg bw/d based on estimated ingestion rates for a 100 g duckling) (Eisler, 1986 as cited in CEPA, 1994b). Male chickens tolerate 100 ppm (approximately 9.7 mg/kg bw/d) in diet with no effects (CEPA, 1994b). Common tern (*Sterna hirundo*) populations in an area where the major prey item contained up to 7.6 ppm (approximately 1.28 mg/kg bw/d based on a sandpipers dietary ingestion rate) exhibited no effects on reproductive success, growth, or clutch size (Custer et al., 1986). Therefore, the NOAEL for adult ducks of 0.63 was used as the TBV for chromium.

Copper is an essential trace metal that stimulates growth when moderately high levels are fed to mammals, but it is highly toxic to aquatic organisms (Amdur et al., 1991; Bodek et al., 1988). Copper is essential for plant growth (Will and Suter, 1995). Copper is one of the

hardness dependent metals for which AWQC are available; this means that as water hardness increases, toxicity decreases according to an exponential equation.

Iron is an essential metal (Amdur et al., 1991). It is generally not considered to be toxic to animals (Bodek et al., 1988). Little information is available for aquatic species regarding toxicity of iron. Iron is a necessary nutrient for plants (Bodek et al., 1988), and no information was found regarding toxic levels of this metal.

Lead is a nonessential metal. Organic lead compounds are readily absorbed from the digestive tract (Amdur et al., 1991). Organic lead compounds are more toxic than inorganic salts because they are more readily bioavailable (USEPA, 1992f). In addition, organic lead compounds have greater lipid solubility, higher stability in biological fluids, and greater assimilation into target tissues such as central nervous system and brain (Amdur et al., 1991). Inorganic lead may be toxic to aquatic and terrestrial biota (Bodek et al., 1988); however, the toxicity is much lower than that due to organic lead. Lead is one of the hardness dependent metals for which AWQC are available; this means that as water hardness increases, toxicity decreases according to an exponential equation. Inorganic lead species are the primary forms of lead in the environment.

There was an extensive review of information regarding the toxicology and ecological effects of lead by the U.S Army and the State and Federal regulatory agencies. The Eden and Garlich (1983) paper, recommended for review for the PSF ERA by the USEPA and U.S. Fish and Wildlife Service, indicates a 10% decrease in egg production relative to controls for birds receiving 50 ppm lead acetate in diet. However, hens on the highest level of dietary lead (400 ppm) exhibited increased egg production following removal of lead from the diet. The authors of the study also point out that if the calcium content of the quail diet was higher, the effects might not have been observed. Other studies show reproductive effects at 500 to 1000 ppm organic lead in diet. Therefore, although the data are used as a point estimate, there is some uncertainty that must be addressed in the toxicity estimate.

Inorganic lead exhibits only 10% absorption across the GI tract (i.e., most of the ingested dose is excreted), whereas lead acetate is much more bioavailable (i.e., 80% absorption). There is thus a 70% difference in absorption that must be incorporated into toxicity

estimates for inorganic lead that are derived from organic lead data. A factor of 4 to 8 was applied to represent the uncertainty in this conversion. The 50 ppm of lead acetate in diet is equivalent to an inorganic lead concentration between 200 and 400 ppm.

Eden and Garlich (1983) provides a body weight of 160 g for quail, and estimates dietary ingestion (DIR) by quail as 20 to 30 g per day. This yields a dietary ingestion rate (DIR) normalized to body weight of 0.12-0.19 g/g bw/day, which is reasonable for quail. A low end for the TBV was predicted by using the 200 ppm diet and low end of the DIR, to obtain a value of 24 mg/kg bw/d. A high end for the TBV was predicted by using the 400 ppm diet and the high end of the DIR, to obtain a value of approximately 76 mg/kg bw/d.

The TBV-High is based on a kestrel study (Pattee, 1984), where the birds were exposed to dietary concentrations of 0, 10, and 50 ppm inorganic lead. Estimates of kestrel dietary ingestion rates (DIR) are 0.29-0.31 g/g bw/d (USEPA, 1993d). Estimates of kestrel dietary ingestion from the study were 50 g/d/bird, and body weights of 110.2 (x - SD) to 151.2 g (x + SD) were presented. The resulting dietary ingestion rates ranged from 0.33 to 0.45 g/g bw/d.

Multiplying the DIR by the dietary test concentration of 50 ppm results in a TBV-High between 14.5 and 22.5 mg/kg bw/d. No effects on reproduction were observed at any test concentration. There is no LOAEL from the paper. The TBV-NOAEL is not expected to have any effects on avian populations since no effects were reported in the population of test animals. Furthermore, the dietary concentrations were presented on a wet-weight basis; on a dry weight basis, the measured concentration in diet was 104 ppm.

A scientifically justifiable estimate of a TBV-High is generated from data indicating 500 ppm lead acetate (organic lead) in diet affect growth and causes anemia in chickens, and 1,000 ppm lead acetate in diet caused soft shelled eggs and decreased hatchability (Pattee, 1984).

A factor of 4 to 8 was applied to convert the organic lead dietary concentration of 500 ppm to a TBV ranging from 320 to 760 mg/kg bw/d. A low end for the TBV was selected by using the 500 ppm diet, the factor of 4, and a DIR of 0.16 kg/kg bw/d. A high end for the

TBV was selected by using the 500 ppm diet, the factor of 8, and high end of the DIR of 0.19 kg/kg bw/d.

Magnesium is an essential elements for animals (Amdur et al., 1991). Calcium is a macronutrient and is considered nontoxic unless present within a receptors diet at extremely high levels (Bodek et al., 1988). Barium is stimulatory but not essential for animals. All three are considered relatively nontoxic at physiological concentrations. Homeostatic mechanisms maintain normal levels of magnesium and calcium, and to a certain extent barium (Bodek et al., 1988).

Manganese salts appear to be among the least toxic of the essential metals. An efficient homeostatic mechanism prevents manganese from accumulating in tissues (Amdur et al., 1991). Toxic or adverse effects due to exposure to manganese are not common (Amdur et al., 1991).

Mercury is a nonessential element for animals (Amdur et al., 1991). Mercury occurs as inorganic and organic forms. Organic mercury is more bioavailable and more toxic than inorganic forms (Eisler, 1987). Inorganic mercury is methylated in biotic and abiotic media (Bodek et al., 1988). Like cadmium, mercury is bioaccumulative and retained in tissues (Eisler, 1987).

Selenium is also an essential trace element that is toxic at greater than optimum doses (Amdur et al., 1991). Selenium is bioconcentrated to some extent by both aquatic and terrestrial species. Plants can concentrate selenium to levels that are toxic to mammals (Bodek et al., 1988). Selenium is toxic to aquatic and terrestrial life. There is relatively little toxicity information for terrestrial wildlife exposed to silver.

Zinc is an essential nutrient for mammals, birds, and plants, but at high concentrations, homeostatic mechanisms can be overcome and zinc toxicity may occur (Amdur et al., 1991; Bodek et al., 1988). Zinc is an essential trace metal that is relatively nontoxic because of efficient homeostatic mechanisms that maintain a proper balance within the body (Bodek et al., 1988). High concentrations in water may adversely affect aquatic life (Jorgensen et al. et al., 1991). Zinc is one of the metals for which AWQC are expressed by an exponential equation that adjusts for decreasing toxicity with increasing water hardness.

15.2.3.1.2 Pesticides and PCBs

The pesticide analytes include the OCPs, which include aldrin, dieldrin, endrin, and ppDDT and metabolites of ppDDT. The OCPs are stable in the environment, and are highly persistent (Amdur et al., 1991). They are lipid soluble, and are highly bioaccumulative (ATSDR, 1989g). In addition, they are toxic to birds and mammals (ATSDR, 1989g). Aldrin metabolizes to dieldrin; dieldrin is bioaccumulative, and produces mortality by affecting the central nervous system (CNS) (ATSDR, 1989g). Endrin is also bioaccumulative, but is more toxic than dieldrin. ppDDT and its metabolites, in addition to being bioaccumulative and toxic, have been associated with eggshell thinning in birds (FWS., 1984). The toxicological literature indicates that avian species are sensitive to OCPs, and combined with their higher exposure rates, avian species are expected to be more at risk than mammalian species. For this reason, the literature search focused on obtaining adequate ecotoxicological data for birds.

Pesticides are not expected to be highly toxic to plants as they were developed to be used on crops. Many pesticides are lacking TBVs for invertebrates because the available toxicological information emphasized dermal contact with sprays, which are likely to contain carriers that increase bioavailability and toxicity (Will and Suter, 1995). Only studies that linked soil concentrations with adverse effects on invertebrates were used.

The PCBs are also stable and persistent in the environment and are bioaccumulative. PCBs interfere with reproductive success in wildlife species and laboratory animals (Amdur et al., 1991). Other toxic effects in birds and mammals include increased induction of microsomal enzymes, immunosuppression, estrogenic activity, and porphyrogenic action (Amdur et al., 1991).

15.2.3.1.3 TPH

Recent toxicity studies for TPH were available and are cited in Table 15.2-48. The use of literature-based data information was considered less uncertain than the approach used in the FPALDER. Toxicity criteria for aquatic life were lacking for TPH; therefore, AWQC values for naphthalene were used to define potential risks of surface water exposure to aquatic life.

15.2.3.2 Uncertainty Factors

Uncertainty factors were applied to the toxicity values obtained in the data review in order to be conservative. Uncertainty factors reduce the TBV, making the acceptable or safe concentrations for daily intake lower. . Sometimes, use of uncertainty factors is too conservative, and results in TBVs that are less than those required for nutrition, or TBVs that are lower than would be experienced by receptors living in a non-polluted environment.

The uncertainty factor approach used at the PSF follows guidance in USEPA (1994e). The approach used to create a receptor-specific NOAEL is outlined as follows:

Duration UFs	Acute or Subchronic LOAEL/10	Creates a NOAEL from short-term studies resulting in adverse effects.
Endpoint UFs	Chronic LOAEL/5	Creates a NOAEL from long-term studies resulting in adverse effects.
	LD50 / 50	Creates a NOAEL from short-term, single-dose studies resulting in lethality of half of the test animals.
Intertaxon UFs	NOAEL (different family-same order) /2	Creates a NOAEL from a study with a non-protected species from same order
	NOAEL (different order - same class) /2	Creates a NOAEL from a study with a non-protected species from same class
	NOAEL (related non-protected species) /2	Adjustment for species of special status in order to protect individuals

When chronic, nonlethal studies were not available for the target receptor, or a surrogate species in the literature reviewed, an uncertainty factor of 50 was applied to acute lethal (i.e., LD50) values for the target receptor of interest or surrogate species. This is consistent with the approach suggested by USEPA, 1994e.

Uncertainty factors for duration or endpoint for birds and mammals appear in Table 15.2-48. Uncertainty factors applied to plants and soil fauna ranged from 1-50 (Table 15.2-49). Intertaxon uncertainty factors appear in Table 15.2-50.

15.2.3.3 Final TBVs

In order to fully characterize risk at PSF, a range of TBVs was used. The most conservative value is the TBV_{Low} . This TBV has all applicable uncertainty factors, and is usually the lowest value obtained from any of the studies reviewed. For some nutrients, this TBV is lower than nutritional requirements and background or ambient levels. This TBV is intended to be a screening tool. If no risks are observed when comparing exposure to the TBV_{Low} , risks to individuals or populations are virtually nonexistent.

The higher value is the TBV_{High} . The TBV_{High} represents the upper bound of acceptable or safe daily intakes. Populations of animals exposed to daily intakes above this range are likely at risk. The range of risks between the TBV_{Low} and the TBV_{High} represent a gray zone, where risks are possible but unlikely.

The Final TBVs for birds and mammals (e.g., the values actually used to create hazard quotients) appear in Table 15.2-51 and 15.2-52. They are receptor-specific because of the intertaxon uncertainty factors which depend on the test species phylogenetic relationship with the key receptor, and whether or not the receptor has special status.

15.2.3.4 Aquatic Life and Amphibians

Chronic Ambient Water Quality Criteria (AWQC) and sediment quality criteria (SQC) were compiled from several sources (Table 15.2-53). A minimum and a maximum of the water and sediment quality criteria were used as TBV_{Low} and TBV_{High} for water and sediment exposure, respectively. In addition, toxicity data for amphibians were compiled from several sources (Table 15.2-54).

The AWQC for PCBs (0.19 ug/L) appear protective of amphibians (LC50 values from 2 ug/L and higher). Napthalene AWQC (24 ug/L) are protective of toxicity to amphibians for exposure to TPH (LC50 of 10,000 ug./L), and possibly anthracene (LC50 range of 25 to 110 ug/L). AWQC for cadmium, lead, and zinc are hardness dependent; the values used were below the adverse effects levels listed for amphibians. There were no AWQC values for aquatic life for aluminum; therefore, this inorganic cannot be compared to toxicity values for amphibians. AWQC were used to represent toxicity to all aquatic species, including amphibians, in the risk assessment.

15.2.4 Risk Characterization

This section of the report compares the EPCs derived in the Exposure Analysis to the TBVs evaluated in the Stress Response Analysis. The uncertainties associated with the assumptions and parameters used in the risk assessment are qualitatively discussed.

15.2.4.1 Uncertainty Analysis

This uncertainty analysis describes the major sources of uncertainty that underlie the assumptions and results of the ecological risk assessment. There are many sources of uncertainty in the risk assessment process. The collection, analysis, and reporting of analytical data for the site introduce uncertainties in the data. Data reported as estimated can result in risks that are overestimated or underestimated. Data reported as being greater than a specific value can result in underestimating the risk when that value is used in the calculations. Data that are below detection limits were used in the risk assessment by dividing them by 2; this procedure could lead to under or overestimation of risk. These uncertainties in the data are compensated for by the collection of multiple samples at each of the study locations, and the use of the UCL95 as the exposure point concentration for each COPC at each study area or site addressed in the risk assessment.

There are additional uncertainties due to the assumptions involved in the exposure estimates. The amount of soil, surface water, and sediment ingested by birds and mammals is expected to vary on an individual basis. Therefore, although exposure intakes are expressed as point estimates, there is a range due to variability in the ingestion rates. Not only does exposure vary on an individual basis, but on a daily and seasonal basis as well, due to movements within the home range, changes in diet, and migration out of the PSF vicinity. The 95th percentile was used in the ecological risk assessment for screening the sites at the PSF. This means that 95% of the individuals exposed will have lower rates of exposure than used to predict risks. This is highly conservative and is likely to over-estimate risk.

Because a biased sampling design was used at the PSF, estimates of the exposure point concentrations are expected to be artificially high. This is because unimpacted areas within each of the study areas were not sampled or were sampled to a lesser extent than visually impacted areas or areas with historic records of contamination. In addition, although the

maximum or UCL95 represents a conservative point estimate of exposure, exposure by individual receptors varies due to varying concentrations of COCs in the environment. The exposure point concentration is therefore expected to overestimate risk at the PSF.

Uncertainty is also introduced by the studies that provide the TBVs, which form the denominator of the HQ. Toxicity studies are often conducted under controlled laboratory conditions, with species other than those occurring at the PSF. When studies were available for review for multiple bird or mammalian species for a given COC, the TBV is less uncertain. Although TBVs are expressed as point estimates, they entail variability due to inter- and intra-specific differences, differences in route of exposure, and differences in chemical species (i.e., water soluble vs. insoluble forms, and valence state), to mention only a few sources of uncertainty. Conservative uncertainty factors were applied to the TBVs, thereby making them lower (more conservative). The TBVs are expected to overestimate risk at the PSF.

Uncertainty in the TBV estimates is reduced by not extrapolating between phylogenetic class; thus, studies utilizing birds (*class Aves*) as the test species were used to estimate risk for birds, and studies utilizing mammals (*class Mammalia*) as the test species were used to address risk for mammals. Ruminant studies (i.e., *bovidae*, *cerevidae*) were avoided when possible because ruminants are not key receptors at the PSF. Where possible, the test animal and the key receptor were in the same order and family. Uncertainty is also reduced by evaluating large numbers of studies. Only the studies used are reported in the toxicity benchmark tables; however, many other studies were evaluated during compilation of the TBV material. Emphasis was placed on reviewing chronic (i.e., long-term) studies where the dose was administered orally, preferably in diet.

The goal of an ecological risk assessment is to quantify risk to populations of ecological receptors, while evaluating risk to individuals of special status species. Therefore, NOAEL values are preferable as TBVs as adverse effects associated with intakes of COCs at these levels are unlikely. Using conservative exposure point concentrations in abiotic media as the basis for intakes, and adjusting the LOAEL or TBV to reflect a NOAEL, is protective of most of the individuals at the site.

Addressing the uncertainty involved with assessing risk to plants involves consideration of the soil properties, as well as the toxicological literature available for plants. In a study by Buchter et al. (1989), 15 inorganics in 11 soil types were studied for adsorption; adsorption influences bioavailability, and thus phytotoxicity. Soil pH and cation exchange capacity (CEC) were significantly correlated with log K_d, the soil-water partition coefficient. For the metals, which included cobalt, nickel, copper, zinc, cadmium, mercury, lead, vanadium, chromium and arsenic, coefficients of variation (CV) ranged from 15.1 to 137.9 percent for log K_d for the different soils.

Root growth is related to aluminum concentration in soil solution, clay content, calcium content, and soil pH (Wright et al., 1989), where the amount of aluminum in soil solution was best evaluated by a mild extraction technique that measured soluble aluminum using calcium chloride. Aluminum in soil exists in many forms, and often much of the aluminum measured by acid extraction is not bioavailable or toxic to plants.

Cobalt was less toxic when applied in localized areas rather than uniformly; plant roots avoided unfavorable zones in the soil (Wallace, 1989a). When uniformly mixed, 75 mg/kg cobalt in soil with a pH of 6.0 decreased vegetative yields by 50 percent, but administered locally, yield decreased by 37 percent. Multiple trace elements may cause antagonistic effects (Wallace, 1989b). Liming of the soil reduced the trace element toxicity. Thus, soil factors play a strong influence on bioavailability and toxicity of metals to plants.

Application of a point estimate TBV is likely to overestimate toxic effects to plants because:

- The soil pH at the PSF is relatively high, thereby reducing metal bioavailability
- Acid extraction (i.e., total metal concentrations) overestimates the bioavailable fraction in soils,
- Native plants at PSF associated with serpentinite soil are adapted for naturally occurring high metal concentrations in soil.

15.2.4.2 Ecological Risk at Each of the RI Sites

The risk to ecological receptors at each of the study areas or sites is discussed in this section. The risk characterization was performed by comparing the estimated exposure intakes to the

toxicity benchmark values for birds and mammals to obtain a Hazard Quotient (HQ), as follows:

$$HQ = \frac{\text{Exposure Intake}}{TBV}$$

where: Exposure Intake = mg/kg bw/d
TBV = mg/kg bw/d
HQ = unitless

In order to calculate risks for the receptors exposed by direct contact, the exposure point concentration in the abiotic media was substituted into the above equation in place of the Exposure Intake. The exposure point concentration for surface water or sediment was compared directly to the toxicity benchmark values for aquatic life (i.e., aquatic plants, invertebrates, fish, or amphibians), whereas the exposure point concentration for soil was compared directly to the TBV for terrestrial plants and invertebrates. The hazard quotient is the ratio of the exposure point concentration to the appropriate toxicity benchmark value. None of the compounds listed as unknowns were evaluated.

The HQs for each individual COPC were summed to obtain an HI for each exposure pathway evaluated and an HI for all pathways combined for each receptor. An HI thus appears for soil ingestion, dietary ingestion, dermal contact, and total exposure. The HI is typically a conservative estimate of risk, because it assumes that adverse effects are additive. For some COPCs with similar modes of toxicological action, this is true. However, many of the metals cause antagonistic effects rather than additive or synergistic effects (Amdur et al., 1991). However, the HIs allow for a rapid, visual estimation of potential risks at each site. The HQs for each site and receptors are presented in Tables 15.2-55 through 15.2-97, and the HIs in Figures 15.2-3 through 15.2-45.

There were two TBVs developed for each receptor in Section 15.2.3. These are referred to as the TBV_{Low} and the TBV_{High} . The TBV_{Low} is based on NOAELs, and in addition, contains uncertainty factors for intertaxon variability. The TBV_{Low} is a conservative intake that is unlikely to result in risk to individuals. The TBV_{High} does not contain intertaxon uncertainty factors, and is based on a toxicological endpoint of some adverse effect. Between these two

values lies the "gray zone", where risk estimates cannot be made conclusively. On one hand, the intakes exceed the conservative NOAELs; however, this does not mean that exposure at these rates will cause adverse effects in individuals or populations, because a NOAEL is not specific. There are no effects at a NOAEL, but that does not mean that a dose 10 times the NOAEL will cause adverse effects at the individual or population level, unless there is a LOAEL that indicates that adverse effects will occur.

The application of the TBV_{Low} results in a high HQ (the HQ_{High}) since the TBV is in the denominator of the HQ equation. The application of the TBV_{High} results in a low HQ (the HQ_{Low}).

As indicated in the Uncertainty Analysis (Section 15.2.4.1) there are many sources of uncertainty inherent in the risk assessment. Therefore, although all estimates of risk are given as "point estimates", there is a range of uncertainty which encompasses them. Because the risk assessment assumptions are often highly conservative, this will lead to overestimation of risk. For example, an extensive uncertainty analysis was performed on lead, a commonly occurring COPC at the PSF, and a COPC for which there is a good deal of toxicological information. The results of the uncertainty analysis indicate lead at 477 mg/kg in soil is an acceptable concentration in the environment (Appendix U). However, given the conservative approach used in the risk assessment (i.e., 95th percentile exposure estimates for each parameter), lead HQs can be as high as 8.

15.2.4.2.1 Nike Facility

Soil samples and sediment samples from open ditches were collected at this site. All terrestrial receptors were evaluated for soil ingestion, dermal contact with soil, and dietary ingestion. The identified COPCs for the Nike Facility include VOCs, SVOCs, PAHs, metals, TPH-D, and pesticides. A summary of the comparison of site exposure point concentrations or exposure intakes to receptor TBV values is presented in Table 15.2-55 and Figure 15.2-3. Results of the risk assessment indicate the following:

- HIs for the American robin, mourning dove, peregrine falcon, western harvest mouse, pocket gopher, and plants and soil fauna exceeded 1 when comparisons were made to the conservative TBV_{Low} .

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 when comparisons were made to the TBV_{High} .
- Lead is the predominant risk driver, resulting in HQs greater than 1 for the American robin, mourning dove, peregrine falcon, and western harvest mouse when these receptors are exposed through soil or dietary ingestion and risk comparisons are made to the TBV_{Low} .
- Lead is not likely to be of concern to the peregrine falcon or western harvest mouse, although the HQ based on the TBV_{Low} exceeds 1, because the HQ based on the TBV_{High} is well below 1.
- Lead and selenium produce an HQ in excess of 1 for the pocket gopher for soil and dietary exposure; however, when the TBV_{High} is considered, these COPCs do not produce risk.
- Several inorganics (arsenic, copper, lead, and zinc) exceed TBV_{Low} values for the protection of plant and soil fauna. Only lead produced an exceedence of the TBV_{High} .
- Zinc resulted in HQs greater than 1 for American robin and the mourning dove based on the TBV_{Low} and the TBV_{High} for exposure by soil or dietary ingestion.
- Zinc resulted in HQs greater than 1 for western harvest mouse based on the TBV_{Low} and the TBV_{High} when exposed through the diet.

Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS.

Table 15.2-56 and Figure 15.2-4 present the HI values for the swale south of the Nike Facility. These risk estimates were obtained by taking the average of sediment concentrations at the Nike Facility in order to represent chemical movement beyond the boundary of the site. The sediment delivery ratio (USEPA, 1988c; Weischmeier and Smith, 1978), or the ratio of sediment eroding from the site to the amount depositing downgradient, was then estimated with the following equation:

$$DR_{sed} = Length^{-0.22}$$

where: DR_{sed} = Sediment Delivery Ratio (unitless)
 Length = Feet

The distance downgradient to the swale is approximately 150 feet. This provides a delivery ratio of 0.3. This ratio was multiplied with the EPCs to obtain EPCs for the swale. Water concentrations were predicted by equilibrium partitioning as described in Section 15.2.2-3. Figure 15.2-4 shows the HI values for each receptor. Risks to the receptors are minimal and appear primarily for the HQs based on the TBV_{Low} . Except for the aquatic invertebrates, all HQs and HIs based on the TBV_{High} are less than 1. The highest risks are for aquatic invertebrates based on sediment exposure. There are no HQs that exceed 1 for terrestrial receptors utilizing the swale for drinking water.

The similarity between the low and high HI estimates is because the chronic AWQC values often were the same. Only chronic risks were evaluated. This is highly conservative given that the seasonal or temporary nature of this swale would result in short-term exposures. There is unlikely to be any significant impact on the swale due to the Nike site. Further evaluation is not recommended from the perspective of ecological risk.

15.2.4.2.2 Crissy Field Study Area

The Crissy Field Study Area was evaluated several ways because of the difference between the current and the projected future land use at the area. Terrestrial receptors in the Building 609, 611, 633, 640/643, and 642 areas, and in the Fill Site 7/EOM shoreline area were evaluated. Additionally, terrestrial receptors were evaluated for exposure to soils from 0 to 15 feet deep within the wetland footprint which includes a portion of Fill Site 7, EOM, and Buildings 609 and 611. Aquatic receptors were also evaluated for the same soil data set as if the soils were sediments. Ground water was used to predict future surface water concentrations of COPCs; this is highly conservative as influx from the Bay is expected to define the physical and chemical characteristics of the Crissy Field future wetland.

15.2.4.2.2.1 Petroleum, Oil, and Lubricants Area (Buildings 640/643 and 642)

Table 15.2-57 and Figure 15.2-5 present the ecological risk assessment for **Building 640/643**. The results of the evaluation of soil and dietary ingestion, and dermal exposure pathways for terrestrial receptors indicate:

- HI values exceeded 1 for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna when comparisons were made between exposure and the conservative TBV_{Low} values.
- HI values exceeded 1 for the American robin, mourning dove, western harvest mouse, and plants and soil fauna when comparisons were made between exposure and the TBV_{High} values.
- Highest risks were predicted for the robin. HQs for barium, cadmium, chromium, lead, TPH, and zinc in soil exceeded 1 for the robin when comparisons were made to the TBV_{Low} values. Cadmium, lead, and zinc in diet also contributed to risk for the robin.

Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS.

Table 15.2-58 and Figure 15.2-6 present the ecological risk assessment for **Building 642**.

The results of the evaluation of soil and dietary ingestion, and dermal exposure pathways for terrestrial receptors indicate no potential for adverse ecological effects. Based on the results of the ERA, this site will not be considered for inclusion in the FS.

15.2.4.2.2.2 Fill Site 7/East of Mason

The potential COPCs for the Fill Site 7/East of Mason shoreline area include several inorganics, VOCs, SVOCs, pesticides and TPH in soil. The potential exposure pathways evaluated were soil ingestion and dermal exposure to all key terrestrial receptors.

Comparison of exposure to receptor TBVs (Table 15.2-59 and Figure 15.2-7) indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 when comparisons were made based on the conservative TBV_{Low} .

- HIs for the American robin and plants and soil fauna were greater than 1 when comparisons were made based on the TBV_{High} .
- Levels of barium, copper, manganese, mercury, ppDDE, and ppDDT produced HQs greater than 1 for either the soil or dietary ingestion pathway for the American robin.
- No individual HQs for any pathway, or the total exposure, exceeded 1 for the mourning dove or western harvest mouse. Only the cumulative HI for total exposure (i.e., the sum of all chemicals and all exposure pathways combined) indicated a potential for risk.
- Levels of antimony and manganese in soil were the only COPCs that produced HQs greater than 1 for plants and soil fauna.

It should be noted that the risk drivers for each receptor of concern identified were often infrequently detected. For instance, ppDDT was detected in only 2 of 32 samples collected. This indicates that the occurrence of these risk drivers is not widespread, therefore the likelihood of exposure and risk is minimal. Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS.

15.2.4.2.2.3 *Crissy Field Future Wetland*

The identified COPCs in soil for the proposed wetland area within Crissy Field include metals, VOCs, SVOCs, TPH, and pesticides. The exposure pathways evaluated for future aquatic life (e.g., plants, invertebrates and fish) were direct contact with surface water and sediment, where sediment was represented by current soil data to a depth of 15 feet. In addition, raccoon, waterfowl, and wading bird exposure to sediment or surface water was also evaluated as a future condition. Current soil concentrations were used as a future sediment exposure point concentration for all receptors; the equilibrium partitioning approach was used to predict future water concentrations from current soil concentrations of organic COPCs. The area was not evaluated as a source of drinking water, since the water will be saline due to influx from the Bay. Comparison of the exposure point concentrations

to the receptor TBVs are provided in Table 15.2-60 and Figure 15.2-8. Results of the comparison for the receptor evaluation indicated the following:

- HQs for sediment exposure by aquatic invertebrates based on current soil concentrations of copper, manganese, mercury, ppDDE, ppDDT, and dieldrin exceeded 1 if the soil concentrations do not change in the process of wetland construction.
- Projected HIs for aquatic invertebrates are low, ranging from 4 based on a TBV_{High} to 32 based on a TBV_{Low} .
- The HIs for the sandpiper range from 0.3 based on a TBV_{High} to 2 based on a based on the TBV_{Low} , indicating there is little chance of risk to sandpipers.
- All HQs and HIs for the other receptors were less than 1, indicating no risk.

The exposure pathways evaluated for terrestrial receptors were soil ingestion, dietary exposure, and dermal exposure to the site soils. Risks to avian and mammalian receptors are low (Table 15.2-61; Figure 15.2-9). The most significant results are:

- The HI for total exposure for the robin was 40 based on the TBV_{Low} , but only 2 based on the TBV_{High} . The HI assumes that all risks are additive.
- There were HIs in excess of 1 for the mourning dove and western harvest mouse, although all individual HQs were less than 1.
- HQs for barium, copper, mercury, manganese, and ppDDT exceeded 1 for the American robin for either the soil or dietary ingestion pathways when comparisons were made to the conservative TBV_{Low} . No individual HQs for any pathway, or for total exposure, exceeded 1 when comparisons were made to the TBV_{High} .
- HQs for antimony and manganese for plants and soil fauna exceeded 1.
- The dietary ingestion pathway produced the greatest risk for the American robin, where HIs were 30 based on the TBV_{Low} , but only 0.9 based on the TBV_{High} . This indicates that risk to this receptor for the dietary ingestion pathway is in the gray zone, and while effects may be possible in isolated individuals, effects on the population are not expected.

The cumulative HIs for most receptors were low or less than 1. Thus, while several COPCs have been identified as potential risk drivers, the total number of pathways and receptors

exhibiting risk is low. Further evaluation of this site is not warranted on the basis of terrestrial ecological risk.

The Crissy Field groundwater was evaluated assuming it would be the sole contributor to the future wetland surface water balance, and also assuming it would contribute 50% or 10% of the total water volume in the wetland. This is conservative (i.e., overestimates risk) because influx from the Bay will define the wetland water quality characteristics. In addition, all of the data were unfiltered; this also overestimates aquatic risk because the metals bound to particulates are not readily bioavailable. The inorganics evaluated as COPCs in groundwater were antimony, barium, beryllium, copper, manganese, and mercury; these inorganics were selected as COPCs because they have the potential to be derived from the overlying fill materials. All organics were evaluated as COPCs. Tables 15.2-62a, b, and c, and Figures 15.2-10a, b, and c present the HIs based on zero, 50%, and 90% dilution by Bay water. There are some potential risks to future aquatic life in the wetland given the current conditions. Furthermore, although inorganic COPCs consisted of antimony, barium, beryllium, copper, manganese, and mercury, these could also be naturally occurring. The risk assessment results indicate that:

- HIs for aquatic life exceed 1, indicating groundwater conditions exceed the minimum chronic AWQC for the 0, 50, or 90% dilution scenarios.
- HIs for aquatic life exceed 1 based on the maximum chronic AWQC for the 0, 50, or 90% dilution scenarios.
- HIs for waterfowl, waders, and raccoons exceed 1 due to predicted dietary ingestion of copper compared to the TBV_{Low} for the zero dilution scenario. There were no exceedences when comparisons were made to the TBV_{High} , however, indicating little potential for adverse population effects.
- HIs for waterfowl and waders exceeded 1 due to predicted dietary ingestion of copper compared to the TBV_{Low} for the 50% dilution scenario. There were no exceedences when comparisons were made to the TBV_{High} , however, indicating little potential for adverse population effects.
- No HIs for avian or mammalian receptors exceeded 1 when exposure was compared to the TBV_{Low} for the 90% dilution scenario.

- Barium, copper, and manganese were the greatest contributors to risk.
- Copper was the only COPC for which HQs exceeded 1 for avian or mammalian receptors.

Because the estimates of risk are so uncertain:

- The ecological risk assessment for Crissy Field will be further evaluated to determine whether this site warrants inclusion into the FS.
- Water and sediments should be sampled after the wetland construction is completed.

15.2.4.2.2.4 Buildings 609 and 633

The COPCs identified for **Building 609** were dieldrin, ppDDE and ppDDT (Table 15.2-63; Figure 15.2-11). Based upon the risk evaluation for soil ingestion, dietary exposure, and dermal exposure to the target receptors, the following risks were identified:

- ppDDT for dietary exposure to the American robin resulted in an HQ of 9 based on the TBV_{Low} and 0.03 based on the TBV_{High} .

The HQs and HIs were less than 1 for the each of the other exposure routes and target receptors that were evaluated. Building 609 is an industrial setting and is not likely to contain sufficient habitat to support populations of passerine birds for a prolonged duration. Therefore, the relative risk to ecological receptors attributable to Building 609 is considered minimal. The dietary exposure route assumes that the COPCs will bioaccumulate and transfer through the food chain components of the robin's diet. Given the infrequent detection of ppDDT within the area, the actual likelihood of this occurring is slight. Based on the results of this ERA, this site will not be considered for inclusion in the FS.

The only COPC identified for **Building 633** was lead (Table 15.2-64; Figure 15.2-12). All terrestrial receptors were evaluated for exposure to soils by soil ingestion, dermal contact, and dietary ingestion. Plants and soil fauna were evaluated for direct contact with soil. The results indicated:

- Lead in soil resulted in an HQ in excess of 1 for the American robin and the mourning dove for soil ingestion and dietary exposure when comparisons were made to the conservative TBV_{Low} .

- Lead in soil resulted in an HQ in excess of 1 for the American robin and the mourning dove when exposure was compared to the TBV_{High} .
- Lead estimated to occur in diet resulted in an HQ greater than 1 for the western harvest mouse and pocket gopher when exposure was compared to the conservative TBV_{Low} , but no risks were apparent for these receptors when the exposure was compared to the TBV_{High} .
- The HQ for total exposure for the robin was 700 based on the TBV_{Low} , but only 6 based on the TBV_{High} .

The remaining pathways and target receptors evaluated resulted in no risks. However, because risks were observed above the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), the ecological risk assessment for Building 633 will be further evaluated to determine whether this site warrants inclusion into the FS.

15.2.4.2.2.5 Sewer Lift Stations

The identified COPCs for Lift Station No. 1 were lead, mercury and zinc in soil (Table 15.2-65; Figure 15.2-13). The potential exposure pathways to the target receptors included soil ingestion, dietary exposure and dermal exposure. These pathways were quantified for all terrestrial target receptors and the results of the HQ comparison indicated the following:

- The HI exceeded 1 for the American robin, mourning dove, western harvest mouse, plants and soil fauna when exposure was compared to the conservative TBV_{Low} .
- No HIs exceeded 1 when exposure was compared to the TBV_{High} , indicating that while some isolated individuals may exhibit adverse effects, the population as a whole is unlikely to be affected.
- Lead in soil resulted in an HQ in excess of 1 for the American robin, mourning dove, western harvest mouse, plants and soil fauna when exposure was compared to the conservative TBV_{Low} .
- Zinc resulted in an HQ in excess of 1 for the American robin for exposure through the diet relative to the TBV_{Low} .
- Zinc levels also exceeded TBV_{Low} , but not TBV_{High} values for plants and soil fauna.

The results of the ERA indicate that isolated individuals may be affected, but that populations are not at risk. Given the industrial setting of this site, and the minimal number of TBV exceedences, it is anticipated that this site would not contribute significant risk to ecological receptors. This site is not recommended for further evaluation in the FS.

The identified COPCs for **Lift Station No. 2** were copper, cyanide, mercury and selenium in soil (Table 15.2-66; Figure 15.2-14). The potential exposure pathways to the target receptors included soil ingestion, dietary exposure and dermal exposure. These pathways were quantified for all terrestrial target receptors and the results of the HQ comparison indicated the following:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna exceeded 1 when exposure was compared to the conservative TBV_{Low} .
- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 when exposure was compared to the TBV_{High} .
- Copper and selenium were the major contributors to risk for plants and soil fauna.
- Copper, mercury and selenium contributed to risk for avian and mammalian receptors.
- The HQs for the remaining pathways and receptors evaluated were less than 1.

Due to the proximity of buildings there is minimal habitat and little likelihood of extensive use by ecological receptors. Because risks were observed above the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), the ecological risk assessment for Sewer Lift Station 2 will be further evaluated to determine whether this site warrants inclusion into the FS.

15.2.4.2.3 Building 900s Series Study Area

A wide variety of ecological receptors may occur in this area due to its proximity to San Francisco Bay. The identified COPCs for the Building 900s site included VOCs, PAHs, arsenic, barium, cadmium, copper, cyanide, dieldrin, mercury, lead, antimony, thallium, zinc, TPH-diesel, Aroclor 1254 and 1260, ppDDD, ppDDE and ppDDT in soils. The TBV for MEK was used to estimate risks to MIBK, and the TBV for TPH-diesel was used to estimate risks due to exposure to TPH. The potential exposure pathways include soil

ingestion, dietary exposure and dermal exposure to terrestrial receptors. In addition, soil ingestion and dermal contact were evaluated for waterfowl and wading birds that could rest in the area. Dietary exposure was not evaluated for waterfowl or wading birds since their feeding is expected to be limited to the shoreline area, and not widespread throughout the Building 900s Study Area. Comparison of site exposure point concentrations to receptor TBVs are presented in Table 15.2-67 and Figure 15.2-15. Results of the HQ evaluation indicate the following:

- HIs exceeded 1 for the American robin, mourning dove, peregrine falcon, western harvest mouse, pocket gopher, and western sandpiper, and plants and soil fauna exceeded 1 when exposure was compared to the conservative TBV_{Low} . HI values were above 1000 for the robin, and above 100 for the dove and the sandpiper.
- HIs exceeded 1 for the American robin, mourning dove, western harvest mouse, western sandpiper, and plants and soil fauna when exposure was compared to the TBV_{High} . HIs were above 10 for the robin.
- Lead produced the highest HQ for any exposure pathway for birds, mammals, and plants and soil fauna based on comparison to the TBV_{Low} and TBV_{High} .
- HQs for lead, PCB 1254, and zinc were greater than 1 for the American robin based on comparison to the TBV_{High} for soil or dietary ingestion.
- Other COPCs that produced HQs in excess of 1 for the American robin were barium, cadmium, copper, ppDDT, DNBP, mercury, PCB 1254, PCB 1260, thallium, and zinc when exposure was compared to the TBV_{Low} .
- Only lead produced an HQ greater than 1 for the mourning dove when exposure was compared to the TBV_{High} .
- COPCs that contribute to the potential risk to plants and soil fauna include zinc, thallium, lead, copper, and cadmium based on comparison to the TBV_{Low} .

Because estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), this site should be considered further to determine if it warrants inclusion in the FS from the perspective of ecological risk.

15.2.4.2.4 DEH Study Area

The identified COPCs for the DEH site include several inorganics, VOCs, PAHs and other SVOCs, TPH-D, and pesticides. The potential exposure pathways attributable to the site include soil ingestion, dietary exposure and dermal exposure to terrestrial receptors.

Comparison of exposure to the receptor TBVs (Table 15.2-68; Figure 15.2-16) indicate the following:

- The HIs for American robin, mourning dove, peregrine falcon, western harvest mouse, pocket gopher, and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{Low} values.
- The HIs for American robin, mourning dove, western harvest mouse, and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{High} values.
- HQs for cadmium, chlordane, chromium, copper, dieldrin, endrin, lead, manganese, ppDDD, ppDDT, selenium and zinc exceeded 1 for the robin based on comparison of exposure to the TBV_{Low} .
- HQs that exceeded 1 for the morning dove were chlordane, chromium, copper, endrin, lead, ppDDT, selenium, and zinc.
- Chlordane was the only COPC that resulted in an HQ greater than 1 for the peregrine falcon. The only pathway for which a risk is suggested is the dietary ingestion pathway. This receptor is unlikely to be at risk given the low magnitude of the exceedence, and the fact that there were no HIs or HQs greater than 1 based on the TBV_{High} .
- COPCs that resulted in HQs in excess of 1 for the western harvest mouse were antimony, cadmium, copper, dieldrin, lead, and selenium when exposure was compared to the TBV_{Low} .
- The only COPC that resulted in an HQ in excess of 1 for the pocket gopher when exposure was compared to the TBV_{Low} was selenium. The only pathway for which an HQ exceeded 1 was the dietary ingestion pathway.
- Observed concentrations of antimony, chromium, copper, manganese, silver, and zinc occur above TBV levels protective of plants and soil fauna.

Following extensive efforts to review the available data for DEH, and a quantitative, comprehensive uncertainty analysis of lead contamination, the risk managers have compiled

a draft decision document, which is now available for public review. This document will address the remediation effort required for this area. The efforts on the behalf of the Federal and State regulators, and the U.S. Army, serve to illustrate the effectiveness of the approach used in the current RI. The current RI uses highly conservative exposure parameters to obtain a highly conservative risk assessment. Any sites that do not present a risk under this approach can be safely assumed to be free of ecological risk. However, risks were identified for DEH on the basis of both the TBV_{Low} and TBV_{High} values. This indicates that the risk assessment can be used as a cost-effective, scientifically defensible, screening tool in the hands of the risk managers.

15.2.4.2.5 Main Post Study Area

There were no detections of COPCs at **Building 215**; therefore, ecological risk was not evaluated at this location.

The only COPC identified for **Building 228** was bis(2-ethylhexy)phthalate in soil (Table 15.2-69; Figure 15.2-17). Comparison of exposure to receptor TBVs indicated no potential risk to terrestrial receptors exposed via ingestion of soil, dietary exposure, or dermal contact. No further evaluation of this site is warranted.

There were no complete exposure pathways at **Building 1057** as all detections of COPCs occurred in sediment within a metal covered vault; therefore, ecological risk was not evaluated at this location.

The COPCs identified for **Building 1167** were lead, mercury and zinc in soil (Table 15.2-70; Figure 15.2-18). The results of the risk evaluation for the terrestrial target receptors exposed via soil ingestion, dietary exposure and dermal exposure are:

- The HIs for American robin, mourning dove, western harvest mouse, and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{Low} values.
- The HIs only for American robin and plants and soil fauna exceed 1 based on comparison of exposure to the TBV_{High} values.
- Lead in soil resulted in HQs greater than 1 for the American robin when exposure was compared to the TBV_{Low} or the TBV_{High} , whereas lead HQs for the mourning dove exceeded 1 based only on the TBV_{Low} .

- Mercury concentrations predicted in diet resulted in HQs greater than 1 for the American robin when exposure was compared to the TBV_{Low} . HQs were less than 1 on the basis of the TBV_{High} . Mercury HQs also exceeded 1 for plants and soil fauna when exposure was compared to the TBV_{Low} , but not the TBV_{High} .
- Zinc in soil is of concern to the American robin, mourning dove and western harvest mouse when comparisons are made to the TBV_{Low} values. No HQs for zinc for exposure by any pathway exceeded 1 when exposure was compared to the TBV_{High} .

This site is immediately adjacent to a building, as well as next to a highway. Therefore, although ecological risk was evaluated, there is a very low potential for ecological receptors to be present. Thus, further evaluation at this location for ecological risk is not warranted.

Aroclor 1260 was identified as the only COPC for **Building 1151** (Table 15.2-71; Figure 15.2-19). Comparison of the exposure point concentration to TBV values for terrestrial receptors exposed via soil ingestion, dietary exposure and dermal contact indicated:

- The HIs for American robin, mourning dove, and western harvest mouse exceed 1 based on comparison of exposure to the TBV_{Low} values.
- Only the HIs for American robin exceed 1 based on comparison of exposure to the TBV_{High} values. The largest HQ was based on the dietary exposure pathway.
- The soil ingestion exposure route is of potential concern only for the American robin and mourning dove based on the conservative TBV_{Low} , whereas dietary exposure is of potential concern only for the American robin and western harvest mouse.
- There were no HQs for the remaining pathways and receptors evaluated that exceeded 1.

Due to development of this area by the YMCA, habitat for potential ecological receptors will be lacking, and therefore the number and types of potential receptors will be minimal. However, PCBs in soil are being addressed as part of the PCB EE/CA. This site is not recommended for further evaluation from the perspective of ecological risk.

15.2.4.2.6 Fill Site 1

The only identified COPCs were bis(2-ethylhexyl)phthalate and fluoranthene in soil (Table 15.2-72; Figure 15.2-20). Comparison of exposure to TBVs for the terrestrial receptors for

soil ingestion, dietary, and dermal exposure produced HQs and HIs less than 1. This area does not present an ecological risk and further investigation is not warranted based on the results of the ERA.

15.2.4.2.7 Landfill 2

The identified COPCs included metals, PAHs, pesticides, and MCP (a chlorinated herbicide) in soil (Table 15.2-73; Figure 15.2-21). The results of the risk evaluation for the terrestrial target receptors exposed via soil ingestion, dietary exposure and dermal exposure are:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 for at least one exposure pathway when exposure was compared to the TBV_{Low} values.
- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 for at least one exposure pathway when exposure was compared to the TBV_{High} values.
- Copper, lead, ppDDT, and zinc resulted in HQs greater than 1 for the American robin and the mourning dove based on the TBV_{Low} . In addition, the barium HQ exceeded 1 for the robin. HQs were higher for the dietary ingestion pathway (e.g., 20 or greater) than the soil ingestion pathway (e.g., 3 or greater) for these receptors.
- Copper, lead, ppDDT, and zinc resulted in HQs greater than 1 for the American robin based on the TBV_{High} .
- Barium, copper, and zinc produced HQs greater than 1 for plants and soil fauna when exposure was compared to the TBV_{Low} ; only barium produced an HQ greater than 1 when exposure was compared to the TBV_{High} .

Because some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted given the TBV_{High}), the ecological risk assessment should be considered further to determine if this site should be evaluated in the FS.

15.2.4.2.8 El Polin Spring

El Polin Spring is in the Landfill 2 area. Because the spring is so small, it is not a significant surface water feature such as Mountain Lake or Lobos Creek. Fish are not present, and the

habitat is not suitable for wading birds or waterfowl as it is heavily forested. The only COPCs in El Polin Spring were inorganics (e.g., aluminum, antimony, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride, iron, lead, manganese, mercury, nickel, vanadium and zinc). Exposure by aquatic receptors (e.g., aquatic plants, invertebrates, or amphibians) was evaluated by comparing surface water concentrations to the AWQC. Surface water ingestion by all terrestrial receptors except pocket gophers was evaluated. Table 15.2-74 and Figure 15.2-22 present the risk assessment results. Significant results indicate the following:

- Levels of copper, barium, cyanide, nickel, cadmium, chromium, iron, lead and manganese in the surface water exceed chronic AWQC values for the protection of aquatic life.
- There are no risks to terrestrial receptors ingesting surface water from El Polin Spring.
- There are no risks to raccoons utilizing the area for either feeding or drinking.

The surface water data for the spring included filtered and unfiltered samples. Therefore, risks to aquatic life may be overestimated. In addition, only the chronic AWQC were used for screening. Because the spring is so small, it is unlikely to support significant populations of aquatic life; therefore, potential risks to aquatic life, even though the HQs range between 10 and 100, are not as relevant as risks to terrestrial receptors utilizing the spring. Based on the results of the ERA, this site is not recommended for further evaluation.

15.2.4.2.9 Transfer Station

The identified COPCs for the Transfer Station (Landfill 3) include VOCs, PAHs, metals, and pesticides in soil. The potential exposure pathways evaluated at the site were soil ingestion, dietary exposure and dermal exposure to terrestrial receptors. Comparison of exposure to the receptor TBVs (Table 15.2-75; Figure 15.2-23) indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna were greater than 1 for at least one pathway based on evaluation against the TBV_{Low} .

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna were greater than 1 for at least one pathway based on evaluation against the TBV_{High} .
- Lead and vanadium were the major risk factors for the American robin and the mourning dove due to soil or dietary ingestion. Lead HQs ranged from 40 to 300 for these receptors based on a TBV_{Low} , whereas lead HQs based on the TBV_{High} were only 2.
- Mercury resulted in HQs greater than 1 for the American robin, mourning dove and western harvest mouse.

The magnitude of the HQs exceeds 100 for some COPCs. Because some estimates of risk exceed the upper bound of the gray zone, further examination of the data is recommended. The ecological risk assessment for Transfer Station will be further evaluated to determine whether this site is warranted for inclusion in the FS.

15.2.4.2.10 Landfill 4 and Fill Site 5

The COPCs identified for Landfill 4 were one SVOC, pesticides, and lead. Endrin TBV values were used to address risks due to exposure to isodrin, and alpha-endosulfan TBVs were used to address potential risks to beta-endosulfan. All terrestrial receptors were evaluated for contact with soils, soil ingestion, and dietary ingestion (Table 15.2-76; Figure 15.2-24). The risk assessment results indicate that:

- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 based on the TBV_{Low} .
- HIs for the American robin and mourning dove, exceeded 1 based on the TBV_{High} .
- Some HQs exceeded 100 based on comparison to TBV_{Low} values. HQs based on the TBV_{High} values were much lower (i.e., 10) for total exposure for the American robin.

The ecological risk assessment for Landfill 4 will be further evaluated to determine whether the results of the ERA warrant inclusion of the site into FS.

The only COPCs for Fill Site 5 are pesticides and fluoranthene in soil. The site is highly disturbed and the receptors that occur would be limited to terrestrial animals, birds, plants and soil fauna. Soil ingestion, dietary exposure and dermal exposure was evaluated for the

identified terrestrial target receptors. In order to evaluate toxicity due to exposure to beta-endosulfan, TBVs for alpha-endosulfan were used. Results of the risk assessment are presented in Table 15.2-77 and Figure 15.2-25. Results of the risk evaluation indicate:

- HQs for ppDDT for dietary ingestion exceed 1 for the American robin based on comparison to the TBV_{Low} .
- There were no HQs or HIs that exceeded 1 for any receptor based on comparison to TBV_{High} values.

The only risk driver for the American robin is ppDDT exposure via the diet. In addition, the dietary pathway is conservative in that risks are more likely to be over-estimated than under-estimated. While some isolated individual birds may experience adverse effects, the populations do not appear at risk. This site is not warranted for further evaluation in the FS from the standpoint of ecological risk.

Fill Site 6 - There were no detections of COPCs at this location; therefore, ecological risk was not evaluated.

15.2.4.2.11 Graded Area 9

- The identified COPCs for Graded Area 9 include aluminum, vanadium, bis(2-ethylhexyl phthalate, PAHs, dieldrin, and TPH-D in soil (Table 15.2-78; Figure 15.2-26). The potential exposure pathways evaluated for all terrestrial receptors were exposure by soil ingestion, dietary exposure, and dermal exposure. Comparison of exposure to receptor TBVs indicated the following:
- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher, and plants and soil fauna exceeded 1 based on the TBV_{Low} and the TBV_{High} .
- HQs for aluminum and vanadium in soil exceeded 1 for the American robin, mourning dove, western harvest mouse, pocket gopher, plants and soil fauna based on a comparison of exposure to the conservative TBV_{Low} .
- The HQ for dieldrin for the American robin dietary ingestion pathway exceeded 1 based on the TBV_{Low} , but not the TBV_{High} .
- The remaining receptors and exposure pathways evaluated did not indicate a potential for risk.

The ecological risk assessment for Graded Area 9 will be further evaluated to determine whether the results of the ERA warrant inclusion of this site into the FS.

15.2.4.2.12 Landfill E

The identified COPCs for Landfill E include silver, mercury, zinc, toluene, several OCPs, one chlorinated herbicide (MCPD), and TPH-D (Table 15.2-79; Figure 15.2-27). The terrestrial receptors were evaluated for exposure by soil ingestion, dietary exposure, and dermal contact. Comparison of COPC exposure point concentrations to receptor TBVs indicated the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceed 1 based on a comparison of exposure to the TBV_{Low} .
- HIs for the American robin and plants and soil fauna exceeded 1 based on a comparison of exposure to the TBV_{High} .
- HQs for mercury, ppDDE, ppDDT, silver, and zinc in soil or diet exceeded 1 for the American robin.
- HQs for ppDDT and silver in soil exceeded 1 for the mourning dove when exposure was compared to the TBV_{Low} , but there were no HQs or HIs that exceeded 1 for this receptor when exposure was compared to the TBV_{High} .
- HQs for mercury, silver and zinc in soil exceeded 1 for plants and soil fauna when exposure was compared to the TBV_{Low} , but only silver produced an HQ in excess of 1 when exposure was compared to the TBV_{High} .
- The remaining receptors and exposure pathways evaluated did not indicate a potential for risk to these receptors.

The ecological risk assessment for Landfill E will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

15.2.4.2.13 Miscellaneous Sites

The following Miscellaneous Sites are addressed in this part of the risk assessment: Building 662, 680, 1351, FPCGS, Lobos Creek and Mountain Lake.

15.2.4.2.13.1 Building 662

The COPCs identified at Building 662 were lead, zinc, bis(2-ethylhexyl) phthalate, and PAHs (Table 15.2-80; Figure 15.2-28). As discussed in Section 15.2.1.3, data for samples collected within the former tank area are not included in the ERA. The potential exposure pathways evaluated were soil ingestion, dietary exposure, and dermal exposure for each of the terrestrial receptors. The results of the risk analysis indicate:

- HIs for the American robin, mourning dove, and plants and soil fauna exceeded 1 based on a comparison to the TBV_{Low} values.
- No HIs exceeded 1 for a comparison to the TBV_{High} values.
- Lead and zinc dietary ingestion HQs for the American robin and mourning dove exceeded 1 when exposure was compared to the TBV_{Low} values.
- Lead HQs for soil ingestion for the robin and dove exceeded 1 when exposure was compared to the TBV_{Low} values.
- The zinc HQ for plants and soil fauna exceeded 1 when exposure was compared to the TBV_{Low} values.

Because the risks estimated at this location fall within the gray zone (i.e., risk is predicted based on the conservative TBV_{Low} values, but not the TBV_{High} values), this site is unlikely to be a significant threat to populations of these receptors. In addition, ecological receptors are unlikely to be present at this location due to its small size and proximity to buildings.

Therefore, the results of the ERA indicate that further evaluation at this site is not warranted.

15.2.4.2.13.2 Building 680

Aroclor 1260 in soil was the only COPC identified in soils at Building 680. The potential exposure pathways evaluated were soil ingestion, dietary exposure, and dermal exposure for each of the terrestrial receptors. A comparison of the exposure point concentrations to the receptor TBVs (Table 15.2-81; Figure 15.2-29) indicates the following:

- The observed concentration of Aroclor 1260 in soil is a potential concern to the American robin, mourning dove, and western harvest mouse based on comparison of exposure to the TBV_{Low} values. HI values were above 100 for the American robin, but 10 or less for the mourning dove and western harvest mouse.

- The HI for total exposure for the American robin exceeded 1 based on the TBV_{High} . However, the magnitude of the HI was low (e.g., only 3), and was due to the dietary ingestion pathway only.

The remaining receptors and pathways evaluated did not indicate any potential for risk at Building 680. Although some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted with the TBV_{High}), there is little likelihood of ecological receptors actually being present at this location due to the future industrial use planned for Building 680.

Therefore, further evaluation of this site from the standpoint of ecological risk is not warranted. However, this site is included in the PCB EE/CA for the protection of human health.

15.2.4.2.13.3 Building 1351

The identified COPCs at Building 1351 were metals, VOCs, SVOCs, and PAHs. Building 1351 is a highly disturbed area; however, terrestrial receptors may incidentally occur and become exposed to COPCs in soil through soil ingestion, dietary exposure, and dermal exposure. All terrestrial receptors were evaluated for exposure by these pathways.

Comparison of exposure point concentrations to receptor TBVs are provided in Table 15.2-82 and Figure 15.2-30, and indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 based on the TBV_{Low} .
- HIs for the American robin and plants and soil fauna exceeded 1 based on the TBV_{High} .
- Cadmium and lead in soil and diet resulted in HQs greater than 1 for the American robin based on a comparison to TBV_{Low} values. Only cadmium resulted in HQs greater than 1 for the American robin when the HQs were based on TBV_{High} values.
- Cadmium and lead in diet resulted in HQs greater than 1 for the mourning dove based on TBV_{Low} values. HQs were less than 1 for the mourning dove when the TBV_{High} values were used.
- Cadmium in diet produced an HQ greater than 1 for the western harvest mouse; however, there were no HQs in excess of 1 based on the TBV_{High} values.

- Cadmium, copper, and zinc produced HQs greater than 1 for plants and soil fauna based on a comparison of exposure to the TBV_{Low} values; however, there were no HQs that exceeded 1 based on a comparison to the TBV_{High} values.

The remaining receptors and pathways evaluated at Building 1351 did not indicate a potential for ecological risk. The ecological risk assessment for Building 1351 will be further evaluated to determine whether the assessment warrants inclusion of this site into FS.

15.2.4.2.13.4 Fort Point U.S. Coast Guard Station (FPCGS)

The identified COPCs at FPCGS were lead, zinc, VOCs, SVOCs including PAHs, ppDDT, and TPH. As discussed in Section 15.2.1.3, analytical results for the soil associated with the former UST north of Building 991 are not included in the assessment. This is a highly disturbed area, however, terrestrial receptors may occur and become exposed to COPCs in soil through soil ingestion, dietary exposure and dermal exposure. All terrestrial receptors were evaluated for exposure by these pathways. Comparisons of exposure to receptor TBVs are provided in Table 15.2-80 and Figure 15.2-30, and indicate the following:

- HIs for the American robin, mourning dove, western harvest mouse, and plants and soil fauna exceeded 1 based on the TBV_{Low} values.
- Only the HIs for plants and soil fauna exceeded 1 based on the TBV_{High} values.
- Zinc and lead in soil, and lead, ppDDT, and zinc in diet resulted in HQs greater than 1 for the American robin based on a comparison to TBV_{Low} values. There were no risks for the American robin when the TBV_{High} values were used.
- Lead in soil and zinc in diet resulted in HQs greater than 1 for the mourning dove based on TBV_{Low} values. There were no risks for the dove when the TBV_{High} values were used.
- No HQs were greater than 1 for the western harvest mouse; only the sum of the chemical-specific HQs (the cumulative HI).
- Several PAH compounds (fluoranthene, pyrene, and phenanthrene), and zinc produced HQs greater than 1 for plants and soil fauna relative to the TBV_{Low} ; however, no HQs exceeded 1 for these receptors based on the TBV_{High} values.

The remaining receptors and pathways evaluated at FPCGS did not indicate a potential for ecological risk. Only plant and soil fauna estimates of risk exceed the upper bound of the

gray zone (i.e., risk is predicted based on the TBV_{High}). The magnitude of the HI is low (between 1 and 10) for plants and soil fauna. The risk assessment assumptions are conservative (i.e., use of total soil metals as opposed to bioavailable metals as the basis of the EPC, sampling design biased towards impacted areas), and as such, are likely to overestimate risk at this site. In addition, the area is disturbed. It is unlikely that significant chemical-related effects would occur at this site. Further evaluation at this location is not warranted from the perspective of ecological risk.

15.2.4.2.13.5 Lobos Creek

The COPCs identified for Lobos Creek were inorganics and SVOCs in surface water, and arsenic in sediments (Table 15.2-84; Figure 15.2-32). The area provides potential habitat for aquatic life, waterfowl, wading birds and terrestrial receptors. Aquatic life can be exposed to COPCs in surface water and sediment; only chronic criteria were used in the evaluation in order to be conservative. Waterfowl, wading birds and all terrestrial receptors except pocket gophers were evaluated for exposure to COPCs in surface water through ingestion. In addition, waterfowl, wading birds, and raccoons may forage (i.e., feed) in the aquatic or riparian habitat along Lobos Creek; therefore, evaluation of the dietary ingestion pathway was performed for these receptors. Waterfowl, wading birds, and raccoons were also evaluated for ingestion and dermal contact with sediments. The risk assessment results indicate:

- HIs exceeded 1 for aquatic life, mallard duck, and sandpipers when comparisons were made to the TBV_{Low} .
- HIs exceeded 1 for aquatic life when comparisons were made to the TBV_{High} . The TBV_{High} for aquatic life is often the same criterion value as the TBV_{Low} ; therefore, a risk range cannot be developed for chronic exposures.
- Concentrations of barium, iron, manganese and lead in surface water are the COPCs of potential concern to aquatic receptors.
- Arsenic in sediment resulted in HQs greater than 1 for aquatic invertebrates based on sediment quality criteria.
- The HQ for lead for the dietary ingestion pathway for waterfowl and wading birds exceeds 1 based on the TBV_{Low} , although surface water ingestion does not contribute

to risk. When the TBV_{High} was used as the basis of the risk comparison, there were no apparent risks.

There was no risk potential identified for the remaining receptors and pathways that were evaluated. Conservative methods were used for the HQ screen for aquatic life in that both filtered and unfiltered data were included in the exposure point concentration in order to increase available sample size information. The sample evidence does not suggest army-related contaminants at this site, however, the ecological risk assessment for Lobos Creek will be further evaluated to determine whether the results of the ERA warrant inclusion of this site into the FS.

15.2.4.2.13.6 Mountain Lake

Mountain Lake potentially receives surface runoff from the golf course, and adjacent park as well as the City of San Francisco and nearby roads that carry a heavy traffic volume. Traffic is associated with lead and other metals, and petroleum hydrocarbons. Deposition of pollutants from air can also occur in this highly urbanized setting. These nonpoint sources of pollution are the most likely potential sources of contamination to Mountain Lake. The identified COPCs for Mountain Lake are consistent with the potential source areas, in that lead and petroleum hydrocarbons were detected in water, and low levels of pesticides were detected in sediments.

Sediment and surface water data were evaluated to assess potential risk to aquatic and terrestrial receptors expected to be in contact with the sediment and surface water media. As Mountain Lake is a significant freshwater resource, it could serve as the primary source of drinking water for birds; therefore, the risk estimates were conservatively calculated without application of an AUF.

Table 15.2-85 presents the HQs for each receptor evaluated at Mountain Lake. In order to obtain risk estimates for TPH for aquatic life, the AWQC for naphthalene was used. The HIs appear in Figure 15.2-33. Results of the risk assessment indicate the following:

- TPH (gas and diesel), barium, cyanide, manganese, and lead in surface water are of potential concern to aquatic life for chronic exposures based on comparison of exposure point concentrations in surface water to the TBVs for aquatic life, which are

the chronic AWQC. HQs for these analytes exceed 1 based on the TBV_{Low} and the TBV_{High} .

- Barium and manganese are similar to concentrations observed in ground water, and are therefore likely to be naturally occurring.
- Pesticides in sediments do not exceed the sediment quality criteria for the protection of aquatic life.
- The petroleum hydrocarbons and lead are most likely due to runoff from the road next to the lake.
- The HQ for lead for the dietary ingestion pathway for waterfowl and wading birds exceeds 1 based on comparison to the TBV_{Low} , although surface water ingestion does not contribute to risk. HQ values for the dietary ingestion pathway for mallard, but not sandpiper, exceed 1 based on the TBV_{High} .
- There are no risks to avian or mammalian receptors for ingestion of surface water or sediment.

There was no risk identified for the remaining receptors and pathways that were evaluated. Conservative methods were used for the HQ screen for aquatic life in that only the chronic criteria were used for screening. In addition, the samples used in the evaluation consisted of both filtered and unfiltered data; chemicals bound to particulates (i.e., the unfiltered data) are not readily bioavailable to aquatic life. However, the risk assessment was conservative in utilizing all available data. Because there are no army sources for inorganics, and HQs due to organics that may be related to army activities (i.e., pesticides) do not exceed 1, this site should not be evaluated further from the perspective of ecological risk.

15.2.4.2.14 Baker Beach Study Area

Each of the subareas of Baker Beach are discussed below.

15.2.4.2.14.1 Baker Beach DA1 Outside the Mounded Landfill Material Area

The identified COPCs for the Baker Beach Disturbed Area 1 (DA1) outside the Mounded Landfill Material area included VOCs, PCB 1254, PAHs, antimony, selenium, TPH-D and pesticides in soil. The potential exposure pathways evaluated were ingestion, dietary

exposure and dermal contact by all key terrestrial receptors. A comparison of exposure to the receptor TBVs (Table 15.2-86; Figure 15.2-34) indicated:

- HIs for the American robin, mourning dove, western harvest mouse, pocket gopher and plants and soil fauna exceeded 1 when comparisons were made based on the conservative TBV_{Low} and TBV_{High} .
- The dietary ingestion pathway was responsible for most of the ecological risk identified for birds and mammals. Dieldrin, ppDDT, PCB, and selenium dietary HQs exceeded 1 based on a comparison of projected dietary exposure to the TBV_{Low} . Only selenium HQs exceeded 1 based on a comparison of projected dietary exposure to the TBV_{High} .
- Antimony and selenium HQs exceeded TBV_{Low} values for plants and soil fauna. Only antimony HQs exceeded the TBV_{High} values for plants and soil fauna.

Because some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted given the TBV_{High}), the ecological risk assessment for Disturbed Area 1 will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

15.2.4.2.14.2 Baker Beach Disturbed Area 1 Mounded Landfill Material Area

The identified COPCs for the Baker Beach DA1 Mounded Landfill Material Area were lead and zinc in soil. The potential exposure pathways evaluated were ingestion, dietary exposure and dermal contact by all key terrestrial receptors. A comparison of exposure to the receptor TBVs (Table 15.2-87; Figure 15.2-35) indicated:

- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs for the American robin, mourning dove, and western harvest mouse exceeded 1 when comparisons were made based on the TBV_{High} .
- The soil and dietary ingestion pathways contributed to risk for terrestrial receptors for both lead and zinc HQs.
- Lead HQs exceeded 100, and zinc HQs exceeded 50, for the American robin for soil or dietary ingestion exposure pathways for exposure relative to the TBV_{Low} . HQs for

lead were above 5, and HQs for zinc were 1 and higher, when the TBV_{High} was used as the basis of the risk comparison.

- Lead and zinc HQs exceeded TBV_{Low} and TBV_{High} values for plants and soil fauna.

Because some estimates of risk exceed the upper bound of the gray zone (i.e., risk is predicted given the TBV_{High}), and several receptors are potentially affected, the ecological risk assessment for Disturbed Area 1 Mounded Landfill Material Area will be further evaluated to determine whether the assessment warrants inclusion of this site into the FS.

15.2.4.2.14.3 Baker Beach Disturbed Area 1 Seep

For the seep at Disturbed Area 1, COPCs identified in the surface water for the ecological risk assessment include several inorganics and miscellaneous parameters. Sediment COPCs include barium, copper, lead, silver, zinc, TPH-D, PCB 1260, and ppDDE. The potential exposure pathways quantitatively evaluated were direct contact by aquatic life and amphibians, and ingestion of surface water by all terrestrial receptors. AUFs were not applied since the seep could attract animals and serve as a disproportionate source of drinking water relative to their home range size. A comparison of exposure to the receptor TBVs (Table 15.2-88; Figure 15.2-36) indicated:

- HIs for aquatic life and amphibians exceeded 1 based on comparison to the chronic AWQC which are the TBVs for aquatic life.
- Barium and manganese HQs for surface water exceeded 1 for aquatic life based on the minimum and maximum AWQC identified.
- TPH-D, PCB 1260, ppDDE, copper, and lead HQs exceeded sediment quality criteria, which were the TBVs for invertebrate exposure to sediments.
- HQs for sediment ingestion by the raccoon exceeded 1 for lead when exposure estimates were compared to the conservative TBV_{Low} , but did not exceed 1 when the basis of the comparison was the TBV_{High} .
- Ingestion of surface water by either birds or mammals does not present a risk.

Although there are exceedences between 10 to 1000, because the area is small, and also could be seasonal, the habitat is too limited to support populations of receptors. Only isolated individuals may be affected. Therefore, further evaluation at this location is not warranted from the perspective of ecological risk.

15.2.4.2.14.4 Baker Beach Disturbed Area 1a

The identified COPCs for the DA1a site included PAHs, OCPs and TPH-diesel in soil. The potential exposure pathways included soil ingestion, dietary exposure and dermal exposure to terrestrial receptors. A comparison of exposure to the receptor TBVs is provided in Table 15.2-89 and Figure 15.2-37. All HQs and HIs were less than 1. Therefore, there is no risk attributable to this site, and further evaluation is not warranted.

15.2.4.2.14.5 Baker Beach Disturbed Area 2

The identified COPCs for DA2 were PAHs, VOCs, TPH-D, and pesticides in soil. The potential exposure pathways evaluated were soil ingestion, dietary exposure, and dermal exposure for all key terrestrial receptors (Table 15.2-90; Figure 15.2-38). Results indicated:

- The only receptor with an HI greater than 1 was the American robin, when comparisons were made to the TBV_{Low} values. ppDDT was identified as the only risk driver to the HI of 6 for this receptor.
- The only risk was due to the dietary ingestion pathway.
- All HIs were less than 1 when the basis of the risk evaluation was the TBV_{High} .

Given the minimal number of risk drivers identified for the pathways evaluated, it appears that the ecological risk attributable to the site is minimal and does not warrant further evaluation. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, further evaluation of this site from the perspective of ecological risk is not warranted.

15.2.4.2.14.6 Baker Beach Disturbed Area 3

The identified COPCs for the DA3 site included inorganics, PAHs, TPH-D, bis(2-ethylhexyl) phthalate, PCB 1254 and pesticides. The potential exposure pathways evaluated were soil ingestion, dietary exposure and dermal exposure to all key terrestrial receptors. A summary of the comparison of exposure to the receptor TBVs (Table 15.2-91; Figure 15.2-39) indicated the following:

- HIs for the American robin, mourning dove, western harvest mouse, and pocket gopher exceeded 1 when comparisons were made based on the conservative TBV_{Low} .

- HIs for the American robin, mourning dove, and western harvest mouse exceeded 1 when comparisons were made based on the TBV_{High} .
- The soil and dietary ingestion pathways contributed to risk for terrestrial receptors.
- Antimony, cobalt, chromium, iron, nickel, lead, and zinc HQs exceeded TBV_{Low} values for plants and soil fauna.
- Antimony, cobalt, chromium, iron, and nickel HQs exceeded TBV_{High} values for plants and soil fauna.
- Lead HQs based on the TBV_{Low} exceeded 1 for the peregrine falcon; however, no HQs exceeded 1 based on the TBV_{High} .

Given the TBV exceedences for multiple pathways and receptors evaluated, the ecological risk assessment for Disturbed Area 3 will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

15.2.4.2.14.7 Baker Beach Disturbed Area 4

The identified COPCs for DA4 were chlordane, ppDDT, and TPH-diesel in soil. The potential exposure pathways evaluated were soil ingestion, dietary exposure and dermal exposure for all key terrestrial receptors. A summary of the comparison of exposure to the receptor TBVs (Table 15.2-92; Figure 15.2-40) indicated the following:

- HIs for the American robin exceeded 1 when comparisons were made based on the TBV_{Low} .
- The dietary ingestion pathway was the largest contributor to risk for the robin.

Ecological risk attributable to the site is minimal. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, it appears that the ecological risk attributable to the site is minimal and does not warrant further evaluation.

15.2.4.2.15 Battery Howe/ Wagner

The identified COPCs for this site include PAHs, TPH-diesel, di-n-butylphthalate, chromium, nickel and antimony in soil. The potential exposure pathways evaluated were soil ingestion and dermal exposure to all key terrestrial receptors. Comparison of exposure to receptor TBVs (Table 15.2-93 and Figure 15.2-41) indicates the following:

- HIs for the American robin, mourning dove, and western harvest mouse exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs for the American robin and mourning dove exceeded 1 when comparisons were made based on the TBV_{High} .
- Chromium and nickel in soil produced HQs in excess of 1 for the American robin and the mourning dove.
- Concentrations of chromium, nickel and antimony in soil exceed TBV levels for the protection of plants and soil fauna.

Of all the receptor and exposure pathways evaluated, only soil ingestion exposure to the American robin, mourning dove and western harvest mouse indicated a potential for risk. Given the TBV exceedences for multiple pathways and receptors evaluated (i.e., exposure exceeds the upper bound of the gray zone), the ecological risk assessment will be further evaluated to determine whether this assessment warrants inclusion of this site into the FS.

15.2.4.2.16 Miscellaneous Follow on RI Sites

The following sections present the ecological risk characterization for the Miscellaneous Follow-on Sites.

15.2.4.2.16.1 Building 302

The identified COPCs for Building 302 included 2,4-D, cyanide, Dicamba, and mercury in soil. The site is a disturbed industrial setting. The potential exposure pathways evaluated were soil ingestion and dermal exposure to all key terrestrial receptors. Comparison of exposure to receptor TBVs (Table 15.2-94 and Figure 15.2-42) indicates the following:

- HIs for the American robin and plants and soil fauna exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs were all less than 1 when comparisons were made based on the TBV_{High} .
- Mercury ingestion through the diet was the greatest contributor to risk for the robin
- Mercury in soil was the greatest contributor to risk for plants and soil fauna.

Given the small number of pathways posing a risk potential to ecological receptors, it appears that this site poses a minimal ecological receptor risk. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few

receptors are potentially affected, this site should not be considered further from the perspective of ecological risk.

15.2.4.2.16.2 Building 669

This site was not evaluated in the ecological risk assessment because no samples were collected for chemical analysis.

15.2.4.2.16.3 Building 1245

The identified COPCs for Building 1245 include di-n-butylphthalate, dieldrin, ppDDE, ppDDT, fluoranthene, and pyrene in soil. The site is a disturbed industrial setting. The potential exposure pathways evaluated were soil ingestion and dermal exposure to all key terrestrial receptors. Comparison of exposure to receptor TBVs (Table 15.2-95 and Figure 15.2-43) indicates that all HIs and HQs are much less than 1 for all receptors. This site does not present an ecological risk, and warrants no further evaluation.

15.2.4.2.16.4 Building 1369

Lead in soil was the only identified COPC for Building 1369. The site is a disturbed industrial setting. The potential exposure pathways evaluated were soil ingestion and dermal exposure to all key terrestrial receptors. Comparison of exposure to receptor TBVs (Table 15.2-96 and Figure 15.2-44) indicate the following:

- HIs for the American robin and mourning dove exceeded 1 when comparisons were made based on the conservative TBV_{Low} .
- HIs were all less than 1 when comparisons were made based on the TBV_{High} .

Given the small number of pathways posing a risk potential to ecological receptors, it appears that this site poses a minimal ecological receptor risk. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, this site should not be considered further.

15.2.4.2.16.5 Building 1388

The only COPC for the Building 1388 site was TPH-diesel in soil. The site is a disturbed industrial setting. The potential exposure pathways evaluated were soil ingestion and dermal

exposure to all key terrestrial receptors. Comparison of exposure to receptor TBVs (Table 15.2-97 and Figure 15.2-45) indicates that HQs and HIs are much less than 1 for all receptors and pathways evaluated.

Given the small number of pathways posing a risk potential to ecological receptors, it appears that this site poses a minimal ecological receptor risk. Because no estimates of risk exceed the upper bound of the gray zone (i.e., no risk is predicted with the TBV_{High}), and few receptors are potentially affected, this site should not be considered further from the perspective of ecological risk.

15.2.4.2.16.6 Building 1750

This site was not evaluated in the ecological risk assessment because no COPCs were identified.

15.2.5 Conclusions

There are several general conclusions which can be made from the risk assessment results.

These are:

- Dermal exposure never results in HQs in excess of 1 for birds or mammals.
- Large raptors, as represented by the red-tailed hawk, do not appear to be at risk at any of the sites.
- Drinking water ingestion does not produce HQs greater than 1 for any of the receptors investigated.

Although HIs (sum of chemical specific HQs) were presented in Section 15.2.4 to visually present risks for each receptor by site (Figures 15.2-3 through 15.2-45), cumulative HIs are not realistic. The assumption is that all toxicity is additive; this is a crude assumption at best. Therefore, the conclusions focus on the results of the ERA as indicated by the sum of the pathway HQs, and for total exposure that exceeds 1.

The magnitude of the HQ does not relate directly to the magnitude of risk in a linear manner, i.e., a HQ of 100 does not infer a 100 fold increase in adverse effects. One reason for this is because the HQ is based on single point estimates derived from multiple different studies, and not a dose response curve from one study. In fact, given the known uncertainties inherent

in the risk assessment, as well as the cumulative effects of numerous conservative assumptions, even an HQ of 10 probably is not a strong indicator of ecological risk. However, larger HQs do indicate some greater potential for adverse effects.

The HQs are based on TBVs which contain several orders of magnitude of applied uncertainty factors (i.e., because the true toxicity values are unknown, ones much lower were used in the risk assessment). Application of uncertainty factors makes some of the TBVs very low; for example, the TBV_{Low} for the peregrine (3.8 mg/kg bw/d) is in the range of that required for avian nutrition (2.4-8.0 mg/kg bw/d).

Many of the sites and areas within the PSF present no or minimal risk to ecological receptors under the exposure scenarios evaluated. Out of approximately 42 sites evaluated (Figures 15.2-3 through 15.2-45), many have HQs that exceed 1 for the TBV_{Low} which may warrant further investigation or evaluation of data. These sites are:

Nike Facility	Landfill E
Nike Swale	Graded Area 9
Crissy Field Building 640/643	Building 662
Fill Site 7/EOM Shoreline	Building 680
Building 609	Building 1351
Crissy Field Building 633	FPCGS
Crissy Field Future Wetland	Baker Beach DA1 Outside the Mounded Landfill Material Area
Crissy Field Sewer Lift Station 1	Baker Beach DA1 Mounded Landfill Material Area
Crissy Field Sewer Lift Station 2	Baker Beach DA1 Seep
Building 900 Series Study Area	Baker Beach DA3
DEH	Baker Beach DA4
Main Post Building 1151	Battery Howe /Wagner
Main Post Building 1167	Building 302
Landfill 2	Building 1369
Transfer Station	Mountain Lake
Landfill 4	Lobos Creek
Fill Site 5	

However, at some of these locations, the area is so highly disturbed by current and/or projected future human use, that there is very little likelihood of ecological receptors utilizing the location with any frequency. If receptors do not exist, the estimated risk results are improbable at best. The locations identified as lacking in natural habitat are:

Building 609	Building 662
Building 1167	Building 680
Building 1151	FPCGS

Those locations that might have adequate habitat to support ecological receptors, and where the HQs for at least one receptor exceed 1 based on the TBV_{High} , are considered candidates for further evaluation of the data. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others. These sites are:

HQs > 1 for the TBV_{Low}	HQs > 1 for the TBV_{High}	Evaluate Further?
Nike Facility	Nike Facility	Yes
Nike Swale		No
Crissy Field Building 640/643	Building 640/643	Maybe
Fill Site 7/EOM Shoreline	Fill Site 7/EOM Shoreline	Yes
Crissy Field Building 633	Building 633	Maybe
Crissy Field Wetland (Terrestrial)		No
Crissy Field Wetland (Aquatic)	Crissy Field Wetland (Aquatic)	Yes
Crissy Field Wetland (Groundwater)	Crissy Field Wetland (Groundwater)	Yes
Crissy Field Sewer Lift Station 1		No
Crissy Field Sewer Lift Station 2	Crissy Field Sewer Lift Station 2	Maybe
Building 900s	Building 900s	Maybe
DEH	DEH	Done
Landfill 2	Landfill 2	Yes
Transfer Station	Landfill 3	Yes
Landfill 4	Landfill 4	Yes
Fill Site 5		No
Graded Area 9	Graded Area 9	Yes
Landfill E	Landfill E	Yes
Building 1351	Building 1351	Maybe
Baker Beach DA1- Outside Mounded Landfill Material Area	Baker Beach DA1 Outside the Mounded Landfill Material Area	Yes
Baker Beach DA1 Mounded Landfill Material Area	Baker Beach DA1 Mounded Landfill Material Area	Yes
Baker Beach DA1 Seep	Baker Beach DA1 Seep	Maybe
Lobos Creek	Lobos Creek	Yes
Mountain Lake	Mountain Lake	No-No Army Sources
Baker Beach Disturbed Area 2		No
Baker Beach Disturbed Area 3	Baker Beach Disturbed Area 3	Yes
Baker Beach Disturbed Area 4		No
Battery Howe /Wagner	Battery Howe /Wagner	Yes
Building 302		No
Building 1369		No

15.2.5.1 Comparison of Risk Assessment Results to the Assessment and Measurement Endpoints

The risk assessment results were further evaluated by consideration of the results compared to the assessment endpoints considered important for the PSF (Table 15.2-1). The potential effects on the assessment endpoints are discussed below.

15.2.5.1.1 Ability of the Crissy Field Study Area to serve as suitable wetland habitat as a future use

There are several significant results of the ERA for Crissy Field. These are:

- There were HQs above 1 for copper, manganese, and mercury, as well as ppDDE, ppDDT, and dieldrin, when the current soil concentrations (to a depth of 15 feet) were assumed to represent future sediment concentrations. The risks were for benthic invertebrates and were based on the sediment quality criteria.
- In order to perform the ERA for the future wetland, it was assumed that groundwater wells in the area would discharge to surface water. Under scenarios considering zero, 50%, and 90% dilution of the groundwater by Bay water, groundwater exposure point concentrations resulted in risks to aquatic life. Only the chronic criteria were used as the basis of estimating risks.

While these results suggest a potential for risk to future aquatic receptors in the wetland, the ERA for this future use is very uncertain. The actual future sediment concentrations are unknown, as soils are likely to be moved during wetland construction. Groundwater wells that were used to project an exposure point concentration may in fact not discharge to surface water. Even if the wells do discharge to surface water, influx from the Bay cannot be determined at this point in time. While three dilution scenarios were examined, these may not represent reality since the volume of water contributed by the Bay relative to that from groundwater is unknown. The ERA recommends that if the wetland is constructed, sampling be performed, to include sediment and water analyses after the wetland becomes stabilized. The absence of critical habitat is a more compelling risk than any hypothetical risks due to theoretical chemical contamination.

15.2.5.1.2 Survivability and reproduction of populations of avifauna (passerines, raptors)

At some locations, avian receptor HQs were high, indicating a potential for adverse effects on avian populations. The HQs are discussed for the American robin and the mourning dove below.

For passerine birds feeding primarily on invertebrates, represented by the American robin, the locations producing potential risks are summarized. Assessments of whether or not habitat exists and if further evaluation appears warranted on the basis of risks to this

receptor are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility	Nike Facility	Yes	Yes
Building 640/643	Building 640/643	Maybe	Maybe
FS7/EOM Shoreline	FS7/EOM Shoreline	Yes	Yes
Crissy Field Future Wetland		Yes	No
Building 609		No	No
Building 633	Building 633	Maybe	Maybe
Sewer Lift Station 1		Yes	No
Sewer Lift Station 2	CFSLS2	Maybe	Maybe
Building 900s	Building 900s	Maybe	Maybe
DEH	DEH	Yes	Done
Building 1151	Building 1151	No	No
Building 1167	Building 1167	No	No
Landfill 2	Landfill 2	Yes	Yes
Transfer Station	Landfill 3	Yes	Yes
Landfill 4	Landfill 4	Yes	Yes
Fill Site 5		Yes	No
Graded Area 9	Graded Area 9	Yes	Yes
Landfill E	Landfill E	Yes	Yes
Building 662		No	No
Building 680	Building 680	No	No
Building 1351	Building 1351	Maybe	Maybe
FPCGS		No	No
BBDA1-Outside Mounded Landfill Area	BBDA1-Outside Mounded Landfill Area	Yes	Yes
BBDA1 - Mounded Landfill Area	BBDA1 - Mounded Landfill Area	Yes	Yes
BBDA2		Yes	No
BBDA3	BBDA3	Yes	Yes
BBDA4		Yes	No
Battery Howe/Wagner	Battery Howe/Wagner	Yes	Yes
Building 302		Yes	No
Building 1369		Yes	No

BBDA = Baker Beach Disturbed Area

For ground feeding herbivorous birds, represented by the mourning dove, the locations producing risk are summarized below. Assessments of whether or not habitat exists and if further evaluation appears warranted are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others.:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility	Nike Facility	Yes	Yes
Building 640/643	Building 640/643	Maybe	Maybe
FS7/EOM Shoreline		Yes	No
Building 633	Building 633	Maybe	Maybe
Sewer Lift Station 1		Yes	No
Sewer Lift Station 2	Sewer Lift Station 2	Maybe	Maybe
Building 900s	Building 900s	Maybe	Maybe
DEH	DEH	Yes	Done
Building 1151		No	No
Building 1167		No	No
Landfill 2		Yes	No
Landfill 3	Landfill 3	Yes	Yes
Landfill 4	Landfill 4	Yes	Yes
Graded Area 9	Graded Area 9	Yes	Yes
Landfill E		Yes	No
Building 662		No	No
Building 680		No	No
Building 1351		Yes	No
FPCGS		No	No
BBDA1-Outside Mounded Landfill	BBDA1-Outside Mounded Landfill	Yes	Yes
BBDA1 - Mounded Landfill Area	BBDA1 - Mounded Landfill Area	Yes	Yes
BBDA3	BBDA3	Yes	Yes
Battery Howe/Wagner	Battery Howe/Wagner	Yes	No
Building 1369		Yes	No

For the peregrine falcon, the locations that have HQs in excess of 1 are presented below.

Assessments of whether or not habitat exists and if further evaluation appears warranted are also presented:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike		Yes	No
Building 900		No	No
DEH		No	Done

For the mallard duck, the results of the ERA are summarized below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike swale		No	No
Crissy Field Future Wetland (0%)		Yes	No
Crissy Field Future Wetland (50%)		Yes	No
Lobos Creek	Lobos Creek	Yes	Yes
Mountain Lake	Mountain Lake	No	No (No Army sources)

For the western sandpiper, the results of the ERA are presented below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike swale		Yes	No
Crissy Field Future Wetland (0%)		Yes	No
Crissy Field Future Wetland (50%)		Yes	No
Building 900s	Building 900	Yes	Yes
Lobos Creek	Lobos Creek	Yes	Yes
Mountain Lake	Mountain Lake	No	No (No Army sources)

15.2.5.1.3 Survivability and reproduction of special status species and plant communities

The risk at Fill Site 5 is considered to be minimal, and special status plant species currently occur in the vicinity. This indicates that Fill Site 5 is not having an adverse effect on special status plants. In addition, the size of Fill Site 5 is 0.8 ac, and the native communities grow on the outskirts of this area, making contact with fill materials unlikely. Any human actions in the area would need to avoid the plant communities.

The Baker Beach Study Area may be a potential threat to plant species in some areas, primarily Disturbed Area 1 and the mounded refuse area within Disturbed Area 1. Disturbed Areas 2, 3, and 4 are unlikely to have effects on plant communities, although HQs for plants

for antimony, cobalt, chromium, iron, nickel, lead, and zinc exceed 1 for the TBV_{Low} at Baker Beach Disturbed Areas 2 and 3. The evidence suggests that Baker Beach is not affecting plant communities, as special status species are currently growing there. The native plants associated with serpentinite outcrops may require high metal concentrations.

The results of the risk assessment do not indicate any adverse effects on the cultural forest in most locations. The results of the comparison of exposure to the TBVs for plants and soil fauna are summarized below.

Sites where $HQ > 1$ Based on TBV_{Low}	Sites where $HQ > 1$ Based on TBV_{High}	Habitat Available?	Evaluate Further?
Nike	Nike	Yes	Yes
Fillsite 7/EOM Shoreline	Fillsite 7/EOM Shoreline	Yes	Yes
Building 640/643	Building 640/643	Maybe	Maybe
Crissy Field Future Wetland	Crissy Field Future Wetland	Maybe	Maybe
Building 633		Maybe	No
Crissy Field Sewer Lift Station 1		Maybe	No
Crissy Field Sewer Lift Station 2		Maybe	No
DEH	DEH	Yes	Done
Building 1167	Building 1167	No	No
Landfill 2	Landfill 2	Yes	Yes
Transfer Station	Transfer Station	Yes	Yes
Landfill 9	Landfill 9	Yes	Yes
Landfill E	Landfill E	Yes	Yes
Building 662		No	No
Building 1351	Building 1351	Maybe	Maybe
Building 900s Series	Building 900s Series	Yes	Yes
FPCGS	FPCGS	No	No
Baker Beach DA1 Mounded Landfill Area	Baker Beach DA1 Mounded Landfill Area	Yes	Yes
Baker Beach DA1- Outside the Mounded Landfill Area	Baker Beach DA1- Outside the Mounded Landfill Area	Yes	Yes
Baker Beach DA3	Baker Beach DA3	Yes	Yes
Building 302		Yes	No
Battery Howe/Wagner	Battery Howe/Wagner	Yes	Yes

15.2.5.1.4 Survivability and reproduction of populations of small mammals that could serve as prey for raptors and other predators

For the western harvest mouse, the results of the ERA are presented below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation

appears warranted are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility	Nike Facility	Yes	Yes
Sewer Lift Station 2	Sewer Lift Station 2	Maybe	Maybe
Building 640/643	Building 640/643	Maybe	Maybe
Building 633		Yes	No
Building 900		Yes	No
DEH	DEH	Yes	No
Landfill 2		Yes	No
Transfer Station	Transfer Station	Yes	Yes
Landfill 4		Yes	No
Graded Area 9	Graded Area 9	Yes	Yes
Building 680		No	No
Building 1351		No	No
BBDA1-Outside Mounded Landfill	BBDA1-Outside Mounded	Yes	Yes
BBDA1-Mounded Landfill Area	BBDA1-Mounded Landfill Area	Yes	Yes
BBDA3		Yes	No

For the valley pocket gopher, the results of the ERA are presented below. Assessments of whether or not habitat potentially exists for this receptor, and whether further evaluation appears warranted are also presented. Sites with a "maybe" designation indicate the adequacy of habitat is more questionable than the others:

Sites where HQ>1 Based on TBV _{Low}	Sites where HQ>1 Based on TBV _{High}	Habitat Available?	Evaluate Further?
Nike Facility0		Yes	No
Building 640/643		Maybe	Maybe
Building 633		Yes	No
Sewer Lift Station 2	Sewer Lift Station 2	Maybe	Maybe
Building 900		Yes	No
DEH		Yes	No
Transfer Station	Transfer Station	Yes	Yes
Landfill 4		Yes	No
Graded Area 9	Graded Area 9	Yes	Yes
BBDA1-Outside Mounded Landfill		Yes	No
BBDA1-Mounded Landfill Area		Yes	No
BBDA3		Yes	No

15.2.5.2 Recommendations

Based on the body of ecological risk assessment results generated in this RI, the following general recommendations are presented.

- Any further efforts should focus only on COPCs that produced HQs greater than 1 based on comparison to the TBV_{High} , as these are the most likely contaminants of concern.
- Evaluation should be focused only on sites that contain adequate habitat.
- Evaluation should be focused only on receptors where there are potential risks.
- Evaluation should be focused only on sites where there are known army-related sources.
- Monte Carlo Uncertainty Analysis may be appropriate for identifying appropriate, site-specific, PRGs.
- Results of the dietary ingestion pathway should be viewed with caution, as this pathway is more uncertain since the food web model was calibrated with literature-based information.

15.3 GLOSSARY OF RISK ASSESSMENT TERMS

Abiotic - non-living.

Absorption - The uptake of a chemical by a cell or an organism, including the flow into the bloodstream following exposure through the skin, lungs, and/or gastrointestinal tract.

Absorption Factor - The percent or fraction of a chemical in contact with an organism that becomes absorbed into the receptor.

Acceptable Risk - A risk level which is considered by society as tolerable.

Acute Toxicity - The development of symptoms of poisoning or the occurrence of adverse health effects after exposure to a single dose or multiple doses of a chemical within a short period of time.

Adsorption - The physical process of attracting and holding molecules of other substances or particles to the surfaces of solid bodies with which the former are in contact.

Amphibian- member of the Class Amphibia.

Analytes- chemicals on the analytical list.

Arboreal- tree-dwelling.

Arithmetic Mean (also Average) - A measure of central tendency for data from a normal distribution, given for a set of n values, by the sum of values divided by n:

$$X_m = \frac{\sum_{i=1}^n X_i}{n}$$

Avian - term for birds.

Avifauna- different kinds of birds or bird species

Background Level - The normal ambient environmental concentration levels of a chemical contaminant.

Benthic- bottom-dwelling

Bioaccumulative - a chemicals tendency to increase in tissue concentration relative to diet or water.

Carcinogenicity - The ability of a chemical to cause cancer in a living organism.

Carnivore - animal that eats meat.

Chronic toxicity - The occurrence of symptoms, diseases, or other adverse health effects that develop and persist over time, after exposure to a single dose or multiple doses of a chemical delivered over a relatively long period of time.

Dermal contact - contact of chemicals with the skin.

Dermal exposure - Exposure of an organism or receptor through skin absorption.

Dose - The amount of a chemical taken in by potential receptors on exposure; it is a measure of the amount of the substance received by the receptor, as a result of exposure, expressed as an amount of exposure (in mg) per unit body weight of the receptor (in kg).

Ecosystem - The interacting system of a biological community and its abiotic (i.e. nonliving) environment.

Ecotoxicity assessment - The measurement of effects of environmental toxicants on indigenous populations of organisms within an ecosystem.

Emergent - plants that have roots in water, with tops above water.

Endpoint - A biological effect used as index of the impacts of a chemical on an organism.

Estuarine - relating to estuary.

Exposure assessment - The qualitative or quantitative estimation, or the measurement, of the dose or amount of a chemical to which potential receptors have been exposed or could potentially be exposed to; it comprises of determining the magnitude, frequency, duration, route, and extent of exposure (to the chemicals or hazards of potential concern).

Exposure pathway - The course a chemical or physical agent takes from a source to an exposed population or organism; it describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site.

Exposure route - The avenue by which an organism contacts a chemical, such as inhalation, ingestion, and dermal contact.

Fossorial - living below the ground.

Geometric Mean - A measure of the central tendency for data from a positively skewed distribution (lognormal), given by:

$$n\sqrt{(X_1)(X_2)(X_3)\dots(X_n)}$$

or,

$$X_{gm} = anti \log \left\{ \frac{\sum_{i=1}^n \log X_i}{n} \right\}$$

Hazard - The inherent adverse effect that a chemical or other object poses. It is that which has the potential for creating adverse consequences.

Herbivore - animal that eats plant material.

Homeostatic - physiological mechanisms that maintain body or physiological function.

Immunosuppression - suppression of the immune system.

Ingestion - An exposure type whereby chemical substances enter the body through the mouth and into the gastrointestinal system.

Inhalation - The intake of a substance by receptors through the respiratory tract system.

Integrated Risk Information System (IRIS) - A USEPA database containing verified reference doses (RfDs) and slope factors (SFs) and up-to-date health risk and USEPA regulatory information for numerous chemicals. It serves as an important source of toxicity information for health and environmental risk assessment.

Invertebrates - animals without backbones.

LDLo- Lowest lethal dose to a test population

Leachate - A contaminated liquid resulting when water percolates, or trickles, through waste materials and collects components of those wastes; leaching usually occurs at landfills and may result in hazardous chemicals entering soils, surface water, or groundwater.

Lentic- term describing still water, pond, or lake.

LOAEL (lowest observed adverse effect level) - The chemical dose rate causing statistically or biologically significant increases in frequency or severity of adverse effects between the exposed and control groups. It is the lowest dose level, expressed in mg/kg body weight/day, at which adverse effects are noted in the exposed population.

LOEL (lowest observed effect level) -The lowest exposure or dose level to a substance at which effects are observed in the exposed population; the effects may or may not be serious.

Lotic- term describing running water or stream ecosystem.

MCL (maximum contaminant level) - A legally enforceable maximum chemical concentration standard that is allowable in drinking water, issued by the USEPA under the SDWA authorities.

Mutagenicity- the ability to cause mutations.

NOAEL (no observed adverse effect level) - The highest chemical intakes at which there are no statistically or biologically significant increases in frequency or severity of adverse effects between the exposed and control groups (meaning statistically significant effects are observed at this level, but they are not considered to be adverse). It is a dose level, expressed in mg/kg body weight/day, at which no adverse effects are noted in the exposed population.

NOEL (no observed effect level) - The dose rate of chemical at which there are no statistically or biologically significant increases in frequency or severity of any effects between the exposed and control groups, (i.e. the highest level at which a chemical causes no observable changes in the species under investigation). It is a dose level, expressed in mg/kg body weight/day, at which no effects are noted in exposed populations.

Omnivore- animal that eats plant material or other animals.

Passerines- member of the Order Passeriformes; perching birds.

Pathway - Any specific route by which a potential receptor or individual may be exposed to an environmental hazard, such as the release of a chemical material.

Poikilothermic- cold blooded; animals that depend on the external environment for temperature regulation.

Raptor- term applied to predatory birds including hawks, falcons, and eagles.

Receptor - Refers to members of a potentially exposed population, e.g., persons or organisms that are potentially exposed to concentrations of a particular chemical compound.

Reference dose (RfD) - The maximum amount of a chemical that the human body can absorb without experiencing chronic health effects; it is expressed in mg of chemical per kg of body weight per day. It is the estimate of lifetime daily exposure of a noncarcinogenic substance for the general human population which appears to be without an appreciable risk of deleterious effects; used interchangeably with ADI.

Remedial Investigation (RI) -The field investigations of hazardous waste sites to determine pathways, nature, and extent of contamination, as well as identify preliminary alternative remedial actions.

Riparian- plant community associated with wetlands or streams.

Risk - The probability or likelihood of an adverse consequence from a hazardous situation or hazard, or the potential for the realization of undesirable adverse consequences from impending events.

Risk assessment - The determination of the potential adverse effects due to hazardous exposure in a particular situation; it is the total process of qualifying or quantifying risks and finding acceptable levels of the risks for an individual, group, or society. It may involve the characterization of the types of health and environmental effects expected from exposure to a chemical substance, estimation of the probability (risk) of occurrence of adverse health effects, estimation of the number of cases, and a recommendation for corrective actions.

Slope factor (SF) - A plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. It is used to estimate an upper bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.

Subchronic - Relates to intermediate duration, usually used to describe studies or exposure levels spanning 5 to 90 days duration.

Submergent-plants that have roots and tops below water surface.

Taxa- a group of organisms organized by scientific classification.

TDL_o- Lowest toxic dose to a test population.

Terrestrial biota- life-forms that live in forests, meadows, or other dry-land habitats.

Toxicity assessment - Evaluation of the toxicity of a chemical based on available human and animal data. It is the characterization of the toxicological properties and effects of a chemical substance, with special emphasis on the establishment of dose-response characteristics.

Trophic- refers to the feeding category of an ecological receptor.

Uncertainty - The lack of confidence in the estimate of a variable's magnitude or probability of occurrence.

Uncertainty factor (UF) - Also called the safety factor, refers to a factor that is used to provide a margin of error when extrapolating from experimental animals to estimate human health risks.

Unit risk (UR) - Measure of the carcinogenic potential of a substance when a dose is received through the inhalation pathway that is based on several assumptions: it is an upper-bound estimate of the probability of contracting cancer as a result of constant exposure over the individual lifetime to an ambient concentration of $1 \text{ ug}/\text{m}^3$.

Upper-bound estimate - The estimate not likely to be lower than the true value.

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