Draft
Group 3 Remedial Investigation Report

at the Santa Susana Field Laboratory
Ventura County, California

Prepared for:

National Aeronautics and Space Administration
Huntsville, Alabama

May 2009

I certify that the Alfa, Bravo, Alfa Bravo Fuel Farm, Storable Propellant Area, Skyline Road, and Building 204 UST sites information contained in or accompanying this submittal is true, accurate, and complete. As to those portions of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments for the sites listed above were prepared at my direction in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted.

Signature: _____ 4/16/09

Joohi R. Sood, P.E
Senior Project Engineer

Date

REGISTERED PROFESSIONAL ENGINEER
JOOHI RASIKA SOOD
NO. C 54918
EXP. 6/10
CIVIL
STATE OF CALIFORNIA

I certify that the Waste Coolant Tank site information contained in or accompanying this submittal is true, accurate, and complete. As to those portions of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments for the sites listed above were prepared at my direction in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted.

Signature: _____ 4/16/09

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Acronyms

ABFF	Alfa/Bravo Fuel Farm
ABS	dermal absorption fraction
ACM	Asbestos-containing material
ADD	Average daily dose
AI	Atomics International
AOC	Area of concern
AOPC	Area of potential concern
AST	Aboveground storage tank
atm-m^3/M	Atmosphere-cubic-meter per mole
ATSDR	Agency for Toxic Substances and Disease Registry
AUF	Area use factor
AWQC	Ambient water quality criteria
BAF	Bioaccumulation factor
BAA	Benzo(a)anthracene
BaP	Benzo(a)pyrene
BBI	Brandeis-Bardin Institute
BCF	Bioconcentration factor
BEHP	Bis(2-ethylhexyl)phthalate
bgs	Below ground surface
Boeing	The Boeing Company
BTAG	Biological Technical Assistance Group
BTEX	Benzene, toluene, ethylbenzene, and xylenes
BTOC	Below top of casing
BW	Body weight
Cal/EPA	California Environmental Protection Agency
CCR	Current Conditions Report
CDD	Chlorinated dibenzo-p-dioxin
CDF	Chlorinated dibenzofuran
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFOU	Chatsworth Formation Operable Unit
CHSC	California Health and Safety Code
cm^2	square centimeter
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COC	Contaminant of concern
COEC	Contaminant of ecological concern
COPC	Contaminant of potential concern
CPEC	Chemical of potential ecological concern
CSF	Cancer slope factor
CSM	Conceptual site model
CTC	Carbon tetrachloride

CTE	Central tendency exposure
2,4-D	Dichlorophenoxyacetic acid
DCA	Dichloroethane
DCE	Dichloroethene
DDE	Dichlorodiphenyldichloroethylene
DG	Data gap
DHS-RHB	Department of Health Services-Radiologic Health Branch
DOE	U.S. Department of Energy
DQE	Data quality evaluation
DQO	Data quality objective
DRO	Diesel range organic
DTSC	Department of Toxic Substances Control
$EC_{20}s$	20-percent effective concentration
ECAO	Environmental Criteria and Assessment Office
Eco-SSL	Ecological soil screening level
ECS	Electrical Control Shak
EFA	Engineering Field Activity
EFH	Extractable fuel hydrocarbons
EIR	Environmental Impact Report
ELCR	Excess lifetime cancer risk
ELV	Expendable Launch Vehicle
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERA	Ecological risk assessment
ESL	Environmental screening level
ETEC	Energy Technology and Engineering Center
^oF	Degrees Fahrenheit
f_{oc}	Fraction of organic carbon
FS	Feasibility study
ft	Feet
GN2	Gaseous nitrogen
gpm	Gallons per minute
GRC	Groundwater Resources Consultants, Inc.
H	Henry's Law Constant
HCPC	High-carbon petroleum constituents
HDMS	Historical Document Management System
HEAST	Health Effects Assessment Summary Table
HERD	Human and Ecological Risk Division
HHRA	Human health risk assessment
HI	Hazard index
HMW	High-molecular-weight
HpCDD	Hptachlorodibenzo-*p*-dioxin
HQ	Hazard quotient
HSWA	Hazardous Waste Storage Area
HxCDF	Hexachlorodibenzofuran
IFC	ICF Kaiser Engineers
IRIS	Integrated Risk Information System

J-E	Johnson and Ettinger
JP	Jet propellant
K_d	Soil-water distribution coefficient
K_{oc}	partition coefficient
K_{ow}	Octanol-water partition coefficient
kg	Kilogram
L	Liter
LADD	Lifetime average daily dose
LCPC	Low-carbon petroleum constituents
LCS	Laboratory control sample
LD50	Lethal dose to 50 percent of test organism
LMW	Low-molecular-weight
LOAEL	Lowest observed adverse effect level
LOEC	Lowest observed effect concentration
LOX	Liquid oxygen
µg/dL	Micrograms per deciliter
µg/kg	Micrograms per kilogram
µg/m^3	Micrograms per cubic meter
MDL	Method detection limit
MEK	methyl ethyl ketone
mg/kg	Milligrams per kilogram
mg/kg-day	Milligrams per kilogram per day
mg/L	Milligrams per liter
mg/m^3	Milligrams per cubic mete
mL/g	Milliliter per gram
MRCA	Mountains Recreation Conservancy Authority
MS/MSD	Matrix spike/matrix spike duplicate
msl	Mean sea level
MWH	MWH Americas, Inc.
NAA	North American Aviation
NASA	National Aeronautics and Space Administration
NCP	National Contingency Plan
NFA	No further action
ng/kg	Nanograms per kilogram
NOAEL	No observed adverse effect level
NOEC	No observed effect concentration
NPDES	National Pollutant Discharge Elimination System
NRWQC	National recommended ambient water quality criteria
NSGW	Near-surface groundwater
NTO	Nitrogen tetroxide
OCDD	Octachlorodibenzo-*p*-dioxin
OCDF	Octachlorodibenzofuran
OEHHA	Office of Environmental Health Hazard Assessment
Ogden	Ogden Environmental and Energy Services Company, Inc.
ORP	Oxidation-reduction potential
OU	Operable unit
PAH	Polycyclic aromatic hydrocarbon

PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzodioxins
PCDF	Polychlorinated dibenzofuran
PCE	Tetrachloroethene
PeCDF	Pentachlorodibenzofuran
PEA	Preliminary Endangerment Act
PEC	Probable effect concentration
PEF	Particulate emission factor
pg/g	Picogram per gram
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
R&D	Research and development
RAGS	Risk Assessment Guidance for Superfund
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RfD	Reference dose
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RJ	Ramjet
RL	Reporting limit
RME	Reasonable maximum exposure
RMHF	Radioactive Materials Handling Facility
RP	Rocket propellant
RWQCB	Regional Water Quality Control Board
SAIC	Science Applications International Corporation
SB	Senate Bill
SMOU	Surficial media operable unit
SOP	Standard operating procedure
SPA	Storable Propellant Area
SQL	Sample quantitation limit
SRAM	Standardized Risk Assessment Methodology
SSFL	Santa Susana Field Laboratory
STI	Sonoma Technology, Inc.
SVOC	Semivolatile organic compound
SWMU	Solid waste management units
TAL	Target analyte list
TBA	Triethyl boron
TCA	Trichloroethane
TCDD	Tetrachlorodibenzo-p-dioxin
TCE	Trichloroethene
TCDD	Tetrachlorodibenzo-p-dioxin
TCDF	Tetrachlorodibenzofuran
TEA	Triethyl aluminum
TEC	Threshold effect concentration

TEF	Toxic equivalency factor
TEQ	Toxicity equivalent
TPH	Total petroleum hydrocarbon
TRV	Toxicity reference value
UCL	Upper confidence limit
UF	Uncertainty factor
USAF	U.S. Air Force
USEFF	Universal Space Engine Flow Facility
USFWS	U.S. Fish and Wildlife Service
UST	Underground storage tank
VC	Vinyl chloride
VCEHD	Ventura County Environmental Health Division
VF	Volatilization factor
VOC	Volatile organic compound
VSI	Visual site inspection
WCT	Waste coolant tank
WDP	Waste discharge permit
WHO	World Health Organization
WoE	Weight of evidence
WPA	Work Plan Addendum
WRS	Wilcoxon Rank Sum

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Executive Summary

…Between 1993 and 2008, thousands of samples have been collected from areas within Group 3 at the Santa Susana Field Laboratory (SSFL). After an extensive evaluation of the data and an assessment of the risk to humans and ecological receptors, the findings show that elevated risks occur only in localized areas in Group 3. After the Group 3 Remedial Investigation (RI) Report is reviewed and approved by the California Department of Toxic Substances Control (DTSC), the Feasibility Study [FS (that addresses the possible cleanup actions to be taken)] will be developed.

SSFL is located approximately 29 miles northwest of downtown Los Angeles, California, in the southeastern corner of Ventura County. SSFL occupies approximately 2,850 acres of hilly terrain and is owned in part by The Boeing Company (Boeing) and in part by the National Aeronautics and Space Administration (NASA). The land ownership is designated by Administrative Areas–Area II and part of Area I are owned by NASA. The remaining part of Area I, along with Areas III and IV and the Undeveloped Land, are owned by Boeing.

Cleanup of the site is governed by DTSC pursuant to the cleanup provisions of the California State Superfund Program (Superfund). For investigation and reporting purposes, the SSFL sites are considered by geographic locale and similar historical use rather than by ownership. These areas of similarity are referred to as Groups. A Group may have sites that are owned and operated by NASA and Boeing. This RI Report presents the results and recommendations for the investigation conducted within Group 3. Group 3 contains six distinct sites, and of those, five are owned by NASA: the Building 204 Underground Storage Tanks (USTs), the Storable Propellant Area (SPA), the Alfa/Bravo Fuel Farm (ABFF), the Bravo Area (including the test stands), and the Alfa Area (including the test stands). There is one additional site located in Group 3 that is owned by Boeing: Waste Coolant Tank (WCT). One additional area within Group 3 is included in this RI report that was investigated by NASA and has been designated as Skyline Road. After the Group 3 RI Report is reviewed and approved by DTSC, the Feasibility Study [FS (which will address the possible cleanup actions to be taken)] will be developed.

Initially, the land at SSFL was used for ranching. Most of the land at SSFL was acquired with the purchase of the Silvernale property in 1954. Area II (currently NASA property) was not used for industrial activities before 1954, when most of the land was purchased by North American Aviation (NAA). NAA owned the land from 1954 to 1958; it was then deeded to the U.S. Air Force (USAF). In the 1970s, the property transferred ownership from the USAF to NASA, which currently owns the property.

Primary NASA activities at SSFL since 1948 have included research, development, and testing of liquid-fueled rocket engines and associated components (pumps, valves, etc.). Rocket engine testing frequency decreased during the 1980s and 1990s and ceased in 2005. Engine testing at SSFL primarily used petroleum-based compounds as the fuel and liquid

oxygen (LOX) as the oxidizer. Trichloroethene (also known as trichloroethylene) (TCE) was the primary solvent used for cleaning rocket engine components and other cleaning purposes.

Extensive sampling of the soil, soil gas, and groundwater at the five Group 3 sites (the Building 204 USTs, the SPA, the ABFF, the Bravo Area, the Alfa Area, and the WCT) and the Skyline Road area has been conducted and is described in this report, along with an assessment of the risks posed to both human and ecological receptors. On the basis of the results of this sampling effort, some additional sampling is recommended for four Group 3 sites and the Skyline Road area to further evaluate the extent of the contamination. The chemicals at the sites are known, and for the most part, the extent of these chemicals has been evaluated. There are a few areas where additional sampling to identify the bounds of the chemical locations is still needed. Most of this sampling is recommended for the subsurface soils, although some sampling of surface soil and soil gas also is recommended.

At DTSC's request, additional sampling of the interior building features and subsurface sewer within Group 3 has been completed. A gridded walkover for debris areas has been completed. The sampling data from the building and sewer sampling, along with the findings from the debris area walkover activities, currently are being evaluated. The RI results are summarized below.

Building 204 USTs. Of the chemicals detected at Building 204, human health risks were identified for dioxins/furans in soil. It is recommended that the localized extent of dioxins/furans in soil be further evaluated. After the further evaluation of the extent of contamination, removal of soils with elevated dioxin/furan concentrations is recommended at this location to reduce human health risks. Elevated human health risks were estimated for the plant consumption pathway for soil. It is recommended that the plant consumption pathway be further evaluated with the agricultural residential exposure scenario once the protocol for evaluating this exposure has been established in consultation with DTSC.

On the basis of the ecological risk assessment (ERA) results, additional investigation and evaluation of dioxin/furan congeners is recommended at the Building 204 Area.

SPA. Potential human health risks were identified for formaldehyde, benzo(a)pyrene (BaP), benzo(a)anthracene (BAA), and methylene chloride in soil for the plant consumption pathway. Additionally, one volatile organic compound [VOC (TCE)] in soil gas contributed to the elevated human health risks. The extraction of soil gases in areas that have elevated TCE concentrations is recommended to reduce the human health risks. It is recommended that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario. The agricultural-based residential exposure scenario will be evaluated once the protocol for evaluating this exposure has been established in consultation with DTSC.

On the basis of the ERA results, no additional investigation or evaluation of soil or soil gas analytes is recommended in the FS.

ABFF. On the basis of the total petroleum hydrocarbon sample results in soil, additional samples are warranted to evaluate the extent in surface and subsurface soil.

Potential human health risks were identified for arsenic in soil. Arsenic was detected at concentrations slightly above the SSFL background level at several sample locations across the ABFF. The maximum detected concentrations of arsenic in soil at 0 to 2 feet (ft) below ground surface (bgs) and 0 to 10 ft bgs were 6.1 milligrams per kilogram (mg/kg) and 7.9 mg/kg, respectively, compared to a mean background value of 4.5 mg/kg. The slightly elevated concentrations of arsenic at the ABFF may be naturally occurring. It is recommended that the presence of arsenic at the ABFF be further evaluated following DTSC's revision of the SSFL background data set.

Arsenic in soil (0 to 2 ft bgs) also contributed to elevated human health risks for the plant consumption exposure pathway for a potential future residential scenario. It is recommended that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario. The agricultural-based residential exposure scenario will be evaluated once the protocol for evaluating this exposure has been established in consultation with DTSC.

On the basis of the ERA results, no additional investigation at the ABFF is recommended in the FS.

Bravo Area. To complete the nature and extent evaluation in the Bravo Area, additional surface soil samples for dioxins, Aroclor-1254, and VOCs are recommended. In the subsurface soil media, additional investigation for the extent of Aroclor-1254 and petroleum aromatic hydrocarbons is recommended. It also is recommended that additional TCE soil gas samples be collected to further evaluate the extent of contamination in the soil gas at the Bravo Area.

Potential human health risks were identified for PCBs in soil. Additionally, three VOCs (naphthalene, carbon tetrachloride, and tetrachloroethene) in soil gas contributed to elevated human health risks. Elevated human health risks for the residential plant consumption pathway were primarily due to PCBs, BaP, cadmium, and TCE in soil. It is recommended that the localized extent of PCBs in soil be further evaluated. It is recommended that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario. The agricultural-based residential exposure scenario will be evaluated once the protocol for evaluating this exposure has been established in consultation with DTSC.

On the basis of the ERA results, two analytes in soil gas (1,1-dichloroethene [DCE] and TCE) were considered to pose potential risks and are recommended for further evaluation in the FS, based on the elevated concentrations detected in shallow soil gas. No soil analytes were warranted additional evaluation.

Alfa Area. To complete the nature and extent evaluation in the Alfa Area, additional surface soil samples for dioxins and four metals (lead, nickel, silver, and zinc) are recommended. In the subsurface soil media, additional investigation for the extent of chromium, diesel range organics (hydrocarbon chains found in diesel fuel), and TCE is recommended. It also is recommended that additional TCE soil gas samples be collected to further evaluate its extent in a westerly direction.

Potential human health risks were identified for arsenic in soil for direct exposure pathways. Human health risks also were identified for TCE and cis-1,2-DCE in soil gas. It

is recommended that the presence of arsenic at the Alfa Area be further evaluated following the revision of the SSFL background data set. The extraction of soil gases in areas that have elevated TCE and cis-1,2-DCE concentrations are recommended at the Alfa Area to reduce human health risks.

TCE and arsenic in soil (0 to 2 ft bgs) also contributed to the elevated human health risks for the plant consumption exposure pathway for a potential future residential scenario. It is recommended that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario. The agricultural-based residential exposure scenario will be evaluated once the protocol for evaluating this exposure has been established in consultation with DTSC.

On the basis of the ERA, PCBs and chromium in soil were found to pose risks to the deer mouse and hermit thrush, respectively, while 2 analytes in soil gas were found to pose potential risks to the deer mouse. On the basis of the isolated hot spots, the presence of the legacy data, and the predicted risks, PCBs and chromium in soil and cis-1,2-DCE and TCE in soil gas are recommended for evaluation in the FS. Additional surface soil sampling to further evaluate the extent of contamination for lead, nickel, silver, and zinc may be recommended for the FS. In addition, subsurface soil samples for chromium, TCE, and diesel range organics, along with TCE soil gas samples, are recommended to further evaluate the extent of contamination at this site.

Skyline Road. To complete the nature and extent evaluation in the Skyline Road Area, it is recommended that additional samples be collected for dioxin analysis in both the surface and subsurface soil media.

Potential human health risks were identified for dioxins for the plant consumption exposure pathway. It is recommended that the agricultural-based residential exposure scenario be evaluated further evaluate the human health risks from plant consumption.

On the basis of the results of the ERA, additional investigation within the Skyline Road Area is not recommended in the FS.

Waste Coolant Tank. There were no human health risks above regulatory thresholds for direct exposure to soil at the WCT. No action currently is recommended based on the results of the risk assessment for the plant consumption pathway. It is recommended that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol for evaluating this exposure has been established in consultation with DTSC.

On the basis of the results of the ERA, no additional investigation is recommended in the FS.

Surficial Media Operable Unit (SMOU) Groundwater. Near-surface groundwater (NSGW) migrating to the deeper Chatsworth Formation Operable Unit (CFOU) groundwater in the Group 3 area has been confirmed at one location and probably is occurring at two others. Contaminant mass was verified in both the SMOU and the CFOU in the vicinity of the spillway as a large input area at the Alfa Test Area. Contaminant mass at the Alfa Test Area exists beneath the water table to approximately 375 ft bgs, which provides evidence of cross media transfer in this area. Cross media transfer of VOCs in the vicinity of the spillway and catch pond system also is possible at the Bravo Test Area, based

on increasing downward soil concentrations, along with soil gas flux and groundwater results in both the SMOU and CFOU. The elevated total petroleum hydrocarbon (TPH) concentrations detected in the weathered bedrock downgradient of the ABFF suggest that cross media transfer may be possible; however, the contamination is localized and the occurrence of NSGW at the SWMU has not yet been verified. The migration of constituents downward to the CFOU is possible via the subsurface interconnected fracture network, even though the CFOU water table is nearly 200 ft bgs throughout most of the Group 3 area.

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1. Introduction and Methodology

This Remedial Investigation (RI) Report presents the results and recommendations for the investigation conducted within the Group 3 Reporting Area in the northern portion of Area II at the Santa Susana Field Laboratory (SSFL). The Remedial Action Program is being conducted at SSFL under the oversight of the California Environmental Protection Agency (Cal/EPA), Department of Toxic Substances Control (DTSC). As discussed in Section 1.1.2, remedial actions at SSFL started under the Resource Conservation and Recovery Act (RCRA) Corrective Action program, but have recently transitioned to the State Superfund program. The RI is being conducted at former operational areas called "RI Sites," (formerly called RCRA Facility Investigation [RFI] sites under the RCRA Corrective Action program). The Group 3 Reporting Area includes six RI sites: the Building 204 Area, the Storable Propellant Area (SPA), the Alpha Area, and the Bravo Area (which includes the Alfa/Bravo Skim Pond), and the Hazardous Waste Coolant Tank (WCT). The area adjacent to Skyline Road also will be included in the Group 3 Reporting Area.

For consistency of presentation, general information concerning SSFL and the RFI program has been taken directly from the Group 4 RFI report prepared by MWH (MWH, 2007a).

1.1 SSFL Description and Background

1.1.1 SSFL Facility Information

SSFL is located approximately 29 miles northwest of downtown Los Angeles, California, in the southeastern corner of Ventura County. SSFL occupies approximately 2,850 acres of hilly terrain, with approximately 1,100 feet (ft) of topographic relief near the crest of the Simi Hills. Figure 1.1-1 shows the geographic location and property boundaries of the site, as well as surrounding communities. The following subsections describe the site use, history, land ownership, surrounding land use, and environmental programs at SSFL. Additional SSFL facility information is provided in the RFI Program Report (MWH Americas, Inc. [MWH], 2004).

1.1.1.1 SSFL Ownership and History

SSFL is owned jointly by The Boeing Company (Boeing) and the National Aeronautics and Space Administration (NASA), and is operated by Boeing. The site is divided into four administrative areas (Areas I, II, III, and IV) and undeveloped land areas to both the north and south (Figure 1.1-2). Areas I, III, and IV are owned by Boeing. Area II is owned by NASA. Ninety acres of Area IV were leased to the U.S. Department of Energy (DOE). The northern and southern undeveloped lands of SSFL were not used for industrial activities and are owned by Boeing. The Group 3 Reporting Area primarily is located in the central portion of administrative Area II.

Before development, the land at SSFL was used for ranching. In 1948, North American Aviation (NAA), a predecessor company to Boeing, began using (by lease) what is now known as the northeastern portion, or administrative Area I, of SSFL. Most of SSFL was

acquired with the purchase of the Silvernale property in 1954, and development of the western portion of SSFL began soon after. Area II was inactive before 1954, when the land was purchased by NAA. NAA owned the land from 1954 to 1958. In December 1958, the property was deeded from Rocketdyne to the U.S. Air Force (USAF) and was operated as USAF Plant 57. In 1973, the property transferred ownership from the USAF to NASA, which currently owns the property. Undeveloped land parcels to the south of SSFL were acquired by Boeing during 1968 and 1976 and to the north during 1998. No site-related operations were conducted in these undeveloped portions of SSFL.

The primary site activities at SSFL since 1948 have included research, development, and testing of liquid-fueled rocket engines and associated components (pumps, valves, etc.) (Science Applications International Corporation [SAIC], 1994). Since 1996, operations at SSFL have been conducted by Boeing. Predecessor companies to Boeing have included the Rocketdyne Propulsion and Power Division (Rocketdyne) of NAA and of the Rockwell Corporation. The vast majority of rocket engine testing and ancillary support operations occurred from the 1950s through the early 1970s; these operations were conducted by Rocketdyne in Areas I and III in support of various government space programs and in Area II on behalf of NASA. Rocket engine testing frequency decreased during the 1980s and 1990s and ceased in 2005. Currently, no rocket engine test areas are in operation. Engine testing at SSFL primarily used petroleum-based compounds as the "fuel" and liquid oxygen (LOX) as the "oxidizer." Trichloroethene (TCE) was the primary solvent used for cleaning rocket engine components and other cleaning purposes. Solid propellant testing was not conducted at the large rocket engine test stands, but was used in small rocket motor testing and various research and development (R&D) programs. Primarily solid propellants, including perchlorate compounds, were used, stored, and tested within Area I.

In addition to the primary facility operation of rocket engine testing, SSFL was used for research, development, and testing of water jet pumps, lasers, liquid metal heat exchanger components, nuclear energy research, and related technologies. Nuclear energy research, testing, and support facilities were located within the 90-acre portion of Area IV that was leased to the DOE and designated as the Energy Technology and Engineering Center (ETEC). Operations were conducted by Atomics International (AI), a division of NAA, and Rocketdyne on behalf of the DOE, with operations primarily occurring from the 1950s through the early 1980s.

1.1.1.2 Surrounding Land Use

Land surrounding SSFL generally is open space or rural residential, although other uses are present. The current land uses of each of the offsite adjacent properties are described briefly below (MWH, 2004). Adjacent land use is shown in Figure 1.1-1.

Northern Adjacent Properties–The adjacent property to the northwest is occupied by the Brandeis-Bardin Institute (BBI) and the adjacent property to the northeast is occupied by the Mountains Recreation Conservancy Authority (MRCA). The BBI is zoned as rural agricultural on Ventura County zoning maps. This designation permits a wide range of agricultural uses. The specific land use permit conditions for the BBI indicate that this property contains religious, teaching, and camping facilities. The MCRA property, which is zoned as open space, currently operates as Sage Ranch Park, a County of Ventura Park, and has a house where the park ranger resides.

Eastern Adjacent Properties–The properties situated immediately adjacent to the east of SSFL are zoned light agricultural, with variances that permit higher-density use (such as mobile home parks). There is a residential community approximately ¼-mile east of SSFL's boundary in Woolsey Canyon. A new residential community is under development ½-mile southeast of SSFL's boundary near Dayton Canyon.

Southern Adjacent Properties–The properties situated adjacent to the south of SSFL are used for residential purposes (Bell Canyon). Dense residential development begins in the San Fernando Valley about 5 miles southeast of SSFL.

Western Adjacent Properties–Most of the properties situated adjacent to the west of SSFL are designated by Ventura County as open space. This land has been and currently is used for cattle grazing. Recently, a portion of Runkle Canyon in this area has been proposed for development.

1.1.2 SSFL Environmental Programs

1.1.2.1 Remedial Action

Remedial actions at SSFL began under the RCRA Corrective Action program, implemented by DTSC pursuant to the corrective action provisions of the California Hazardous Waste Control Law (California Health and Safety Code [CHSC], Division 20, Chapter 6.5). The RCRA Corrective Action program is used at sites that hold a RCRA permit for onsite treatment, storage or disposal of hazardous waste. Senate Bill (SB) 990, which became effective on January 1, 2008, requires that a response action taken or approved at SSFL be carried out in accordance with the provisions of CHSC Division 20, Chapter 6.8, the Carpenter-Presley-Tanner Hazardous Substance Account Act, commonly referred to as the State Superfund program. This requirement is being incorporated into the revised Consent Order for Remedial Action governing the remedial action program at SSFL, which is expected to be finalized by the time this report is published.

State Superfund actions must be based on the requirements of the Federal Comprehensive Environmental Response, Compensation and Liability Act's (CERCLA) National Contingency Plan (NCP), and on other requirements. The RCRA Corrective Action and State Superfund processes are generally similar, but use different terminology for similar activities. Both processes use a five-phase approach that includes an initial site assessment, detailed site investigation, evaluation of remedial alternatives, selection of the final remedy, and implementation of the remedy. The terminology used to describe each phase is listed below:

RCRA CORRECTIVE ACTION AND STATE SUPERFUND TERMINOLOGY

Activity	RCRA Corrective Action	State Superfund
Initial Site Assessment	RCRA Facility Assessment (RFA)	Preliminary Endangerment Assessment (PEA)
Site Investigation	RCRA Facility Investigation (RFI)	Remedial Investigation (RI)
Remedial Alternative Evaluation	Corrective Measures Study (CMS)	Feasibility Study (FS)

RCRA CORRECTIVE ACTION AND STATE SUPERFUND TERMINOLOGY

Activity	RCRA Corrective Action	State Superfund
Remedy Selection	Statement of Basis	Remedial Action Plan (RAP)
Remedy Implementation	Corrective Measures Implementation (CMI)	Remedial Design/Remedial Action (RD/RA)

To comply with SB 990 requirements, State Superfund terminology is used to describe the activities performed for Group 3 that are described in this report. Because the technical requirements for performing an RFI and an RI are the same, changing from the RCRA Corrective Action to the State Superfund process does not affect work performed previously. RCRA Corrective Action terminology will still be used to describe activities performed prior to the Group 3 RI because that was the program in place at that time. In addition, the remedial action site designations used under the RCRA Corrective Action program (for example, solid waste management unit [SWMU] and area of concern [AOC]) will be retained to avoid confusion.

The first phase of the remedial action process was performed to identify SWMUs and AOCs, which are units that have used, stored, or handled hazardous materials or hazardous wastes. The RFA for SSFL was completed in 1994 (SAIC, 1994).

The remedial action program is currently in the RI (formerly RFI) phase. During the RI, additional AOCs (beyond those listed in the RFA) have been identified and investigated at SSFL (MWH, 2004). A total of 135 SWMUs and AOCs have been identified at SSFL, and those undergoing closure as part of the RI Program have been grouped by location for purposes of investigation and are called "RI sites" (formerly called "RFI sites"). RI sites have been grouped for reporting as described in Section 1.1.2.3. The RFI Program Report (MWH, 2004) listed 51 RFI sites (now called RI sites). Further evaluation has resulted in a new total of 57 RI sites. Four sites were added to include land surrounding the permitted facilities (Area I Burn Pit, Radioactive Materials Handling Facility [RMHF], Building 133, and Building 029). Two sites were added when leach fields were regrouped to allow for planned reporting. The 57 RI sites identified for investigation at SSFL are shown in Figure 1.1-3. For ease of presentation in Figure 1.1-3, and as reported in previous documents (MWH, 2004), the Boeing and DOE leach fields not associated with an existing RI site have been grouped together (a DOE group and a Boeing group) and listed as additional RI sites.

The RI includes characterization of relevant environmental media present at SSFL. Investigations of environmental media have been conducted following DTSC-approved work plans (ICF Kaiser Engineers [ICF], 1993; Groundwater Resources Consultants, Inc. [GRC], 1995a, 1995b; Ogden Environmental and Energy Services Company, Inc. [Ogden], 1996, 2000a, 2000b; Montgomery Watson, 2000b; MWH, 2001, 2003e, 2003f, 2005c). The scope and extent of previous sampling at SSFL are described in the RFI Program Report (MWH, 2004).

The objectives of the RI are to characterize the nature and extent of chemical contamination in environmental media, to evaluate risks to potential receptors, to gather data for the FS, and to identify areas for additional work (DTSC, 1995). Site action recommendations

resulting from the RI are categorized into: 1) further evaluation in the FS; 2) no further action (NFA); 3) interim source area stabilization measures to control contaminant migration (Stabilization Areas) while cleanup plans are prepared; and 4) data gap (DG) areas for further evaluation. Stabilization Areas may be included within FS Areas.

The FS (formerly CMS) phase of the remedial action program is an evaluation of remedial alternatives for areas identified for further evaluation during the RI. The FS also may include further evaluation of uncertainties identified in the RI related to risk assessment, delineation of chemicals requiring cleanup, or characterization of new chemical source areas identified during the preparation of the Group 3 RI Report. FS plans are prepared for DTSC review and the findings are published in a final FS report for DTSC approval. During the RD/RA (formerly CMI), the remedial action program moves from cleanup planning to cleanup implementation and confirmation and monitoring sampling. The complete SSFL cleanup plan will be evaluated in an environmental impact report (EIR) before implementation. Public review and comment will be included during several steps in this process before the selection and implementation of cleanup activities.

1.1.2.2 RCRA Programs

Following transition of the remedial action program from RCRA Corrective Action to State Superfund, the following RCRA-related activities continue under the oversight and jurisdiction of the DTSC: closure of inactive RCRA units, and compliance and permitting of operating RCRA units. In some instances, these programs overlap with the remedial action program (for example, closed RCRA units within RI sites that are investigated as part of a corrective action). These programs are described in more detail in the RFI Program Report (MWH, 2004).

1.1.2.3 Other Environmental Programs

In addition to the remedial action and RCRA programs, other federal, state, and county environmental programs are being conducted at SSFL, including permitting for air emissions, surface water discharges, and other site investigation and closure activities. Information regarding environmental programs conducted at SSFL is provided in the RFI Program Report (MWH, 2004). Because these other environmental programs overlap and occur within some of the RI sites, they are described briefly below:

- Waste discharge permits (WDPs) have been issued to SSFL by the Regional Water Quality Control Board (RWQCB) since 1958. Currently, surface water discharges from SSFL are regulated under a National Pollutant Discharge Elimination System (NPDES) permit issued by the RWQCB, beginning in 1984. Surface water discharges are monitored regularly at 18 NPDES locations, as shown in Figure 1.1-2.

- Fuel storage tanks at the site are now included in the remedial action program under DTSC oversight. Historically, underground storage tanks (USTs) were regulated by the Ventura County Environmental Health Division (VCEHD). Aboveground storage tanks (ASTs) were regulated by the RWQCB.

- Closure of nuclear testing and research facilities in Area IV is being performed under the DOE's jurisdiction. The California Department of Health Services–Radiologic Health Branch (DHS-RHB) oversees the Boeing-owned Radioactive Materials License, conducts

facility verification surveys, evaluates the radioactive facility cleanup, and conducts environmental monitoring.

1.1.2.2 Operable Units at SSFL

Since the early 1980s, SSFL site characterization has proceeded along two parallel paths: one for groundwater and the other for soil and related surficial media. In 1999, DTSC formalized this approach by identifying two operable units (OUs) (DTSC, 1999). As defined by the U.S. Environmental Protection Agency (EPA), an OU is a discrete entity that may be composed of various attributes, including the characteristics of the affected media, geographical location, vertical and aerial considerations, specific site problems, and potential exposure pathways. The OUs identified at SSFL are consistent with this definition and incorporate different geographical portions of the site, project phases, and exposure pathways. Two OUs have been identified at SSFL through discussion with the DTSC based on an understanding of where chemicals are present today, where they may migrate in the future, and how either human or ecological receptors may be exposed to those chemicals (DTSC, 1999). The OUs at SSFL are as follows:

- The Surficial Media OU (SMOU), comprised of saturated and unsaturated soil, sediment, surface water, near-surface groundwater (NSGW), air, biota, and weathered bedrock. NSGW occurs within alluvium or weathered bedrock.
- The Chatsworth Formation OU (CFOU), comprised of the Chatsworth formation groundwater and both saturated and unsaturated unweathered (competent) bedrock.

The Surficial OU consists primarily of soil, sediment, and surface water, which potentially are affected by spills. Also included in this OU are NSGW, air, biota, and the upper weathered portion of the bedrock. These additional media have been included in the Surficial OU because chemicals released into soil, sediment, or surface water could directly contact, or potentially be transferred to, NSGW, surface seeps or springs, air, biota, and weathered bedrock. Direct exposure to surficial media by receptors is possible, although the type of exposure may vary based on location (steep drainage terrain versus flat upland terrain). These potential surficial media exposures in Group 3 are evaluated in the risk assessments completed for the RI sites within this group.

The CFOU consists of groundwater and associated unweathered, competent bedrock of the Chatsworth formation, which is comprised of thickly bedded sandstone with interbeds of siltstone and shale. This unit has been affected by the downward migration of chlorinated solvents (primarily TCE) from surficial spills and/or by dissolved phase contaminants transported to and within Chatsworth formation groundwater. In contrast to surficial media, because of its nature and depth (typically more than 70 ft below ground surface [bgs]), it is that unlikely human or ecological receptors would be exposed directly to chemicals in the unweathered, deeper bedrock. Direct exposures to Chatsworth formation groundwater only could occur through the installation of a drinking water well, or at a surface seep or spring supplied by Chatsworth formation groundwater. Indirect exposures to chemicals in Chatsworth formation media (bedrock or groundwater) also are considered as part of the RI site risk assessments. These potential direct and indirect groundwater exposures in Group 3 are evaluated in the risk assessments completed for the RI sites within this group. As stated above, a goal of the RI Program is to characterize chemical impacts in

all relevant environmental media at SSFL. This goal is achieved by combining and integrating site data from the characterization programs for both OUs. Similarly, the goal of the RI risk assessment is to evaluate risks from all relevant environmental media. This goal is accomplished by combining the estimated risk associated with exposure pathways for both OUs. Several possible pathways of chemical migration across or between OUs have been identified. Each of these potential pathways is included in the risk evaluations of the Surficial OU and the CFOU, as described further in Section 1.5.

1.1.2.3 RI Program and Reporting Approach

As described in the RFI Program Report (MWH, 2004), the data quality objective (DQO) process (EPA, 1994, 2000) was used to guide the SSFL RI. The problem statement developed for the Surficial OU RI (termed RFI in that document) is as follows:

> *"Comply with regulatory requirements by characterizing the nature and extent of contamination in surficial media (soil matrix, soil vapor, sediment, surface water, near surface groundwater, air, biota, and weathered bedrock)."*

Five decision questions were identified during the DQO development and have been used to guide the data collection and evaluation process for the Surficial OU RI, as listed below:

1. Has historical information regarding chemical use areas and chemical releases been used to identify potential source areas?
2. Have source area sampling and analysis plans been developed to characterize the nature and extent of contamination?
3. Is the nature and extent of contamination at potential source areas in RI sites characterized sufficiently for risk assessment?
4. Have potential human health and ecological impacts been assessed?
5. Have characterization and risk assessment results been used to make site action recommendations for the FS?

Although developed for the Surficial OU, these five questions are relevant for the overall RI Program at SSFL. The RI reporting approach has been designed to answer these questions in a comprehensive, integrated manner for large areas of the site. On the basis of input from the DTSC, SSFL has been divided into 10 Group Reporting Areas, as shown in Figure 1.1.-4. The Group Reporting Areas have been established to accomplish the goal of providing a comprehensive, integrated description of site data from all media across large, interrelated areas of the site. As such, the Group RI Reports include the evaluation of data from both OUs to determine characterization completeness, transport and fate of contaminants, and assessment of potential risks to receptors. As necessary, offsite areas will be included in the RI evaluation of SSFL-related impacts. Group Reporting Areas generally were identified based on natural topographic constraints at SSFL, but groundwater plume extents, RI site responsibility, and operational boundaries also were considered. The Group Reporting Areas shown in Figure 1.1-4 serve to facilitate the evaluation of all migration pathways, and therefore, capture the appropriate site data for risk assessment.

The focus and objective of the Group Reports is to provide DTSC with sufficient information so that site action decisions regarding Surficial Media can be made and FS evaluation areas

determined. Because the CFOU investigation is ongoing while the Group Reports are being prepared, FS recommendations regarding groundwater will be provided in a final Sitewide Groundwater Report, which will be submitted at the completion of the CFOU investigation. However, groundwater-related risks are presented in the risk assessments and considered with the Surficial OU risks in making FS recommendations.

Two aspects of the Surficial Media RI will be addressed after all Group RI Reports are prepared. In both of these cases, some Surficial Media recommendations will be in addition to those presented in the Group Reports. The first involves the completion of the CFOU investigation described above. Because all media are being assessed for potential risks to receptors in the current Group RI Reports, new data resulting from the ongoing CFOU investigation must be reassessed for contribution to Surficial Media risks and, if necessary, additional areas recommended for FS evaluation. This assessment of subsequent CFOU data will be included in the Sitewide Groundwater Report.

The second aspect that affects the Surficial Media site action recommendations for the FS is a sitewide evaluation for large-home-range receptors (mule deer and hawk). An assessment of potential risks to these receptors will be performed once sufficiently large areas of SSFL have been evaluated and presented in the Group RI Reports. Estimated large-home-range receptor risks will be reported in a Sitewide Large-Home-Range Risk Assessment Report, which also will identify any additional areas that should be considered for FS evaluation resulting from that assessment.

These two additional aspects of RI reporting will serve to confirm and finalize the areas to be evaluated in the FS as described in this (and other) Group RI Reports. The areas recommended for further evaluation in this report can confidently be carried forward into the FS, because it is believed that additional, not fewer, areas will be identified by subsequent sitewide RI evaluations.

Previous RFI reports submitted to the DTSC for review include Groups 2, 4, 6, and 8.

1.1.3 Scope and Objectives of the Group 3 RI Report

The Group 3 RI Report presents RI findings and FS recommendations for the central portion of Area II. The scope and objectives of the Group 3 Report are described below, as well as the content and format of this report.

1.1.3.1 Scope

The Group 3 Reporting Area consists of approximately 188 acres within the central portion and expanding to the northern portion of Area II (Figure 1.1-4). Adjacent areas to the Group 3 Reporting Area include the RFI Group 2 and Boeing-owned undeveloped land and offsite areas to the north, Group 4 and offsite areas to the south, Group 1b and offsite areas to the east, and Groups 6 and 9 to the west. Reporting Group 3 consists of NASA RI sites; other areas belong to Boeing.

The following seven RI sites are included in the Group 3 Reporting Area:

- **Building 204** (Plant Services) AOC–includes former waste oil UST (UT-50); Buildings 223, 796, and 760; and areas of former USTs UT-48 and UT-49.
- **SPA** includes the Surface Impoundment-1 and drainage (SWMU 5.16), and the Surface Impoundment-2 and drainage (SWMU 5.17).
- **Alfa/Bravo Fuel Farm** (ABFF) AOC includes the storm water basin and a former UST (UT-52) across from the fuel farm.
- **Bravo** includes the inactive Alfa/Bravo Skim Pond (SWMU 5.12), the test area (SWMU 5.13), the test stand waste tank (SWMU 5.14), the former skim pond and drainage (SWMU 5.15), and the Area II Air Stripping Tower (SWMU 5.27). Buildings 213 (Control Center) and 217 (Pretest Building) also are included as AOCs because of their leachfields.
- **Alfa** includes the test area (SWMU 5.9), the test area tanks (SWMU 5.10), and the former skim and retention ponds (SWMU 5.11). Buildings 208 (Control Center) and 212 (Pretest Building) also are included as AOCs because of their leachfields.

The **Skyline Road Area** does not include a listed SWMU or AOC, but samples were collected near a set of ASTs used to hold potable process water and also adjacent to a power pole holding a set of elevated transformers. The **WCT Area** includes SWMU 5.7 and is owned and operated by Boeing. Adjacent to the WCT is the Hazardous Waste Storage Area (HWSA), which also is owned and operated by Boeing. The DTSC currently is conducting oversight for the remedial action for this RI site. The HWSA Container Storage Area (SWMU 5.8) was operated jointly by NASA and Boeing and received regulatory closure status by the DTSC in 1998.

It should be noted that the RI site boundaries shown in the maps and figures in this report are not meant as administrative boundaries, but rather serve as outlines that encompass the primary operational activities at a site. As described in Sections 2 through 8, RI sampling extended outside of these boundaries, as necessary, to evaluate the nature and extent of potential contamination and to assess potential migration pathways.

1.1.3.2 Objectives

This report has the following objectives:

- To present characterization results in the Group 3 Reporting Area and to identify the nature and extent of chemical contamination in environmental media.
- To present human health risk assessment (HHRA) and ecological risk assessment (ERA) results based on chemicals present in the Group 3 Reporting Area.
- To present risk-based recommendations for site actions, including NFA areas, areas recommended for further evaluation in the FS, and areas recommended for source stabilization.

As stated above, the Surficial Media areas recommended for further FS evaluation are considered to be defined sufficiently for FS planning, although supplemental areas or

volumes may be added following the completion of the Sitewide Groundwater Report and/or the Sitewide Large-Home-Range Risk Assessment Report.

1.1.3.3 Content and Format

This report is organized as follows:

Section 1 presents an overview of the SSFL site as a whole, the methodology for the Group 3 RI, and the organization of this report.

Sections 2 through 8 present the RI results for the Building 204 Area, SPA, ABFF, Bravo Area, Alfa Area, Skyline Road Area, and WCT Area, respectively. Each section presents the following information:

- Background and history
- RI characterization activities
- RI characterization results
- Nature and extent of contamination
- Conceptual site exposure model
- Fate and transport analysis for chemicals detected in surface media
- HHRA
- ERA
- Summary of findings and recommendations

Section 9 presents recommendations for consideration during the FS, including a summary of findings for Group 3, a summary of human health and ecological risks, a discussion of cross-media transfer of contaminants of concern (COCs), and recommendations for areas to be carried forward into the FS.

Section 10 provides the references used in preparing this report.

The appendixes are as follows:

- **Appendix A**–Ecological Surveys Conducted in April 2008, Santa Susana Field Laboratory, Ventura County, California
- **Appendix B**–Building 204 Area, SWMU 5.5
- **Appendix C**–Storable Propellant Area
- **Appendix D**–Alfa/Bravo Fuel Farm
- **Appendix E**–Bravo Area, SWMUs 5.12, 5.13, and 5.14
- **Appendix** F–Alfa Area, SWMUs 5.9, 5.10, and 5.11
- **Appendix G**–Skyline Road Area
- **Appendix H**–Hazardous Waste Coolant Tank, SWMU 5.7
- **Appendix I**–Groundwater Laboratory Data
- **Appendix J**–Building Feature Documentation Logs

1.2 Physical Setting of the Reporting Area

1.2.1 Climate and Meteorology

For consistency of presentation, general information concerning climate and meteorology at SSFL was taken directly from the Group 4 RFI report prepared by MWH (2007).

Climate and meteorological data have been collected for SSFL since the 1960s. The climate falls within the Mediterranean sub-classification, and monthly mean temperatures range from 50 degrees Fahrenheit (°F) during the winter months to 70°F during the summer months (SAIC, 1994). During the summer months (April through October), an onshore wind pattern occurs because of the proximity of the adjacent Pacific Ocean; during the winter months, this wind pattern is interrupted by weather fronts (SAIC, 1994). Wind measurements have been collected at SSFL in Area IV west of the Group 4 Reporting Area. A wind rose diagram from January to December 2001 is presented in Figure 1.2-1 and indicates that the prevailing wind pattern is northwest-southeast (Sonoma Technology, Inc. [STI], 2003). This wind rose pattern is consistent with the historical data collected both in the 1960s and in the 1990s.

Precipitation at SSFL is normally in the form of rain, although snow occasionally has fallen during the winter months. Precipitation at the site has averaged approximately 18 inches per year between 1960 and 2007, as shown in Figure 1.2-2. The annual precipitation has ranged from a low of 5.7 inches in 2002 to a maximum of 41.2 inches in 1998. Precipitation has been measured at SSFL daily during rainstorms at two onsite stations. The monthly precipitation for the 6-year period from October 2000 through June 2008 is presented in Figure 1.2-3. Most of the annual precipitation at SSFL occurs between November and March, consistent with the regional precipitation pattern of southern California.

1.2.2 Physiography

SSFL is located within the Pacific Mountain System, Pacific Border Province, Los Angeles Ranges (also know as the Transverse Ranges) physiographic region. Generally, the Transverse Ranges represent a complex of tectonic forces resulting from the interaction of the Pacific and the North American plates along the San Andreas Fault. The Transverse ranges are oriented predominantly east-west. The Transverse Ranges include the Santa Ynez Mountains, the San Rafael Mountains, the Sierra Madre Mountains, the Topatopa Mountains, the Santa Susana Mountains, the Simi Hills, the Santa Monica Mountains, the San Gabriel Mountains, the Puente Hills, the Chino Hills, and the San Bernardino Mountains.

The Transverse Ranges are characterized by extreme differences in geologic age and composition, varying from sedimentary rocks in the western Santa Ynez and Santa Monica mountains to primarily granitic and metamorphic rock in the eastern regions, where they terminate abruptly in the San Gabriel and San Bernardino mountains.

Located in the Simi Hills, SSFL occupies approximately 2,850 acres of hilly terrain that expresses approximately 1,100 ft of topographic relief (Figure 1.2-4). The highest surface elevation at SSFL occurs near the center of the site at an approximate elevation of 2,245 ft above mean sea level (msl). The highest surface elevations at SSFL occur in two general

bands that strike along a northeast-southwest trend, consistent with the geology of area. The lowest elevation occurs at the eastern property boundary and has an elevation of approximately 1,1,75 ft above msl. The lower elevations at SSFL occur primarily along the eastern, southern, and north-central to northwestern perimeters of the property. A broad, relatively flat area of topography exists in the northwestern portion of SSFL that is referred to as the Burro Flats area (MWH, 2003f).

Group 3 RI sites range in elevation from approximately 1,800 ft above msl at the western area (SPA RI) of the group to approximately 1,950 ft above msl at the eastern boundary (Alfa RI). The area is dissected by several perennial drainages.

1.2.3 General Geology and Hydrogeology at the Santa Susana Field Laboratory

The regional geology and hydrogeology have been reported extensively in previous documents submitted to the DTSC. Brief summaries are provided below. Detailed information regarding the geology and hydrogeology is provided in the site-specific sections (Sections 2 through 8).

1.2.3.1 Summary of Geology

SSFL is located in the Transverse Ranges of southern California, characterized by north-south compression that has produced geologic structures such as faults, synclines, and anticlines that are elongated in an east-west direction. Primary geologic units present at SSFL are the Quaternary Alluvium and the Cretaceous Chatsworth formation. The Chatsworth is overlain by the Simi Conglomerate Member of the Paleocene Santa Susana formation in the northern part of the site, and is faulted against the Santa Susana formation in the western part of the site. To the south, the Chatsworth is overlain by southward dipping late Tertiary formations. Structurally, SSFL is located on the southern flank of an east-west striking and westward plunging syncline that passes through the central part of the Simi Valley (MWH, 2003f). The attitude of the stratigraphic sequence at SSFL reflects the local structural setting, with bedding exhibiting a northeast/southwest strike and dips ranging from 25^{o} to 40^{o} to the northwest. The regional geology is depicted in Figure 1.2-5. A geologic map of the SSFL area is presented in Figure 1.2-6. These geologic formations are described below:

Quaternary Alluvium/Colluvium–Alluvial soils are generally thin and typically 5 to 15 ft thick at SSFL. The extent of alluvial soils at the SSFL is presented in Figure 1.2-7. Alluvial soils usually occur in topographic lows and along stream drainages. Stream drainage generally corresponds to troughs and depressions on the top of the Chatsworth formation, which are thought to be related to zones of bedrock weakness characterized as areas of greater fracture density and intensity and enhanced weathering a thin alluvial veneer covers a broad expanse in the Burro Flats area. Disturbed soils also have been used as fill material in developed portions of SSFL. Thick fill soils (up to 35 to 40 ft) have been identified in the northeast and north-central sections of SSFL. The alluvium generally consists of weathered Chatsworth formation sediments and is usually a fine-grained silty sand (MHW, 2003e). Colluvium, consisting of sediment deposited or built up by gravity at the foot of steep slopes, sometimes will be found in association with alluvial deposits.

Chatsworth Formation–Most of SSFL is underlain by the Cretaceous Chatsworth formation, which consists of interbedded sandstone and shale deep-sea turbidite deposits. The

Chatsworth formation has been divided into the lower Chatsworth formation and the upper Chatsworth formation. The upper Chatsworth formation has been further subdivided into the Sandstone 1 and Sandstone 2 units (Figure 1.2-7). Further subdivision of these sandstone units has resulted in the naming of multiple members. A series of thin shale, siltstone, and sandstone beds, known collectively as Shale 2, separate the older Sandstone 1 deposits from the overlying Sandstone 2 deposits. The Chatsworth formation is subject to weathering (chemical and physical), both at the surface and within the subsurface. Weathered Chatsworth formation rocks generally exhibit fracture traces that have been oxidized and overall colors of various shades of yellow, brown and grey. Depths to weathered Chatsworth formation rocks vary across the Group 3 study area. Weathered bedrock thickness can be on the order of tens of feet thick and, in some areas, greater than 100 ft thick. Higher fracture density, both laterally and vertically, can contribute to wider and deeper weathered bedrock sections.

Stratigraphy. SSFL Group 3 RI units are underlain by members of the Sandstone 1 and Sandstone 2 units of the Chatsworth formation (MWH, 2007a). Thicknesses of Sandstone 1 and 2 at SSFL can reach 1,900 ft and 1,200 ft, respectively. The Shale 2 unit is situated between the Sandstone 1 unit and the Sandstone 2 unit and transects the Group 3 study area. The Shale 2 unit consists of upper and lower fine-grained sub-units separated by a middle sandstone sub-unit. The thickness of the Shale 2 unit varies from 150 ft to approximately 175 ft.

The northern section of the Group 3 RI study area is underlain by deposits of various member of the Sandstone 2 unit (MWH, 2007a). These units, from oldest to youngest (geographically from southeast to northwest), consist of the Silvernale member, the SPA member, the Lower Burro Flats member, the Expendable Launch Vehicle (ELV) member, and the Upper Burro Flats member.

Two lenticular fine-grained units with limited areal extent, Shales 1A and 1B, are defined within Sandstone 1 (MWH, 2007a). The Happy Valley and Woolsley members are finer-grained units of Sandstone 1 that are present in the subsurface in the Group 3RI study area. The southeastern section of Group 3 is underlain by deposits of the Sandstone 1 Sage Member, which consists predominantly of medium-grained sandstone with minor interbeds of siltstone and shale.

Structure. Structural features and rock discontinuities are integral components of the geologic setting at SSFL, both of which are numerous at SSFL and the surrounding area (MWH, 2007a). Geologic structures at SSFL have been defined as three different categories– faults and fault zones, deformation bands, and structures. With respect to groundwater, rock discontinuities are the most significant structural features at the facility. Rock discontinuities generally are defined as zones of weakness in a rock mass and also are characterized as fractures, which include faults, partings along bedding planes, and near-vertical joint sets. Collectively, these structural features make up the systematic interconnected fracture network in the Chatsworth formation.

The North-, Middle-, and South Bravo deformation bands are present at the southwestern boundary of the Group 3 RI. The North Bravo deformation band strikes approximately $N60^0W$ and has been reported as dipping to the southwest approximately 70^0. Displacement at the scale of inches has been noted along two separate traces, one to the

north and another to the south. The North Bravo deformation band expresses itself geomorphically as a linear drainage that is locally defined by a 5- to 15-foot-deep and relatively narrow slot in rock (MWH, October 2005). The Middle Bravo deformation band is poorly exposed, but defined by a well-developed topographic lineament and deformation bands found adjacent to the lineament. Where exposed, 2 to 3 ft of apparent down to the south vertical separation is shown. A dip of more than 70^0 to the southwest and northeast has been observed. The South Bravo deformation band is well exposed and easily identified on aerial photographs. The strike is approximately N80^0W and the dip is approximately 70^0 to the south. Displacement of less than one-half inch to the south has been observed.

The Coca Fault occurs to the south of the Bravo beds. The fault extends east to west across nearly the entire SSFL boundary and is believed to merge with another major fault (the Burro Flats fault) to the west. Displacement across the fault is difficult to ascertain. The fault's dip has been measured to be N76^0W.

The North Fault lies north of the Group 3 study area. It traverses the SSFL's northern boundary from west to east. Its structure is described as complex, with different structural styles depending on location. It has been divided into three distinct structural domains (eastern, central, and western domains). The central domain bounds the Group 3 study area to the north. In this area the fault exhibits several deformation bands and several faults with significant apparent displacements. Dip angles of 60^0 to the south and north have been observed. The trace of the fault in the central section is based primarily on a weakly developed aerial photo lineament that is defined by small topographic benches and variations in the density of outcrops.

A variety of ways to identify fractures and their characteristics has been used at SSFL, including aerial photographs, outcrop inspections, rock cores, and borehole geophysics. The major findings are summarized as follows:

- Aerial photos studies indicate that the fracture spacing north of the Shale 2 unit (northern section of SSFL) is on the order of 100 ft and commonly exceeds 200 ft, while the fracture density in the southern section of SSFL typically is less than 50 ft.
- Fractures identified from 11 core logs show average fracture spacing ranging from every 1 to2 ft, although fracture spacing was highly variable with depth and unfractured intervals of 20 ft or more were common. The orientations of the fractures are independent of the bedding and jointing features.
- Borehole geophysical logging at 26 locations indicated that the downhole fracture spacing ranged between 1 and 2 ft, on average. Data evaluation has not revealed any specific patterns in the spatial distribution of fractures in the subsurface.
- Stereonets, rose diagrams, and fracture dip diagrams do not reveal any particular pattern in the fracture orientation; however, it can be generalized that most of the fractures dip more than 40^0 and the majority of fractures are oriented northeast-southwest (parallel to the strike of the Chatsworth formation) (MWH, October 2005).

1.2.3.2 Summary of Hydrogeology

Since mid-2001, groundwater has been classified as either near-surface groundwater (that water which is present in alluvium, colluvium, and/or weathered bedrock) or Chatsworth formation groundwater (that which is found in unweathered bedrock beneath SSFL) (Haley and Aldrich, 2007). This approach was approved by the DTSC (DTSC, 2007a) for the purposes of HHRAs and ERAs, is consistent with the DTSC-approved OU approach, and is adopted herein. The DTSC has requested that groundwater definitions be revised to reflect continuity between groundwater that may be perched versus that which is vertically continuous (DTSC, 2007b). In each Group 3 RI site-specific section, groundwater occurrence is evaluated to determine whether perched water exists above the local water table or is interconnected to the unweathered bedrock flow system of the Chatsworth formation.

First encountered groundwater typically exists under water table conditions and may be encountered in alluvial and colluvial deposits, weathered bedrock, or unweathered Chatsworth formation rocks. First-encountered groundwater can be found at depths as shallow as approximately 4 ft bgs to depths greater than 500 ft bgs. Aquifer tests have demonstrated that a well-interconnected fracture network (both vertically and horizontally) extends throughout the subsurface.

The areal extent of NSGW (which was extensively mapped in February 2002) is shown in Figure 1.2-8 (MWH, 2003d) and closely reflects the areal distribution of alluvial and colluvial deposits, as shown in Figure 1.2-7. The occurrence of NSGW is variable–ephemeral in some areas and perennial at others, particularly in weathered bedrock. Groundwater monitoring wells completed in both alluvial and weathered bedrock will, on occasion, be dry. The direction of NSGW flow varies spatially and generally depends on the orientation of valleys and their slope. NSGW in Group 3, which occurs primarily at the Alfa and Bravo sites, generally flows westward (MWH, 2003f). Groundwater flow in the unweathered bedrock flow system of the Chatsworth formation is variable and difficult to define due to the complex flow paths that develop because of the interconnected fracture network.

A conceptual model of NSGW occurrence and flow paths is provided in Figure 1.2-9. Linear areas of low topographic expression that are aligned with stream drainage patterns typically correspond to zones of bedrock weakness resulting from areas of high fracture density in the Chatsworth formation. Bedrock weakness is characterized by troughs and depressions that form wedges where relatively thick weathered bedrock sections are formed by enhanced weathering. Subsequent deposition of colluvium and alluvium in the stream drainage completes the NSGW hydrostratigraphic unit, where converging lines of flow from infiltration, shallow groundwater flow, and bedrock flow concentrate pore water and create preferential flow paths.

Groundwater springs and/or seeps have been found both in ephemeral drainages in the southern section of SSFL and offsite to the north and east of SSFL (MWH, 2003f), but none has been found within the boundary of the Group 3 study area.

The fractured Chatsworth formation is the principal water bearing system at SSFL. Chatsworth formation groundwater occurs regionally, rather than being localized in extent, as with NSGW. Depths to water measured in Chatsworth formation wells (where groundwater is not vertically continuous with NSGW) range between 60 and 300 ft bgs and

can vary over short distances (MWH, 2004). Chatsworth groundwater occurs in secondary porosity features (fractures, bedding planes, and joints) where most groundwater movement occurs. Groundwater also occurs within the matrix of the sandstone (in between fractures and bedding planes), but little to no movement of this water occurs within the rock matrix. The matrix hydraulic conductivity is approximately an order-of-magnitude lower than the bulk hydraulic conductivity of the Chatsworth formation, indicating that the hydraulic conductivity of the formation is dominated by the fractures within the bedrock (Montgomery Watson, 2000).

In this conceptual model, the rock matrix provides the storage volume, while the interconnected fracture network dominates the bulk rock mass hydraulic conductivity. The heterogeneity exhibited by the Chatsworth formation is more pronounced in areas adjacent to faults and deformation bands.

From an analysis of hydrogeologic data, five groundwater units have been established at SSFL (Montgomery Watson, 2000). Group 3 SWMUs are contained within Groundwater Units 2 and 3. In the northern portion of Group 3 (Building 204 and SPA Areas), the groundwater flow in Unit 3 is generally north and northwest. The estimated rate of groundwater discharge along the northern boundary of the unit ranges from 5 to 10 gallons per minute (gpm), based on gradient and bulk hydraulic conductivity observations (Montgomery Watson, 2000).

The remaining SWMUs for Group 3 are within Groundwater Unit 2. The groundwater flow in this unit is generally west to east in the Bravo Area and northwest to southeast in the Alfa Area.

1.2.3.3 Hydrogeologic Properties

Hydraulic conductivities have been estimated from short-duration, single-well pumping tests at some Chatsworth formation wells located near or in the Group 3 study area. Summaries of these hydraulic conductivities are provided in Table 1.2-1.

Lateral near-surface groundwater gradients were calculated for the Alfa, Bravo, and SPA sites for measurements taken in March 2001, November 2001, and May 2003. The results are listed in Table 1.2-2.

Vertical hydraulic gradients were calculated for select wells at the SPA RI site on March 6, 2001. The results are summarized in Table 1.2-3. HAR-12 and HAR-14 are completed in weathered bedrock of the Chatsworth formation and are considered NSGW monitoring locations. PZ-057 is screened in weathered bedrock and HAR-05 is screened in unweathered Chatsworth formation.

1.2.3.4 Recharge

A detailed analysis of groundwater recharge was conducted by MWH and reported in December 2003 (*Technical Memorandum, Analysis of Groundwater Recharge, Santa Susana Field Laboratory, Ventura County, California,* MWH, December 2003). Two quantitative techniques (water balance method and chloride balance method) and one qualitative method (characterizing the occurrence, relative concentration, and distribution of stable hydrogen and oxygen isotopes) were used to estimate recharge at the SSFL. Quantitative estimates based on data beginning in 1997 through 1999 show infiltration ranging from 23 to

26 percent of precipitation or from 14 to 20 percent of total inflow to the SSFL drainage area using the water balance method. These values should be regarded as upper limits to estimates because of uncertainties surrounding measuring surface water runoff and evapotranspiration. Varying evapotranspiration scenarios result in infiltration ranging from 11 percent to 44 percent of precipitation based on vegetative cover. The qualitative chloride mass balance method provided an estimate of recharge of 6 percent of precipitation, and when uncertainties were factored in, an estimate ranging from 1 to 12 percent of precipitation resulted. Using an annual average of 20 inches of precipitation, recharge estimates vary from an average of 0.2 inch to 8.8 inches annually.

The qualitative methods using stable hydrogen and oxygen isotopes were not used to quantify recharge but to provide information regarding the nature of recharge. Some previous investigators thought recharge might be rapid and occur in focused areas of SSFL. The MWH study did not support that contention, and instead indicated that Chatsworth formation groundwater has a narrow range and consistent ratio of hydrogen and oxygen isotopes, thus indicating well-mixed groundwater.

The estimated recharge to the Chatsworth formation groundwater (using the chloride mass balance technique) was refined in 2007 with the collection of site-specific data collected over a 14-month period in 2006 and 2007 (MWH, 2007b). Two bulk deposition collectors were installed at SSFL from which precipitation was collected and analyzed for chloride, phosphate, conductivity, and density. Chloride concentrations in precipitation water were compared with those in groundwater, and resulted in an estimate of recharge ranging from 2 to 7.2 percent of annual rainfall (0.4 to 1.3 inches per year based on an average of 18.6 inches rainfall per year) (MWH, 2007; SSFL Groundwater Advisory Panel, June 2008).

1.2.4 SSFL Surface Water Features

The occurrence of surface water at SSFL is intermittent. That which does not seep into the ground is collected in one of four major drainages and conveyed offsite (Figure 1.2-10). Most of the surface water from SSFL runs off the southern property boundary through Bell Canyon and into Bell Creek, which subsequently discharges into the Los Angeles River. The eastern portion of the facility drains through Dayton Canyon into Dayton Creek and joins with Bell Creek to form the Los Angeles River. The northwestern perimeter drains northward into Meier Canyon, which discharges into Arroyo Simi. The northeastern and north-central portions of SSFL drain into the Northern Drainage, which connects to the Meier Canyon drainage offsite to the north of SSFL on property owned by the BBI. NPDES outfalls monitor discharges from these drainages. Other drainages where no operations occur include the Runkle Canyon, Woolsey Canyon, and Eastern drainages (MWH, 2003f).

The Group 3 RI sites are located in the northern drainage and southern Bell Canyon drainage. There probably are several ephemeral streams in the Group 3 study area. Groundwater flows in the surficial media within the Alfa and Bravo RI sites are generally east to west, along the topographic lows associated with the stream drainage.

There are four perennial ponds or surface water bodies in SSFL. The ponds have been used to collect storm water runoff, treated groundwater, and operational water. There are six skim ponds or retention ponds (SWMU 5.11, 5.15, 5.12, 5.16, and 5.17) located in the Group 3

study area. The skim and retention ponds received and stored waste generated from activities conducted at the associated RI sites.

Numerous ephemeral and perennial springs and seeps, most of which occur in the area surrounding SSFL, have been identified (Figure 1.2-11). Seeps are defined as any location where water is observed discharging from the subsurface; this includes locations with flowing water, ponded water, and wetness, but no observed ponding or active flow. The definition includes features normally referred to as "springs." No springs or seeps have been identified within the boundaries of the Group 3 RI sites; however, several have been identified in the drainage basin north of the Group 2 RI site and in the southern undeveloped area of SSFL.

1.2.5 Habitat

A broad-scale evaluation of habitats present at SSFL was conducted, as reported in the Biological Conditions Report (MWH, Appendix I, 2005e). This survey documented the occurrence of 16 different habitat types within SSFL–freshwater marsh, open water, unvegetated drainage channels, coast live oak woodland, southern coast live oak riparian forest, southern willow scrub, mulefat scrub, baccharis scrub, Venturan coastal sage scrub, chaparral, native grassland, nonnative grassland, ruderal, rock outcrop, eucalyptus woodland, and developed. Habitat surveys specific to Group 3 were not reported in MWH (2005e).

To characterize the presence and condition of the habitats in Group 3, site-specific field surveys were conducted at each of the five Group 3 RI sites in early April 2008. These surveys identified the nature and spatial extent of the habitat and land cover types present at each site, and reported whether there was evidence of stress among resident plants[1]. Incidental observations of animals or animal signs also were recorded. Habitat and land cover types in each of the RI sites are summarized in Table 1.2-4 and shown in Figure 1.2-12. Habitats at each RI site are described briefly below. The complete details of the field surveys, including a checklist, photographs, and site-specific habitat maps for each RI site, are presented in Appendix A. The habitats are summarized below:

- *Building 204 Area*–The Building 204 Area is approximately 4.08 acres; of those, 37 percent is developed (pavement, roads, or buildings). Ruderal vegetation, grassland, or rock make up approximately 23, 7, and 2.5 percent of the site, respectively. Shrub/scrub vegetation (mulefat, coast live oak, and laurel sumac) was observed to cover 2 percent of the site. Multiple bird and mammal species (house finch, red-tailed hawk, western scrub-jay, white-throated swift, California towhee, spotted towhee, gopher [burrows], coyote [scat], and rodents [burrows]) were observed to use the site. The western fence lizard also was observed at the site.

- *SPA*–The SPA Area is approximately 4.96 acres; of those, 36 percent is developed (pavement, roads, or buildings). Dense shrub/scrub (coast live oak, yerba santa, coyote brush, and milk thistle) covers 22.4 percent of the site. Woodland and ruderal vegetation are the next most dominant habitat types, covering 16 and 10 percent of the site, respectively. Stressed vegetation was observed over approximately 15 percent of

[1] Observations of stressed vegetation are a critical component of the qualitative assessment of risks to the plant community and a prerequisite for a quantitative risk evaluation for plants [Section 1.5.4].

the site. Multiple bird and mammal species (spotted towhee, western scrub-jay, house finch, Anna's hummingbird, yellow-rumped warbler, dark-eyed junco, American goldfinch, Nuttall's woodpecker, house wren, California towhee, gopher [burrows], kangaroo rat [burrows], deer [tracks], cottontail rabbit, ground squirrel, and coyote [scat]) were observed to use the site. Additionally, the western fence lizard was observed. Standing dead woody vegetation provides evidence that this site burned in the 2005 Topanga Fire.

- *ABFF*–The ABFF Area is approximately 1.62 acres; of this acreage, more than one third is developed (paved, roadways, or buildings). Approximately 33 percent of the site is dense shrub/scrub (yerba santa and deer weed), with ruderal vegetation (red-stemmed filaree, red brome, and short-pod mustard) covering approximately 23 percent of the site. Woodland cover is limited to approximately 2.5 percent. Stressed vegetation was observed over approximately 5.5 percent of the site. Multiple bird and mammal species (house finch, spotted towhee, California towhee, house wren, Nuttall's woodpecker, hooded oriole, song sparrow, red-tailed hawk, American crow, American goldfinch, European starling, gopher [burrows], and California ground squirrel) were observed to use the site. Additionally, the western fence lizard was observed.

- *Bravo*–The Bravo Area is approximately 8.86 acres and is predominantly dense shrub/scrub habitat (almost 40 percent), with coast live oak, yerba santa, coyote brush, and laurel sumac that exceed 5 feet in height. Approximately 20 percent of the Bravo area is open field, dense ruderal vegetation, generally 12 inches or less in height. Paved or developed areas cover approximately 28 percent of the site. Multiple bird and mammal species (Bewick's wren, spotted towhee, dark-eyed junco, house finch, California towhee, California quail, common raven, Anna's hummingbird, gopher [burrows], vole [runways], cottontail rabbit, and coyote [scat]) were observed to use the site. Additionally, western fence lizards, grasshoppers, and crickets were observed.

- *Alfa*–The Alfa Area is approximately 7.54 acres. Dominant land cover types include ruderal vegetation (28 percent), riparian woodland (25 percent), and rock (15.5 percent). Developed areas (pavement, roadways, and buildings) cover 3.7 percent of the area. Stressed vegetation (a peach tree, laurel sumac, and dead and stressed vegetation in drainage) was observed in the Alfa area and represents 24 percent of the land cover. Some of the stressed vegetation along the drainage may be a result of herbicide spraying along roads. Multiple bird and mammal species (spotted towhee, house finch, dark-eyed junco, violet-green swallow, white-crowned sparrow, western scrub-jay, American goldfinch, Anna's hummingbird, red-tailed hawk, California quail, blue-gray gnatcatcher [in riparian area], American kestrel, California ground squirrel, gopher [burrows], coyote [scat], mule deer [tracks and scat], cottontail rabbit, bat [guano on rocks], and fox [scat]) were observed to use the site. Additionally, western fence lizards, grasshoppers, and crickets were observed.

- *Skyline*–The Skyline Drive area, approximately 5.6 acres, contains a substantial number of cleared areas, roadway corridors, and areas that currently support structures, facilities, or other developments. The road, buildings, and associated developed areas constitute about 23 percent of the land cover at this site. Although extensive woodland does not occur within the site, several coast live oaks were documented along drainages

away from the project area. This woodland habitat covers 1.5 percent of the site. Venturan coastal sage scrub (29.3 percent), annual grassland (13.1 percent), and ruderal vegetation (7.3 percent) are the most common vegetation types throughout the site. Bird species observed during the site visit include American crow, Anna's hummingbird, black phoebe, bushtit, California quail, house finch, house and white-crowned sparrows, Lesser goldfinch, mourning dove, red-tailed hawk, rock pigeon, spotted towhee, turkey vulture, and western meadowlark. Mammals observed onsite include desert cottontail, California ground squirrel, and coyote.

- *WCT*–The WCT Area is small, approximately 0.1 acre. The dominant land cover types include ruderal vegetation (73 percent) and shrub/scrub (15.6 percent). Developed areas (pavement, roadways, and buildings) cover 11 percent of the area. Although stressed vegetation was observed immediately adjacent to the WCT, none was observed within this site. Multiple bird and mammal species (California towhee, red-tailed hawk, spotted towhee, American goldfinch, common raven, coyote [scat], cottontail rabbit, western fence lizard) were observed to use the site.

1.3 Previous Investigations, Interim Actions, and Monitoring

The primary investigations and actions referenced for the Group 3 RI are summarized below. These investigations and actions were driven by RCRA and state standards and regulations, and were approved and overseen by various agencies.

Interim measures for groundwater contamination were initiated in the late 1980s under RWQCB oversight. The ongoing groundwater pump and treatment systems, now under a DTSC permit, are a continuation of this interim measure (MWH, 2004).

An RFA conducted for EPA in 1989 by SAIC identified 122 SWMUs and AOCs at SSFL. These included units that have used, stored, or handled various hazardous materials. When finalized in 1994, the RFA included 3 additional sites, for a total of 125 SWMUs and AOCs at SSFL. During the subsequent phase of remedial action, 10 additional AOCs were identified at SSFL (MWH, 2004).

A Current Conditions Report (CCR) was completed by ICF in 1993, describing existing site conditions, history, operation, and previous sampling results for SWMUs and AOCs identified in the RFA. As part of the CCR sampling event, accelerated cleanup actions were conducted at three sites following approval by DTSC. The CCR included the original RFI Work Plan, which proposed to investigate 21 SWMUs and AOCs that were grouped into 13 RFI sites (now called RI sites) (MWH, 2004).

Investigations conducted in 1983, 1987, and 1988 identified sediment effects at the Alfa/ Bravo Skim Pond (ABSP). Sediment was excavated to bedrock in 1988. As a result of the excavation and confirmation sampling in 1993, closure was granted by DTSC in 1994. A post-closure permit was issued by the DTSC in 1995 (NASA, 2008).

Concurrent investigations were initiated on the Alfa and Bravo skim ponds and drainages in 1983. Soil, soil gas, and sediment samples were collected. Low TCE concentrations were found during additional sampling activities conducted in 1993 (Ogden, 1996). The Alfa and

Bravo skim ponds have not received closure and currently are in the RFI phase (MWH, 2004).

The SPA impoundments SPA-1 (SWMU 5.16) and SPA-2 (SWMU 5.17) initially were sampled in 1987. The concrete liners and underlying soil were excavated in 1988. Excavations were backfilled with clean soil from the Burro Flats area of SSFL. The excavations were re-excavated in 1989 because compaction was not conducted in 1988. Confirmation sampling was conducted in 1993 from each of the former impoundments. By 1994, both impoundments received closure by Ventura County Department of Health Services (McLaren/Hart, 1994).

Investigations of the Alfa and Bravo Test Stands were conducted from 1993 through 2007. Soil and soil gas samples were collected (ICF, 1993; MWH, 2007). In 2008, paint chips were collected from the test stands and analyzed for polychlorinated biphenyls (PCBs). Three aroclors (1248, 1254, and 1260) were detected in the paint chips, at concentrations ranging from 670 to 7060 µg/kg.

In 1988, three USTs were removed from the Building 204 area. A 1,500-gallon diesel UST (UT-48) was located along the eastern side of Building 204, a 10,000-gallon gasoline UST (UT-49) was located south of Building 204, and a 500-gallon waste oil UST (UT-50) was located southeast of Building 204. Stained soil was removed from the UT-49 and UT-50 excavations. In 1991, VCEHD granted clean closures for UT-49 and UT-50. Following a limited investigation in 1995, closure was requested for UT-48. In 1996, VCEHD granted closure for UT-48 (MWH, 2004).

Additional investigation was conducted in 1993, north of Building 204. A soil gas sample was collected and analyzed for volatile organic compounds (VOCs). The laboratory analysis did not report detections of VOCs at levels above the detection limits (MWH, 2005).

At the ABFF RI site, a 12,000-gallon gasoline UST (UT-52) was removed and clean closure was granted in 1994 by VCEHD (MWH, 2004).

An RFI Work Plan Addendum (WPA) was completed by Ogden in 1996 based on DTSC's comments on the CCR RFI Work Plan. The report included the history, operations, and previous sampling of all SWMUs and AOCs not included in other environmental programs at SSFL. As a preliminary sampling event to support the WPA development, a metals sampling program was implemented for the RFI. The metals sampling and analysis results were summarized in the RCRA RFI WPA, Volume I (Ogden, 1996). In 1996, the WPA was approved by DTSC; it included the evaluation of 64 SWMUs and AOCs grouped into 34 RFI sites. During RFI activities from 1996 to 1998, 3 additional AOCs were identified and the total number of RFI sites was expanded to 37 (MWH, 2004).

As part of the investigation, between 1996 and 2001, multiple soil samples were collected around the fuel tanks of the ABFF, including Building 2507. Soil samples were collected at 0.5, 7, and 10 ft bgs. The laboratory results indicated the presence of light to heavy-ranged hydrocarbons. Acetone and xylenes were detected at 10 ft bgs near Building 2507 (MWH, 2005).

1.4 Group 3 Data Evaluation Process

In this Group 3 RI Report, analytical data were evaluated by comparison against the screening criteria developed for SSFL, as outlined in the Standardized Risk Assessment Methodology (SRAM) Work Plan (MWH, 2003b). The SRAM was developed with input from DTSC to provide a standardized regulatory-accepted approach to assess human health and ecological risks related to assessments of chemicals present in various media. The provisions of the SRAM allow the work to be "evergreen" through time, such that the methods and assumptions presented in the document may be modified in the future based on scientific advancements or changes in regulatory guidance or policies.

The data requirements and selection criteria addressed in the SRAM were implemented as part of the Group 3 RI data evaluation process, as discussed in Section 1.5. Methods for selecting representative data sets for groundwater, PCBs, and total petroleum hydrocarbon (TPH) constituent concentrations also are provided in the SRAM and were incorporated into the data selection and evaluation process. The data selection criteria and methodologies described in the SRAM are common to all risk assessments for SSFL, and have been developed in conjunction with DTSC. Screening Candidate Compounds

The data requirements and selection criteria addressed in the SRAM were implemented as part of the Group 3 RI data evaluation process. The details of the RI screening process are discussed in Section 1.5. Methods for selecting representative data sets for groundwater, PCBs, and TPH constituent concentrations also are provided in the SRAM and were incorporated in the data selection and evaluation process. The data selection criteria and methodologies described in the SRAM are common to all risk assessments for SSFL, and have been developed in conjunction with DTSC.

Samples were collected at each site where releases may have occurred from each medium that was present. Samples were located in biased locations (selected based on a knowledge of site conditions) and analyzed for the contaminants of potential concern (COPCs) identified for that site on the basis of the site-specific conceptual site model (CSM). Samples were collected from the Group 3 sites in various phases, with the most recent round of sampling being conducted in 2008.

Other indicators were evaluated as part of the data screening process that might indicate a release to the environment has occurred. The frequency of detection of a parameter was evaluated by reviewing the parameters that were detected in more than 5 percent of the samples when 20 or more data points were collected. This frequency of detection (in this example, 25 percent) could indicate that a release had occurred, and further sampling would then be conducted. In addition, tentatively identified compounds were evaluated in the data quality evaluation (DQE) (Section 1.7) and screened to assess the likelihood they were identified and whether they should be carried forward in the data evaluation process.

1.4.2 Data Presentation

The parameters detected at each site in Group 3 are listed in tables introduced in the appropriate subsections of this report in a media-specific manner. The parameters that exceeded the screening criteria are shown in figures, along with the major features of a particular site. Parameters such as VOCs, semivolatile organic compounds (SVOCs), and

metals are shown in the same figures in groups of two or three. The parameters were grouped in this fashion to facilitate the evaluation of the extent of contamination in the sampled media.

1.4.3 Risk Assessment

The data evaluation process culminated in risk assessments performed systematically following guidelines set forth in the SRAM. The selection of COPCs followed a sequential, multi-step process of screening data from each investigational unit. Chemicals of potential ecological concern (CPECs) and exposure point concentrations (EPCs) were then identified in the problem formulation stage in accordance with methodology established in the SRAM. These values were incorporated into the exposure assessment and risk characterization process, following a consistent technical approach described in detail in Section 1.5.

1.5 Remedial Investigation Approach

1.5.1 Presentation of Site Background and History

The site background and history for RI Group 3 was developed based on historical SSFL documents; interviews; information provided by SSFL personnel; and site reconnaissance of the buildings, features, and other areas.

During 2007 and 2008, Boeing compiled historical documents, records, and depositions from previous legal actions related to SSFL operations. These documents were reviewed for relevance to the various RI site groups, scanned, and placed into a searchable electronic database called the Historical Document Management System (HDMS). For the historical document review, approximately 12,137 historical documents applicable to RI Group 3 were reviewed using the HDMS.

The process used to review these documents included the following:

- A review of the historical documents for new processes, operations, or areas not yet investigated
- A review of the historical documents for potential new COPCs or chemical releases or use areas

Of the 12,137 historical Group 3-related documents, 225 documents were identified as potentially having new information pertaining to Group 3. These 225 documents were reviewed in more detail to summarize the following:

- Number of documents with new information identified
- Potential new COPCs identified
- Potential new release areas

After a review of the sources described above, any new data gaps that were identified relating to chemical use areas, potential release areas, or COPCs were identified and further investigated. The new historical information (data gaps) has been incorporated into the RI data gap evaluation and sampling program. The results of the RI data gap evaluation are presented in this RI report under the Site Background and History section for each RI site.

1.5.2 Source, Nature, and Extent of Contamination

Sections 2 through 8 of this RI report discuss the nature and extent of contamination at each site in Group 3. Figure 1.5-1 is a flow chart showing the data evaluation process for the nature and extent evaluation.

The CSM portion of these sections includes two subsections–the first subsection provides a comprehensive evaluation of historical operations at each of the sites. The second subsection provides, on the basis of the site history, the existing analytical data for the environmental media, potential sources, migration pathways, exposure routes, and receptors, as a conceptual site exposure model for each site.

In addition, Sections 2 through 8 examines the contamination migration potential through an environmental contaminant fate and transport evaluation. The factors that influence the fate and transport, including the site's physical features, source characteristics, and extent of contamination in site media, were combined to form the basis of the contaminant fate and transport evaluation. The site-specific subsections describe the results of these evaluations.

1.5.3 Human Health Risk Assessment Overview and Methods

The objective of an HHRA is to assess whether the environmental media at these sites could pose unacceptable risks to human health and might require remedial action, or if the media are eligible for an NFA designation. Potential health risks to humans are estimated by identifying the COCs present at a site, the toxicity of those contaminants, and the potential human exposure to those contaminants. Sampling and analysis provide information regarding the presence of chemicals at a site. The evaluation of health risks is conducted in the risk assessment by incorporating chemical toxicity and exposure estimates for each COC. The risks associated with exposure to surficial media (soil and sediment), indirect groundwater (vapor migration), and direct groundwater (drinking water) are estimated, as are the total risks from these media. The HHRAs include an evaluation of the potential health risks to human receptors associated with the current site conditions and proposed future uses of the site.

The HHRA results for each site are summarized in Sections 2.7, 3.7, 4.7, 5.7, 6.7, 7.7, and 8.7 of this report.

The HHRA was performed following the guidelines in the SRAM [MWH, 2005b]. The approaches outlined in the SRAM were derived, in part, following the HHRA guidance in the following documents:

- *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (Cal/EPA, 1996)
- *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* (Cal/EPA, 2004)
- *Risk Assessment Guidance for Superfund (RAGS)–Volume I: Human Health Evaluation Manual, Part A* (Interim Final) (EPA, 1989)
- *RAGS, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (EPA, 2004)

- Software for Calculating UCLs, ProUCL Version 4.0 (EPA, 2008 [Online])
- *Exposure Factors Handbook, Volume I: General Factors* (EPA, 1997a)

Finally, risk assessment guidance from the California Office of Environmental Health Hazard Assessment (OEHHA) was used, where appropriate.

The objective of the SRAM (MWH, 2005b) is to provide a consistent approach for risk assessment at the investigational units at SSFL. Although each investigational unit is unique, many have similar potential contaminants, exposure pathways, and receptors.

Therefore, a consistent technical approach for all investigational units at SSFL has been proposed. The SRAM provides the following HHRA methods:

- **Data Evaluation.** The requirements and selection criteria for the data collected in each media to be used for the risk assessment.
- **Identification of COPCs.** The criteria for the selection of COPCs in soil, groundwater, soil gas, sediment, and surface water that will be quantitatively evaluated in the HHRA.
- **Exposure Assessment.** The human health receptors, exposure pathways, exposure points, derivation of EPCs, and intake estimates.
- **Toxicity Assessment.** A description of the toxicity criteria used in the HHRA.
- **Risk Characterization.** The procedures for calculating cancer risk estimates and non-cancer hazard indexes (HIs), as well as a summary of the risk estimates for each Group 3 RI site.
- **Uncertainty Assessment.** A general description of the uncertainties, limitations, and assumptions associated with each step of the HHRA process.

Each of these methods is described in more detail in the following subsections.

1.5.3.1 Data Evaluation

Sample analytical results were evaluated to determine their suitability for use in the risk assessment. The data quality assessment performed on the sampling results followed the criteria provided by EPA in the *Guidance for Data Usability in Risk Assessment (Part A), Final* (EPA, 1992d). The data assessment was based on five criteria–data source review, documentation, analytical methods and detection limits, data review and validation, and data quality indicators (representativeness and completeness). In addition to these data requirements, specific methods for selecting representative data sets for groundwater, PCBs, and TPH constituent concentrations were followed for each risk assessment.

The five criteria of the data assessment are discussed in detail in the following subsections.

Data Source Review. The objective of the data source review was to ensure that appropriate analytical and non-analytical data are used in the HHRA. Data collected during the Group 3 RI are considered current, while data collected before the Group 3 RI activities are considered historical. Historical data sources were used to identify sampling locations and analytical approaches for the RI. Historical data were used to indicate industry-specific analytes and general levels of contamination and trends, to identify exposure pathways of

concern, to develop sampling design, and to select appropriate analytical methods. The quality of the historical data, including the sampling and analytical techniques, detection limits, and data quality, was reviewed before the data were used in the HHRA. The use of historical data in the quantitative risk assessments is discussed in the presentation of the site-specific risk assessment results in Sections 2.7, 3.7, 4.7, 5.7, 6.7, 7.7, and 8.7.

Documentation. The purpose of the documentation review was to ensure that each analytical result could be associated with a sampling location and that the sample was collected according to the appropriate procedures. This objective was achieved by evaluating the manner in which samples were managed by the field sampling teams and laboratories. Three types of documentation were used to track samples and analytical methods: 1) chain-of-custody forms; 2) standard operating procedures (SOPs); and 3) field sampling and analytical records.

In addition to documentation from the current sampling activities, historical data obtained from previous reports were reviewed, as appropriate. The criteria used to evaluate information contained in the previous reports included the following:

- Map(s) of sampling locations
- Rationales for sampling design and procedures
- Identification of sample collection and preparation methods
- Identification of analytical methods
- Analytical results
- Sample-specific detection limits
- Sample-specific qualification of the analytical results
- Description of the data review
- Description of the field conditions and physical parameters

Analytical Methods and Detection Limits. For an analytical result to be usable for the risk assessment process, the sample collection, preparation, and analytical methods should appropriately identify the chemical form or species, and the specified sample detection limit should be at or below a concentration that is associated with toxicologically relevant levels (benchmarks). The significance of detection limits greater than benchmark levels were evaluated on a case-by-case basis in the uncertainty section for each investigational unit. Data reduction includes resolving multiple results for a single constituent reported using different analytical methods (for example, naphthalene reported using both SW8260 and SW8270) to produce a single value for each constituent per sample.

Data Review and Validation. All sample data collected and used in the HHRA were reviewed and validated. The data were validated following the guidelines outlined in EPA's *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (1994e), and EPA's *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (1994f).

Soil, soil gas, and water sample data were validated based on the following criteria: sample management (appropriate containers, preservatives, documented chain-of-custody, and holding times), method blank sample results, blank spikes and laboratory control sample (LCS) results, surrogate recoveries, matrix spike/matrix spike duplicate (MS/MSD) recoveries and precision, reporting limits (RLs), and field quality control (QC) sample results (equipment blanks, field blanks, and field duplicates).

Data that were collocated duplicates, laboratory confirmation samples, or agency split samples were only used for DQE and were not quantitatively included in the HHRA.

The data validation procedures met the overall project DQOs. Data qualifiers were assigned to data with associated qualification codes, which denote the specific reason for the qualification.

Laboratory confirmation or agency split sample data were used to assess data quality, but were not used quantitatively in the risk assessment. Estimated values flagged with a "J" qualifier were treated as detected concentrations. Data qualified as rejected (flagged "R") were not used in the risk assessment.

Data Quality Indicators–Representativeness and Completeness. Data representativeness was determined by evaluating how well the samples described the investigation unit conditions (that is, were samples appropriately placed to reveal potential releases and were all of the compounds potentially related to activities at the investigational unit analyzed). To determine data completeness, sample results were evaluated to verify whether enough sample results were retained after validation to adequately characterize the investigational unit. Additionally, data were reviewed to determine if the variability of chemical concentrations in time and space were characterized adequately.

Soil Data Selection Criteria. For the purposes of this HHRA, soil samples were grouped into two data groups for evaluation of the specific exposure scenarios associated with each soil depth interval, as follows:

- Surface Soil : 0 to 2 ft bgs
- Subsurface Soil: 0 to 10 ft bgs

Soil data were used to quantify both indirect exposures (inhalation of ambient and indoor air and ingestion of edible plants) and direct exposures (dermal contact and ingestion) for potential human receptors.

Soil Gas Data Selection Criteria. Soil gas data were used to estimate indirect exposures, including the inhalation of indoor air and ambient air. In accordance with the Cal/EPA vapor intrusion guidance (DTSC, 2004) soil gas data collected from 5 ft bgs or deeper are preferred for use in risk assessments.

Groundwater Data Selection Criteria. Groundwater that occurs within the alluvium or weathered bedrock is defined as NSGW, while groundwater in unweathered, competent bedrock of the Chatsworth formation is defined as Chatsworth formation groundwater. At SSFL, NSGW primarily is monitored by wells and piezometers constructed with open intervals within the alluvium and/or weathered bedrock. However, some NSGW at the site also is monitored by deeper wells constructed with screened or open intervals within both the overlying weathered bedrock and deeper unweathered (competent) bedrock.

Because of the complexity of the data available for the SSFL HHRA, selection criteria were used to select the groundwater data used. These criteria include the definition of and

identification of CFOU and NSGW monitoring wells, and the selection of the water quality data set, as described below:

1. Definition of NSGW Monitoring Wells:

    a) Monitoring wells completed within the alluvium and/or weathered bedrock; or

    b) Monitoring wells completed within the deeper, competent bedrock that have a screened or open interval exposed to the alluvium and weathered bedrock, and historical water levels that have risen to that alluvium and weathered bedrock interface.

2. Definition of CFOU Groundwater Monitoring Wells:

    a) Monitoring wells completed within the deeper unweathered, competent bedrock of the Chatsworth formation.

3. Selection of Water Quality Data Set:

    a) Groundwater monitoring data from the most recent 3-year period were evaluated to determine whether the data adequately reflected the water concentrations to which potential receptors would be exposed. All historical groundwater data were evaluated to ensure representativeness for the 3-year period used. In addition, groundwater data from upgradient monitoring wells were evaluated to determine what chemicals might migrate and result in future exposures.

    b) If a compound previously was detected in groundwater and not represented in the analytical suite for the most recent consecutive 3-year period, then the most recent data over a consecutive 3-year period when that compound was analyzed were used.

    c) The analytes represented in the CFOU or NSGW data set were compared with those mobile compounds (VOCs and perchlorate) selected as COPCs in soil and soil gas, and the need for the inclusion of certain mobile soil or soil gas COPCs as CFOU or NSGW COPCs was determined.

If discrete depth water quality monitoring data within the alluvium or weathered bedrock were available for a well, those data were used instead of standard water quality data collected from deep, open boreholes.

PCB Extrapolation Methodology. As described in Section 2.7 of the SRAM (MWH, 2005b), potential risks associated with PCBs were assessed using two different methods: 1) risks associated with the 12 "dioxin-like" PCB congeners using the toxicity equivalency approach (Van den Berg et al., 2006); and 2) risks associated with a total aroclor mixture (EPA, 1996a). Potential risks associated with the 12 PCB congeners and potential risks associated with aroclor mixtures are presented separately in the HHRA. The PCB extrapolation methods described in Section 2.7 of the SRAM (MWH, 2005b) were used to estimate the concentrations of each of the 12 PCB congeners in samples for which only aroclors historically have been detected.

The extrapolation factors used in the HHRA at SSFL are summarized in Table 2-5 of the SRAM (MWH, 2005b). Aroclor-to-PCB extrapolation factors were developed to predict PCB congener concentrations, as described in the following equation:

$$C_{congener} = EF \times C_{Aroclor}$$

Where,

$C_{congener}$ = Predicted PCB congener concentration in soil (nanograms per kilogram [ng/kg])

$C_{Aroclor}$ = Measured aroclor concentration in soil (micrograms per kilogram [µg/kg])

EF = Aroclor-to-PCB congener extrapolation factor ([ng/kg]/[µg/kg])

Total Petroleum Hydrocarbon Extrapolation Methodology. The risks associated with TPH impacts commonly are included in risk assessments based on the petroleum constituent concentrations rather than on the TPH results, because toxicity criteria for TPHs are not well established or approved within the regulatory community. For the purposes of evaluation in this HHRA, petroleum chemical constituents include low-carbon petroleum constituents (LCPCs) [benzene, toluene, ethylbenzene, and xylenes (BTEX)] and high-carbon petroleum constituents (HCPCs) [polycyclic aromatic hydrocarbons (PAHs), 2-methylnaphthalene, and naphthalene]. The TPH extrapolation methods described in Section 2.8 of the SRAM (MWH, 2005b) were used to estimate the concentrations of the petroleum chemical constituents. The TPH extrapolation factors used in the HHRA at SSFL are summarized in Table 2-8 of the SRAM (MWH, 2005b).

TPH extrapolation factors were used to predict LCPC and HCPC concentrations, as described in the following equations, respectively:

$$C_{LCPC} = EF \times C_{C08-C11}$$

Where,

C_{LCPC} = Predicted BTEX, naphthalene, or 2-methylnaphthalene concentration in soil (milligrams per kilogram [mg/kg])

$C_{C08-C11}$ = Measured C08-C11 TPH fraction concentration in soil (mg/kg)

EF = TPH-to-LCPC extrapolation factor ([mg/kg]/[mg/kg])

$$C_{HCPC} = EF \times C_{C11-C30}$$

Where,

C_{HCPC} = Predicted PAH concentration in soil (mg/kg)

$C_{C11-C30}$ = Sum of measured C11-C14, C14-C20, and C20-C30 TPH fraction concentrations in soil (mg/kg)

EF = TPH-to-HCPC extrapolation factor ([mg/kg]/[mg/kg])

1.5.3.2 Identification of Contaminants of Potential Concern

To ensure that the focus of the HHRA was on site-related chemicals, COPCs were selected using several criteria. COPCs are those constituents that are carried through the human health risk quantification process. During the course of the HHRA, the COPCs are evaluated to identify and prioritize which constituents, if any, are estimated to pose unacceptable risks. COPCs are identified separately for each exposure medium (soil, soil gas, and groundwater), based on the exposure scenarios described in Section 1.5.3.3.

The criteria used to select COPCs ensured that site-related chemicals that might pose a human health risk were included in the evaluation and, if risks were above the acceptable levels, subsequently would be included in remedial response actions. The selection of COPCs relies on a sequential, multi-step process of screening data from each investigational unit, as described in the following text.

Screening Criteria. The criteria used to select COPCs ensured that site-related chemicals that might pose a human health risk were included in the evaluation and, if risks were above the acceptable levels, subsequently would be addressed in remedial response actions. The following criteria were used to select COPCs for the HHRA:

1. Chemicals were detected at an investigational unit using validated laboratory analyses.
2. Chemicals occurred above a 5-percent detection frequency and/or historical use at the investigational unit.
3. Chemicals were present in excess of the concentrations observed in laboratory or field blanks.
4. For metals and for chlorinated dibenzo-p-dioxins and dibenzofurans (collectively referred to as dioxins), the measured concentrations were in excess of soil background or groundwater comparison concentrations.

Further details regarding the COPC selection process are provided in Section 3.1 of the SRAM (MWH, 2005b).

Excluded data are documented in the HHRA subsection for each site, including the rationale for the removal.

Comparison of Site Data to Soil Background and Groundwater Comparison Concentration Data. DTSC's risk assessment policy indicates that metals and dioxins should be included as COPCs if the site-specific analytical data indicate conditions are in excess of "background" (DTSC, 1997). This subsection discusses two screening approaches–a simple comparison of investigational unit data with comparison data (comparison method) and the use of the Wilcoxon Rank Sum (WRS) test.

For groundwater, the maximum concentration in the groundwater comparison data set was the groundwater comparison concentration. If the maximum unit concentration did not exceed the groundwater comparison concentration, then the chemical was excluded as a COPC. If the maximum unit concentration exceeded the groundwater comparison concentration, then the data sets were evaluated further by performing the WRS test.

As discussed in Appendix D of the SRAM (MWH, 2005b), the comparison method was not used for selecting COPCs in soil.

Further details about the WRS test are provided in Section 3.3 of the SRAM (MWH, 2005b).

Background Comparison Methods for Dioxins. Only the seventeen 2,3,7,8-dioxin congeners were evaluated in the HHRA (EPA, 1989c). An extensive database of background concentrations in various environmental media has been compiled by EPA for use in risk assessment and other scientific applications (EPA, 1994c). Therefore, the HHRA applies a soil background delineation similar to the procedures described for metals to dioxin data, except that a modification was required to account for the fact that dioxins often occur as mixtures.

Consistent with a Human and Ecological Risk Division (HERD) memorandum (DTSC, 1998a) on establishing dioxin background, a graphical representation of relative chlorinated dibenzo-p-dioxin (CDD) and chlorinated dibenzofuran (CDF) concentrations in samples (a "radar" plot) was compared to similar presentations for background to determine qualitatively if the site samples are similar to background. This analysis was done for five congener groups: tetra-CDD/CDFs, penta-CDD/CDFs, hexa-CDD/CDFs, hepta-CDD/CDFs, and octa-CDD/CDFs. Because only the 2,3,7,8-substituted CDDs and CDFs are of toxicological interest, the five group concentrations were calculated as the sum of the concentrations of each 2,3,7,8-substituted congener within the chlorination group, on a per-sample basis. In cases where a congener was detected a least once in a given media at an investigational unit, it was assumed to be present in other samples of the same media at that unit. When a congener was thus assumed to be present at an investigational unit, but was not detected in a sample, then the concentration in that sample was estimated as one-half the sample quantitation limit (SQL). In cases where a specific congener was never detected in a given media at an investigational unit, then that congener was assumed to not be present in that media at that unit, and was not included in the summation of congeners within its respective congener group at that unit.

Following the graphical evaluation, the same approach used to evaluate metals was used to evaluate investigational unit and soil background CDD/CDF data sets. The data sets were evaluated by application of the WRS test (or as applicable, the Gehan Test) to determine consistency with soil background concentrations. In the case of CDD/CDFs, the WRS test (or as applicable, the Gehan Test) evaluation was performed on the five congener groups, as described in the SRAM (MWH, 2005b). If the WRS test (or as applicable, the Gehan Test) was implemented, a Bonferroni correction to the statistical significance threshold, α , was applied. Because the critical significance level applied to single inorganic compounds is 0.05, the corrected term for comparison of the five CDD and CDF groups was 0.01 (0.05/5).

Because CDD and CDF compounds frequently appear as mixtures, an additional requirement for the evaluation of investigational unit data was that all "groups" of CDD and CDF classes must be shown to be consistent with soil background concentrations. If such a demonstration could not be made, all CDD and CDF compounds must have been considered in the risk assessment. Because a groundwater comparison concentration data set was not developed for the potential presence of dioxins in groundwater, the approach described above for soil also was applied for groundwater.

1.5.3.3 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the investigational unit may come into contact with constituents in exposure media. It addresses exposures that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed, the routes by which individuals may become exposed, and the magnitude, frequency, and duration of potential exposures.

Conceptual Site Model. A generalized CSM for SSFL was developed based on field observations, current and future site use scenarios, and data collected to date during environmental programs at SSFL (Figure 1.5-2).

Potential Human Receptors. Potential human receptors are populations potentially exposed to chemicals, either onsite or as a result of chemical migration to offsite areas. The current potential human receptors are current site workers and trespassers. Onsite workers, residents, and visitors (for example, recreationists who might occupy the site in the future in the event of a change in property use) are future potential human receptors. The exposure scenarios listed in the SRAM (MWH, 2005b) for evaluation in the HHRA are current site workers and trespassers, as well as future onsite residents and visitors. A more likely future use of SSFL is for recreational purposes, and recreationists are the most plausible future human receptors. California SB 990 states that response actions at SSFL also should consider hypothetical future agricultural and residential land uses.

Given the potential future land use, the following receptors will be addressed in the HHRA for each site:

- Future onsite adult industrial workers
- Hypothetical future onsite adult and child recreationists
- Hypothetical future onsite adult and child residents

Potentially Complete Exposure Pathways. Potential exposure pathways were considered to assess whether they might be "complete" (receptors can come into contact with compounds from the site), "incomplete" (no exposure is possible), or "potentially complete" (exposure may occur if site conditions change). The generalized CSM includes complete or potentially complete exposure pathways for receptors that may occur, either at certain locations or throughout SSFL. Complete or potentially complete exposure pathways include direct contact with soil, sediment, weathered bedrock, surface water, air, and groundwater (including seeps and springs), as well as indirect exposure to chemicals in soil via uptake into plants. There are no seeps and springs located within the seven Group 3 sites; therefore, the seeps and springs exposure pathway was not evaluated.

Also, in accordance with California SB 990, a hypothetical future agricultural exposure scenario will be evaluated. This scenario will include the consumption of beef, eggs, milk, swine, fruits, and vegetables. However, pending final agreement of the input assumptions considered in the scenario, an assessment of the subsistence agricultural exposure scenario will be included in a supplemental risk assessment report separate from this RI Report.

Additional information about the selection of exposure pathways is discussed in the SRAM (MWH, 2005b).

Human Exposure Models. Human exposure models provide the basis for quantifying potential exposure to COPCs. The exposure models are based on the calculation of an internal dosage for each COPC. For noncarcinogenic effects, the dosage is averaged over the period of exposure and is referred to as the average daily dosage (ADD). For carcinogenic effects, the dosage is averaged over a lifetime and is referred to as the lifetime average daily dosage (LADD).

Consistent with current DTSC (1992) and EPA (1989a) guidance, the following general equation was applied to assess the chemical dosage for each complete or potentially complete exposure pathway considered in the HHRA:

$$Dosage = \frac{C \times IR \times EF \times ED \times B}{BW \times AT}$$

where:

Dosage = ADD (milligrams per kilogram per day [mg/kg-day]) for noncarcinogens

LADD (mg/kg-day) for carcinogens

C = chemical concentration in environmental medium (mg/kg soil; milligrams per liter [mg/L] water; or, milligrams per cubic meter [mg/m^3] air)

IR = intake rate (mg soil/day; liter [L] water/day; or, m^3 air/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

B = bioavailability (fraction)

BW = body weight (kilogram [kg])

AT = averaging time (days)

Additional details regarding each specific exposure pathway are discussed in Section 5 of the SRAM (MWH, 2005b).

Estimation of Exposure Point Concentrations. EPCs are estimated constituent concentrations with which a receptor may come into contact, and are specific to each exposure medium. For direct contact routes of exposure to soil and groundwater (incidental ingestion and dermal contact), EPCs are represented by concentrations directly measured in soil or groundwater samples collected from the Group 3 sites. EPCs also can be estimated through prediction (modeling). In the HHRAs for the Group 3 sites, measured concentrations were used whenever available and appropriate.

EPCs were estimated for several chemical classes (inorganics, volatiles, and high- and low-molecular weight SVOCs, as defined in DTSC [1994]) for the following media–soil, air, sediment, surface water, groundwater, and produce.

Data collected from the 0- to 2-ft-bgs and 0- to 10-ft-bgs depth intervals during field investigations at the site formed the basis for soil/surface sediment (hereafter collectively referred to as soil) EPCs used to estimate chemical-specific dosages for the ingestion of and

dermal absorption from soil pathways. Deterministic estimates of soil EPCs were calculated for all investigations.

Groundwater EPCs for the Surficial OU were developed on an investigational unit basis. EPCs were the maximum concentrations measured from NSGW wells from within a particular investigational unit and from areas that were upgradient from the investigational unit. For the CFOU, EPCs were the maximum concentrations measured from the Chatsworth formation groundwater at an investigational unit, in a Reporting Area, or upgradient from these areas. Groundwater monitoring data from the most recent 3-year period were evaluated to determine whether this process adequately reflects water concentrations to which potential receptors will be exposed. All historical groundwater data from this 3-year period were used. If adequate groundwater data for metals were not available, the potential groundwater concentration was estimated by using a soil-to-groundwater leachate model.

For the inhalation route, EPCs were estimated using modeling approaches consistent with the risk assessment guidance. Soil-derived vapor and dust concentrations in ambient air were estimated using volatilization factors (VFs) and particulate emission factors (PEFs), derived as described in Section 1.5.3.3. Data, including soil gas measurements, collected during the field investigations of areas overlying groundwater were the basis for modeling the volatilization of COPCs from groundwater to indoor and ambient air. In cases where soil gas data were not available, groundwater and bulk soil concentrations were used. Indoor air concentrations were estimated for each VOC detected in soil gas using the *Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings, Updated 2003* (SG-ADV Version 3.1; 02/04) (EPA, 2003). This model was adjusted to use DTSC-specific values in lieu of EPA default values for the toxicity factors, building ventilation rates, crack-to-total-area ratios, and soil-building pressure differential. Additional details regarding the Johnson and Ettinger (J-E) input parameters and equations are described in Section 6.4 of the SRAM (MWH, 2005b).

In cases where it was determined that existing groundwater data, either near-surface or Chatsworth formation groundwater (depending on the groundwater source), were representative of specific seeps or springs, then existing groundwater data were used as EPCs for seeps and springs. If the groundwater source was not representative of specific seeps, then those seeps and springs were sampled and those data were used as EPCs.

Surface water sampling and analysis were used for EPCs for surface water pathways.

EPCs in home-grown produce were estimated in accordance with Section 5.5 of the SRAM (MWH, 2005b), using bio uptake models to estimate the transfer of COPCs from the top 2 ft of soil to both root-zone and aboveground (leaf and fruit) portions of edible plants.

EPC Calculation Approach. The EPCs for exposure pathways associated with soil, soil gas, and groundwater at the Group 3 sites were estimated by aggregating concentration data from samples collected for each medium (and in the case of soil, for each depth interval of 0 to 2 ft bgs or 0 to 10 ft bgs).

For the reasonable maximum exposure (RME) case, the EPCs for risk estimation were calculated by using the best statistical estimate of an upper bound on the average exposure concentrations, in accordance with EPA guidance for statistical analysis of monitoring data

(EPA, 1989, 1992, 2002). The 95% upper confidence limit (UCL) on the mean concentration is considered by these guidance documents as a conservative upper bound estimate that is not likely to underestimate the mean concentration and probably overestimates that concentration. EPCs were calculated for each analyte using EPA's statistical program ProUCL, Version 4.0 (EPA, 2008). This procedure identifies the statistical distribution type (that is, normal, lognormal, or non-parametric) for each constituent within the defined exposure area and computes the corresponding 95% UCL for the identified distribution type. The maximum detected concentration is used in place of the 95% UCL when the calculated 95% UCL is greater than the maximum detected value.

For the central tendency exposure (CTE) case, the EPCs for risk estimation were calculated as the arithmetic mean concentration of the sample data for each medium and data group, in accordance with Section 6 of the SRAM (MWH, 2005b).

EPCs for COPCs in soil, soil gas, and groundwater are summarized in Appendixes B through H for both the RME and CTE cases. As indicated, the EPCs for some constituents are based on the maximum detected value rather than the 95% UCL. Factors affecting the distribution of the data (resulting in the selection of the maximum detected value rather than the 95% UCL) include small sample size, low frequency of detection, and/or wide variability. Using maximum detected values for EPCs may contribute to overestimation of risk (this and other uncertainties are discussed in Section 1.5.3.6).

EPC Approach for Dioxins/Furans. EPCs for "dioxin-like" congeners of polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were adjusted in accordance with the 2005 World Health Organization (WHO) toxic equivalency factor (TEF) approach (Van den Berg et al., 2006). The purpose of using the WHO TEF adjustment is to account for the relative carcinogenic potency of dioxin-like PCDDs and PCDFs relative to 2,3,7,8-tetrach-lorodibenzo-p-dioxin (TCDD).

Human Exposure Assumptions. The estimation of exposure requires numerous assumptions to describe potential exposure situations. Upper-bound exposure assumptions are used to estimate RME conditions to provide a bounding estimate on exposure. The RME case is defined as the highest exposure that is reasonably expected to occur at a site. The intent of the RME scenario is to estimate a conservative exposure case that is still within the range of possibilities. In addition to RME assumptions, average exposure assumptions are used to estimate CTE conditions to represent the typical case. The exposure assumptions used are specific to a hypothetical residential exposure scenario, consistent with assumed unrestricted future land use. The range of risk estimates bounded by the CTE and RME cases provides an indication of the most plausible range over which residential risks may occur under most conditions at the site.

Calculation of Chemical Intake. Exposure that is normalized over time and body weight is termed intake (expressed as milligrams of chemical per kilogram of body weight per day [mg/kg-day]). The method for the computation of intake for the Group 3 site exposure scenarios is described in the following subsections; the intake results are provided in the risk calculation tables in Appendixes B through H.

The exposure assumptions for estimating chemical intake from the ingestion of constituents in soil are listed in Table 1.5-1 for the adult resident, Table 1.5-2 for the child resident,

Table 1.5-3 for the adult recreational user, Table 1.5-4 for the child recreational user, and Table 1.5-5 for the industrial worker. The exposure assumptions for ingestion, dermal contact, and inhalation are in accordance with Tables 5-2 and 5-3 of the SRAM (MWH, 2005b) and generally are based on values provided in Cal/EPA and EPA guidance documents.

Incidental Ingestion of Soil. The following equation is used to calculate the intake associated with the incidental ingestion of constituents in soil for the hypothetical adult and child resident, adult and child recreational user, and industrial worker scenarios:

$$Intake = \frac{C_s \times IRS \times EF \times ED \times 10^{-6} kg/mg}{BW \times AT}$$

Where:

CS	=	Constituent concentration in soil (mg/kg)
IRS	=	Soil ingestion rate (mg/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Dermal Contact with Soil. Chemical intake from dermal contact with soil for the hypothetical adult and child resident, adult and child recreational user, and industrial worker scenarios is estimated using the following equation:

$$Intake = \frac{C_S \times SA \times ABS \times AF \times EF \times ED \times 10^{-6} kg/mg}{BW \times AT}$$

Where:

C_S	=	Constituent concentration in soil (mg/kg)
SA	=	Exposed skin surface area (square centimeter [cm^2])
ABS	=	Fraction of constituent absorbed from soil to skin (unitless)
AF	=	Soil to skin adherence factor (mg/cm^2)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Dermal absorption fraction (ABS) values are derived from the EPA's *Supplemental Guidance for Dermal Risk Assessment* (EPA, 2004) and are listed in Table 1.5-6.

Inhalation of Ambient Dust and Vapors from Soil. Chemical intake from the inhalation of dust and vapors from ambient air for the hypothetical adult and child resident, adult and child recreational user, and industrial worker scenarios is estimated using the following equation:

$$Intake = \frac{C_s \times INH \times \left(\frac{1}{PEF} + \frac{1}{VF} \right) \times EF \times ED}{BW \times AT}$$

Where:

C_S	=	Constituent concentration in soil (mg/kg)
INH	=	Inhalation rate (m^3/day)
PEF	=	Particulate emissions factor (m^3/kg)
VF	=	Volatilization factor (m^3/kg)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Adult body weight (kg)
AT	=	Averaging time (days)

The VFs for the VOCs identified as COPCs in soil were calculated using the Jury Model described in EPA's *Soil Screening Guidance: Users Guide* (EPA, 1996) and are provided in Table 1.5-7. The PEF used was the default value recommended by EPA Region 9 (2004b).

Ingestion of Groundwater. The following equation is used to calculate the intake associated with ingestion of constituents in groundwater for the hypothetical adult and child resident, adult and child recreational user, and industrial worker scenarios:

$$Intake = \frac{C_w \times IRW \times EF \times ED}{BW \times AT}$$

Where:

C_w	=	Constituent concentration in groundwater (mg/L)
IRS	=	Water ingestion rate (L/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

In accordance with the SRAM (MWH, 2005b), the intake of VOCs from the dermal and inhalation routes of exposure is assumed to be equivalent to the intake from the ingestion route.

Ingestion of Homegrown Produce. The following equation is used to calculate the intake associated with the ingestion of constituents in homegrown produce for the hypothetical adult and child resident scenarios: $Intake = \frac{C_p \times IRP \times EF \times ED}{BW \times AT}$

Where:

C_p	=	Constituent concentration in produce (mg/kg, wet weight basis)
IRS	=	Produce ingestion rate (kg/day, wet weight basis)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

The concentration term C_p reflects COPC uptake from soil (0 to 2 ft bgs) to both aboveground (leaf and fruit) produce concentrations and to belowground (root) produce. The consumption rate data listed in Tables 1.5-1 and 1.5-2 for fruits and vegetables are not specific to aboveground and belowground produce. Therefore, it is conservatively assumed that one-half an individual's total produce consumption is associated with aboveground produce and one-half is associated with belowground plants. This assumption is considered conservative because it is highly unlikely that most individuals consume a higher amount of belowground produce than aboveground produce, yet the biotransfer factors (used to estimate EPCs) for belowground produce are 35 times greater than those for aboveground produce. The biotransfer factors used to estimate uptake into produce are listed in Table 1.5-8.

1.5.3.4 Toxicity Assessment

The relationship between the dosage of a chemical and the probability of an adverse health effect in the exposed population is characterized in the toxicity assessment portion of the HHRA. The dosage-response assessment for the COPCs identified for each investigational unit is discussed in this subsection. Chemicals were identified as having carcinogenic and/or noncarcinogenic toxicity criteria and were evaluated in accordance with OEHHA and DTSC guidelines (DTSC, 1992, 1994; OEHHA, 2003). The hierarchy of sources for toxicological criteria is as follows:

1. OEHHA (http://www.oehha.ca.gov/risk/chemicalDB/index.asp)
2. Integrated Risk Information System (IRIS) (EPA, 2005a)
3. Health Effects Assessment Summary Table (HEAST))EPA, 1997)
4. EPA criteria documents
5. Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles
6. Environmental Criteria and Assessment Office (ECAO)
7. Other sources

The toxicity criteria used in the HHRA are provided in Table 1.5-9.

The toxicity criteria used to assess dioxin and coplanar PCB congeners are based on TEFs developed by WHO and published by Van den Berg et al. (2006). TEFs are measures of the relative toxicity of a dioxin or coplanar PCB congener to the toxicity of 2,3,7,8-TCDD. For risk assessments conducted at SSFL, dioxin and PCB congener-specific TEFs were applied to toxicity criteria (that is, the cancer slope factor [CSF] for 2,3,7,8-TCDD) to generate congener-specific toxicity values that were then applied to congener-specific exposure levels to estimate risk.

1.5.3.5 Risk Characterization

In the risk characterization component of the HHRA process, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects, as described in the subsections below.

Although this HHRA produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Any actual risks are likely to be lower than these estimates. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them, as described in Section 1.5.3.6.

Estimation of Carcinogenic Risks. The potential for cancer effects is evaluated by estimating the excess lifetime cancer risk (ELCR). This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to site constituents occurs). For example, a 2×10^{-6} ELCR means that, for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by two cases of cancer. In the United States, the background probability of developing cancer for men is a little less than one in two, and for women a little more than one in three (American Cancer Society, 2003).

Potential carcinogenic health risks were characterized for each COPC identified as a potential human carcinogen. Potential carcinogenic health risks were characterized as the upper-bound probability of an individual developing cancer over a lifetime as a result of exposure to a site-related chemical under specific exposure scenarios. The incremental probability of developing cancer (the theoretical excess [above background] carcinogenic risk) is the risk attributed to exposure to the COPCs at the site (EPA, 1989) and is independent of chemical exposures in our daily lives that are not related to SSFL.

For each COPC identified as a potential human carcinogen, the theoretical upper-bound excess cancer risk was based on the LADD and a factor relating dosage to cancer risk (the CSF). CSFs were used to characterize carcinogenic risk. These values are, in general, upper-bound estimates on the slope of the cancer-response and exposure relationship rather than accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA, 1989). The following equation (EPA, 1989a; DTSC, 1992) was applied to estimate the cancer risk for each relevant exposure pathway:

$$Risk = Intake \times CSF$$

Where:

Risk = Excess lifetime cancer risk (unitless probability)
Intake = Chronic daily intake averaged over a lifetime (mg/kg-day)
CSF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$

Although synergistic or antagonistic interactions might occur between cancer-causing constituents and other constituents, information generally is lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, cancer risks are treated as additive within an exposure route in this assessment. This is consistent with the EPA guidance regarding risk assessment of chemical mixtures (EPA, 1986). For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used:

$$Risk_T = \sum_1^N Risk_i$$

Where:

$Risk_T$ = Total cancer risk from route of exposure
$Risk_i$ = Cancer risk for the i^{th} constituent
N = Number of constituent

Additional details regarding the estimation of carcinogenic health effects are discussed in Section 8.1 of the SRAM (MWH, 2005b).

Estimation of Noncarcinogenic Health Effects. For non-cancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular constituent with the highest level of exposure that is considered protective (that is, its reference dose [RfD]). Potential noncarcinogenic adverse health effects were characterized for each COPC exhibiting noncarcinogenic health effects. The ratio of the intake divided by the RfD is termed the hazard quotient (HQ):

$$HQ = Intake / RfD$$

Where:

HQ = Non-cancer hazard quotient from route of exposure
Intake = Chronic daily intake averaged over the exposure duration (mg/kg-day)
RfD = Non-cancer reference dose (mg/kg-day)

When the HQ for a constituent exceeds 1 (that is, exposure exceeds the RfD), there is a concern for potential non-cancer health effects. To assess the potential for non-cancer effects posed by exposure to multiple constituents, an HI approach was used according to EPA guidance (EPA, 1989). This approach assumes that the non-cancer hazard associated with exposure to more than one constituent is additive; therefore, synergistic or antagonistic interactions between constituents are not accounted for. The HI may exceed 1 even if all of the individual HQs are less than 1. In this case, the constituents may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect. The HI is calculated as follows:

$$HI = \sum_1^N Intake_i \Big/ RfD_i$$

Where:

HI = Non-cancer hazard index
$Intake_i$ = Chronic daily intake of the i^{th} constituent (mg/kg-day)
RfD_i = Reference dose of the i^{th} constituent (mg/kg-day)
N = Number of constituents

Additional details regarding the estimation of noncarcinogenic health effects are discussed in Section 8.2 of the SRAM (MWH, 2005b).

Characterizing Risks from Lead, Dioxins, PCBs, and PAHs. If lead was selected as a COPC, potential risks from lead concentrations were evaluated using methods different from those conventionally used for other carcinogens and noncarcinogens. The risks resulting from the uptake of lead were evaluated using the DTSC LeadSpread 7 calculation spreadsheet from the Cal/EPA Web site (Cal/EPA, 2006b). The model calculates blood lead levels from exposure to soil lead concentrations, in addition to other routes. A default blood lead level of 10 micrograms per deciliter (µg/dL) of blood is considered a level of concern that triggers intervention to reduce exposure. As recommended by DTSC, the 90th, 95th, 98th, and 99th percentile blood lead concentrations predicted by the model were evaluated for both children and adults. If the lead concentrations in site media resulted in a calculated blood lead level below 10 µg/dL in 95 to 99 percent of the potentially exposed population, no unacceptable risk exists. Additional details about characterizing risks from lead are discussed in Section 8.5.1 of the SRAM (MWH, 2005b).

The specific dioxin and coplanar PCB congeners that were considered in the HHRAs at SSFL are the 17 2,3,7,8-substituted dioxin congeners and 12 non-ortho- and mono-orthosubstituted coplanar congeners for which TEFs were developed by WHO and published by Van den Berg et al. (2006). The congeners and TEFs are summarized in Table 1.5-10.

Risk estimates for dioxins and coplanar PCBs were based on the assumption that all 17 of the 2,3,7,8-substituted dioxin congeners and 12 coplanar PCB congeners are present in all samples at some level when at least one congener is detected in a single sample in a given media at an investigational unit. The concentrations for those congeners not detected in sample media were estimated at one-half the SQL. In cases where a congener was never detected in a given media at an investigational unit, that congener was assumed not present.

For each of the 12 PCB congeners and 17 dioxin congeners, one of two approaches was taken for estimating risks. PCB congener and dioxin TEFs were applied to the CSF for 2,3,7,8-TCDD, and risks were estimated by multiplying the estimated congener-specific CSFs (based on 2,3,7,8-TCDD) by the respective congener-specific LADDs.

It is not appropriate to include both estimated aroclor risks and PCB congener risks in the cumulative risk estimate, because this would essentially be "double-counting." Therefore, DTSC has requested that only aroclor risks be included in the cumulative risk estimates, and that PCB congeners risks be presented with the risk estimates for other chemicals but not included in the cumulative risk estimate. Additional details regarding characterizing risks from PCBs and dioxins are discussed in Section 8.5.2 of the SRAM (MWH, 2005b).

For the purpose of evaluation in SSFL RI HHRAs, petroleum chemical constituents include BTEX and PAHs. To adequately assess the potential risks associated with TPH in environmental media, a site-specific extrapolation methodology has been developed to allow correlation between the TPH fraction concentration and petroleum constituent concentrations (Section 1.5.3.1). When TPH was detected in the gasoline range, then BTEX compounds were added as COPCs. When TPH was detected in the diesel range, then PAHs were added as COPCs. Concentrations of BTEX or PAHs were determined by using the site-specific extrapolation factors. Additional details regarding the characterization of risks from PAHs are discussed in Section 8.5.3 of the SRAM (MWH, 2005b).

Risk estimates related to the soil gas pathway are presented separately in the HHRA and discussed in the uncertainty section (Section 1.5.3.6), as requested by DTSC.

The risk estimates for the plant uptake exposure pathway are presented separately from other estimated risks to facilitate evaluation by risk managers.

Summary and Conclusions. The HHRA results will be used to help identify areas within Group 3 that require further action (additional site characterization or remediation). The results of the risk assessment are presented in a format that allows the risk manager to integrate and weigh decision factors appropriately and optimally (MWH, 2005). An important risk management consideration is that new data may become available subsequent to the completion of the risk assessment. Risk managers should consider newly published information (site-specific or chemical-specific) as it becomes available to ensure that the final site decisions are protective of human health.

1.5.3.6 Uncertainty Discussion

The risk assessment results are based on conservative risk assessment methods and assumptions (MWH, 2005). Therefore, it is important that uncertainties associated with the risk assessment process be addressed to place the numerical risk estimates in proper perspective. The discussions of uncertainties are largely qualitative and are presented for each of the investigational units within Group 3. The uncertainty discussion focuses on those COPCs with the greatest contribution to the cumulative risk.

Uncertainties associated with the results of the HHRA are a function of both the "state of the practice" of risk assessment in general and UFs specific to the investigational unit. The HHRA is subject to uncertainty with regard to a variety of factors, including the following:

- Environmental sampling and analysis
- Fate and transport estimation
- Exposure assessment
- Toxicity assessment
- Risk characterization

Environmental Sampling and Analysis. Uncertainties associated with sampling and analysis include the inherent variability (standard error) in the analysis, the representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. The quality assurance (QA)/QC program used in the investigation serves to reduce these errors, but it cannot eliminate all errors associated with sampling and analysis. The degree to which sample

collection and analyses reflect real EPCs partly determines the reliability of the risk estimates.

Fate and Transport Estimation. This HHRA makes simplifying assumptions about the environmental fate and transport of COPCs. Specifically, it is assumed that no constituent loss or transformation occurs in the future, and that the constituent concentrations detected in soil and shallow groundwater remain constant during the assessed exposure duration. In cases where natural attenuation or other degradation processes are significant, the analytical data chosen to represent EPCs may overstate actual long-term exposure levels.

Exposure Assessment. The estimation of exposure requires many assumptions to describe potential exposure situations. There are uncertainties regarding the likelihood of exposure, the frequency of contact with contaminated media, the concentrations of constituents at exposure points, and the time period of exposure. The assumptions used tend to simplify and approximate actual site conditions and may overestimate or underestimate the actual risks. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard. This HHRA evaluates an assumed unrestricted residential land use. To the extent that future uses are actually more limited than assumed here for residential use (for example, a more plausible recreational use), exposures and risks would be proportionately lower than reported here.

Toxicity Assessment. Uncertainties in toxicological data can influence the reliability of risk management decisions. The toxicity values used for quantifying risk in this assessment have varying levels of confidence that affect the usefulness of the resulting risk estimates.

Sources of uncertainty associated with the toxicity values used in the toxicity assessment include the following:

- Extrapolation of dose-response data derived from high dose exposures to adverse health effects that may occur at the low levels seen in the environment
- Extrapolation of dose-response data derived from short-term tests to predict effects of chronic exposures
- Extrapolation of dose-response data derived from animal studies to predict effects on humans
- Extrapolation of dose-response data from homogeneous populations to predict effects on the general population

The levels of uncertainty associated with the RfDs for the COPCs (as judged by EPA) are expressed as uncertainty factors (UFs) and modifying factors and are provided in IRIS or HEAST. For those chemicals suspected of resulting in cancer effects, uncertainty, in part, is expressed in terms of EPA's weight of evidence (WoE) classification system, as listed in Table 1.5-9.

Dermal exposures are different from oral exposures because not all of a constituent that comes into contact with a person's skin travels across the various layers of epidermal tissue, as indicated by a skin permeability factor, and because the toxic effects produced from this route of exposure may not be the same as when the constituent is ingested. In lieu of available toxicity values for the dermal route, this HHRA uses oral toxicity values to

estimate the effects of dermally available constituents. This approach may result in an underestimate or an overestimate of risks, depending on whether a constituent is more or less toxic by the dermal route versus by ingestion.

Risk Characterization. In the risk characterization phase, the assumption is made that the total risk of developing an adverse effect from aggregate exposure to site constituents is the sum of the HQs or cancer risks estimated for exposure to each individual constituent. This approach does not account for the possibility that chemicals act synergistically or antagonistically.

1.5.3.7 Use of Risk Assessment Results in the RI and FS Process

The HHRA results will be used to help identify areas in Group 3 that require further action (additional site characterization or remediation). Generally, estimated cancer risks within the range 10^{-6} to 10^{-4}, and HIs less than 1, are considered to be acceptable for the purpose of making remedial decisions (EPA, 1989). Although this HHRA produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Actual risks are likely to be lower than these estimates. Interpretation of the risk estimates provided should consider the nature and WoE supporting these estimates, as well as the magnitude of uncertainty surrounding them, as described in Section 1.5.3.6.

The results of the risk assessment will be presented in a format that allows the risk manager to integrate and weigh decision factors appropriately and optimally (MWH, 2005). An important risk management consideration is that new data may become available subsequent to the completion of the risk assessment. Risk managers will consider newly published information (site-specific or chemical-specific) as it becomes available to ensure that the final site decisions are protective of human health.

The use of the risk assessment results in the RI and CMS process is discussed in Section 10.

1.5.4 Ecological Risk Assessment

This subsection presents the general approach used for conducting ERAs at RI sites within Group 3 at SSFL. ERAs specific for each of the seven sites in Group 3 (Building 204 Area, SPA, ABFF, Bravo, Alfa, Skyline, and WCT) are presented as part of the RI discussions specific to each site (Sections 2 through 8). These ERAs, prepared to support the Group 3 RI, describe potential exposures and effects to resident biota from chemical stressors associated with past activities within each site. The results of these ERAs are intended to assist risk managers in determining whether remedial actions are needed and, if so, what scale is required.

Because the ERAs for all seven areas will be conducted in the same manner, using many of the same assumptions and supporting data, the approach for and information common to all of these ERAs is presented in this initial section to reduce repetition. The common data and supporting information will be referenced in each of the RI site-specific risk assessments as appropriate.

1.5.4.1 Approach

ERAs for Group 3 are conducted in phases, as recommended by the SRAM (MWH, 2005b; DTSC, 1996; and EPA, 1997). Each phase is more detailed and focused than the one preceding it, and data from one phase are used to determine whether further studies are needed to meet the objectives of the assessment. It includes both a scoping and a predictive assessment, as defined by DTSC (1996).

The scoping assessment uses the most conservative exposure assumptions. The results of the scoping assessment are used to determine the chemicals, receptors, and exposure pathways to be carried forward to the predictive assessment.

The predictive assessment uses more realistic assumptions for estimating exposure and effects. In some instances, the procedures outlined in the SRAM (MWH, 2005b) have been updated to reflect current state-of-the-practice for ERAs that have been agreed to by representatives of NASA, Boeing, and DOE. These changes result in a more robust risk assessment and provide more information for risk managers to use in making remedial decisions. Deviations and/or updated methods from the SRAM (MWH, 2005b) are identified and explained in Section 1.5.5.2 with respect to the nature of the deviation and the overall impacts to the ERA.

The results of the ERA will be used to make recommendations, as follows:

- "NFA with respect to ecological risk" will be recommended for sites where *de minimus* risk (most conservative HQs or HIs are less than 1) to ecological receptors is identified for small home range species (representative species that spend most of their life spans within the investigational unit). This NFA finding is tentative pending the completion of the risk assessment for species with large home ranges (representative species that spend most of their life spans outside of the site or that forage across multiple sites[2]). Sites will not be definitively recommended for NFA until cumulative risks to large home range representative species are evaluated across multiple sites.
- Further evaluation by risk managers will be recommended as part of the FS process for individual sites or site combinations where the WoE indicates potential adverse effects to ecological receptors. This evaluation will include the selection of an appropriate remedial alternative (including no action). As appropriate, natural resource trustees, including the California Department of Fish and Game (CDFG) and the U.S. Fish and Wildlife Service (USFWS), must be consulted in the selection of a remedial alternative.
- A Phase III Impact Assessment may be recommended as part of the FS process for sites where significant uncertainties exist in the WoE risk estimate or where it is determined that remediation may cause adverse effects to ecological receptors or their habitats.

[2] Note that the evaluation of cumulative risks to receptors with large home ranges will be the focus of a subsequent risk assessment report and is beyond the scope of this report.

1.5.4.2 Guidance

The ERAs for Group 3 were performed in general accordance with the following guidance:

- SRAM Work Plan (MWH, 2005b)
- *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities* (DTSC, 1996)
- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment, Interim Final* (EPA, 1997)
- ECO Updates, Volume 1, Numbers 1 through 5 (EPA, 1991a, 1991b, 1992a, 1992b, 1992c)
- ECO Updates, Volume 2, Numbers 1 through 4 (EPA, 1994a, 1994b, 1994c, 1994d)
- ECO Updates, Volume 3, Numbers 1 and 2 (EPA, 1996a, 1996b)
- *Final Guidelines for Ecological Risk Assessment* (EPA, 1998)
- *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (EPA, 1999)
- *The Role of Screening-level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments* (EPA, 2001)

1.5.4.3 Organization

Each of the ERAs is organized following the framework recommended by EPA (1998), which consists of three main components: Problem Formulation, Analysis, and Risk Characterization (shown conceptually in Figure 1.5-3). The evaluations conducted as part of this ERA are described and discussed in the following subsections:

- **Problem Formulation**. Contains the information necessary to focus the remainder of the ERA. It describes the location and ecological setting of the site; discusses selection of assessment endpoints and measures; identifies sources of contaminants, CPECs, potential ecological receptors, and exposure pathways; and develops the ecological CSM. The general components of the Problem Formulation are included in this subsection. Information specific to each RI site is located in the site-specific Problem Formulation.
- **Analysis**. Presents the technical evaluation of potential exposures and adverse effects through the Exposure Characterization and the Ecological Effects Characterization:
  - Exposure Characterization–Describes exposure assumptions and models and presents the exposure estimates for selected representative species.
  - Ecological Effects Characterization–Presents an overview of the toxicity information available for each representative species.

  The approach to exposure characterization, which is consistent across all sites, is described later in this section. EPCs and modeled exposure results specific for each RI site are presented in each site-specific ERA. The ecological effects characterization, which is consistent across all sites, is presented later in this section and referenced in each site-specific ERA.

- **Risk Characterization**. Integrates the Problem Formulation and the Analysis to estimate the likelihood of impacts to ecological receptors from exposure to CPECs. It also presents uncertainties and limitations associated with the risk assessment data and methodology. The approach to risk characterization and many uncertainties are consistent across all sites and are described later in this section. Risk characterization results and uncertainties specific for each RI site are presented in each site-specific ERA.
- **Conclusions and Recommendations.** Summarizes the overall conclusions and recommendations that can be drawn about potential ecological risks associated with CPECs.

1.5.4.4 Problem Formulation

The Problem Formulation integrates available information (sources, contaminants, effects, and environmental setting) and serves to provide focus to the ERA. It includes a description of the site setting, identification of the ecological management goals and the important aspects of the site to be protected (referred to as "assessment endpoints"), the means by which the assessment endpoints will be evaluated (measures of exposure and effects), and the identification of CPECs. The end product of the problem formulation is a CSM that describes the contaminant sources and transport mechanisms, evaluates potential exposure pathways, and identifies the representative species that were used to assess potential ecological risk to those and other similar species. Whereas the general components of the Problem Formulation are presented and described here, site-specific variations to the Problem Formulation are presented in the section for each RI site.

Site Background. This subsection briefly describes the physical location and ecological setting of the RI site, and the historical activities that may have resulted in releases of hazardous substances. This is a site-specific component of the Problem Formulation and is presented separately for each RI site.

Ecological Management Goals, Assessment Endpoints, and Measures. The identification of ecological management goals, assessment endpoints, and measures provide the focus of the ERA, link the ERA with the site characterization and the nature and extent portions of the RI Report, and ensure that the methodologies and results of the ERA are technically sound.

Ecological Management Goals are statements of the desired ecological conditions for the site. They must be established according to a realistic assessment of the current status of the ecological community and potential current and future land uses at the site. The ecological management goal for all Group 3 RI sites is stated as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.

Assessment Endpoints are an expression of the important ecological values that should be protected at a site (Suter, 1990, 1993; Suter et al., 2000; EPA, 1998). The assessment endpoints are developed according to known information concerning the contaminants present, the ecological setting of the site (current and potential future conditions), and the ecological management goals.

The assessment endpoints for SSFL are listed in Table 1.5-11 and are applicable to all terrestrial and aquatic and wetlands habitats. Assessment endpoints specific to each RI site in Group 3 are identified in the section for each RI site.

Measures used in this ERA are predictive of the assessment endpoints (EPA, 1998). The three categories of measures include the following:

- Measures of Exposure–Used to evaluate how exposures could be occurring
- Measures of Effects–Used to evaluate the response of the assessment endpoints when exposed to contaminants
- Measures of Ecosystem and Receptor Characteristics–Used to evaluate the ecosystem characteristics that could affect exposure or response to contaminants

Measures identified for an ERA can be from one or more of the above categories, depending on the complexity of the ERA. Criteria considered in the selection of measures are as follows:

- Corresponds to or is predictive of an assessment endpoint
- Readily measured or evaluated
- Appropriate to the scale of the site
- Appropriate to the temporal dynamics
- Appropriate to the exposure pathway
- Associated with low natural variability
- Disruptive (minimally) to ecological community and species variability

Measures of exposure and effects associated with assessment endpoints for SSFL are listed in Table 1.5-11. These measures are applicable to all terrestrial and aquatic and wetlands habitats. Measures specific to each RI site in Group 3 are identified in the section for each RI site.

Ecological Conceptual Site Model. The CSM is a written and visual presentation of predicted relationships among stressors, exposure pathways, and assessment endpoints. It includes a description of the complete exposure pathways and outlines the potential routes of exposure for each assessment endpoint. A CSM diagram for ecological exposures was developed for SSFL in general (Figure 1.5-4). CSMs specific to the receptors and pathways unique to each RI site within Group 3 are presented in each appropriate section.

The primary contaminant sources at SSFL include chemical use and storage, accidental spills and releases, ASTs and USTs, drainage channels and impoundments associated with rocket testing, and waste disposal areas. Primary release mechanisms include spills, leakage, and prior waste disposal practices. Secondary sources of potential contaminants are soils, sediment, and surface water. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, soil and sediment erosion, leaching from soil and surface water into groundwater, and surface discharge from groundwater.

Complete or potentially complete exposure pathways from contaminated soil, sediment, surface water, groundwater, and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals

resident in or associated with site soils. Additionally, terrestrial plants potentially may be exposed to contaminated groundwater via uptake. Although benthic invertebrates, fish, and amphibians may be exposed to contaminants via surface water or sediment, benthic invertebrates primarily are exposed through sediment, and fish and amphibians primarily are exposed through surface water. Terrestrial and aquatic wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in surface water through ingestion and to contaminants in soil or sediment by incidental soil or sediment ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial and aquatic invertebrates, fish, and wildlife (amphibians, reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). The potential exposure pathways for ecological receptors at SSFL are summarized in Table 1.5-12, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

Identification of Representative Species. Representative species are selected from those species that are either known to occur or may occur at the site. They are chosen to reflect the assessment endpoints for the ERA because their exposures are expected to be "representative" of other species in their functional group or trophic level. In general, representative species are selected using the following criteria:

- Receptor is considered essential to, or indicative of, healthy functioning ecosystems.
- Receptor is vital to the structure and function of the food web.
- Receptor is representative of an ecological guild or niche.
- Receptor has a small home range.
- Receptor is susceptible to bioaccumulation or biomagnification of CPECs (higher trophic-level predators).
- Receptor is likely to be exposed to CPECs or to serve as a link between viable exposure pathways and CPECs.
- Receptor occurs at the site, or habitat is available to support the selected receptor.
- Toxicological data are readily available in the literature for the receptor.
- Receptor is known or suspected to be sensitive to contaminants, thus providing a protective estimate of exposure and risk to other members of the guild.

Representative species were identified in the SRAM (MWH, 2005b) from each trophic level to fulfill as many of the criteria listed above as possible. Species assessed at the population[3] level include all other birds and mammals for which protection of populations is important. Receptors assessed at the community level consist of terrestrial and/or aquatic plants and invertebrates that provide forage or prey for higher trophic levels or support habitat quality and require protection at a community[4] level. The representative species that are evaluated

[3] A population is defined as a group if inter-breeding individuals of the same species occupy a given area.

[4] A community is a collection of individuals of different species that occupy a given area.

in the ERAs at SSFL are listed in Table 1.5-13. Representative species specific to each RI site are identified in each appropriate section of this report.

A brief profile for each selected receptor is presented below.

Terrestrial Habitats. The following representative species are evaluated for terrestrial habitats at SSFL.

Terrestrial Plants. Terrestrial plants are a primary producer and are evaluated at the community level. They include a wide variety of grasses and forbs. Terrestrial plants are a vital part of the food chain, serving as a main food source for both herbivorous and omnivorous species. Terrestrial plants also are directly exposed to CPECs in the soil, may bioaccumulate CPECs, and can be used to assess the status of the habitat.

Soil Invertebrates. Soil invertebrates are primary consumers and are assessed at the community level. They comprise a wide range of species, including earthworms, ground and flying insects, and spiders. Soil invertebrates primarily serve as food sources for omnivorous and insectivorous birds and mammals and may bioaccumulate CPECs.

Hermit Thrush. The hermit thrush is considered representative of primary and secondary consumers and is evaluated at the population level. The hermit thrush is found in mixed woods, forests, parks, and thickets. Its breeding range extends from Alaska east across Canada and south to California, and it winters mainly in the United States. The hermit thrush has been observed frequently at SSFL. It is primarily insectivorous during the breeding season and becomes more omnivorous during the winter. The hermit thrush builds a cup nest of moss, twigs, or grasses on or near the ground (Jones and Donovan, 1996; Ransom, 1981).

Red-tailed Hawk. The red-tailed hawk is a tertiary consumer and is evaluated at the population level. The red-tailed hawk is found in a variety of habitats including woodlands, farm country, prairies, marshes, mountains, and deserts. Its range extends from Alaska to south Central America; wintering is primarily south of British Columbia. Red-tailed hawks are primarily carnivorous, feeding on rodents and other small mammals, but will prey on other birds, lizards, snakes, and large insects, depending on availability. Platform nests are built close to the tops of trees or other tall structures where trees are scarce (EPA, 1993; Ransom, 1981).

Deer Mouse. The deer mouse represents primary and secondary consumers and is evaluated at the population level. It also was selected to represent burrowing mammals and because it serves as prey for other representative species (red-tailed hawk and bobcat). It has the widest distribution of any *Peromyscus* species and resides in dry-land habitat including alpine tundra, coniferous and deciduous forests, grasslands, and deserts. Deer mice are omnivorous and opportunistic, feeding mainly on seeds, arthropods, some green vegetation, roots, fruits, and fungi. The deer mouse gets a high proportion of its water requirements from the nonseed plant materials in its diet (EPA, 1993).

Mule Deer. The mule deer is a primary consumer and is evaluated at the population level. These herbivores are found in coastal forests, brushy areas, rocky uplands, desert shrubs, and chaparral habitats. Their range extends from southern Alaska to Mexico and throughout the western United States. The Pacific coast black-tailed deer are considered a

subspecies of the mule deer. They feed on grass heads, grass leaves, stems and roots, and forb leaves (Ransom, 1981).

Bobcat. The bobcat is representative of secondary and tertiary consumers and is evaluated at the population level. Bobcats are found in forests, swamps, deserts, and mountains, although they prefer scrub, thickets, and broken country. Their range extends from southern Canada to Mexico and throughout most of the continental United States. The bobcat preys primarily on rabbits and hares, but will hunt anything from insects and small rodents to deer, depending on location and habitat, season, and abundance. The bobcat is territorial and largely solitary, although there is some overlap in home ranges.

Aquatic/Wetland Habitats. Aquatic and wetland habitats as defined for SSFL include seasonal wetlands and ephemeral ponds. Seasonal drainage ditches are evaluated as terrestrial exposures rather than aquatic. The following representative aquatic organisms are evaluated in one or more of the aquatic habitats.

Aquatic Plants. Aquatic plants represent primary producers and are evaluated only as a food source for other representative receptors. Aquatic plants serve as major food items for several species in the food chain and provide refuge and nesting habitats for various species.

Aquatic Invertebrates/Benthic Macroinvertebrates. For the purposes of this ERA, the term "aquatic invertebrates" refers to water-column organisms and "benthic macroinvertebrates" refers to sediment-associated organisms. They both represent primary consumers and are evaluated at the community level. Aquatic invertebrates and benthic macroinvertebrates may bioaccumulate CPECs through the food chain.

Fish. Fish represent primary and secondary consumers and are evaluated at the population level. Fish primarily serve as prey for piscivorous birds and can bioaccumulate CPECs.

Great Blue Heron. Great blue herons were assessed at the population level. They feed primarily on fish, but also feed on amphibians, crustaceans, aquatic insects, and plants. They are widespread throughout the United States and are found in ponds, marshes, and lakes wherever fish are plentiful. Great blue herons nest in or near wetlands where tall trees provide safe sites for heronries. They lay three to seven bluish-green eggs in a stick nest, and several nests may be in the same tree (Udvardy, 1993).

Selection of Chemicals of Potential Ecological Concern. The CPECs for all Group 3 sites were identified through several data evaluation procedures and selection criteria. These criteria generally were as outlined in the SRAM (MWH, 2005b), with some additional discussion in Section 1.4 of this report; however, some deviations and modifications were made. The CPECs were selected as follows:

1. A chemical is detected at the site using validated laboratory analyses. Data validation was completed for all aspects of the RI and validated data are reported in the RI Characterization Results section of each RI site section.

2. A chemical is present in excess of concentrations observed in laboratory field blanks. This step was completed as part of the data evaluation and reduction steps completed for all aspects of the RI and the results are reported in Section 1.4 of the main text.

3. A chemical occurs above a 5-percent detection frequency. This step was applied only when there were at least 20 data points for the chemical.

4. A chemical historically was used at the site. This step was not followed, so this is a deviation from the SRAM (MWH, 2005b). All chemicals meeting other criteria were retained for risk assessment regardless of potential historical use.

5. Metals and dioxins and furans are present in excess of soil and groundwater comparison concentrations. Soils were compared to the background data set using the WRS Test, as described in the SRAM (MWH, 2005b). Groundwater data were compared to a background comparison concentration and then evaluated using the WRS Test, as described in the SRAM. A chemical determined to be consistent with background concentrations using the WRS Test may still be retained as a CPEC if the maximum detected concentration is significantly greater than the maximum background concentration, the sample was located in an area that potentially could have been affected by metals, and the SQLs were elevated above the ecological screening levels (ESLs).

6. The SQL for a chemical exceeds the ESL. ESLs will be used in the CPEC selection process to ensure that SQLs for chemicals in soil, sediment, and water samples are sufficiently low to identify chemicals that may present risks. For the purpose of CPEC selection, if there are a sufficient number of the SQLs in a data set below the ESL to conclude that the chemical is not present at concentrations that could pose an ecological risk, and all other criteria are met, then the chemical will be excluded as a CPEC. Justification (sample size, frequency of detection, and number of SQLs below the ESL) will be presented in the risk assessment in cases where a chemical with one or more SQLs at levels exceeding the ESL is excluded as a CPEC.

7. Extrapolation of TPH and PCB data. Data for TPH or PCBs will be extrapolated to estimate TPH- or PCB-constituent concentrations (PAHs, BTEX, and arolors) at sites where these data are not already available. If constituent data are available at a given site, this extrapolation will not be conducted. This is a deviation of the SRAM (MWH, 2005b), which states that all TPH and PCB results will be extrapolated, regardless of the availability of constituent data.

8. If a VOC analyte was detected in soil and also was analyzed for in soil gas, inhalation exposure for the VOC was based on the soil gas measurement, regardless of whether the VOC was detected in soil gas or not. If a VOC was detected in soil but not analyzed for in soil gas, it was retained and a concentration in soil gas was modeled from the soil concentration. This modeled concentration was then evaluated in the soil gas screening.

Chemical data that met the CPEC selection criteria were identified separately for each RI site in Group 3 and are presented in the analyses for each RI site.

1.5.4.5 Analysis

The analysis phase links the problem formulation (Section 1.5.4.4) with the risk characterization (Section 1.5.4.6) and consists of the technical evaluation of ecological and chemical data to determine the potential for ecological exposure and effects, as shown in Figure 1.5-3. The analysis phase includes the exposure characterization and the ecological

effects characterization. These two components are used to evaluate the relationships among receptors, potential exposures, and potential effects. The results provide the information necessary to estimate potential risks to the representative species under the conditions defined for Group 3.

Exposure Characterization. The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). Exposure is defined as the co-occurrence of a stressor (chemical) and a receptor in both space and time. For risk to be present, there must be exposure. The methods used to estimate exposure including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs are described in this subsection.

Exposure Models. The exposure model describes the relationships and equations used to estimate how much of a given chemical in a given medium is being taken up by the receptor via a given exposure route. These relationships may be simple or complex depending on the receptor involved and the number of exposure routes being evaluated. Two exposure models are used in this ERA–the concentration-based model and a dosage-based model.

Concentration-based Exposure Models

The exposure model for several of the groups of ecological receptors is simple, and is expressed as the concentration of each chemical in the medium to which the receptor is most likely exposed. The ecological groups for which this exposure model is used are as follows:

- Terrestrial plants (soil; only when qualitative evaluation indicates potential stress)
- Soil invertebrates (soil)
- Aquatic plants (sediment and surface water)
- Aquatic invertebrates (surface water)
- Benthic macroinvertebrates (sediment)
- Burrowing mammals (soil gas inhalation only)

Dosage-based Exposure Models

The exposure model for birds and mammals is much more complex. Birds and mammals experience exposure through multiple pathways, including the ingestion of abiotic media (soil and surface water), biotic media (food), and inhalation of or dermal contact with abiotic media. To address these multiple pathways, modeling is required. Exposure via ingestion pathways is described below. Inhalation exposure is evaluated using the concentration-based model. Dermal exposure was not quantitatively evaluated in this ERA.

Ingestion exposure estimates for birds and mammals are generated according to the following:

- Receptor-specific exposure factors (or life-history parameters)
- Estimated exposure concentrations in food sources and bioaccumulation potential
- Area use factors (AUFs)
- EPCs for abiotic media

The end product of the exposure estimate is a dosage (amount of chemicals per kilogram receptor body weight per day [mg/kg-day]) rather than a medium concentration, as is the case for terrestrial and aquatic plants and invertebrates. This is a function of both the

multiple pathway approach and the typical methods used in toxicity testing for birds and mammals. Exposure estimates for birds and mammals followed one of the following generalized food chain uptake exposure models (modified from Suter et al. [2000] and cited in the SRAM [MWH, 2005b]):

Hermit thrush and deer mouse:

$$Ej = [Soil_j \bullet Ps \bullet FIR] + [\sum_{i=1}^{N} Bij \bullet Pi \bullet FIR] + [Water_j \bullet WIR]$$

Red-tailed hawk, bobcat, and mule deer:

$$Ej = [\sum_{i=1}^{N} Bij \bullet Pi \bullet FIR] + [Water_j \bullet WIR]$$

Great blue heron:

$$Ej = [Sediment_j \bullet Ps \bullet FIR] + [\sum_{i=1}^{N} Bij \bullet Pi \bullet FIR] + [Water_j \bullet WIR]$$

Where:

E_j	=	Total exposure (mg/kg-day)
$Soil_j$	=	Concentration of chemical in soil (mg/kg)
$Sediment_j$	=	Concentration of chemical in sediment (mg/kg)
$Water_j$	=	Concentration of chemical in water (mg/L)
P_s	=	Soil/sediment ingestion rate as a proportion of diet
FIR	=	Total food ingestion rate for the representative species (kg_{diet}/kg body weight [BW]/day)
WIR	=	Total water ingestion rate for the representative species (L/kg BW/day)
B_{ij}	=	Concentration of chemical (j) in biota type (i) (mg/kg)
P_i	=	Proportion of biota type (i) in diet

Exposure Factors. Species-specific life history factors are needed to estimate exposure to CPECs for each representative species. These include body weight; food, water, and media ingestion rates; diet composition; and respective proportion of each diet component. These parameters were used as cited in the SRAM (MWH, 2005b) and are summarized in Table 1.5-14.

Bioaccumulation Potential. The measurement and/or estimation of concentrations of CPECs in wildlife food is necessary to evaluate how much of a receptor's exposure is via food versus direct uptake of contaminated media. Although the preferred data are direct measurements of concentrations in samples collected from the site, such data were not available for any RI site in Group 3. Site-specific bioaccumulation factors (BAFs) were developed in the SRAM (MWH, 2005b). These values were used if available; if not, other literature-reported values or regression models were used. If literature values or reliable models were not available for a given chemical, then a conservative default bioaccumulation

value of 1 was used. The AUFs for the Group 3 sites are listed in Table 1.5-15. Bioaccumulation factors and uptake models for terrestrial receptors are summarized in Tables 1.5-16 and 1.5-17. Biota and sediment accumulation factors and uptake models for aquatic receptors are summarized in Tables 1.5-18 and 1.5-19.

Area Use Factors. The AUF is used to modify the risk estimates based on how much time the receptor may actually spend onsite. The AUF is a ratio of the size of the site relative to an animal's foraging range. For animals with a small home range, the AUF defaults to 1. The AUFs are estimated using the following equation:

$$AUF = \frac{EA}{FRx}$$

Where:

AUF = Area use factor
EA = Exposure area (hectares)
FRx = Foraging range for target species x (hectares)

An AUF is not used for estimating exposures in the scoping assessment (receptors were assumed to spend 100 percent of their time at the site). Receptor-specific AUFs are used in the predictive assessment. The AUFs for each receptor are defined in each Group 3 RI site section.

Exposure Point Concentrations. The concentration of a CPEC in a given medium to which potential ecological receptors and representative species would most likely be exposed is referred to as the EPC. This ERA used three different EPCs, including the maximum detected concentration, the RME, and the CTE. The maximum detected concentration was taken from all samples collected at a given RI site that met the data quality requirements for the CPEC. The maximum represents a "worst case" exposure. The CTE concentration was the arithmetic mean as specified by the SRAM (MWH, 2005b) and represents an "average" exposure. The RME concentration (generally the 95%UCL) was calculated using the most recent version of ProUCL, as specified by the SRAM. The RME concentration represents a conservative estimate of average exposure. Taken together, these three EPCs describe the range of expected exposure, from average to most extreme, for a given CPEC, and will help inform subsequent risk management decision-making.

The RME EPC was calculated following the most recent parametric (distributional) and nonparametric EPA recommendations as offered in ProUCL (EPA, 2006; 2007). EPA released Version 4.0 of ProUCL in 2007 for general usage; it offers new approaches for calculating UCLs of the mean, particularly when non-detects are present. These new approaches consider a large variety of inputs including the perceived distribution of the detected results (if no perceived distribution is acceptable, nonparametric alternatives are offered), sample size, variability, and skewness.

The ProUCL decision tree for UCLs of the mean is large, with parametric approaches for left-censored data sets (those with nondetects) centering on maximum likelihood estimates for use as proxy substitutions. These estimates attempt to complete the censored left tail of the data using information available from the available detected data. The distributions available in ProUCL include normal, lognormal, and gamma distributions.

Nonparametric approaches are available when a discernable distribution cannot be identified. When non-detects are present, the primary nonparametric approach involves the Kaplan-Meier approach. Depending on the data, the Kaplan-Meier approach may be applied with aspects of a student *t* approach or one of various "bootstrap" approaches. When all results are detected, other nonparametric approaches (such as the Chebyshev approach) are used.

Calculations using the Chebyshev approach adhere to EPA's recommendation of sometimes using a 97.5% or 99% Chebyshev UCL when sample size, variability, and skewness suggest unusually high uncertainty. These elevated-confidence UCLs are not offered in an attempt to alter the overall confidence that the true mean falls below the calculated UCL (95%), but to recognize the results of EPA's Monte Carlo studies, which indicate that under such conditions, a 95% Chebyshev UCL tends not to offer sufficient coverage of the true mean. Thus, these special Chebyshev UCLs remain attempts to offer the best 95% UCL despite the nomenclature describing higher confidence (97.5% or 99%).

The most appropriate method for calculating the UCL for each CPEC is based on sample size, goodness of fit to distributions, variability, and skewness. Note: if there are more than four data points, but only one is a detected value, ProUCL does not calculate a UCL. In these cases, the UCL was calculated using the Chebyshev method with ½ the reported value for non-detects.

The RME EPC for each CPEC at each RI site was determined based on the following decision rules:

- If there are fewer than four data points (samples), then the EPC defaults to the maximum detected concentration.
- If there are four or more data points, then the UCL recommended by ProUCL is used as the EPC.
- If the UCL is greater than the maximum detected concentration, then the EPC defaults to the maximum detected concentration.

Site-specific EPCs are reported in each RI site section.

Ecological Effects Characterization. The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Stressor-response (effects) data that may be used to evaluate ecological risks resulting from chemical exposures make up three general categories: literature-derived or site-specific single-chemical toxicity data, site-specific ambient media toxicity tests, and site-specific field surveys (Suter et al., 2000). Site-specific toxicity studies and quantitative field surveys were not conducted for this ERA. Therefore, single-chemical toxicity data found in the literature were the basis for determining toxicity reference values (TRVs).

TRVs were classified into three categories–ESLs, Low TRVs, and High TRVs. ESLs are screening values that integrate conservative exposure assumptions and no observed adverse effect levels (NOAELs) into a value expressed as a media-based chemical concentration. Low TRVs include NOAELs, no observed effect concentrations (NOECs), low Biological

Technical Assistance Group (BTAG) values, threshold effect concentrations (TECs), and chronic national recommended ambient water quality criteria (NRWQC). High TRVs reflect a mid-range exposure at which adverse effects might occur based on a chronic or sub-chronic exposure. High TRVs include the lowest observed adverse effect levels (LOAELs), lowest observed effect concentrations (LOECs), 20-percent effective concentrations (EC_{20}s), high BTAG values, and probable effect concentrations (PECs). Toxicity results with other endpoints were used in the absence of preferred effect levels and were modified with UFs.

Tables 1.5-20 and 1.5-21 provide the soil gas modeling parameters and the chemical properties for VOCs, respectively. The ESLs are summarized in Table 1.5-22; the lowest soil ESL is listed in Table 1.5-23. The ESLs for most chemicals are those listed in the SRAM (MWH, 2005b); however, some values were revised based on a review of the calculations and literature used to derive the values, in agreement with MWH (conference calls between MWH and CH2M HILL staff, April 2008).

The TRVs for soil invertebrates were obtained primarily from sources listed in the SRAM (MWH, 2005b), followed by EPA's ecological soil screening levels (Eco-SSLs), Efroymson et al. (1997), and literature searches. The TRVs for terrestrial plants are listed in Table 1.5-24; the TRVs for soil invertebrates are summarized in Table 1.5-25.

The Low TRVs for birds and mammals were obtained from the studies used to develop the ESLs in the SRAM (MWH, 2005b), where available. High TRVs were obtained from the same study and source as the Low TRVs when possible. TRVs for analytes that were not listed in the SRAM, or for which no TRV was identified in the SRAM, were obtained first through searches of the SRAM-recommended sources listed below, followed by searches of the open literature:

- EPA IRIS–http://cfpub.epa.gov/ncea/iris/index.cfm
- ATSDR–http://www.atsdr.cdc.gov/
- *Toxicological Benchmarks for Wildlife: 1996* (Sample et al., 1996)
- EPA Region 9 BTAG TRVs developed for the U.S. Navy (Engineering Field Activity West [EFA West], 1998)

For this assessment, the Low TRV is considered to be within the range of a NOAEL; the High TRV is considered to be within the range of a LOAEL. The use of both a Low TRV and High TRV provides a range of HQs that reflect the range of estimated risk between a no effect and a possible effect level. The TRVs for birds, based on ingestion, are listed in Table 1.5-26. The TRVs for mammals, based on ingestion, are listed in Table 1.5-27 and the TRVs for mammals, based on inhalation, are listed in Table 1.5-28.

The TRVs for benthic macroinvertebrates exposed to sediment were obtained primarily from sources listed in the SRAM (MWH, 2005b), but values selected from those sources reflected the consensus-based values as opposed to strictly the lowest values. In addition, marine values were used only when freshwater values were not available as opposed to the use of either marine or freshwater (depending on which was lower) in the SRAM. TRVs for sediment are listed in Table 1.5-29.

The TRVs for fish and other aquatic organisms exposed to surface water were obtained primarily from the sources listed in the SRAM (MWH, 2005b) and included chronic NRWQC, secondary chronic values (Tier II values), and TRVs obtained from other literature searches. The TRVs for surface water are listed in Table 1.5-30.

The toxicological studies compiled in the TRV tables were evaluated for endpoints and assigned UFs, if necessary, to normalize the endpoints to a Low or High TRV equivalent. Per the SRAM (MWH, 2005b), the UFs applied were as follows:

- Lethal Dose to 50 percent of test organisms (LD50) to NOAEL: UF = 100
- LD50 to LOAEL: UF = 10
- LOAEL to NOAEL: UF = 5
- Subchronic to chronic: UF = 2

The determination of whether a toxicity study was subchronic or chronic was made using the following guidelines:

- A chronic exposure in mammals is equivalent to at least 50 percent of a species' lifespan, based on technical support information for the Great Lakes Water Initiative Wildlife Criteria (EPA, 1995a, b; Sample et al., 1996). For example, exposures of 1 year or greater would be considered chronic exposures for studies on laboratory rodents (with life spans of about 2 years).
- Little information is available concerning the life spans of birds used in toxicity tests. Consistent with Sample et al. (1996), avian studies where the exposure duration was greater than 10 weeks are considered chronic studies.
- In addition to duration, the time when contaminant exposure occurs is critical. Reproduction and development periods (mating, gestation, and lactation) are particularly sensitive life stages due to the stressed condition of the adults and the rapid growth and differentiation occurring within the embryo (Sample et al., 1996). Because benchmarks are intended to evaluate the potential for adverse effects on wildlife populations consistent with SSFL assessment endpoints) and consistent with Sample et al. (1996), exposures that occur during most of a species' reproduction and development period (critical life stage) are considered to represent chronic exposures.
- Sources of TRVs such as IRIS, HEAST, ATSDR, EFA West (1998, BTAG values), and Sample et al. (1996) occasionally apply different UFs than those used in the SRAM (MWH, 2005b) to adjust a study to what is labeled a "Chronic NOAEL." For IRIS, HEAST, and ATSDR, the details of the study were reviewed and the criteria in the first bullet above are used. If the details of the study are not presented or are not sufficiently complete to make a determination, then the interpretation made by the source document are used. In the case of EFA West (1998) and Sample et al. (1996), the final derived chronic NOAEL (or Low TRV) values will be used.

1.5.4.6 Risk Characterization

The risk characterization evaluates the evidence linking exposures to CPECs with their potential ecological effects on the representative species identified for Group 3. This evaluation is completed through the integration of information gathered in the problem

formulation, the results of the analysis, and other lines of evidence. For the Group 3 ERAs, the evidence to be evaluated consisted of measured chemical concentrations in abiotic media (soil, sediment, surface water, and/or soil gas as appropriate), modeled concentrations in biota (food-chain uptake), exposure estimates for representative species, toxicity information obtained from the literature, and quantitative and/or qualitative risk evaluations. Three main components comprise the risk characterization: the risk estimation, risk description, and uncertainty analysis. These three components are used together to identify the final contaminants of ecological concern (COECs) and recommendations for Group 3.

Risk Characterization Process. A sequential process was used to integrate the three components of the risk characterization. The process includes the elements required by the SRAM (MWH, 2005b), as well as additional refinements that result in a more robust ERA and provide risk managers with more information for making risk management decisions for the site. The risk characterization process includes the risk estimation through the calculation of HQs and HIs, and the risk description and uncertainty analysis through the interpretation of HQs and HIs via WoE.

The risk characterization process for each medium is described below. The procedures for calculating HQs and HIs are described in the risk estimation subsection, the interpretation of results is presented in the risk description, and the description of uncertainties is presented in the uncertainty analysis subsection.

Soil. The generalized risk characterization process for soil is presented in Figure 1.5-5 and includes an evaluation of direct exposures for soil invertebrates and modeled dietary exposure risk estimates using two EPCs (CTE and RME) and two TRVs (Low TRV and High TRV). The process for the burrowing small mammal (the deer mouse) accounts for the potential for exposures during burrowing at greater depths than those for other wildlife, as shown in Figure 1.5-6. Calculations include HQs and HIs, which are described in Section 1.5.4.

For soil invertebrates, the maximum detected concentration of a CPEC is compared to the LOAEL or High TRV for soil invertebrates (Figure 1.5-5). If the maximum detected concentration does not exceed the High TRV, that individual chemical can be concluded to present no unacceptable risk to soil invertebrates. If the maximum detected concentration exceeds the High TRV, sample locations that exceed are identified. When High TRV-based HQs exceed 1, those chemicals are retained for potential remedial decisions (hot spot removal) as part of the FS. The decision to perform a FS will depend on the number of chemicals that exceed High TRVs, the clustering of samples with contaminants in excess of the High TRVs, and the magnitude of the High TRV exceedances.

Risks to terrestrial plants initially are evaluated qualitatively, using field observations to assess whether resident vegetation displays visible signs of impaired health. If the field observations suggest effects to resident plants, soil concentration data are evaluated using literature-derived effects data in a manner comparable to that described above for soil invertebrates.

Birds and mammals experience multi-media exposure, which requires modeling of the dietary dose for comparison to TRVs. Dietary exposure (described in Sections 1.5.4.4 and

1.5.4.5) is estimated for all bird and mammal receptors based on both RME and CTE surface soil (0 to 2 ft), sediment, and surface water concentrations (where available) (Figure 1.5-5). The process for evaluating the deer mouse is slightly different, as described below. Both the RME and CTE exposure estimates are compared to Low and High TRVs. HQs for each chemical and HIs for groups of like chemicals are calculated. The WoE will be used to identify chemical and chemical groups for potential remedial decisions in the FS. The decision to perform an FS will depend on the threshold (Low or High TRV) exceeded and magnitude of exceedance, the bioavailability of the chemical, and the availability and quality of habitat for the receptor at the site.

Because some small mammals burrow, they may experience exposure over depths ranging from the surface to 6 ft bgs. The general soil risk characterization process (Figure 1.5-5) was modified to accommodate the soil depth (Figure 1.5-6). To identify the soil depth range representing the greatest exposure, maximum detected soil concentrations in the 0- to 2-, 0- to 4-, and 0- to 6-foot-depth ranges are compared to the small mammal ESLs. HIs over all chemicals are calculated for each depth range. The depth with the greatest total HI is selected for more detailed RME and CTE exposure modeling, which is conducted and evaluated as described above for other wildlife receptors.

Because inorganics are naturally occurring, they are expected to occur in soil samples from any given site. In an effort to determine the incremental risk associated with each inorganic (that is, the risk in excess of that attributable exclusively to background concentrations), background risks were calculated for inorganics that failed the screen for one or more receptors by dividing the background RME soil concentration by the TRV for the appropriate receptor. Background HQs were then subtracted from site HQs to determine the incremental risk HQ.

Soil Gas. The process for evaluating the potential risk that soil gas may present to small mammals is outlined in Figure 1.5-7. The maximum detected soil gas concentration is compared to the mammalian inhalation ESL. If the maximum detected soil gas concentration is less than the inhalation ESL, that individual chemical can be concluded to present no unacceptable risk to burrowing mammals. The maximum detected soil gas concentration also is compared to alternate NOAEL-based inhalation TRVs presented by Gallegos et al. (2007). Samples that exceed the inhalation ESL or alternate TRVs are identified. The WoE is used to identify chemicals for potential remedial decisions in the FS. The decision to perform an FS will depend on the number of chemicals that exceed the TRVs, the clustering of samples with contaminants in excess of Low or High TRVs, and the magnitude of exceedances.

Sediment. The screening process for sediment (Figure 1.5-8) is conceptually similar to that for soil invertebrates. The maximum detected concentrations of chemicals are compared to sediment ESLs (which are equivalent to Low TRVs or TECs). Chemicals that fail this screen are carried forward and the maximum detected concentration is the compared to the High TRV (or PEC) for sediment. If the maximum detected concentration does not exceed the High TRV, that individual chemical can be concluded to present no unacceptable risk to benthic macroinvertebrates. If the maximum detected concentration exceeds the High TRV, sample locations that exceed are identified. When High TRV-based HQs exceed 1, those chemicals are retained for potential remedial decisions (hot spot removal) as part of the FS.

The decision to perform an FS will depend on the number of chemicals that exceed the High TRVs, the clustering of samples with contaminants in excess of the High TRVs, and the magnitude of the High TRV exceedances.

Surface Water. The screening process for surface water (Figure 1.5-9) is conceptually similar to that for sediment. The maximum detected concentrations of chemicals are compared to Low TRVs (which in this case are chronic ambient water quality criteria [AWQCs]). If the maximum detected concentration does not exceed the Low TRV, that individual chemical can be concluded to present no unacceptable risk to aquatic organisms. If the maximum detected concentration exceeds the Low TRV, sample locations that exceed are identified. When the Low TRV-based HQs exceed 1, those chemicals are retained for potential remedial decisions (hot spot removal) as part of the FS. The decision to perform an FS will depend on the number of chemicals that exceed the High TRVs, the clustering of samples with contaminants in excess of the High TRVs, and the magnitude of the High TRV exceedances.

Risk Estimation. The risk estimation focuses primarily on quantitative methods to evaluate the potential for risks. The results of the quantitative risk estimation are presented as HQs and HIs.

HQs were developed for two types of comparisons using the indicated equations:

1. Direct comparisons of measured concentrations in soil, soil gas, sediment, or surface water to the respective TRVs for each CPEC. These comparisons were conducted for soil invertebrates and terrestrial plants exposed to soil, borrowing mammals exposure to soil gas, benthic macroinvertebrates exposed to sediment, and aquatic plants and other aquatic organisms exposed to surface water, according to the following equation:

$$HQ = \left(\frac{EPC\ (mg/kg\ or\ mg/m^3\ or\ \mu g/L)}{TRV\ (mg/kg\ or\ mg/m^3\ or\ \mu g/L)} \right)$$

2. Comparisons of estimated total exposure dosages via the food-chain uptake model to effects dosage TRVs. These comparisons were conducted for birds and mammals exposed to soil or sediment, surface water, and food, according to the following equation:

$$HQ = \left(\frac{Exposure\ dosage\ (mg/kgbw/d)}{receptor-specific\ TRV\ (mg/kgbw/d)} \right)$$

HIs, calculated only for dietary exposures to birds and mammals, were developed for specific classes of chemicals assuming similar modes of action for chemicals within those classes. HIs were calculated for the following classes, when available:

- Dioxins/furans (and dioxin-like PCBs)
- PAHs
- Aroclors
- PCBs
- Phthalates
- Organochlorine pesticides

- Organophosphorous pesticides
- Volatile organics
- TPHs

The HI was calculated as follows:

$$HI = \sum HQs\,(chemicals\ in\ class)$$

Risk estimates were derived from the combinations of EPCs and TRVs for each representative receptor, as described in Section 1.5.4.6. Chemicals or chemical classes with HQs or HIs greater than 1 were retained for further evaluation in the risk description; all other CPECs (HQs and HIs less than 1) were not considered to pose an unacceptable risk to ecological receptors and were removed from further consideration.

Risk Description. The risk description incorporates the results of the risk estimates, along with any other available and appropriate lines of evidence to evaluate potential chemical impacts on ecological receptors in Group 3. Chemicals with HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of the COECs includes receptor groups potentially affected, exceedances of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created specifically for this report as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.

2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.

3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.

4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.

5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.

6. No Risk–All HQs and associated HIs<1.

7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Uncertainty Analysis. Uncertainties are inherent in all aspects of an ERA. The nature and magnitude of uncertainties depend on the amount and quality of the data available, the

degree of knowledge concerning site conditions, and the assumptions made to perform the risk assessment. A qualitative evaluation of the major uncertainties associated with ERAs for all RI sites in Group 3 is outlined below. Uncertainties that are specific to any RI site are presented in the each site-specific section, as appropriate.

Problem Formulation. Representative species were selected to reduce uncertainty and to focus on species that are both maximally exposed and representative of the wildlife using the site. However, differences among species, including physiology, reproductive biology, or foraging habits, can result in different exposures and sensitivities to different chemicals.

- No site-specific data regarding CPEC concentrations in wildlife foods at Group 3 sites were available for avian and mammalian exposure estimate calculations. Therefore, concentrations in food items were estimated using SSFL site-specific BAFs or literature-derived bioaccumulation models. The suitability of the literature-derived bioaccumulation models to conditions at the site is unknown. Therefore, concentrations of CPECs in biota present at the site and, consequently, the dietary exposures of birds and mammals, may be either higher or lower than values estimated in this ERA that were based on literature-derived bioaccumulation models.

Exposure Characterization.

- No avian and mammalian life history data specific to Group 3 were available; therefore, exposure parameters either were modeled according to allometric relationships (food ingestion rates) or data from the same species in other portions of its range. Because diet composition, including food, water, and soil, may not accurately reflect individuals present at the site, potential risks may either be overestimated or underestimated.

- Several exposure routes were considered minor and were not included in the exposure analysis. Although exposure via these other routes still contributes to the total risk to each receptor, potential risks could have been underestimated because these routes were not quantified.

- Dermal contact with soil, sediment, or surface water is considered to be a minor secondary route of exposure for birds and mammals. Dermal contact is of concern primarily with organic chemicals that are lipophilic (have an affinity for fats) and can cross the epidermis of the exposed organism. Although some CPECs are highly lipophilic (for example, dichlorodiphenyldichloroethane [DDE]) and can bioaccumulate, they are of greater concern in the food-chain pathway as opposed to direct contact.

Ecological Effects Characterization.

- Literature-derived toxicity data from laboratory studies were the only toxicity data used to evaluate risks to all receptor groups. Effects observed in laboratory species were assumed to be indicative of effects that would occur in wild species. The suitability of this assumption is unknown. Therefore, potential risks may either be overestimated or underestimated.

- Toxicity data were not available for all CPECs or media considered in this ERA. CPECs for which toxicity data were unavailable were not evaluated, or surrogate toxicity data were used. The potential risks may be overestimated or underestimated.

- Bioavailability of CPECs was assumed to be 100 percent. This is a conservative estimate and may overestimate risks to receptors at the site.

Risk Characterization.

- Potential ecological risks were quantified using the HQ approach. The magnitude of the HQ indicates the potential for ecological risk, but is not an exact estimation of risk. For example, the actual risk from a chemical with an HQ of 70 could be less than that for a chemical with an HQ of 20 because of uncertainties involved in estimating exposure, selection of effects criteria (TRVs), or other field conditions.

- Data necessary to estimate potential risks from all pathways for all chemicals in the food-chain uptake model were not always available. For these chemicals and/or areas, the food-chain uptake model was completed using the available data.

Conclusions and Recommendations. The overall ERA conclusions and recommendations specific to each RI site in Group 3 are presented in each site-specific section. The conclusions will identify chemicals that present risks, the estimated magnitude of that risk, the receptors to which they present risk, and if possible, the sample locations (or other attributes) that drive risk. Chemicals that present no risks also will be identified. Recommendations for additional data collection and further evaluation or consideration of remediation (FS) will be made depending on the nature and magnitude of the risk conclusions.

1.5.5 Deviations from SRAM

The SRAM (MWH, 2005b) provides the primary guidance for conducting and reporting HHRAs and ERAs at SSFL. Although all reasonable efforts have been made to perform risk evaluations in accordance with the SRAM, because of progress in the development of risk assessment methodologies and tools since the SRAM was prepared, and subsequent identification of areas where enhancements were appropriate, deviations from the SRAM-dictated approaches were necessary in some cases. Deviations from the SRAM for both the HHRAs and ERAs are summarized below.

1.5.5.1 Human Health Risk Assessment Deviations

As described in Section 1.5.3, the HHRA was performed following the guidelines in the SRAM (MWH, 2005b). Because risk assessment science and regulatory policy change with time, provisions are included in the SRAM (MWH, 2005b) that allow the proposed approach to be modified to reflect scientific advancement or changes in regulatory guidance or policies. The deviations in risk assessment methods from those provided in the SRAM (MWH, 2005b) are listed below:

- This HHRA addresses residential exposure scenarios, in addition to adult and child recreational user and industrial worker scenarios. A more likely future use of SSFL is for recreational purposes, and recreationists are the most plausible future human receptors. However, in accordance with California SB 990, response actions at SSFL also should consider a hypothetical future agricultural residential land use. This is a deviation from the SRAM (MWH, 2005b). The exposure scenarios listed in the SRAM are current site workers and trespassers, as well as future onsite residents and visitors. This agricultural residential scenario will include the consumption of beef, eggs, milk,

swine, fruits, and vegetables. However, pending final agreement of the input assumptions considered in the scenario, the assessment of the subsistence agricultural exposure scenario will be included in a supplemental risk assessment report separate from this RI Report.

- The toxicity criteria used to assess dioxin and coplanar PCB congeners were the 2005 WHO TEFs published by Van den Berg et al. (2006), as opposed to the WHO TEFs published by Van den Berg et al. (1998), as stated in the SRAM (MWH, 2005b). In addition, the chemical-specific toxicity criteria that were used in the HHRA have been updated since their inclusion in the SRAM.

1.5.5.2 Ecological Risk Assessment Deviations

Deviations from the SRAM (MWH, 2005b) guidance for performing ERAs are summarized below:

- The TRVs for benthic macroinvertebrates exposed to sediment were obtained primarily from sources listed in the SRAM (MWH, 2005b), but values selected from those sources reflected the consensus-based values (McDonald et al., 2000) as opposed to strictly the lowest values. In addition, marine values were used only when freshwater values were not available, as opposed to the use of either marine or freshwater (depending on which was lower) in the SRAM (MWH, 2005b).
- ESLs–Several opportunities to enhance the process used to develop the ESLs reported in the SRAM (MWH, 2005b) were found. Several discussions were held between MWH and CH2M HILL to address the underlying interpretive issues, as well as to review the ESLs for chemicals that were identified as risk drivers. Items that were agreed to between MWH and CH2M HILL include the following:
  - Establishing the criteria for the interpretation of mammalian and avian toxicity studies as required for correct application of UFs
  - Hierarchy for the selection of ESLs for sediment and surface water
  - Review and/or correction of mammalian soil ESLs (approximately 100 chemicals), bird ESLs (4 chemicals), soil invertebrate ESLs (7 chemicals), surface water ESLs (approximately 38 chemicals), and sediment (approximately 37 chemicals). Corrected mammalian ESLs and toxicity values are summarized in Table 1.5-31.
- Selection process for CPECs. The selection criteria were generally as outlined in the SRAM (MWH, 2005b); however, some deviations were made, as noted below:
  - Chemical is present in excess of the concentrations observed in laboratory field blanks. This step was completed as part of the data evaluation and reduction steps completed for all aspects of the RI.
  - Chemical historically was used at the site. This step was not followed, because it is too subjective. All chemicals meeting other criteria were retained for risk assessment regardless of potential historical use. Site-specific BAFs were developed in the SRAM (MWH, 2005b) for many chemicals and were used if available (with the exception of perchlorate). If a site-specific BAF was not available, other literature-

reported values or regression models were used. If literature values or reliable models were not available for a given chemical, then a conservative default bioaccumulation value of 1 was used. Perchlorate was discussed with MWH and DTSC and a revised BAF for plants was proposed and accepted.

- Selection of TRVs. The SRAM (MWH, 2005b) uses only one set of TRVs to evaluate potential risks (Low TRVs). Three levels (ESLs, Low TRVs, and High TRVs) were used in preparing this RI Report to provide a risk range for WoE regarding COECs.

- Use of allometric scaling. The SRAM specifies using allometric scaling when receptor and test animal body weight differs by more than 100 times. Per recent discussions with DTSC and MWH, it is recognized that allometric scaling is no longer in favor with DTSC because it is not scientifically supported. Allometric scaling of toxicity data, therefore, has been removed from all analyses.

- EPCs. The SRAM (MWH, 2005b) uses the CTE and an RME (which is the 95% UCL) for estimating risk. For this RI Report, the maximum concentration was used, in addition to the CTE and RME. This approach assists in expanding the WoE for COECs by delineating maximum exposures.

- Determination of the RME exposure level. The SRAM (MWH, 2005b) forces the RME to be a 95% UCL even when ProUCL recommends a different value, which can be a 97% UCL or even a 99% UCL. In this RI Report, it is proposed that the recommended ProUCL output be used for the RME (unless the UCL exceeds the maximum detected value, in which case it defaults to the maximum detected value). Unlike the SRAM, in this report, it is proposed that EPA's recommendations be followed, which sometimes results in a 97.5% or 99% Chebyshev UCL when sample size, variability, and skewness suggest unusually high uncertainty. These elevated-confidence UCLs are not offered in an attempt to alter the overall confidence that the true mean falls below the calculated UCL (95%), but to recognize the results of EPA's Monte Carlo studies, which indicate that under such conditions a 95% Chebyshev UCL tends not to offer sufficient coverage of the true mean. Thus, these special Chebyshev UCLs remain attempts to offer the best 95% UCL despite the nomenclature describing higher confidence (97.5% or 99%).

- Risk characterization processes. The risk estimation processes include the basic comparisons specified in the SRAM (MWH, 2005b), but also include the additional calculations using more TRVs and EPCs.

- HIs. The SRAM (MWH, 2005b) specified that certain HIs be developed for specific classes of chemicals assuming similar modes of action for chemicals within those classes. HIs were calculated for these, as well as some additional classes (as requested by DTSC):

  - Dioxins/furans (and dioxin-like PCBs)–specified in the SRAM (MWH, 2005b)
  - PAHs–specified in the SRAM
  - Aroclors–specified in the SRAM
  - PCBs–specified in the SRAM
  - Phthalates-additional
  - Organochlorine pesticides-additional
  - Organophosphorous pesticides-additional

- Volatile organics-additional
- TPHs–specified in the SRAM

1.6 Fate and Transport Evaluation Approach Overview for Group 3

This subsection examines contamination migration potentials through an environmental contaminant fate and transport evaluation. The site physical characteristics, source characteristics, and extent of contamination are combined to form the basis of the contaminant fate and transport.

1.6.1 CSM: Contaminant Sources, Release Mechanisms, and Migration Pathways

The various CSMs of the contaminant sources, release mechanisms, and migration pathways are shown in Sections 2 through 8 for each site. Waste on the surface or buried in the ground may contaminate surface and subsurface soil. Runoff and erosion may move contaminants to surface water and sediment. Contaminants buried in subsurface soil may leach to groundwater. For areas that have high levels of VOCs, air is also a medium of interest for exposure evaluations.

1.6.2 Potential Routes of Migration

The primary mechanism for contaminant transport from the source areas at a site is evaluated in this subsection. Typically, the migration pathways are likely to be surface runoff, particularly when a site is located on an incline. Other media affected by surface runoff include the sediments and surface water if a surface water body is present in the vicinity. Other potential migration pathways include contaminants in soil and buried waste materials and contaminated surface water migrating vertically downward, which may leach through the vadose zone and be transported into the groundwater system. Surface soil also may be released to the air by wind erosion.

Another potential contaminant pathway is the migration of contaminants from surface soil into the subsurface. Infiltration of rainfall may leach some contaminants into subsurface soil and subsequently into the groundwater system.

1.6.3 Contaminant Persistence

The mobility and persistence of the potential contaminants at the site are determined by their physical, chemical, and biological interaction with the environment. Mobility is the potential for a chemical to migrate from a site, and persistence is a measure of how long a chemical will remain in the environment.

Various basic physical and chemical properties affect the transport of chemicals in the environment at the site. The fate and transport evaluation of the COCs that are identified for each site will be conducted using their respective physical and chemical properties to assess the most probable fate at the individual sites. In general, chemicals that are soluble, volatile, or leachable tend to be mobile. Mobile chemicals are likely to be released and transported from the source and are not persistent, whereas persistent chemicals tend to

remain localized in the SA and are resistant to chemical and biological degradation reactions. The following are considered to be the most important properties:

- Sorption
- Volatilization
- Degradation
- Transformation
- Bioaccumulation

Sorption is the tendency for chemicals to adsorb to and desorb from materials in the media through which the contaminants are being transported. The subsurface materials likely to sorb chemicals typically are clays and organic material. In addition, inorganic chemicals adsorb onto iron, manganese, and aluminum oxyhydroxide or oxide coatings on soil and sediment grains. The conventional measure of sorption for a chemical is the soil-water distribution coefficient (K_d). The K_d for organic chemicals is the product of a partition coefficient (K_{oc}) and the fraction of organic carbon (f_{oc}). In general, chemicals with a K_{oc} greater than 10,000 milliliters per gram (mL/g) (many SVOCs) have high degrees of adsorption and consequentially low mobility, whereas chemicals with a K_{oc} lower than 1,000 mL/g (many VOCs) have lower degrees of adsorption and consequentially higher mobility.

Volatilization is the tendency for some chemicals, particularly VOCs, to change from a liquid or adsorbed state to a gas. A conventional measure of volatility is Henry's Law Constant (H). Compounds with H values higher than 10^{-3} atmosphere-cubic-meter per mole (atm-m^3/M) are expected to volatilize readily from water to air, whereas those with H values lower than 10^{-5} atm-m^3/M are relatively non-volatile. Most inorganic chemicals are not volatile under normal temperature and pressure conditions.

Degradation is the transformation of one chemical to another by such processes as hydrolysis, photolysis, and biodegradation. Hydrolysis is the reaction of a chemical with water and photolysis is the result of exposing the chemical to light. Degradation commonly is expressed as a half-life that composites the degradation by whatever processes may be operating.

Transformation occurs when metals are increased or reduced in a valence state by oxidation or reduction, respectively. Transformation may have a significant effect on the mobility of a metal, either increasing or decreasing it. Transformation can be caused by oxidation-reduction potential (ORP) and pH changes and by microbial or non-microbial (abiotic) processes.

Bioaccumulation is the extent to which a chemical will partition from water into the lipophilic parts (fat) of an organism. Bioaccumulation commonly is estimated by the octanol-water partition coefficient (K_{ow}). Chemicals with high values of K_{ow} tend to avoid the aqueous phase and to remain in soil longer or bioaccumulate in the lipid tissue of exposed organisms. The accumulation of a chemical in the tissue of the organism can be quantified by a bioconcentration factor (BCF), which is the ratio of the concentration of the chemical in the tissue to the concentration in the water. BCFs are both contaminant-specific and species-specific. Inorganic chemicals and SVOCs tend to have higher K_{ow} values, so they bioaccumulate more extensively than VOCs.

1.7 Data Quality Evaluation Summary

1.7.1 Data Quality Evaluation Summary

Analytical data from the SSFL RI sampling for Group 3 were assessed in accordance with the procedures and specifications contained in the *Surficial Media Operable Unit Quality Assurance Project Plan (RFI QAPP)* (MECx, October 2008). This section and Table 1.7-1 briefly summarize the overall results and quality of the data for Group 3. Data flags were assigned according to the QC acceptance limits defined in the QAPP, as follows:

- J = Analyte concentration was considered an estimated value because one or more QC specifications were not met, or concentration was greater than the method detection limit (MDL), but less than the project quantitation limit (low-level detects).
- R = Rejected result; identification and/or quantitation could not be verified because critical QC specifications were not met.
- U = Analyte was not detected.
- UJ = Analyte was not detected. The sample quantitation limit was estimated.

Overall, the data collected from Group 3 during this investigation were of acceptable quality. Out of approximately 57,360 reported results, 1,403 data points were qualified as not detected because of low-level blank contamination (2.4 percent), 1,440 data points were qualified as estimated concentrations due to QC exceedances (2.5 percent), and 1,541 data points were qualified as estimated concentrations because of low-level detects (2.7 percent). There were 19 data points rejected due to low matrix spike/matrix spike duplicate recovery (0.03 percent). The overall data were 99.97 percent complete, and except for the rejected results, the data can be used in the project decision-making process as qualified.

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2. Building 204 Area

2.1 Building 204 Site Background and History

The Building 204 Area has operated as the Plant Services building for Areas I, II, III, and IV at SSFL, providing equipment maintenance, automotive maintenance and repair, and building maintenance services. The Building 204 Area consists of five buildings that were constructed in 1956. As mentioned in Section 1, the Group 3 Area SSFL buildings have been discussed in previous reports with three-digit numbers, but the numbers have since been changed to four-digit numbers, with an additional "2" being added as a prefix to the original building numbers. The investigation area will be referred to as the Building 204 Area, but individual buildings discussed in the text and presented in the figures will use the current four-digit nomenclature. Three former USTs were located at Building 2204. Some of these features are designated as SWMUs or AOCs. These features are further described below.

2.1.1 SWMUs and AOCs

At the Building 204 Area there is one SWMU and one AOC, as described below. SWMU 5.5 is the former Building 2204 waste oil UST, which is designated as UT-50. This 500-gallon tank formerly was used to store waste oil from automotive maintenance operations and was located near the southeastern corner of Building 2204. UT-50, installed in the early 1960s, was removed in 1988 under VCEHD oversight.

The AOC at the Building 204 Area encompasses a pair of USTs, UT-48 and UT-49. Tank UT-48 was a 1,500-gallon fuel oil UST on the eastern side of Building 2204. Tank UT-49 was a 10,000-gallon UST used to store gasoline and was located south of Building 2204. Both of these tanks were removed in 1988 under VCEHD guidance. Organic odors in the excavation pit from UT-49 were noted at the time of removal (Ogden, 1996). As a result of these observations, the over-excavation of the original tank backfill materials, native soil, and some weathered Chatsworth formation bedrock was removed. The excavation extended to a depth of 12 to 13 ft bgs and approximately 1 foot beyond the outer walls of the tank. The excavation was backfilled with clean pea gravel and capped with asphalt (Ogden, 1996b). Near UT-48, additional sampling conducted in 1996 did not detect BTEX or TPH in soils in this portion of the site. Subsequent sampling was conducted in 1989 for UT-49. The samples penetrated bedrock in the center of the former excavation. Concentrations of TPH and BTEX were detected in the soil samples overlying bedrock and from the uppermost portion of the bedrock (Ogden, 1996c). On the basis of these results and subsequent groundwater monitoring data, VCEHD closed UT-48 and UT-49 in 1991 (MWH, 2004).

2.1.2 Site History

The Building 204 Area was acquired by NASA in 1973, along with the remainder of the Area II property (known as USAF Plant 57 under ownership of the U.S. Air Force [USAF]). Five buildings are located in the Building 204 Area. These buildings also are collectively

called the Service Area. One of these buildings (2205) is no longer in use. Also, flammable storage cabinets are located adjacent to one of the service area buildings and portable storage units are located in this area for storing equipment, hazardous materials, and paints. The buildings and facilities, along with their related purposes, are described in more detail below.

Building 2204 was constructed in 1956 and serves as the maintenance building. Located within the building is an automotive maintenance and repair bay, workshop area, carpenter shop, hazardous materials storage area, and offices. USTs located near this building include a former 1,500-gallon fuel oil UST (UT-48), a former 10,000-gasoline UST (UT-49), and a 500-gallon waste oil UST (UT-50) as described in Section 2.1.1.

In 1997, a hydraulic oil release was observed during the replacement of an automobile hoist in the automotive maintenance and repair bay on the southern side of Building 2204. Following the discovery of the leak, a limited excavation of approximately 20 to 30 cubic yards of contaminated soil was conducted to a depth of approximately 13 ft bgs. Because of the physical and safety constraints related to the indoor excavation, the lateral and vertical extents was not evaluated sufficiently (The Boeing Company, 1998a). To minimize the risk of additional hydraulic oil releases to the underlying soil, the underground hydraulic hoist was replaced with an aboveground hoist (The Boeing Company, 1998b). A second belowground hydraulic hoist in the automotive maintenance and repair bay was drained of any hydraulic oil and is no longer in operation (NASA, 2005).

In the garage area of Building 2204, storage of hazardous materials such as motor oil, gear oil, automatic transmission fluid, grease, and ethylene glycol was observed during a 2005 visual site inspection (VSI). A hazardous waste accumulation point for oily rags, waste oil/water, waste PCB ballasts, waste aerosol cans, and spent lead acid batteries also was located in the garage area of 2204 (NASA, 2005).

A covered area (no building number) used for metal cutting is located immediately to the west of Building 2204. The coolant used for the metal cutting equipment has always been water based (NASA, 2005). A storage room for electrical equipment is located in this same area.

Building 2205 is located in a paved area to the north of Building 2204. The building was constructed in 1956 and at one time was used as the paint shop, according to a 1965 Master Plan (NASA, 1965). However, at a later date, the building was used as the lunch room for the Building 2204 employees. The building has since been closed and is no longer in use.

Building 2233 is located in a paved area to the north of Building 2204. Formerly, the building was used primarily for paint storage; however, during the 2005 VSI, the building was empty (NASA, 2005). In 2008, the building was being used to store landscape maintenance equipment. The construction date of this building is unknown.

Building 2760 is located to the south of Building 2204. This building is used as the Maintenance Supply Shed and also houses a large air compressor that services Building 2204. On the western side of the building, a storage area for engine oil, transmission fluid, hydraulic oil, and ethylene glycol was observed during a 2005 VSI of the building. Although not present during the 2005 VSI, a former 500-gallon diesel AST formerly existed on the southern side of the building (MWH, 2005).

Building 2796 is located to the north of Building 2204. This building is the current paint shop and machine shop. The construction date is unknown; however, the building is listed in the 1965 Master Plan as the "Paint Spray Shed." According to interviews with SSFL personnel, the paint booth formerly used an air purifying system described as a waterfall curtain and sump located on the northwestern side of the building (NASA, 2005). Numerous flammable storage cabinets are located to the west of Building 2796.

2.1.2.1 Site Inventories

Inventories of the buildings, tanks, transformers, and chemicals used at the Building 204 Area were compiled during the preparation of this RI report. This information was obtained from historical document reviews, facility drawings, and VSIs. These features are shown in Figure 2.1-1, as applicable. The inventories are included in the following tables:

- Building Inventory–Table 2.1-1
- Transformer Inventory–Table 2.1-2
- Tank Inventory–Table 2.1-3
- Chemical Inventory–Table 2.1-4

2.1.3 Site Chemical Use Areas

The Building 204 Area functions as the Plant Services Area for SSFL, with buildings that are used for automotive and equipment maintenance and repairs, a paint booth, a carpenter shop, hazardous materials and hazardous waste storage. Chemicals used in these buildings included petroleum products, gasoline, diesel, coolants, sealants, cleaners, paints, thinners, and primers. Table 2.1-4 provides a chemical inventory of the hazardous materials used or stored at the buildings, as described below.

Building 2204 was reported to have stored petroleum products, gasoline, diesel, coolants, sealants, cleaners, primers, paints, thinners, primers, and PCB ballasts (Rockwell International, 1983; 1990).

The exact inventories of chemicals used or stored at Buildings 2205 and 2233 are unknown. However, based on the previous usage as a paint shop and paint storage building, respectively, it is likely that paints, thinners, and primers historically were used or stored at these buildings.

Building 2760 was reported to have stored engine oil, diesel oil, transmission fluid, hydraulic oil, and ethylene glycol (NASA, 2005).

Building 2796 is used as the paint spray booth and machine shop. Chemical usage and storage at this building includes paints, thinners, primers, and machining oils (Rockwell International, 1983; 1990).

2.1.4 Site Conditions

The Building 204 Area is currently active. Most of the facility is intact and used for minor automotive repair work at SSFL. As noted earlier, the three primary USTs (UT-48, 49, and 50) were removed in 1988 and the excavations were filled with pea gravel and capped with asphalt.

2.1.5 Site Habitats/Land Cover

The Building 204 Area is approximately 4.1 acres, of which 17 percent is wooded with evergreens (coast live oak). Developed and paved areas, ruderal vegetation, and rock cover approximately 62 percent of the site. Open field with dense annual grass, 18 inches in height, covers approximately 7 percent of the Building 204 area. Patchy shrub/scrub vegetation (mulefat, coast live oak, and laurel sumac), ranging from 2 to 5 feet in height, were observed to cover 2 percent of the site. Multiple bird and mammal species (house finch, red-tailed hawk, western scrub-jay, white-throated swift, California towhee, spotted towhee, gopher [burrows], coyote [scat], and rodents [burrows]) were observed to use the site. The western fence lizard also was observed at the site. The habitats and land cover present at the Building 204 Area are shown in Figure 2.1-2.

2.1.6 Historical Document Reviews

As described in Section 1.5.1, a historical document review was completed of documents applicable to the Group 3 RI. As a result of this historical document review, there were three new potential features identified.

According to interviews conducted with SSFL personnel in 2005, a vehicle washing area was located to the west of Building 2796 on the road that leads down the hill toward the Old Conservation Yard. Washing of vehicle undercarriages occurred no more than twice a month since approximately 1980 during the winter months. No solvents were reported to have been used during the washing activities (NASA, 2005).

In interviews conducted with SSFL personnel in 2005, it was reported that residual paint and solvent were deposited on the hillside to the west of Building 2796. The area is approximately 20 ft by 100 ft. Disposal of residual paints and solvent at this location occurred until approximately 1991. It is unknown when this practice was initiated (NASA, 2005).

According to interviews conducted with SSFL personnel in 2005, a paint booth air filtration waterfall curtain was located on the northwestern corner of Building 2796. Paints used at this booth were reported to be lacquer-based, polymer-based, water-based, and enamel-based. The exact operation dates of the waterfall curtain are unknown. It was removed sometime between 1990 and 2000 (NASA, 2005).

2.2 RI Characterization Activities

This subsection describes the sampling objectives, sampling scope, and key decision points associated with evaluating the nature and extent of chemical impacts for the surface soil, subsurface soil, and groundwater at the Building 204 Area.

2.2.1 Sampling Objectives

To evaluate the extent of potential chemical effects on the Building 204 Area, soil and soil gas samples were collected. The objectives of the investigation were as follows:

- Evaluate the lateral and vertical extent of chemical impacts.
- Evaluate the potential gradients of chemicals.
- Develop a sufficient data set for performing a risk assessment.

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results and/or previous remediation activities
- Fate and transport characteristics of chemicals
- SSFL background concentrations of parameters
- SSFL SRAM-based screening concentrations for human health and ecological receptors

2.2.2 Sampling Scope

Provided in this report are the characterization results for soil matrix and soil gas information. The total numbers of samples collected as part of this report for soil matrix samples and soil gas samples are summarized below:

- Soil Matrix: 198 samples
- Soil gas: 40 samples

These samples were collected between 1989 and 2009 to identify the potential chemical impacts associated with the activities at the Building 204 Area. Section 2.4 summarizes these soil samples. An NSGW investigation has not been conducted at this site.

2.2.3 Key Decision Points

The site-specific decision points identified for the Building 204 Area represent the assumptions and/or decisions made during the sampling phase component of this RI, as follows:

- For historical sample points where the sample depth had not been recorded, it was assumed that these sample points were taken between the 0- to 2-foot-bgs range.

2.3 RI Characterization Results

The characterization results from the previous soil matrix and soil gas investigations at the Building 204 Area are summarized below.

2.3.1 Soil Matrix and Soil Gas Findings

Samples were collected at the Building 204 Area from 1989 through 2009. Four subsurface soil samples were collected in 1989 in response to the UT-49 tank removal. Samples were analyzed for metals, TPHs, and VOCs. Four VOCs were detected beneath the excavated area at elevated concentrations. The extent of the VOCs has been evaluated sufficiently

through additional sampling. Data were included in the 1996 RFI Work Plan Addendum (Ogden, 1996a) and the closure reports in regard to the UST removals at this site. In 1993, VOCs in a vapor screen were sampled in this area at 4 ft bgs; however, the results yielded no analytical detections.

To evaluate potential contamination related to the Building 204 Area operations and chemical storage history, and as a result of the 1996 Work Plan Addendum, surface soil and subsurface soil samples were collected in 1997 and 1998. Additionally, upon completion of an aerial photography review (Lockheed, 1997), sampling plans and approaches were developed in conjunction with the DTSC, and metals, PCBs, SVOCs, TPHs, and VOCs were sampled and analyzed. During the late-1990s investigation, only TPHs were detected at concentrations that exceeded the applicable screening criteria.

From 2000 through the present, RFI characterization sampling (currently RI sampling) was conducted to support the development of this RI report. Each stage of the investigative process is outlined in the RFI Report (MWH, 2004). To summarize, this AOC was investigated through soil and soil gas sampling, which was followed as recently as early 2009 by rounds of step-out sampling to further evaluate the nature and extent of VOCs. Dioxins, PCB-aroclors, metals, TPHs, SVOCs, and VOCs were detected at concentrations that exceeded the applicable screening criteria in the Building 204 Area. Additional details regarding the analytes detected at this site as a result of the previous investigations performed are described in Section 2.4. The HHRA and ERA for the analytes detected at this site are provided in Sections 2.7 and 2.8, respectively.

2.3.2 Groundwater Findings

2.3.2.1 Background

The Building 204 Area (Figure 2.3-1), which includes SWMU 5.5 and one AOC, is an approximately 2-acre site in the northern portion of Area II. The elevation varies from approximately 1,830 ft above msl to 1,920 ft msl across the site. Six wells and piezometers are located within the boundary of the Building 204 Area and provide information regarding groundwater conditions. These wells and piezometers are listed in Table 2.3-1, along with construction summaries. The locations are shown in Figure 2.3-2.

NSGW has not been observed at this site during investigations previous to this RI. RI activities at the Building 204 Area included the installation of two piezometers, PZ-151 and PZ-152 (Figure 2.3-1), which were installed in November 2008. Both piezometers were installed within the weathered section of the Chatsworth formation. The screened intervals were constructed at the base of the weathered bedrock zone. Construction logs and boring logs for PZ-151 and PZ-152 are provided in Appendix B.

PZ-151 was installed west of Building 204 in an area of subsurface soil contaminants to investigate the potential for NSGW in underlying weathered bedrock. PZ-152 was installed south of Building 204 near monitoring well RD-26. It was located within the footprint of the underlying CFOU VOC plume between two drum storage areas to investigate the potential for NSGW. NSGW was not observed in the piezometers at the time of installation. On January 6, 2009, and January 26, 2009, the piezometers were dry.

Chatsworth formation monitoring wells at the Building 204 Area include RD-26 and RD-60. RD-26 was installed in 1989 to investigate potential impacts to groundwater from the site USTs. RD-60 was installed in 1993.

2.3.2.2 Local Geology

The Building 204 Area, throughout most of its areal extent, is underlain by deposits of the Upper Chatsworth Formation, Sandstone 2, Upper Burro Flats Member (Figure 2.3-1). The Upper Burro Flats Member consists predominantly of medium-grained sandstone with minor interbeds of siltstone and shale. Approximately 400 ft north of the site is the east-west trending north fault. Approximately 100 ft south of the area, the ELV Member outcrops. The ELV Member, which marks the boundary between the Upper and Lower Burro Flats Members, consist of fine-grained sandstone, siltstone, and shale. Beds strike northeast-southwest and dip between 25 and 40 degrees to the northwest.

During RI rock-coring activities at PZ-151 and PZ-152, the materials encountered included alluvium/colluvium and weathered bedrock of the Chatsworth formation. Alluvial/ colluvial material consisted of olive brown to dark fine sand to silty sand with some interbedded siltstone and sandstone. During previous drilling activities, orange to medium-brown, silty to clayey sands were encountered. The thicknesses of alluvial/colluvial deposits encountered during drilling activities at the Building 204 Area ranged from 4 ft to 8 ft.

Weathered bedrock encountered in PZ-151 and PZ-152 consisted predominantly of weathered sandstone with some interbedded weathered shale, siltstone, and lean clay. Colors ranged through shades of gray, brown, and yellow. Textures typically were medium grained. Unweathered Chatsworth formation rocks were encountered at 80 ft bgs in PZ-151 (advanced to 82 ft bgs) and at 45 ft bgs in PZ-152 (advanced to 47 ft bgs).

Cross-sections A-A', and B-B' traverse the Building 204 Area (Figures 2.3-2 and 2.3-3). Where known, the thickness of alluvial/colluvial deposits, weathered bedrock, and depth to unweathered bedrock are shown. Generally, depths to the top of unweathered Chatsworth formation rocks at the Building 204 area are speculative because of a lack of sufficient detail in historic lithologic logs. Recent water level data also are shown in Figures 2.3-2 and 2.3-3.

2.3.2.3 Local Hydrogeologic Setting

NSGW has not been observed at the Building 204 Area. The two piezometers (PZ-151 and PZ-152) recently installed in the weathered section of the Chatsworth formation were dry at the time of installation and were still dry in January 2009. Additional measurements are planned in 2009 to investigate the potential for a seasonal occurrence of NSGW at these locations.

Chatsworth formation groundwater is regionally extensive across the Building 204 Area as it is across SSFL. Hydrographs of wells completed in the Chatsworth formation are shown in Figure 2.3-4. The depths to Chatsworth formation groundwater extend from approximately 60 to 100 ft bgs. A comprehensive discussion of hydrogeologic characteristics of the Chatsworth formation is provided in the *Technical Memorandum Conceptual Site Model Movement of TCE in the Chatsworth Formation SSFL* (Montgomery Watson, 2000) and the Geologic Characterization of the Central SSFL (MWH, 2007b).

2.3.2.4 Characterization Results Chatsworth Formation Groundwater

Groundwater characterization of the Chatsworth formation is based on sampling events that have occurred between 1985 to the present. These data are termed "legacy" data. Sampling has been conducted for a variety of analytical groups that have varied over time and location.

Table 2.3-2 summarizes the legacy data from Chatsworth formation wells RD-26 and RD-60. The Chatsworth formation groundwater is under a separate regulatory program within the RCRA corrective action program at SSFL and has been designated as its own operable unit, the CFOU. Investigations pertaining to Chatsworth formation groundwater were not conducted during this RI. However, groundwater quality data are summarized below because of the potential for vertical contaminant transport pathways from surface or near-surface source areas to the Chatsworth formation.

Chatsworth formation wells in the Building 204 Area have been sampled for the following analytical groups:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- Energetic parameters
- General chemistry analytes
- Hydrocarbons (fuel-related compounds)
- Organo-chlorine pesticides

The following subsections discuss the results of each analytical group in further detail. Table 2.3-3 summarizes detections from the available legacy data. Table 2.3-4 lists metals concentrations over time and compares total concentrations versus dissolved concentrations by sample and location. Table 2.3-5 summarizes the most recently available data and compares the results with screening level criteria, where available. The groundwater analytical data used to evaluate site conditions are provided in Appendix I.

Volatile Organic Compounds. Twenty-two VOCs have been detected as shown in Table 2.3-3. The most frequently detected compounds are TCE, cis-1,2-dichloroethene (DCE), 1,2-dichloroethane (1,2-DCA), trichloromethane, 1,1-DCE, 1,1-DCA, and carbon tetrachloride (CTC). The remaining 15 compounds were detected only 5 or fewer times over the entire data set.

Multi-analyte time trend charts for RD-26 and RD-60, for TCE, cis-1,2-DCE, and 1,2-DCA are provided in Figure 2.3-5. Figure 2.3-6 presents single-analyte time trend charts for TCE, cis-1,2-DCE, and 1,2-DCA concentrations at RD-26 and RD-60.

Table 2.3-5 summarizes the most recent VOC results from available data. RD-60 had concentrations of TCE, cis-1,2-DCE, 1,2,3-trichloropropane, and 1,1-DCA above screening levels. RD-26 had concentrations of TCE at levels above the screening levels.

Semivolatile Organic Compounds. Three SVOCs have been detected in Chatsworth groundwater (1,4-dioxane, n-nitrosodimethylamine, and bis(2-chloroethyl)ether) (Table 2.3-3). Screening levels have been exceeded for these three compounds in the most recent available data.

Phthalates. Phthalates have not been detected in the Chatsworth groundwater.

Metals. Detections that exceeded the screening criteria in the available legacy data are summarized in Table 2.3-3. Selenium, magnesium, and copper are the metals that have exceeded the screening levels the most frequently. Copper, magnesium, and selenium exceeded the screening levels in the most recent data (Table 2.3-5). Table 2.3-4 provides a comparison of the total metals concentrations with the dissolved metals concentrations by sample and location. The data set is insufficient to develop conclusions regarding relationships between dissolved and total concentrations and the effects of sample turbidity on metals concentrations in groundwater.

Polycyclic Aromatic Hydrocarbons. PAHs have not been detected in the Chatsworth formation groundwater at the Building 204 Area.

General Chemistry. General water quality analytes (common anions and cations) have been measured in Chatsworth groundwater. Detections and exceedances are reported in Table 2.3-3 for the available legacy data and in Table 2.3-5 (most recent available data). The most recent data had exceedances of chloride, sulfate, fluoride, and nitrogen.

Hydrocarbons (Fuel-related Compounds). Hydrocarbons C6-C12 have been detected in Chatsworth groundwater at well RD-60 at concentrations that exceeded the screening levels historically and in the most recent data set.

Organo-chlorine Pesticides. Organo-chlorine pesticides have not been detected in Chatsworth formation groundwater at the Building 204 Area.

2.3.3 Surface Water Findings

There are no surface water features at the Building 204 Area. Surface water samples were not collected during this RI investigation.

2.3.4 Completeness of Characterization

Areas of known exceedances and potential contamination at the Building 204 Area were investigated further by evaluating the existing data and collecting additional groundwater samples. The predominantly detected contaminants in CFOU groundwater at the Building 204 Area are VOCs, primarily TCE and its daughter products with 1,2,3-trichloropropane, and 1,1-DCA. These SVOCs generally were not detected in the Building 204 Area groundwater samples other than n-nitrosodimethylamine , bis(2-chloroethyl)ether, and 1,4-dioxane. Selenium, magnesium, and copper are the metals most frequently detected at levels above the screening levels; most metals detected in groundwater were near background concentrations. Groundwater has been sampled and analyzed for chemicals at locations near operational areas, and the CFOU analytical results indicate no relationship between the known operations and soil/soil gas data.

Chemical use areas have been evaluated sufficiently for risk assessment and to support the RI recommendations.

2.3.4.1 NSGW Characterization

The occurrence of NSGW at the SSFL is limited in extent, ephemeral and believed to be related to seasonal variations in precipitation. NSGW has not been observed in the Building 204 Area; however, newly installed piezometers (PZ-151 and PZ-152) will be sounded for the presence of groundwater across several seasons, including late winter and early spring events when precipitation is expected to increase. If sufficient groundwater is present, sampling of the groundwater will occur and be reported in an addendum to this RI report.

5.3.4.2 Surface Water

There are no surface water features at the Building 204 Area; therefore, no surface water samples were collected as part of this RI.

2.4 Building 204 Area Nature and Extent

Surface soil, subsurface soil, and soil gas samples were collected from the Building 204 Area, per the protocol described in Section 2.2 and the data provided in Appendix B. Figure 2.4-1 shows the locations of surface and subsurface soil samples collected as part of this RI investigation. Table 2.4-1 lists the parameters analyzed in the sample media at the Building 204 Area. The nature and extent of contamination that exceeded the comparison criteria values in the media sampled are described below.

2.4.1 Surface Soil Nature and Extent

A total of 110 surface soil samples (up to 2 ft bgs were collected at this site and analyzed for one or more of the following: dioxins, TAL metals (including hexavalent chromium), PCBs (aroclors and congeners), and organochlorine pesticides. Table 2.4-2 lists the parameters detected in the surface soil samples at the Building 204 Area.

Two surface soil samples, BUBS1065 and BUBS1069, were collected in the vicinity of the three USTs that have been removed from this site (UT-48, 49, and 50) and analyzed for pesticides, metals, SVOCs, TPHs, and VOCs. Three TPH groups and 16 metals were detected across these 2 samples; however, neither sample reported an exceedance. These samples, along with other surface soil samples, will be discussed in detail in the following subsections.

2.4.1.1 Parameters Exceeding Criteria

The nature and horizontal extent of parameters encountered at concentrations exceeding their respective comparison criteria are described below.

Dioxins. A total of 7 surface soil samples were analyzed for dioxins at this site, including both CDDs and CDFs. Dioxins were detected in all 7 of the surface soil samples collected. The current approach to assessing the toxicity of these mixtures is to use information regarding the toxic potency of the different congeners to convert the congener concentrations to a toxicologically equivalent concentration of the most potent congener,

2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The samples were evaluated for nature and extent by comparing the frequency of the different CDDs and the CDFs that exceeded the screening criteria at each location. The CDD and CDF exceedances were added together according to the chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD toxicity equivalent (TEQ) values were compared to the ecological screening criterion (4.3 pictograms per gram [pg/g]) and the more conservative human health screening criterion (1.3 µg/kg). These data are summarized in Table 2.4-3.

Each of the sample locations analyzed for dioxins had 2,3,7,8-TCDD TEQ values reported at levels exceeding the human health (1.3 pg/g) and ecological screening criteria (4.3 µg/kg). The highest TEQ for mammals, which is compared to the human health criterion, was 647.594 pg/g (BUBS0022S01), and the highest TEQ for birds, which was the most conservative comparison for ecological risk, was 520.315 pg/g (BUBS0022S01). All 7 surface soil samples are in the vicinity of a transformer pole south of Service Area Road, south of Building 2760. Figure 2.4-2 shows the extent of the 2,3,7,8-TCDD TEQs in surface soil at this site. These exceedances, reported in 2006 and 2008, are the highest dioxin concentrations found in Area II, Group 3. The most likely contributor to these concentrations is the wildfire that spread throughout SSFL in 2005; the treated wood used for the power pole probably would leave elevated concentrations of dioxins post-combustion. Additional sampling concentrically from the power pole may be required to evaluate the horizontal extent of dioxins at this site. The vertical extent of these parameters is addressed in Section 2.4.2.

Metals. Metals were detected in all 66 surface soil samples collected and analyzed for 1 or more metals parameter, exceeding the applicable screening criteria at 34 of the sample locations. Of the metals detected in the surface soil at this site, 13 metals were reported at concentrations exceeding 1 or more of the criteria. The metals exceedances are described below.

Only 1 exceedance each was reported for aluminum, barium, chromium, and nickel, each at concentrations suggestive of natural occurrence. Aluminum was detected at a concentration of 24,000 mg/kg (BUBS0020) and barium was detected at 160 mg/kg (BUBS0021), compared to their background values of 20,000 mg/kg and 140 mg/kg, respectively. Chromium was detected at 37.7 mg/kg (BUTS03S01) and nickel at 40.3 mg/kg (BUTS03S02), compared to their background values of 37 mg/kg and 29 mg/kg, respectively. These sole exceedances are indicative of natural occurring concentrations and probably are not related to operations at this site. The horizontal extents of aluminum, barium, chromium, and nickel have been addressed sufficiently at this site.

Two exceedances of boron were reported in the Building 204 Area at concentrations of an estimated 11.6 J mg/kg (BUTS09) and 31.8 mg/kg (BUTS03S02), surpassing the ecological criterion (6.76 mg/kg) and its background value (9.7 mg/kg). Elevated concentrations of boron were detected in the westernmost portion of this area and are horizontally bound by samples exhibiting non-exceeding concentrations of the parameter. The horizontal extent of boron has been evaluated adequately.

Antimony, chromium VI, and mercury were detected an elevated concentrations at this site. The 4 antimony exceedances ranged in concentration from an estimated 11.7 J mg/kg (BUTS03S02) to 14.9 mg/kg (BUBS1030), each exceeding its human health and ecological criteria and is similar to the background value (8.7 mg/kg). The 3 chromium VI

exceedances ranged from 0.863 mg/kg (BUBS1058) to 3.04 mg/kg (BUBS1059), each surpassing its ecological (0.20 mg/kg) and human health criteria (0.39 mg/kg). Elevated concentrations of mercury were reported in five samples, ranging from 0.13 mg/kg (BUBS1032) to 0.39 J mg/kg (BUBS1008), each exceeding its ecological screening criterion (0.1 mg/kg); the highest concentration detected also surpassed its human health criterion of 0.3 mg/kg). Antimony and mercury exceedances mostly were found in the westernmost samples collected in this area. Additional sampling to the west may be warranted to further evaluate the extents of antimony and mercury at this site. Chromium VI was detected in and around Building 2796, the paint spray booth. Historically, automotive coatings have had chromium VI additives to help with gloss retention. Additional samples may be required to the south and east of Building 2796 to evaluate the horizontal extent of chromium VI at this site. The extents of antimony, mercury, and chromium VI are illustrated in Figure 2.4-3.

Eight cadmium exceedances and 9 exceedances of both copper and lead were reported in the Building 204 Area from a combined 14 surface soil sampling locations. Elevated concentrations of cadmium ranged from an estimated 1.4 J mg/kg (BUBS1017) to an estimated 14.7 J mg/kg (BUBS1028), each exceeding the applicable screening criteria and its background value (1 mg/kg). Elevated concentrations of copper ranged from 31.8 mg/kg (BUTS03S01) to 631 mg/kg (BUTS03S02), also exceeding its human health and ecological criteria, exceeding its background value (29 mg/kg). Lead exceedances ranged from 38.1 mg/kg (BUBS1031) to an estimated 552 J mg/kg (BUTS03S02), also exceeding its screening criteria, with detections exceeding the background value of 34 mg/kg. These exceedances are found mostly in the northwestern portion of this site and the extent has been evaluated sufficiently through additional surface soil sampling. However, additional sampling of these parameters may be required to the west of station BUBS0019 and in the vicinity of Building 2796. The horizontal extents of cadmium, copper, and lead are shown in Figure 2.4-4.

Silver and zinc were the most prevalent parameters detected in the Building 204 Area, having 12 and 14 exceedances reported, respectively. Elevated concentrations of silver ranged from 0.95 mg/kg (BUBS1028 and BUBS1077) to 49.9 mg/kg (BUTS03S02), each exceeding its ecological criterion (0.54 mg/kg); nine of the silver detections also exceeded its human health criterion of 1.1 mg/kg. Silver exceedances mostly were encountered in the northwestern portion of the site, where additional sampling may be required to evaluate the extent evaluation to the west. Zinc exceedances ranged from 120 mg/kg (BUBS1032) to 786 mg/kg (BUBS1054), each surpassing its ecological (21 mg/kg) screening criterion, with 3 also surpassing its human health criterion of 370 mg/kg. Similar to silver, zinc exceedances were primarily concentrated in the west-northwest portion of the site, an area that may require additional sampling to the west to evaluate horizontal characterization of several metals. Additional sampling for silver and zinc in a westerly direction appears to be warranted. The extents of silver and zinc in the surface soil are illustrated in Figure 2.4-5.

Additional sampling to the west of this area appears to be warranted for several metals parameters in the surface soil, in particular, to the west of sampling stations BUBS0019, BUBS1028, and BUBS1032. The vertical extents of these parameters and other metals detected at elevated concentrations in the subsurface soil are addressed in Section 2.4.2.

PCB Aroclors/Congeners. PCB congeners were analyzed in 11 surface soil samples at this site, none of which had exceeding concentrations reported.

PCB aroclors were analyzed at 47 surface soil locations at this site, 17 of which reported elevated concentrations of a combined 3 PCB aroclors. Aroclor-1248 was detected once at an elevated concentration of 59.4 µg/kg (BUBS1041), exceeding its ecological screening criteria (11.4 µg/kg). No samples were collected due north of station BUBS1041, although additional sampling to the south, east, and southwest have evaluated the exceedance in the upgradient and downgradient directions sufficiently. This location is on the southeastern corner of a substation. The extent of Aroclor-1248 has been addressed sufficiently, because the substation to the north is the likely source.

A total of 9 Aroclor-1254 and 5 Aroclor-1260 surface soil exceedances were reported in the Building 204 Area. Aroclor-1254 was detected at concentrations ranging from an estimated 77 J µg/kg (BUBS0024) to an estimated 1,600 J µg/kg (BUBS0019). Each reported exceedance surpassed the ecological screening criterion of 77 µg/kg, and 8 of the 9 concentrations also exceeded its human health (89 µg/kg) criterion. Elevated concentrations of Aroclor-1260 ranged from 126 µg/kg (BUBS1046) to an estimated 990 J µg/kg (BUBS0019), each exceeding its human health criterion (89 µg/kg) and ecological screening criterion (77 µg/kg). Aroclor-1254 and Aroclor-1260 were detected at elevated concentrations across the Building 204 Area, with noted concentrations south of the northwest substation, near the western debris area, and near the transformer pole south of Service Area Road. It appears that additional sampling is warranted to evaluate the PCB exceedances beyond the AOC boundary of this site. The extents of Aroclor-1254 and Aroclor-1260 in the surface soil are shown in Figure 2.4-6. The vertical extents of these parameters are addressed in the following subsection.

Pesticides. Fifty-one surface soil samples were analyzed for the organochlorine pesticide hexachlorobenzene, none of which had an exceedance reported. The analytical results for the pesticide investigation in the subsurface soil will be described in the following subsection.

SVOCs. SVOCs were analyzed at 77 locations in the surface soil samples collected at the Building 204 Area. Three SVOCs, including 1 phthalate and 1 PAH, were detected at concentrations that exceeded their respective screening criteria. Phenol and di-n-butyl phthalate were each detected once at concentrations that exceeded the screening criteria. Phenol was detected at a concentration of 16,800 µg/kg (BUBS1011) and di-n-butyl phthalate was detected at an estimated 503 J µg/kg (BUBS1028), each of which exceeded its ecological and human health criteria. Although station BUBS1028 lies on the western edge of this area, the lack of exceedances across this area suggests that these parameters have been evaluated sufficiently in the Building 204 Area. Benzo(a)pyrene (BaP) had 4 exceedances reported in this area, with concentrations ranging from an estimated 14 J µg/kg (BUBS0027) to an estimated 87.1 J µg/kg (BUBS1028), each exceeding its human health screening criterion of 11.4 µg/kg. Each of these exceedances was encountered along the western edge of the Building 204 Area, and additional sampling may be warranted to evaluate horizontal extent in the westerly direction. BaP, however, is evaluated sufficiently to the north, south, and east through additional sampling. The horizontal extent of BaP in the surface soil is illustrated in Figure 2.4-7.

TPHs. TPHs were analyzed at 58 locations in the Building 204 Area. Two groups, lubricant oil range (C20-C30) organics and extractable fuel hydrocarbons (EFH) (C21-C30), were detected at concentrations that exceeded their common ecological and human health screening criteria of 100,000 µg/kg. Lubricant oil range organics were reported at estimated concentrations of 140,000 J µg/kg (BUBS04) and 360,000 J µg/kg (BUBS02). These stations, located south of Building 204, are evaluated sufficiently downgradient by a non-detection of this group at station BUBS09. Additionally, nearby stations were sampled for EFH (C21-C30), a similar organic carbon range; these samples sufficiently evaluate the lubricant oil range organics concentrically. The horizontal extent of the lubricant oil range (C20-C30) organics has been evaluated adequately.

Six exceedances of the EFH (C21-C30) group, ranging from an estimated 125,000 J µg/kg (BUBS1066) to 1,880,000 µg/kg (BUBS1056), were detected at this site. These exceedances appear to be spread out north and south across the eastern portion of this area. The horizontal extent appears to have been evaluated sufficiently in the northern, western, and southern directions; however, additional sampling to the east may be required to evaluate this EFH group. The extent of EFH (C21-C30) in the surface soil is shown in Figure 2.4-8.

VOCs. Fifty-five surface soil samples were analyzed for 1 of more VOC parameters; one station, BUBS1064, reported a PCE exceedance of 0.731 J µg/kg, which surpassed its human health criterion of 0.43 µg/kg. This station is on the western side of Building 204 and is encompassed by additional surface soil samples that did not have elevated concentrations of PCE reported. The horizontal extent of VOCs in the surface soil at this site has been evaluated adequately. The vertical extent of VOCs is addressed in the following subsection.

2.4.2 Subsurface Soil Nature and Extent

A total of 88 subsurface samples (greater than 2 ft bgs) were collected from 64 sampling stations to a maximum depth of 25 ft bgs at the site. The subsurface soil at the site was analyzed for 1 or more of the following: dioxins, target analyte list (TAL) metals, PCB aroclors, organochlorine pesticides, SVOCs, TPHs, and VOCs. Seven subsurface soil samples were analyzed for hexavalent chromium (included in the metals discussion). Table 2.4-4 lists the parameters detected in the subsurface soil samples at the Building 204 Area.

Two subsurface soil samples, BUBS1065 (4.5 to 5 ft bgs) and BUBS1069 (4 to 4.5 ft bgs), were collected in the vicinity of three USTs that have been removed from this site (UT-48, 49, and 50) and analyzed for metals, pesticides, SVOCs, TPHs, and VOCs. One TPH group, 2 SVOCs, and 16 metals were detected across these 2 samples; however, neither sample had an exceedance reported.

Dioxins. One subsurface soil sample, BUBS1020, from 4.5 to 5 ft bgs, was analyzed for dioxins. No dioxin parameters were detected at elevated concentrations in this sample, which is the downgradient sampling station for dioxin exceedances in the surface soil at the southern transformer pole. Dioxins are more likely to be spread across the surface by being air blown; therefore, the vertical extent of dioxins has been addressed sufficiently.

Metals. Forty-five samples were collected from 32 sampling stations at the Building 204 site and analyzed for metals. Of those, 4 samples exhibited elevated concentrations of a combined 11 metals. The vertical extents of these metals are described below.

Barium, mercury, molybdenum, and vanadium each were detected once at a concentration that exceeded their respective screening criteria, but were similar to their background values. Barium was detected at a concentration of 157 mg/kg (BUBS1044, 3.25 to 3.75 ft bgs), compared to its background value of 140 mg/kg. Mercury was detected at 0.2 mg/kg (BUBS1077, 4.5 to 5 ft bgs), compared to its background value of 0.09 mg/kg. Molybdenum was detected at 10 mg/kg (BUBS1077, 4.5 to 5 ft bgs), compared to its background value of 5.3 mg/kg, and vanadium was detected at 67.2 mg/kg (BUBS1061, 9.5 to 10 ft bgs), compared to its background value of 62 mg/kg. Each of these parameters may be occurring naturally at these reported concentrations and is unlikely to be related to operations at this site. The vertical extents of barium, mercury, molybdenum, and vanadium have been evaluated adequately.

Boron, lead, silver, and zinc also were detected once each at elevated concentrations, with all four exceedances being encountered at BUBS1044, 3.25 to 3.75 ft bgs. Additionally, each parameter exceeded both its ecological and human health criteria, but was similar to its respective background value. Boron was detected at a concentration of 31.1 mg/kg and lead was detected at 128 mg/kg, compared to their background values of 9.7 and 34 mg/kg, respectively. Silver was detected at 26.8 mg/kg and zinc at 828 mg/kg, compared to their background values of 0.79 and 110 mg/kg, respectively. A deeper sample, from 3.5 to 4 ft bgs, was collected at station BUBS1044, thus providing a vertical boundary for these parameters. The vertical extents of boron, lead, silver, and zinc have been addressed sufficiently.

Two each exceedances of antimony, cadmium, and copper were reported in this area. Elevated detections of antimony were 11.5 mg/kg (BUBS1000, 2.75 to 3.25 ft bgs) and 25.3 mg/kg (BUBS1044, 3.25 to 3.75 ft bgs), which exceeded the applicable screening criteria and antimony's background value (8.7 mg/kg). Cadmium was detected at 1.1 mg/kg (BUBS1077, 4.5 to 5 ft bgs) and 2.9 mg/kg (BUBS1044, 3.25 to 3.75 ft bgs), which exceeded its ecological (0.0045 mg/kg) and background (1 mg/kg) screening criteria, the latter also exceeding its human health criterion of 1.7 mg/kg. Copper was detected at 54 mg/kg (BUBS1077, 4.5 to 5 ft bgs) and 146 mg/kg (BUBS1044, 3.25 to 3.75 ft bgs), which also exceeded its ecological (1.1 mg/kg) and background (29 mg/kg) screening values, the latter also exceeding its human health criterion of 68.6 mg/kg. The exceedances exhibited at stations BUBS1044 and BUBS1077 are evaluated vertically through samples collected at these stations at deeper intervals. The antimony exceedance was detected at the bedrock interface; however, it is bound horizontally in the subsurface media by crossgradient and downgradient samples collected at similar or deeper intervals. The vertical extents of antimony, cadmium, and copper have been evaluated adequately.

Aluminum, chromium, chromium VI, and nickel were not detected at elevated concentrations in the subsurface soil at this site; the vertical extents of these parameters have been assessed sufficiently. The vertical extents of metals in subsurface soil in the Building 204 Area have been evaluated sufficiently.

PCBs Aroclors/Congeners. PCB aroclors were analyzed in 26 subsurface soil samples collected from 22 sampling stations. Two parameters, Aroclor-1254 and Aroclor-1260, were detected at elevated concentrations in 5 samples spanning 4 locations. The vertical extents of these PCBs are described below.

Three exceedances of Aroclor-1254 were reported in the subsurface soil at this site, with concentrations ranging from 103 µg/kg (BUBS1044, 3.25 to 3.75 ft bgs) to 8,090 µg/kg (BUBS1077, 4.5 to 5 ft bgs). Each of these detections exceeded it human health (89 µg/kg) and its ecological (77 µg/kg) screening criterion. These exceedances are grouped in the northwestern portion of this AOC and were detected down to the subsurface bedrock interface. The two exceedances exhibited at BUBS1077 showed a decreasing trend, because the concentrations decrease with depth. The Aroclor-1254 exceedances are evaluated sufficiently horizontally through additional sampling at similar or deeper intervals. The vertical extent of Aroclor-1254 has been evaluated sufficiently, as shown in Figure 2.4-9.

Four exceedances of Aroclor-1260 were detected in the subsurface soil media at this site, with concentrations ranging from 82.2 µg/kg (BUBS1077, 9 to 9.5 ft bgs) to 49,000 µg/kg (BUTS08, 5.5 to 6 ft bgs). Each of these exceedances surpassed its ecological screening criterion of 77 µg/kg, and two also exceeded its human health (89 µg/kg) criterion. These exceedances also were encountered in the deepest intervals sampled, at the subsurface bedrock interface. These exceedances were detected in the deepest intervals sampled at these four stations. Horizontally, elevated concentrations of Aroclor-1260 are evaluated sufficiently by additional sampling, suggesting that its vertical extent has been sufficiently investigated, as shown in Figure 2.4-10.

Aroclor-1248 was not detected at an elevated concentration in the subsurface soil at this site; hence, the vertical extent of its surface soil exceedance has been evaluated adequately. However, additional sampling may be warranted to further evaluate aroclors in the surface soil, which may lead to additional subsurface soil sampling if the additional surface soil samples show elevated concentrations of aroclors.

Pesticides. Thirty-five subsurface soil samples from 24 sampling stations were analyzed for the organochlorine pesticide hexachlorobenzene; none of the samples had reported exceedances. Therefore, the extent of pesticides at this site has been evaluated adequately.

SVOCs. A total of 56 subsurface soil samples from 43 sampling stations were analyzed for 1 or more SVOC parameter at this site. Of those, 6 samples from 4 stations had elevated concentrations of six SVOCs reported, 5 of which are classified as PAHs. Their vertical extents are described below.

Benzo(a)anthracene (BAA), benzo(b)fluoranthene, chrysene, and phenanthrene each were detected once at a concentration that exceeded its applicable screening criteria, each at station BUTS08, 3.5 to 4 ft bgs. BAA was detected at an estimated 3,000 J µg/kg, which exceeded its human health criterion of 600 µg/kg. Benzo(b)fluoranthene was detected at an estimated 6,200 J µg/kg (BUTS08, 3.5 to 4 ft bgs), exceeding its human health (600 µg/kg) and ecological (5,500 µg/kg) screening criteria. Chrysene was detected at an estimated 8,600 J µg/kg, which exceeded its human health (6,000 µg/kg) and ecological (2,400 µg/kg) criterion. Phenanthrene was detected at an estimated 1,900 J µg/kg, which exceeded its ecological (1,300 µg/kg) screening criteria. This station, BUTS08, was sampled at a deeper

interval, 8.5 to 9 ft bgs, but did not have a detection reported of any of these 4 PAHs. The vertical extents of BAA, benzo(b)fluoranthene, chrysene, and phenanthrene have been evaluated sufficiently.

Phenol was detected twice at BUBS1061 at concentrations of 5,360 µg/kg (4.5 to 5 ft bgs) and 5,960 µg/kg (9.5 to 10 ft bgs), each of which exceeded its ecological (5,000 µg/kg) screening criteria. These were the only 2 subsurface soil samples collected at this station. However, this station, located on the western edge of Building 204, is encompassed by additional sampling in similar intervals that did not have a reported phenol exceedance. Phenol has been evaluated sufficiently vertically in the subsurface soil at the Building 204 Area.

Four BaP exceedances were detected in this area, with concentrations ranging from 45.9 µg/kg (BUBS1080, 4.5 to 5 ft bgs) to an estimated 1,700 J µg/kg (BUTS08, 3.5 to 4 ft bgs), each of which exceeded its human health screening criterion of 11.4 µg/kg. The BaP subsurface soil exceedances are grouped along the western edge of the Building 204 Area, the same area in which the BaP surface soil exceedances were encountered. Additional sampling in a westerly direction may be warranted to evaluate the horizontal extent of BaP in the surface and subsurface soil. The extent of BaP in the subsurface soil at this site is illustrated in Figure 2.4-11.

TPHs. A total of 62 subsurface soil sampled from 43 stations were analyzed for TPHs in the Building 204 Area. Of those, 4 samples had elevated concentrations reported of 3 TPH groups at levels exceeding their common ecological and human health screening criteria of 100,000 µg/kg. Diesel range (C14-C30) organics and EFH (21-C30) each was detected once at elevated concentrations of 250,000 µg/kg (BUTS01S04, 13 ft bgs) and 172,000 µg/kg (BUTS1077, 4.5 to 5 ft bgs), respectively. Station BUBS1077 was sampled in a deeper interval, 9 to 9.5 ft bgs, that did not have a TPH exceedance reported. Therefore, the vertical extent of the EFH (C21-C30) group has been evaluated adequately. The diesel range organics exceedance was encountered in the deepest interval of the BUTS01 group; however, it is encompassed by subsurface soil samples that did not have an exceedance reported, including a sample collected to the south at a deeper interval (BUBS08, 13.5 ft bgs). Because the diesel range organics exceedance was detected at the bedrock interface, its vertical extent has been evaluated sufficiently.

Lubricant oil range (C20-C30) organics were detected in 3 subsurface soil samples at levels exceeding the screening criteria, with concentrations ranging from an estimated 650,000 J µg/kg (BUTS01S02, 4 ft bgs) to 82,000,000 µg/kg (BUTS08, 3.5 to 4 ft bgs). Station BUTS08 was sampled in a deeper interval, 7.5 to 8 ft bgs, which did not have a lubricant oil range organics detection reported. This TPH group was detected in all 4 of the BUTS01 samples, grouped in the southern end of Building 2204, where the two lower-level exceedances were detected. However, these sampling stations are encompassed by additional sampling that did not have a detection of TPHs reported, including a sample from BUBS08 collected at 13.5 ft bgs. The vertical extent of the lubricant oil range organics have been addressed sufficiently, as shown in Figure 2.4-12.

VOCs. Forty-six subsurface soil samples were collected to a maximum depth of 25 ft bgs in the Building 204 Area and analyzed for VOCs. Four parameters were detected once at levels exceeding their respective screening criteria in 1 subsurface soil sample: SB-B204-3, 15 to 20 ft bgs. Benzene was detected at a concentration of 2,300 µg/kg and chlorobenzene at

16,000 µg/kg, each of which exceeded their human health criteria of 0.13 µg/kg and 97 µg/kg, respectively. Toluene was detected at 13,000 µg/kg and total xylenes were detected at 99,000 µg/kg, exceeding both their ecological (3,400 and 64,000 µg/kg) and human health (300 and 150 µg/kg) criteria, respectively. This sampling station was collected on the western side of the former UST from 20 to 25 ft bgs also, which did not have any VOC detections reported. Additionally, a sample collected from beneath the former UST, SB-B204-2 (17 to 22 ft bgs) did not have a reported VOC exceedances. The vertical extent of VOCs in the Building 204 Area has been evaluated adequately.

2.4.3 Soil Gas Nature and Extent

Forty soil gas samples were collected in the Building 204 Area from 34 locations to a maximum depth of 14 ft bgs. Figure 2.4-13 exhibits the sampling locations where soil gases were collected and analyzed for VOCs in the Building 204 Area. Two VOCs, benzene and toluene, were detected in the samples at levels exceeding the screening criteria. Table 2.4-5 lists the parameters detected in the soil gas samples collected in this area. The extent of VOCs encountered via soil gas sampling at this site is described below.

One benzene exceedance was detected as a soil gas at an estimated concentration of 38 J micrograms per cubic meter (µg/m^3) (BUSV1053, 4.5 to 5 ft bgs), exceeding its human health criterion of 36 µg/m^3. This exceedance was detected at the subsurface bedrock interface; there are several vapor sampling stations to the west and south that did not have benzene exceedances reported. Although there are a lack of samples to the north and east in this area, the analytical results from the neighboring ELV Area (discussed in the Group 2 RFI [NASA, December 2008]) did not have any benzene detections reported in the soil gas samples collected. Therefore, the extent of benzene vapors in the Building 204 Area has been evaluated sufficiently.

Four toluene vapor exceedances were reported in this area at concentrations ranging from an estimated 90 J µg/m^3 (BUSV1054, 4.25 to 4.75 ft bgs) to 2,800 µg/m^3 (BUSV06, 14 ft bgs), each of which exceeded its ecological screening criterion of 84 µg/m^3. The 3 toluene vapor exceedances detected at the bedrock interface in the northeastern portion of this site are evaluated sufficiently by additional samples collected in similar and deeper intervals. Similar to the benzene exceedance, the sampling results presented for the ELV Area in the Group 2 RFI (NASA, December 2008) provided extent in a northeasterly direction. The extent of toluene as soil gas, therefore, has been evaluated adequately, as shown in Figure 2.4-14.

2.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the Building 204 Area is described Section 2.8.1.4.

2.6 Fate and Transport Analysis for Chemicals Detected in Surficial Media

2.6.1 Contaminant Sources and Release Mechanisms

The primary release mechanisms for contamination at the Building 204 Area are automotive maintenance operations, automotive painting operations, potential releases from chemicals stored in the area (including the USTs), and debris deposited west of the buildings at this site. Secondary release mechanisms may be related to equipment that burned in the 2005 wildfire, and potential releases related to the power substation to the northwest of the main Building 204 AOC.

2.6.2 Potential Routes of Migration

The primary pathway for contaminant transport from the source areas at this site is the vertical migration of contaminants from the surface soil to subsurface soil. A secondary transport mechanism for this site includes the release of surface soil to the air by wind erosion or volatilization.

2.6.3 Contaminant Persistence

Dioxins, inorganics, PCBs, SVOCs, TPHs, and VOCs were detected in the soil at the Building 204 Area at levels above their respective screening criteria. Additionally, VOCs were detected in the soil gas at concentrations at levels above their screening criteria. This subsection describes the chemicals applicable to this area.

2.6.3.1 Parameters Exceeding Criteria

Dioxins, inorganics, PCBs, SVOCs, TPHs, and VOCs are described below.

Dioxins. Dioxins are characterized by extremely low vapor pressures, high log K_{ow}, high K_{oc}, and extremely low water solubilities. Their strong adsorption to soil, low water solubilities, and high K_{oc} values indicates that the rate of transport from unsaturated zone soils to the water table via rain infiltration would be extremely low.

Because dioxins have low vapor pressure, they are not very volatile and tend to stay bound to particles. Dioxins also have low solubility; thus, aerially deposited dioxins tend to stay adsorbed to soils in the top few millimeters in surface soil.

Inorganics. Several metals were detected at this site at levels above the screening criteria. Many metals are naturally occurring and their reported presence may or may not indicate a contaminant release. The mobility of metals is complex and depends on several factors such as the overall groundwater composition, pH, metal complex formation, valence state of the metal, and cation-ion exchange capacity. Metals typically are not volatile. In the water phase, the total metal concentration includes the dissolved metal concentration and the suspended metal concentration, which is sorbed to colloidal particles. Therefore, elevated metals concentrations in groundwater may be due to the suspended load and not just to the dissolved aqueous chemistry.

PCBs. PCBs are persistent in the environment. Aroclor-1254 and Aroclor-1260 are characterized by low water solubility, moderate volatility, high affinity for organic matter, and high resistance to chemical or biological degradation. They will strongly sorb to soil and do not tend to leach to groundwater. In surface water, they will partition to sediment and sorb to organic matter. PCBs will bioaccumulate in aquatic organisms.

SVOCs. PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. High-molecular weight (HMW) PAHs are more likely to be transported via particulate emissions, while low-molecular weight (LMW) PAHs have a greater tendency to volatilize (ATSDR, 1995). In general, PAHs are more likely to sorb to soil or organic matter than to partition significantly to water. Photolysis and biodegradation are two common attenuation mechanisms for PAH compounds (Howard, 1991). Animals and microorganisms can metabolize PAHs to products that ultimately reach complete degradation.

TPHs. TPHs are defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. The lighter petroleum products such as gasoline contain constituents with higher water solubility and volatility and lower sorption potential than heavier petroleum products such as fuel oil. Data compiled from gasoline spills and laboratory studies indicate that these light-fraction hydrocarbons tend to migrate readily through soil, potentially threatening or affecting groundwater supplies. In contrast, petroleum products with heavier molecular weight constituents, such as fuel oil, generally are more persistent in soils because of their relatively low water solubility and volatility and high sorption capacity (Stelljes and Watkin, 1991).

VOCs. VOCs are characterized by relatively high vapor pressures, Henry's Law constants, and generally high solubility in water. VOCs have a tendency to partition to the vapor phase from either soil or surface water and could be released through volatilization from contaminated soil. The sorption potential of VOCs is variable; some may persist in soil or sediment, while some are highly mobile in soil. VOCs will leach to groundwater and may persist, depending on their ability to degrade or transform in the environment.

2.6.4 Contaminant Migration

The primary source for contaminant migration is from potential leaks and spills associated with chemicals used in operations and stored at this site. Secondary sources may the debris areas west of the main operations and the substation to the northwest of the primary Building 204 AOC.

2.6.5 Surface Soil Contaminants

Dioxins, metals, PCBs, SVOCs, and TPHs have been identified in the surface soil at levels above the background and/or health-based risk criteria. The following observations were made for contaminants in surface soil:

- Dioxins were detected in all 7 of the surface soil samples collected, each with reported 2,3,7,8-TCDD TEQ values exceeding the human health and ecological screening criteria. All 7 locations were in the vicinity of a power pole, south of Service Area Road, which was affected by the wildfires of 2005.

- Of the metals detected in the surface soil in the Building 204 Area, 13 metals were reported at concentrations exceeding 1 or more of the criteria. Most metals will require further evaluation to asses the horizontal extent to the west of the primary AOC.
- Of the 47 sample locations collected for PCBs in the surface soil at this site, 3 PCB-aroclors (Aroclor-1248, 1254, and 1260) were reported at concentrations exceeding the comparison criteria in the surface soil. Higher concentrations were detected in the northwestern portion of the site, near the relatively large substation.
- Of the 77 surface soil samples analyzed for SVOCs, 6 had reported exceedances of a combined 3 SVOC parameters, including 1 phthalate and 1 PAH.
- Of the 58 surface soil locations collected for SVOCs in the surface soil samples in the Building 204 Area, 2 TPH groups exceeded the screening criteria at 8 locations. The EFH (C21-C30) group have been evaluated adequately in an easterly direction.

2.6.6 Subsurface Soil Migration

The following observations were made for the contaminants in subsurface soil:

- Dioxins were not detected in the 1 subsurface soil analyzed, which was located near the surface soil exceedances. Dioxin migration appears to be limited to the surface soil at this site.
- Of the 45 samples analyzed for metals, 4 exhibited elevated concentrations of a combined 11 metals parameters. The vertical extent characterization appears to indicate that vertical migration is limited.
- Of the 26 subsurface soil samples analyzed, 5 exhibited elevated concentrations of 2 PCB aroclors–Aroclors-1254 and 1260. The vertical migration appears to have been evaluated sufficiently.
- Six samples had elevated concentrations of a combined 5 SVOC parameters, 4 of which were PAHs.
- Of the 62 subsurface soil samples analyzed for TPHs, 4 exhibited exceedances of a combined 3 TPH groups. The vertical migration of TPHs in the Building 204 Area have been sufficiently evaluated.
- Four VOCs were detected once, at 1 location, beneath former UST UT-49. A nearby, deeper interval sample suggests that these parameters are not migrating vertically.

2.6.7 Soil-to-Groundwater Migration

The relationship among the chemicals detected in soil, soil gas, and groundwater has been evaluated to assess whether soil chemical concentrations have affected the groundwater quality. Soil chemical concentrations were reviewed and compared with available groundwater concentrations immediately south of the Building 204 Area. The evaluation was based on the chemicals detected, background concentrations, spatial distribution, and hydrogeologic conditions. The evaluation provides conclusions regarding soil sources for detected chemicals in groundwater.

NSGW has not yet been encountered at the Building 204 Area; therefore, groundwater affected by soil contamination in the immediate area cannot be confirmed at this time, even though the presence of NSGW is unlikely. Site conditions will be assessed by evaluating NSGW in piezometers PZ-151 and 152 if water is present during the rainy season. Soil and soil gas results do not indicate potential source areas for constituents, mainly TCE and other VOCs, detected in the Chatsworth formation groundwater. The input location for the CFOU TCE plume beneath the Building 204 Area has not been determined, but the RI results indicate its source is not from within the SMOU study area.

2.7 Human Health Risk Assessment for Building 204 Area

The objective of this HHRA is to assess whether the environmental media at the Building 204 Area could pose risks to human health at levels that might require remedial action, or risk at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil and soil gas at the Building 204 Area. The methods and guidance documents used in the preparation of this HHRA are discussed in Section 1.5.3 of this report. A discussion of the HHRA results for the Building 204 Area is presented below. The results are summarized in Section 2.9.2.

The concentration data, input parameters, and results of the HHRA for the Building 204 Area are presented in Appendix B. An index of the tables (Appendix B human health RA Tables Index) is provided and can be used to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated non-cancer HIs.

2.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the Building 204 Area, based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

2.7.1.1 Data Evaluation

The soil and soil gas analytical data at the Building 204 Area were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.5.3.1. Sediment and surface water data were not collected as part of the RI site characterization activities. NSGW is not present at the site. The locations of the soil and soil gas samples used in this HHRA are shown in Figures 2.4-1 and 2.4-13. The samples used in this HHRA are listed in Table B.2.1-1 by medium, sample ID, sampling depth interval, and date of collection. Table B.2.1-2 lists the target receptor populations by medium. Descriptive summary statistics of these data are provided in Table B.2.1-3.

2.7.1.2 Identification of COPCs in Soil

The results of the COPC screening process for soil at 0 to 2 ft bgs and 0 to 10 ft bgs are listed in Table B.2.1-3. Detected analytes in soil at the Building 204 Area were compared to background levels. COPCs identified in soil (0 to 2 ft bgs) included 2 inorganics (barium, and iron) and 46 organics. COPCs identified in soil (0 to 10 ft bgs) included 1 inorganic (barium) and 49 organics.

2.7.1.3 Identification of COPCs in Soil Gas

The results of the COPC screening process for soil gas at 3 to 10 ft bgs are presented in Table B.2.1-3. Nine COPCs were identified in soil gas.

2.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the Building 204 Area may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential exposures. Figure 1.5-2 depicts the conceptual exposure model for the Building 204 Area. Table B.2.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

2.7.2.1 Identification of Receptors

The Building 204 Area recently was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the industrial worker and recreationist exposure scenarios were evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

2.7.2.2 Identification of Exposure Pathways

Future residents and industrial workers were assumed to be exposed to soil gas (modeled for migration to indoor air and ambient air) and soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). Future recreationists were assumed to be exposed to soil gas (modeled for migration to ambient air) and soil (0 to 2 ft bgs). Inhalation exposures were quantified for the migration of soil gas to ambient air and indoor air. Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the Building 204 Area are provided in Table B.2.1-6.

2.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs, soil at 0 to 10 ft bgs, and soil gas at the Building 204 Area are listed in Table B.2.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts, ambient air, indoor air, and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for non-volatile COPCs. The derivation of the PEF for soil is listed in Table B.2.1-5.

Ambient air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs to ambient air and migration from groundwater to ambient air. Parameter values used for soil gas-to-air migration and for estimating the

ambient air EPCs related to soils are listed in Table B.2.1-8. Parameter values used for estimating ambient air EPCs related to groundwater also are listed in Table B.2.1-8. The estimated ambient air concentrations from the migration of volatile COPCs in soil are listed in Tables B.2.1-9 and B.2.1-10.

Indoor air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs using the J-E Model (EPA, 2004e). The parameter values used in the J-E Model (EPA, 2004e) are presented in Table B.2.1-8. The estimation of indoor air concentrations from soil gas are presented in Tables B.2.1-11 through B.2.1-14.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b). COPC concentrations in edible plant tissues from soil at 0 to 2 ft bgs are presented in Table B.2.1-15.

2.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate chemical intakes for potential adult and child residential, adult and child recreationist, and industrial worker receptors at the Building 204 Area. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix B. See the Appendix B human health RA Tables Index for the exposure parameters and chemical intakes for each exposure scenario.

2.7.3 Risk Characterization

In the risk characterization component of the HHRA process, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.5.

The exposure assumptions, EPCs, toxicity factors, and risk characterization results tables for this HHRA are presented in Appendix B (Appendix B human health RA Tables Index**)**. The risk calculation tables present the estimated ELCRs and non-cancer HIs for potentially exposed receptors and individual exposure routes for soil, indoor air, and ambient air at the Building 204 Area, as well as the cumulative risks and HIs across the exposure routes for the RME and CTE scenarios. Table B.2.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are listed in Table B.2.5-2.

2.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from

soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-6} for the CTE case to 4×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.1 for the CTE case to 1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 7×10^{-5} for the CTE case to 4×10^{-3} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 6 for the CTE case to 136 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. Dioxins/furans (based on the 2,3,7,8-TCDD TEQ concentrations) are the primary contributors to the ELCR and HI for the plant consumption route. Dioxins/furans contribute 96 to 99 percent of the total ELCR and 69 to 72 percent of the total HI for the plant consumption pathway. The highest concentrations of dioxins/furans in soil (0 to 2 ft bgs) were detected at sample locations BUBS0022S01 and BUBS0022S70, both of which are southeast of Building 2204 and outside the Building 204 Area boundary (Figure 2.4-1). The 2,3,7,8-TCDD TEQ concentrations were 6.48×10^{-4} mg/kg at BUBS0022S01 and 2.05×10^{-4} mg/kg at BUBS0022S70. The 2,3,7,8-TCDD TEQ concentrations at these two sample locations were approximately an order of magnitude greater than the 2,3,7,8-TCDD TEQ concentrations at other sample locations at the Building 204 Area.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-6} for the CTE case to 4×10^{-5} for the RME case. The CTE ELCR estimate is equal to the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.08 for the CTE case to 1 for the RME case. The CTE and HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-7} for the CTE case to 5×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The HI estimates for non-cancer effects range from 9×10^{-4} for the CTE case to 0.002 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from $1x\ 10^{-9}$ for the CTE case to 6×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from $1x\ 10^{-5}$ for the CTE case to 2×10^{-5} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

2.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-6} for the CTE case to 9×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 1 for the CTE case to 9 for the RME case. The CTE HI estimate is equal to the regulatory threshold value of 1 and the RME HI estimate exceeds the regulatory threshold of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 7×10^{-5} for the CTE case to 1×10^{-3} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 9 for the CTE case to 150 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. Dioxins/furans (based on the 2,3,7,8-TCDD TEQ concentrations) are the primary contributors to the ELCRs and HIs for the plant consumption route. Dioxins/furans contribute 96 to 99 percent of the total ELCR and 69 to 72 percent of the total HI for the plant consumption pathway. As previously mentioned, the highest concentrations of dioxins/furans in soil (0 to 2 ft bgs) were detected at sample locations BUBS0022S01 and BUBS0022S70, both of which are southeast of Building 2204 and outside the Building 204 Area boundary (Figure 2.4-1).
- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-6} for the CTE case to 1×10^{-4} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the

RME ELCR estimate is equal to the upper end of the regulatory risk range. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.8 for the CTE case to 9 for the RME case. The CTE HI estimate is less than the regulatory threshold of 1 and the RME HI estimates exceeds the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-7} for the CTE case to 4×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.005 for the CTE case to 0.006 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-9} for the CTE case to 4×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 6×10^{-5} for the CTE case to 7×10^{-5} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

2.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposures to COPCs in soil and soil gas were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-7} for the CTE case to 1×10^{-5} for the RME case. The RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.008 for the CTE case to 0.3 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have

migrated to ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-11} for the CTE case to 6×10^{-10} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 6×10^{-7} for the CTE case to 3×10^{-6} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

2.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposures to COPCs in soil and soil gas were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. A hypothetical future recreationist child (15-kg body weight) was assumed to be exposed for 350 days per year over 6 years for the RME case and 6 years for the CTE case. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-6} for the CTE case to 3×10^{-5} for the RME case. The CTE ELCR estimate is equal to the lower end of the regulatory risk range of 1×10^{-6} to 1 x 10-4 and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.2 for the CTE case to 3 for the RME case. The CTE HI estimate does not exceed the regulatory threshold value of 1 and the RME HI estimate does exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-10} for the CTE case to 1×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 4×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

2.7.3.5 Hypothetical Future Industrial Worker Exposure Scenario

Potential industrial worker exposure to COPCs in soil and soil gas were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust

in ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-7} for the CTE case to 6×10^{-5} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.07 for the CTE case to 1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-7} for the CTE case to 6×10^{-5} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.05 for the CTE case to 1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated inside a future industrial building. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 3×10^{-4} for the CTE case to 6×10^{-4} for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-9} for the CTE case to 5×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 1×10^{-5} for the CTE case to 2×10^{-5} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

2.7.4 Uncertainty Discussion

Uncertainties associated with the results of this HHRA are a function of both the "state of the practice" of HHRA in general and of the UFs specific to the Building 204 Area. A discussion of the general HHRA uncertainty is presented in Section 1.5.3.

2.8 Ecological Risk Assessment for Building 204 Area

2.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to the RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the Building 204 Area are described below.

2.8.1.2 Site Background

The Building 204 Area has operated as the Plant Services Building for Areas I, II, III, and IV at SSFL, providing equipment maintenance, automotive maintenance and repair, and building maintenance services. The Building 204 Area is made up of five buildings that were constructed in 1956. Three former USTs were located at Building 2204. A more detailed discussion of the site conditions and history is presented in Section 2.1.

The Building 204 Area is approximately 4.1 acres; of those, 37 percent is developed (pavement, roads, or buildings). Ruderal vegetation, grassland, or rock account for approximately 23, 7, and 2.5 percent of the site, respectively (Figure 2.8-1). Shrub/scrub vegetation (mulefat, coast live oak, and laurel sumac) was observed to cover 2 percent of the site. Multiple bird and mammal species (house finch, red-tailed hawk, western scrub-jay, white-throated swift, California towhee, spotted towhee, gopher [burrows], coyote [scat], and rodents [burrows]) were observed to use the site. The western fence lizard also was observed at the site.

2.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the Building 204 Area is the same as that for the Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the Building 204 Area are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 2.8-1).
- Representative species and receptor groups considered for the Building 204 Area include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

2.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the Building 204 Area is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the Building 204 Area is described below and presented in Figure 2.8-2.

The primary contaminant sources at the Building 204 Area include discharges as a result of vehicle and equipment maintenance, equipment cleaning activities, and storage of hazardous wastes. Primary release mechanisms include spills and leakage to the ground surface from storage of chemicals and vehicle maintenance activities or leaks to subsurface soils from the USTs. Soil is the secondary source of potential contaminant. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater.

Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). Table 2.8-2 provides additional descriptions of potential exposure pathways for the ecological receptors at the Building 204 Area, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

2.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil and soil gas are listed in Table 2.8-3. Summary statistics for those detected analytes are listed in Table 2.8-4. A central tendency background comparison for metals and for dioxins/furans in soils was conducted to assess whether the analytes were consistent with background (Table 2.8-5). The volatile organics in soil and soil gas are compared in Table 2.8-6. Non-detect analytes were evaluated by comparing the maximum SQLs against the minimum ESL and determining the exceedance frequency of the SQLs (Table 2.8-7). The CPECs identified for the Building 204 Area are summarized in Table 2.8-8. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 2.8-9, 2.8-10, and 2.8-11, respectively. EPCs for soil gas from 0 to 6 ft bgs are listed in Table 2.8-12. Calculations for extrapolating soil gas concentrations from soil concentrations are listed in Table 2.8-13.

2.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 2.8.1) with the risk characterization (Section 2.8.3) and consists of the technical evaluation of ecological and chemical data to evaluate the potential for ecological exposure and effects. Generalized components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the Building 204 Area is presented below.

2.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including

receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this subsection.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the Building 204 Area. Because the Building 204 Area is strictly terrestrial, exposure is based on soil and soil gas and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

Although the Building 204 Area is 4.1 acres, the spatial extent of samples associated with the site is 6.24 acres. More than 60 percent of the land cover at this site consists of buildings, pavement, rock, ruderal, or stressed vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) and soil gas were calculated for the Building 204 Area, according to the approach outlined in Section 1.5.4.4. These values are presented in Tables 2.8-9 through 2.8-12. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 2.8.3).

2.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for the receptors at SSFL are summarized in Section 1.5.4.4. No effects data specific to the Building 204 Area are available. Consequently, the ESLs, Low TRVs, and High TRVs for terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

2.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the Building 204 Area. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the Building 204 Area. The results of these comparisons are presented below.

2.8.3.1 Risk Estimation

The risk estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 2.8-14 through 2.8-21, with Table 2.8-22 summarizing the risk estimation for terrestrial exposures. Table 2.8-17 presents an analysis of the depth intervals for evaluation of burrowing animals (deer mouse). The 0- to 6-foot-bgs depth interval had the greatest HI; therefore, the data from this depth were used to evaluate the deer mouse.

2.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with any other available and appropriate lines of evidence to evaluate potential chemical impacts on ecological receptors in SSFL's Group 3. Chemicals that had HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of COECs

includes receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.
2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.
5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.
6. No Risk–HQs and associated HIs<1.
7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Seven soil analytes (barium, hexavalent chromium, iron, 2,3,7,8-TCDD TEQ, PCB TEQ, 2,4-dinitrophenol, and hexachlorobenzene) were found to have one or more HQs greater than 1 under any scenario (Table 2.8-24). The other soil analytes and/or analyte groups were found to pose no risk (HQs and HIs were less than 1) to receptors under any scenario (maximum concentration for plants, invertebrates, and soil gas exposures; CTE and RME concentrations for birds and mammals) at the Building 204 Area.

Three inorganics, barium, iron, and sodium, were identified at elevated levels relative to background, based on the non-parametric central tendency background comparisons for soil (Table 2.8-5). Although no background data were available for hexavalent chromium, onsite total chromium concentrations were not significantly different from background. Barium and iron had one or more HQs above 1 for at least one receptor in the refined screen. TRVs generally were not available for sodium. On the basis of the risk ranking discussed above, barium was found to pose a medium risk (1<HQs<2 for High TRV [RME], but HQ>10 for Low TRV [RME]) and iron was found to pose to pose high risk (HQs>5 for High TRV [RME]).

Risks from barium are predicted for the hermit thrush, based on the high TRV and RME in the refined screen (HQs of 1), and for the deer mouse, with a RME high TRV-based HQ of 1.4. High TRV-based HQs for the deer mouse, based on the CTE, also exceeded 1 (1.4). Risks were not predicted for other wildlife, plant, or invertebrate receptor. Although 81 percent of samples collected in the 0- to 6-foot-bgs interval and 89 percent of the samples collected in the 0- to 2-foot-bgs sample interval exceeded the background RME concentration of 65.3 mg/kg, the incremental risk is still low (Table 2.8-23). The high TRV-based incremental HQs were less than 1. This result suggests that the most of the predicted exposure is associated with naturally occurring barium concentrations. Consequently, the overall risk from barium is acceptable.

Hexavalent chromium had an HQ of 15 for terrestrial invertebrates, but had no predicted risk for wildlife receptors. Additionally, only 3 detected concentrations (of 15 samples) exceeded the soil invertebrate TRV of 0.2 mg/kg ; therefore, the risks from hexavalent chromium are acceptable.

The risks from iron were predicted for the mule deer, based on the low TRV and RME in the refined screen (HQ=5.2), and for the terrestrial invertebrates HQ of 21. High TRV-based HQs for the wildlife receptors were less than 1. The predicted risk was considered high because a high TRV-based HQ was greater than 1. Of the 5 samples collected, only 1 had a concentration above the RME background concentration (18,600 mg/kg) and the incremental risk generally was considered low (Table 2.8-23). This result suggests that most of the predicted exposure is associated with naturally occurring iron concentrations. Consequently, the overall risk from iron is acceptable. In addition to barium, dioxin/furan and PCB congeners (based on the evaluation of 2,3,7,8-TCDD TEQs), were found to fail one or more screens for one or more receptors (Table 2.8-23). The risks from dioxin/furans were considered high, with one or more high TRV-based HQs above 5. Both the deer mouse and hermit thrush had high TRV-based HQs above 1, based on the RME (HQs = 87 and 9, respectively). On the basis of the CTE, these HQs dropped to 15 and 2, respectively. Dioxin/furans were analyzed in 7 samples. The maximum DIOXTEQ was detected at BUBS0022S01, followed by the DIOXTEQ at BUBS0022S70. The congener 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin (1,2,3,4,6,7,8-HpCDD) was the largest contributor to the mammal TEQ, while 2,3,4,7,8-pentachlorodibenzofuran (2,3,4,7,8-PeCDF) was the largest contributor to the bird TEQ. On the basis of the high predicted risk from dioxin/furans and the low sample size (n=7), additional investigation is recommended. On the basis of the PCBTEQ, none of the high TRV-based HQs exceeded 1 under any scenario. The low TRV-based HQs for the hermit thrush (HQ=1.1) and deer mouse (HQ=3.4) were both greater than 1 but less than 5, based on the RME. On the basis of the CTE, both low and high TRV-based HQs were less than 1 for the hermit thrush; for the deer mouse, the low TRV-based HQ was 1.7, while the high TRV-based HQ was less than 1. Because the magnitude of exceedance generally was low for both receptors and none of the high TRV-based HQs were above 1, the overall risks from PCB congeners are considered to be low.

Two non-detect analytes, 2,4-dinitrophenol and hexachlorobenzene, had one or more HQs above 1, based on the maximum SQL. On the basis of the RME screen, the high TRV-based HQ for the hermit thrush was 15 for 2,4-dinitrophenol, although the CTE-based HQs were less than 1. On the basis of these HQs, the risk for 2,4-dinitrophenol is considered to be high. It should be noted, however, that risk based on the RME screen was based on the

maximum SQL of 194 mg/kg. The remaining 50 samples had SQLs of 7.4 mg/kg or less. On the basis of the second highest SQL, the resulting HQs for the deer mouse are less than 1, while the high TRV-based HQ for the hermit thrush is less than 1 and the low TRV-based HQ is 5.7. For hexachlorobenzene, the low and high TRV-based HQs for the deer mouse both were greater than 1, with respective RME-based HQs of 290 and 1,000; therefore, the risk is considered to be high. However, based on the CTE screen, the low TRV-based HQ was 9.3 and the high TRV-based HQ was 2.6. It should be noted that the RME screen was based on the maximum SQL (97 mg/kg). All of the other 50 samples had SQLs of 3.47 mg/kg or less. On the basis of the second highest SQLs, the resulting HQs for the hermit thrush were less than 1 and the high TRV-based HQ is 10. Because these analytes were both non-detect, the RME screen was conducted using the maximum SQL, and the risk probably is driven by only a few samples that had elevated SQLs. Therefore, this evaluation is considered conservative and risk is acceptable.

Soil gas CPECs were identified and evaluated as part of this ERA. Ten analytes were detected in soil gas, 1 non-detect was carried forward based on a comparison of SQLs to ESLs, and concentrations of 17 analytes were modeled based on detections in soil (Table 2.8-13). Of these, one analyte had an HQ greater than 1 (Table 2.8-17). 1,1,2-TCA, a non-detect analyte, had an HQ of 18. The TRV for this analyte is conservative and was derived from an LD50 using an uncertainty factor of 100. The application of the uncertainty factor may overestimate or underestimate a no-effect level. Additionally, this evaluation used the maximum SQL and TRVs based on a no effect level. If the mean SQL was used, the HQ would be 4. Consequently, the risk from the evaluated VOCs is acceptable.

Tables 2.8-24 and 2.8-25 list the soil chemicals of ecological concern and the soil gas COECs, respectively.

2.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component in all risk assessments. Generalized uncertainties for ERAs in SSFL's Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- Samples were collected outside of the site boundary in an effort to evaluate potential releases from the Building 204 Area. If sample concentrations decreased with distance from the site, the inclusion of these additional data may underestimate risk in the core portion of the site when these data are integrated into the RME and CTE calculations.
- Aroclor data were not evaluated in this assessment because PCB congener data were available and were used to calculate a TCDD TEQ. PCBs and dioxin/furans were evaluated based on the 2,3,7,8-TCDD TEQs. Concentrations of aroclors were low, and these are not expected to be significant COCs.
- No screening levels were available to evaluate the TPH data; however, PAH data were available and no risks from these constituents were predicted.

2.8.4 Conclusions and Recommendations

Of the soil analytes that were evaluated, dioxin/furans were found to pose a high risk to the ecological receptors evaluated at the Building 204 Area. Barium and iron were found to

pose medium and high risks, respectively, to birds and mammals, but based on the low incremental risk, the overall risk was considered insignificant. Of the remaining soil analytes, 45 posed no risk and 3 lacked TRVs. No analytes in soil gas were considered to pose inhalation risks to burrowing mammals.

On the basis of the high predicted risk and low sample size, dioxin/furan congeners are recommended for additional evaluation in the CMS.

2.9 Summary of Findings and Recommendations for the Building 204 Area

2.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of potential contaminants at the Area II Building 204 Area, 110 surface soil, 88 subsurface soil, and 40 soil gas samples were collected. Of the surface soil samples collected, dioxins (compared as 2,3,7,8-TCDD TEQ), 13 metals (including hexavalent chromium), 3 PCB aroclors, 3 SVOCs, 2 TPH groups, and 1 VOC exceeded the applicable screening criteria. The parameters that exceeded the criteria are listed in Table 2.9-1. Although the data indicate some migration downgradient to the west and some of the exceedance locations are evaluated sufficiently by samples that did not have reported exceedances, additional sampling for several parameters in this area appears warranted. Dioxins were detected at the highest concentrations throughout Group 3 around the transformer pole south of Service Area Road; additional sampling surrounding that area probably is warranted. Seven metals (antimony, cadmium, copper, lead, mercury, silver, and zinc) appear to not be sufficiently characterized to the west of this area; these parameters were detected in the westernmost samples collected. Chromium VI exceedances were limited to the area of Building 2796, and additional sampling to the south and east may be required to further evaluate extent. Two PCBs, Aroclors-1254 and 1260, were detected, notably in the northwestern portion of this site, near the relatively large substation. Additional PCB investigation may be required around this feature to further evaluate PCBs in this area. One PAH, BaP, was detected at elevated concentrations in the westernmost samples, and similar to several metals, characterization of this parameter appears to be insufficient in the westerly direction.

In the subsurface soil samples collected, 11 metals, 2 PCB aroclors, 6 SVOCs, 3 TPH groups, and 4 VOCs were detected at concentrations that exceeded 1 or more of the applicable screening criteria. Most parameters detected at elevated concentrations appear to have been evaluated adequately vertically, with a few exceptions. Metals have been evaluated adequately in the subsurface soil. The vertical extent of PCBs, as the sampling results show currently, has been addressed sufficiently. However, additional sampling appears warranted in the surface soil, and additional subsurface soil sampling for PCB aroclors may be appropriate, based on the results of the surface soil sampling results. Similar to surface soil conditions, PAHs may need to be further investigated in a westerly direction to further evaluate BaP. The extents of TPHs and VOCs in the subsurface at this site have been evaluated adequately.

Two VOCs, benzene and toluene, were reported at levels exceeding the applicable screening criteria in soil gas collected at the site. These exceedances were encountered mostly in the

northeastern portion of the site near Building 2233. The likely source of the soil gas contamination is solvent spills from paint thinners stored in this area. The extent of VOCs as soil gases has been addressed sufficiently at this site.

2.9.2 Risk Assessment Summary

The human health and ecological risks at Building 204 are summarized in the following text.

2.9.2.1 Summary of Human Health Risks

This subsection summarizes the HHRA performed for the Building 204 Area. The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), and soil gas. The methods used to prepare the HHRA are described in Section 1.5.3. The results of the HHRA for the Building 204 Area are presented in Section 2.7.

The surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), and soil gas samples collected during the RI sampling activities were evaluated for use in the HHRA. Surface water and sediment samples are not evaluated in this HHRA, because they were not present during the RI site characterization activities. The HHRA data set is listed in Table B.2.1-3 in Appendix B. The COPCs identified from the Building 204 Area HHRA data set for each exposure area are listed in Table B.2.1-4.

The potential future receptors at the Building 204 Area include recreationists, workers, and residents. The Building 204 Area and surrounding area is likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report. The assumed exposure pathways for future residents, workers, and recreationists are shown in Figure 1.5-2.

Generally, estimated cumulative cancer risks (ELCRs) less than the regulatory risk range (range of 1 in a million [1×10^{-6}] to 1 in 10,000 [1×10^{-4}]) and estimated non-cancer hazards (HIs) less than the regulatory threshold value of 1 are considered acceptable (EPA, 1993). Estimated ELCRs within the 1×10^{-6} to 1×10^{-4} range are managed on a site-specific basis. Table B.2.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are listed in Table B.2.5-2.

The following exposure scenarios for the Building 204 Area exceed or are within the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)

- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)

The primary contributor to the ELCR for the soil exposure pathways is 2,3,7,8-TCDD TEQ (ranging from 97 to 99 percent of the ELCR estimate) (Table B.2.5-2).

The following exposure scenarios for the Building 204 Area are less than the regulatory risk range for carcinogenic COPCs:

- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of soil gas COPCs) and indoor air (migration of soil gas COPCs)

The following exposure scenarios for the Building 204 Area exceed the regulatory threshold values for non-cancer COPCs:

- Hypothetical future child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future child recreationist exposed to soil (0 to 2 ft bgs)

The primary contributor to the HI for the soil exposure pathways is 2,3,7,8-TCDD TEQ (ranging 96 to 99 percent of the ELCR estimate) (Table B.2.5-2).

The following exposure scenarios for the Building 204 Area are less than the regulatory threshold value for non-cancer COPCs:

- Hypothetical future adult residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult recreationist exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of soil gas COPCs) and indoor air (migration of soil gas COPCs)

The ELCR estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory risk range. The primary contributor for this scenario is 2,3,7,8-TCDD TEQ (ranging from 96 to 99 percent). The HI estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory threshold value. The primary contributors for this scenario are 2,3,7,8-TCDD TEQ (ranging from 69 to 72 percent) and 2,4-dimethylphenol (ranging from 25 to 26 percent).

As described in Sections 1.5.3.6 and 2.7.4, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

2.9.2.2 Summary of Ecological Risks

Of the soil analytes that were evaluated, dioxin/furans were found to pose a high risk to the ecological receptors evaluated at the Building 204 Area. Barium and iron were found to pose medium and high risks, respectively, to birds and mammals, but based on the low

incremental risk, the overall risk was considered to be insignificant. Of the remaining soil analytes, 45 posed no risks and 3 lacked TRVs. No analytes in soil gas were considered to pose inhalation risks to burrowing mammals.

2.10 Recommendations for Building 204 Area

To complete the nature and extent evaluation in the Building 204 Area, additional surface soil samples for dioxins, 8 metals (antimony, cadmium, chromium VI, copper, lead, mercury, silver, and zinc), 2 PCBs (Aroclor-1254 and Aroclor-1260a), and 1 PAH (BaP) are recommended. In the subsurface soil media, additional investigation for the extent of BaP is recommended. In addition, as noted, additional subsurface soil sampling for PCBs may be warranted based on the results of potential step-out sampling for PCBs in the surface soil media.

Potentially significant human health risks were identified for dioxins/furans (based on the 2,3,7,8-TCDD TEQ concentrations) in soil (0 to 2 ft bgs and 0 to 10 ft bgs). It is recommended that the localized extent of dioxins/furans in soil be further evaluated. After the further evaluation of the extent of contamination, removal of soils with elevated dioxin/furan concentrations is recommended at this location to reduce human health risks. Elevated human health risks were estimated for the plant consumption pathway for soil (0 to 2 ft bgs). It is recommended that that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC.

On the basis of the ERA results, additional investigation and evaluation of dioxin/furan congeners is recommended at the Building 204 Area.

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3. Storable Propellant Area (SPA)

3.1 SPA Background and History

The Area II SPA was used to store bulk quantities of hazardous materials, mostly in connection with tests conducted at the Alfa and Bravo Testing Facilities. A historical review suggested that this site was active from approximately 1956 until 2005. Nine buildings, 14 tanks, drum storage areas, and 2 treatment ponds are associated with and within the SPA site boundary. Some of these features are designated as SWMUs or AOCs. These features are described further below.

3.1.1 SWMUs and AOCs

Two SWMUs have been designated within the SPA. SWMU 5.16 and SWMU 5.17 commonly are called SPA-1 and SPA-2, respectively; each is a surface impoundment and drainage area. These areas were used to contain and treat hazardous wastes, such as those composed of TCE, petroleum, hydrazine-based fuels, DCE, vinyl chloride (VC), and methyl ethyl ketone (MEK). The surface impoundments primarily were used for emergency propellant spills; however, they also were used in the drum and tank rinsing activities. Both SPA-1 and SPA-2 and their associated drainage lines were gunite-lined. Discharge lines eventually lead to the Silvernale Reservoir. The reported capacity for SPA-1 was 41,300 gallons, while the capacity of SPA-2 was a reported 18,000 gallons.

Use of these SWMUs ended in 1985 and excavation and removal of the liners began in 1988. Backfill was added and the drainage lines were capped. Closure efforts concluded in June 1989.

3.1.2 Site History

The SPA was acquired by NASA in 1973, along with the remainder of the Area II property (known as USAF Plant 57 under ownership of the USAF). The buildings and facilities associated with the SPA and their related purposes are outlined below.

Construction dates currently are unavailable for most of the buildings at the SPA; however, it is likely that most of the area was developed in the mid-1950s along with the rest of the Area II operations used to support the Test Stand activities. Building 2519 was the primary storage area for hazardous materials and propellant ingredients. Building 2761 has been identified as a weigh station. Buildings 2769, 2770, 2925, and 2926 were general purpose storage sheds for equipment and supplies. Items such as palates, heavy equipment, general purpose tooling, and other miscellaneous items were stored in these areas. Additionally, it was reported that 200 gallons of sodium hexametaphosphate 25-percent solution and 6,400 pounds of activated carbon also were stored at Building 2770. Buildings 2777 and 2928, which were situated to the northeast of the main SPA location, were used to house hydrogen peroxide. Finally, Building 2927 was used to house petroleum-based fuels.

Two concrete pads located at this site were used to store oxidizers (nitrogen tetroxide (NTO), hydrogen peroxide, sulfuric acid, and fluorine) and fuels (petroleum-based) independent of one another. Drums were rinsed with small quantities of solvent at these sites, which were bermed and led to channels that fed the SPA retention ponds. However, spill containment was not installed until 1992. Thirteen ASTs were observed at the SPA during a 1996 site visit. Five ASTs were located at this site with a combined capacity of approximately 75,000 gallons to store Rocket Propellant (RP)-1 fuel. The contents and uses of the other ASTs primarily are unknown, although it is likely they would have been used to hold fuels and oxidizing agents for engine testing conducted at the facility. It also is likely that one or more of these tanks would have been used to contain tank and drum rinsate residuals from other portions of SSFL before the residuals were transferred to the now removed SP-1 and SP-2 ponds (MWH, 2004).

3.1.2.1 Site Inventories

Inventories of the buildings, tanks, transformers, and chemicals used at the SPA were compiled during the preparation of this RI Report. This information was obtained from historical document reviews, facility drawings, and VSIs. These features are shown in Figure 3.1-1, as applicable. The inventories are included in the following tables:

- Building Inventory–Table 3.1-1
- Transformer Inventory–Table 3.1-2
- Tank Inventory–Table 3.1-3
- Chemical Inventory–Table 3.1-4

3.1.3 Site Chemical Use Areas

The SPA primarily was used to store petroleum-based fuels and oxidizers for use in engine testing activities. Relatively small quantities of solvents also were stored at the SPA, which would account for the main chemical usage in this area during drum and tank rinsing.

3.1.4 Site Conditions

The SPA is currently inactive. Most of the buildings associated with the SPA have been demolished, except for a few open-air awnings that stand in the southwestern, northwestern, and northeastern portions of the site. Most of the area has been fenced in and the two access gates are kept locked. Some concrete building pads and asphalt driveways still exist at the SPA.

3.1.5 Site Habitats/Land Cover

The SPA covers approximately 5 acres. Approximately 20 percent of the site maintains dense shrub/scrub (coast live oak, yerba santa, coyote brush, and milk thistle), ranging from 2 to 5 ft in height. Open field with patchy ruderal vegetation (red-stemmed filaree and red brome) that is less than 10 inches in height also covers 20 percent of the site. Woodland cover at this site is approximately 15 percent. Multiple bird and mammal species (spotted towhee, western scrub-jay, house finch, Anna's hummingbird, yellow-rumped warbler, dark-eyed junco, American goldfinch, Nuttall's woodpecker, house wren, California towhee, gopher [burrows], kangaroo rat [burrows], deer [tracks], cottontail rabbit, ground squirrel, and coyote [scat]) were observed to use the site. Additionally, the western fence

lizard was observed. Standing dead woody vegetation provides evidence that this site burned in the 2005 Topanga Fire. The habitats and land cover present at the SPA are shown in Figure 3.1-2.

3.1.6 Historical Document Reviews

As described in Section 1.3.1, a historical document review was completed of documents applicable to the Group 3 RI. As a result of this historical document review, one new potential feature was identified.

An area described as the Lower SPA was identified during the historical document search. This area was used to store hydrogen peroxide, sulfuric acid, aqueous formaldehyde, trioxane, and caustic soda (Rockwell International, 1979).

3.2 RI Characterization Activities

This subsection describes the sampling objectives, sampling scope, and key decision points associated with evaluating the nature and extent of chemical impacts for the surface soil, subsurface soil, soil gas, and groundwater at the SPA.

3.2.1 Sampling Objectives

To further evaluate the extent of potential chemical effects on this site, soil, soil gas, and groundwater samples were collected. The objectives of the investigation were as follows:

- Evaluate the lateral and vertical extent of chemical impacts.
- Evaluate the potential gradients of chemicals.
- Develop a sufficient data set for performing a risk assessment.

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results and/or previous remediation activities
- Fate and transport characteristics of chemicals
- SSFL background concentrations of parameters
- SSFL SRAM-based screening concentrations for human health and ecological receptors

3.2.2 Sampling Scope

Provided in this report are the characterization results for soil matrix, soil gas, and groundwater information. The total numbers of analytical samples collected as part of this report for soil matrix samples, soil gas samples, and groundwater samples are summarized below:

- Soil matrix: 145 samples
- Soil gas: 59 samples
- Groundwater: 10 samples

These samples were collected between 1987 and 2009 to identify the potential chemical impacts associated with the activities at the SPA. Section 3.4 provides a detailed summary of these samples.

3.2.3 Key Decision Points

The site-specific decision points identified for the SPA represent the assumptions and/or decisions made during the sampling phase component of this RI, as follows:

- For historical sample points where the sample depth had not been recorded, it was assumed that these sample points were taken between the 0- to 2-foot-bgs range.

3.3 RI Characterization Results

The characterization results from the previous soil matrix, soil gas, groundwater, and surface water investigations at the SPA site are summarized below.

3.3.1 Soil Matrix and Soil Gas Findings

Surface soil samples were collected at this site from 1987 through 2009. Four surface soil and two subsurface samples were collected in 1987 in the SPA Area and analyzed for fluoride, pH, hexachlorobenzene, SVOCs, and VOCs. No exceedances were encountered. To further evaluate this site, subsequent soil investigations from 1993 through 1995 were conducted; 17 surface soil samples were collected and analyzed for dioxins, select VOCs, kerosene range organics, and general chemistry. VOCs and kerosene range organics were detected at concentrations exceeding the screening criteria during these sampling efforts. The data were included in the 1996 RFI WPA (Ogden, 1996a; 1996b; 1996c) and the closure reports in regard to the skim ponds present at this site.

In 1997, a bulk of the initial risk characterization sampling was conducted for the SPA. The sampling approach is outlined in the 1996 RFI WPA (Ogden, 1996a; 1996b; 1996c),which was developed in conjunction with the DTSC. Collected samples were analyzed for metals, PCBs, SVOCs, TPHs, and VOCs. Lead, lubricant oil range (C20-C30) organics, and PAHs were detected at elevated concentrations in the soil media. Three VOCs were detected in the soil gas phase during this time, the most prominent being TCE.

From 2001 through the present, RI characterization sampling was conducted to support the development of this report. Initial AOCs were recognized, and after further investigations, additional AOCs were added. Each stage of the investigative process is outlined in the RFI Report (MWH, 2004). To summarize, AOCs were investigated through soil, soil gas sampling, and NSGW sampling, which was followed as recently as 2009 by rounds of step-out sampling to further evaluate extent. Dioxins, inorganics, TPHs, SVOCs, and VOCs were detected at concentrations that exceeded the applicable screening criteria at the SPA. Additional details regarding the analytes detected at this site as a result of the previous investigations performed are described in Section 3.4. The HHRA and ERA for the analytes detected at this site are provided in Sections 3.7 and 3.8, respectively.

3.3.2 Groundwater Findings

3.3.2.1 Background

The SPA AOC (Figure 3.3-1) is an approximately 5-acre site in the central portion of Area II. The elevation varies from approximately 1,830 feet above msl in the central section of the site to approximately 1,800 feet msl at the eastern and western margins of the site. Fifteen wells and piezometers are located within the boundary of the SPA Area and provide information regarding near-surface and Chatsworth formation groundwater conditions. These wells and piezometers are listed in Table 3.3-1, along with construction summaries. The locations are shown in Figure 3.3-1.

NSGW conditions at the SPA Area were investigated prior to this RI through three piezometers (PZ-056, PZ-057, and PZ-058) installed in December 2000, as well as a total of six HAR-series wells (HAR-12, 13, 14, and 15 installed in May 1987 and HAR-30 and 31 installed in June 1987).

RI activities at the SPA Area included the installation of two piezometers, PZ-157 and PZ-158 (Figure 3.3-1), in November and December 2008 within the weathered section of the Chatsworth formation. Screened intervals were constructed in potential water-bearing zones that were identified during rock coring activities. Unweathered Chatsworth formation was encountered at each location. Construction logs and boring logs for the recently installed piezometers PZ-157 and PZ-158 are provided in Appendix C.

PZ-157 was installed to delineate the northern extent of NSGW occurrence and VOC effects on groundwater near a TCE discharge pipe. PZ-158 was installed to provide control to assess alluvium and weathered bedrock thickness and groundwater occurrence, and to delineate the western vertical and horizontal extents of potential chemical effects on NSGW.

Chatsworth formation monitoring wells at the SPA Area include HAR-05, 06, 22, and 23, which were installed in May and June 1987 as part of a sitewide hydrogeologic assessment program.

3.3.2.2 Local Geology

The SPA Area is underlain by deposits of the Sandstone 2 unit of the Chatsworth formation, which consists (from oldest to youngest deposits) of the Silvernale member, the SPA Member, and the Lower Burro Flats member (Figure 3.3-1). All units strike southwest-northeast and dip approximately 30 degrees to the northwest.

The Silvernale member is the stratigraphically lowest member of the Sandstone 2 unit and consists almost entirely of medium- and fine-grained sandstone, although locally thin, lenticular conglomerates are present. The thickness of the Silvernale member varies from approximately 110 ft to 160 ft (MWH, 2007b). The SPA member, which is poorly exposed in outcrop, is reported to consist of thin-bedded shale, siltstone, and sandstone, with shale and siltstone comprising more than 50 percent. Its thickness is estimated to vary from 15 to 30 ft (MWH, 2007b). The Lower Burro Flats member underlies the northern section of the SPA Area. It consists of interbedded shale, siltstone, and sandstone in which shale and siltstone make up much more than 50 percent of the total thickness. The thickness of the Lower Burro Flats member ranges from approximately 300 ft to 370 ft.

During the RI rock-coring activities at PZ-157 and PZ-158, the materials encountered included alluvium/colluvium, weathered bedrock of the Chatsworth formation, and unweathered Chatsworth formation rocks. Alluvial/colluvial material consisted of dark yellowish-brown silty sand. The thickness of alluvial/colluvial deposits encountered during the drilling activities at the SPA Area ranged from less than 1 foot at PZ-057 on the western side of the SPA Area to 12 ft near the northeastern margin of the SPA Area.

Weathered bedrock encountered at PZ-157 and PZ-158 consisted predominantly of weathered sandstone with some interbedded weathered siltstone and shale. Conglomerate was encountered only rarely. Colors ranged through shades of gray, brown, and yellow. Textures typically were medium grained.

Unweathered Chatsworth formation was encountered at PZ-157 at a depth of 32 ft bgs and consisted of olive brown to gray, fine- to medium-grained sandstone. Unweathered Chatsworth formation was encountered at PZ-158 at a depth of 21 ft bgs and consisted of gray, medium-grained sandstone

Cross-sections A-A', B-B', C-C', and D-D' traverse the SPA Area (Figures 3.3-2 through 3.3-5). Where known, the thickness of alluvial/colluvial deposits, weathered bedrock, and depth to unweathered bedrock are shown. The most recent water level data also are provided.

3.3.2.3 Local Hydrogeologic Setting

Near-surface Groundwater. NSGW at the SPA Area has been found to occur in the weathered bedrock section of the Chatsworth formation. The depth to NSGW varies seasonally and yearly (as shown in Figure 3.3-6). Figure 3.3-7 is a potentiometric map of NSGW occurrence within the Group 3 RI boundary. NSGW wells located in the northwestern section of the SPA Area indicate a northwesterly flow, whereas NSGW wells in the northeastern section of the SPA Area indicate a southeasterly flow. The stratigraphic placement of wells does not readily account for the apparent directional differences because of the similar stratigraphic placement of wells at each general location. The direction of NSGW flow at well cluster HAR-12, 13, and 14 in the northwestern section of the SPA Area is northward toward an unnamed drainage. The trace of the drainage system may reflect subsurface conditions (such as enhanced fracturing) that influence the NSGW flow toward it. A similar effect may be controlling flow direction in the eastern section of the SPA Area; however, drainages exist to the north (the same drainage that exists north of the HAR-12, 13, and 14 cluster) and to the east.

Water level soundings taken in recently installed piezometers PZ-157 and PZ-158 indicate the presence of water. Measurements taken between January 6 and January 26, 2009, suggest that changes in elevation may be in response to NSGW level fluctuations and not remnant drilling fluids collecting or draining from these piezometers. Insufficient water column thicknesses of less than 0.5 ft at either location do not allow well development at this time. Water levels are being monitored periodically to assess if and when development and sampling can occur.

Chatsworth Formation Groundwater. Chatsworth formation groundwater is locally extensive across the SPA Area, as it is regionally extensive across the SSFL. Hydrographs of wells completed in the Chatsworth formation are shown in Figure 3.3-6. The hydrographs show

that near-surface and Chatsworth formation groundwater are in communication with each other, as indicated by similar elevations and similar responses to seasonal and yearly fluctuations.

A comprehensive discussion of hydrogeologic characteristics of the Chatsworth formation is provided in the *Technical Memorandum Conceptual Site Model Movement of TCE in the Chatsworth Formation SSFL* (Montgomery Watson, 2000) and the Geologic Characterization of the Central SSFL (MWH, 2007b).

3.3.2.4 Near-surface Groundwater Characterization Results

Both near-surface and Chatsworth formation groundwater characterization is based on sampling events that have occurred from 1987 to the present. These data are termed "legacy" data. Sampling has been conducted for a variety of analytical groups (VOCs and metals) that have varied over time and location. The following discussion of characterization results is divided into NSGW and Chatsworth formation groundwater. Although the Chatsworth formation groundwater is the subject of a separate programmatic investigation and has been designated as its own OU (the CFOU), sampling results are summarized herein to provide a comparison with NSGW characterization.

NSGW has been sampled at nine locations from July 1987 through November 2008. Two piezometers (PZ-157 and PZ-158) recently were installed to provide additional information regarding the occurrence and quality of NSGW. To date, an insufficient quantity of NSGW has been present at these locations, which has prevented samples from being collected.

Table 3.3-2 summarizes the historical (legacy) analytical sampling events for NSGW at the SPA Area. Analytical groups for which sampling has occurred include the following:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- PCB congeners
- Aroclors
- Dioxins
- Energetic parameters (explosives-related compounds)
- General chemistry analytes
- Organo-chlorine pesticides
- Organo-phosphate pesticides

The following subsections discuss the results of each analytical group in further detail. Table 3.3-3 summarizes the detections of analytes for each group; the data include available legacy data. Table 3.3-4 lists the metals concentrations over time (only analyses for dissolved concentrations of metals have been conducted). Table 3.3-5 summarizes the most recently available data and compares the results with the screening level criteria, where available. The groundwater analytical data used to evaluate the NSGW conditions are provided in Appendix I.

Volatile Organic Compounds. The VOC detections in NSGW at the SPA Area are summarized in Table 3.3-3. Twenty-one VOCs have been detected throughout the history of sampling of NSGW monitoring wells at the SPA Area. The VOCs that have exceeded screening level criteria include 1,1-DCE, CTC, 1,21,2-trichloro-1,2,2-trifluoroethane, trans-1,2-DCE, cis-1,2-DCE, and 1,2-DCE.

The most frequently detected VOCs include TCE, 1,1-DCE, chloroform, 1,1,1-trichloroethane (TCA), CTC, 1,1,2-trichloro-1,2,2-trifluoroethane, trans-1,2-DCE, cis-1,2-DCE, and 1,1-DCE.

Time trend charts showing TCE and its daughter products of cis-1,2-DCE, trans-1,2-DCE, and VC (VC is included to illustrate the TCE degradation series) for each location are shown in Figure 3.3.-8. The highest concentrations of these compounds have been detected at HAR-14 in the northwestern section of the SPA Area. The most recent data indicate that TCE has exceeded the screening criteria at HAR-14. Individual time-trend charts for TCE, cis-1,2-DCE, trans-1,2-DCE, and VC in NSGW are shown in Figure 3.3-9.

VOCs detected in NSGW at SPA include compounds that typically have not been detected at other Group 3 RI sites. These additional VOCs include 1,1-DCE, chloroform, 1,1,1-TCA, CTC, 1,1,2-trichloro-1,2,2-trifluoroethane, and 1,1-DCE. Time-trend charts for these compounds by location are shown in Figure 3.3-10.

The most-recent screening level exceedances of VOCs include tetrahydrofuran, chloroform, CTC, TCE, chloroform, and 1,1,-trichloro-1,2,2-trifluoroethane (Table 3.3-5).

Recently installed piezometers PZ-157 and PZ-158 have not been sampled because of a lack of sufficient or any NSGW. Once sufficient water is available, samples will be collected. The results will be reported as an addendum to this RI report.

Semivolatile Organic Compounds. SVOCs that have been detected in NSGW samples include 1,4-dioxane, n-nitrosodimethylamine, dichlorophenoxyacetic acid (2,4-D), and 2,4-dimethylphenol (Table 3.3-3). The latter two SVOCs have been detected only once. The most-recent detections of n-nitrosodimethylamine and 1,4-dioxane exceeded the screening level criteria.

Phthalates. Three phthalates have been detected and include bis(2-ethylhexyl)phthalate (BEHP), di-n-butyl phthalate, and diethyl phthalate (Table 3.3-3). None of the most recent detections of BEHP and di-n-butyl phthalate have exceeded the screening criteria (Table 3.3-5).

Polycyclic Aromatic Hydrocarbons. PAHs have not been detected (Tables 3.3-3 and 3.3-5).

Metals. Metals detected in NSGW are summarized in Table 3.3-3. Both dissolved and total metals concentrations (when analyzed) are presented in Table 3.3-4.

The most recent results indicate that eight metals exceeded the screening-level criteria. These metals are identified in Table 3.3-4. Table 3.3-3 summarizes the historical detections of metals in the HAR-series NSGW monitoring wells. The results primarily represent dissolved concentrations. The highlighted concentrations represent the screening criteria exceedances.

PCB Congeners. PCB congeners were analyzed in groundwater samples from HAR-14 and HAR-15 in 1995 and again in 1999 (Table 3.3-2). No PCB congeners were detected.

Aroclors. Aroclors were analyzed in HAR-12, HAR-14, HAR-15, and HAR-30 samples (Table 3.3-2). No aroclors have been detected (Tables 3.3-3 and 3.3-5).

Dioxins. Dioxins were analyzed in HAR-12, HAR-14, HAR-15, and HAR-30 (Table 3.3-2). No dioxins have been detected.

Energetic Parameters (Explosive Compounds). No energetic parameters have been detected (Tables 3.3-3 and 3.3-5).

General Chemistry Analytes. General water quality analytes (common anions and cations) have been analyzed in NSGW. The detections and exceedances are reported in Tables 3.3-3 and 3.3-5.

Fluoride and nitrate are the most frequently exceeded analytes. Chloride, sulfate, nitrate, and fluoride concentrations in the most recently analyzed NSGW samples have exceeded the screening level criteria (Table 3.3-5).

Organo-chlorine Pesticides. Organo-chlorine pesticides have not been detected in NSGW at the SPA Area (Tables 3.3-3 and 3.3-5).

Organi-phoshate Pesticides. Organo-phosphate pesticides have not been detected in NSGW at the SPA Area (Tables 3.3-3 and 3.3-5).

3.3.2.5 Chatsworth Formation Groundwater Characterization Results

Chatsworth formation groundwater has been sampled at four locations from 1987 to the present. Chatsworth formation groundwater, defined as a regional groundwater unit and separate OU (CFOU), which is the focus of a sitewide RI, has its own RCRA corrective action program at SSFL and has been designated as the CFOU. No characterization of Chatsworth formation groundwater was conducted as part of this RI. However, groundwater quality data are summarized below because of the vertical succession of the OUs and their potential interconnection as regards contaminant transport.

Table 3.3-6 summarizes the historical (legacy) analytical sampling events of the Chatsworth formation groundwater monitoring wells (HAR-05, HAR-06, HAR-22, and HAR-23) at the SPA Area. Analytical groups that have been sampled include the following:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- Energetic parameters (explosives-related compounds)
- General chemistry analytes
- Organo-chlorine pesticides

The following subsections discuss the results of each analytical group in further detail. Table 3.3-7 summarizes the detections of analytes for each group, and the data include the

available legacy data. Table 3.3-8 lists the metals concentrations over time, including the total concentrations and dissolved concentrations (when both were analyzed) by sample by location. Table 3.3-9 summarizes the most recently available data and compares the results with the screening level criteria, where available. The groundwater analytical data used to evaluate the Chatsworth formation site conditions are provided in Appendix I.

Volatile Organic Compounds. The VOCs that were detected are listed in Table 3.3-6. Sixteen VOCs have been detected; the most frequently detected include TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-dichloroethane, 1,1-DCE, and VC. The screening levels for these compounds were exceeded in the historical sampling results. The highest concentrations generally have been detected in HAR-6 in the southeastern section of the SPA Area. Figure 3.3-11 presents time trend charts showing TCE and its daughter products of cis-1,2-DCE, trans-1,2-DCE, and VC over time in samples collected from the Chatsworth formation wells at the SPA Area. Figure 3.3-12 shows concentration trends of TCE, cis-1,2-DCE, trans-1,2-DCE, and VC at each Chatsworth formation monitoring well.

The most-recent detections that exceeded the screening levels include TCE, cis-1,2-DCE, VC, and 1,1-dichloroethane (Table 3.3-9). Exceedances have occurred in samples from HAR-6, HAR-22, and HAR-23.

Semivolatile Organic Compounds. Three SVOCs were detected, including n-nitrosodimethylamine, isopropanol, and n-nitroso-di-n-propylamine (Table 3.3-7). The screening level for n-nitrosodimethylamine was exceeded in the most recent available data (Table 3.3-9).

Phthalates. BEHP and di-n-butyl phthalate have been detected (Table 3.3-7). Di-n-butyl phthalate was the most recently detected compound (1987) (Table 3.3-9). Its concentration did not exceed the screening criteria (Table 3.3-9).

Polycyclic Aromatic Hydrocarbons. No exceedances or detections of PAHs have occurred (Tables 3.3-7 and 3.3-9).

Metals. Metals have been analyzed infrequently from the Chatsworth formation wells at the SPA Area (Table 3.3-6) and only for dissolved concentrations. The screening criteria for the historic results were exceeded for potassium and manganese (Table 3.3-3). Table 3.3-4 summarizes the historical detections of metals. The most recent data (Table 3.3-9) indicate that the manganese detections exceeded the screening criteria at HAR-06 in February 2007.

Energetic Parameters (Explosive-related Compounds). No exceedances or detections have occurred (Tables 3.3-3 and 3.3-5).

General Chemistry. General water quality analytes (such as common anions and cations) were analyzed in NSGW samples. The detections and exceedances are reported in Table 3.3-7 for the available legacy data and in Table 3.3-9 for the most recent available data. The most recent exceedances occurred for chloride, fluoride, nitrate, and sulfate.

Organo-chlorine Pesticides. Organo-chlorine pesticides have not been detected in the Chatsworth formation groundwater at the SPA Area (Tables 3.3-3 and 3.3-5).

3.3.3 Surface Water Findings

Surface water features at the SPA Area consist of small drainages that are dry throughout most of the year. Surface water releases through this drainage are monitored under an NPDES permit.

Surface water samples were not collected during this RI investigation because of the seasonally dry conditions.

3.3.4 Completeness of Characterization

Areas of known exceedances and potential contamination at the SPA Area were further investigated by evaluating existing data and collecting additional groundwater samples. The predominantly detected contaminants in groundwater at the SPA Area are VOCs, primarily TCE and its daughter products. These VOC detections are consistent with the affected groundwater in the CFOU in the immediate study area. SVOCs generally were not detected in SPA Area groundwater samples other than n-nitrosodimethylamine and 1,4-dioxane. Several metals were detected infrequently at levels above their screening values; most metals detected in groundwater were near background concentrations. Groundwater has been sampled and analyzed for chemicals at locations near the operational areas and the analytical results are consistent with the known operations and/or with the soil/soil gas data.

Chemical use areas are delineated sufficiently for risk assessment and for the support of RI recommendations.

3.3.4.1 Near-surface Groundwater Characterization

The occurrence of NSGW at the SSFL, including the SPA Area, is ephemeral and believed to be related to seasonal variations in precipitation. Newly installed piezometers (PZ-157 and PZ-158) have been sounded for the presence of groundwater and when sufficient groundwater is present, groundwater sampling will occur and be reported in an addendum to this RI report. Additional synoptic gauging of piezometers for the occurrence of NSGW and sampling of NSGW, when present, is planned across several seasons, including late-winter and early-spring events when precipitation is anticipated to increase. The current NSGW monitoring network should provide sufficient sampling locations to evaluate groundwater in the SMOU under optimum conditions.

Legacy data provide an abundant foundation for evaluating groundwater quality, past and present. The results indicate that NSGW, although limited in aerial extent and thickness, primarily has been affected by a limited number of VOCs. The data also suggest there have been potential impacts from metals. The Chatsworth formation groundwater impacts are similar to those exhibited in the NSGW results.

3.3.4.2 Surface Water

No surface water samples were collected as part of this RI.

3.4 SPA Nature and Extent

Surface soil, subsurface soil, and soil gas samples were collected at the SPA, per the protocol described in Section 3.2 and the data provided in Appendix C. Figure 3.4-1 shows the historical and most recent surface and subsurface soil samples collected as part of this RI. Table 3.4-1 lists the parameters analyzed in the sample media at the SPA. The nature and extent of contamination that exceeded the comparison criteria values in the media sampled are described below.

3.4.1 Surface Soil Nature and Extent

A total of 84 surface soil samples were collected at this site and analyzed for one or more of the following: TAL metals, PCB aroclors, pesticides, SVOCs, TPHs, and VOCs. Dioxins were not sampled in the SPA, because dioxins are not known to be associated with the SPA. Table 3.4-2 lists the parameters detected in the surface soil samples within the SPA.

3.4.1.1 Parameters Exceeding Criteria

The nature and horizontal extent of the parameters encountered at concentrations exceeding their respective comparison criteria are described below.

Metals. Metals were detected in 39 surface soil samples analyzed for metals, exceeding both the human health and/or ecological screening risk criteria at 4 of the sample locations. Of the metals detected in the surface soil at this site, 7 were reported at concentrations that exceeded 1 or more of the criteria. The metals exceedances are described below.

The most elevated metals concentrations were copper, silver, and manganese. Copper was detected at a concentration of 104 mg/kg (SPBS1000), exceeding its background value (29 mg/kg), its ecological criterion (1.1 mg/kg), and its human health criterion (68.6 mg/kg). Silver was detected at concentrations of 8.7 mg/kg (SPBS1013) and 1.4 mg/kg (SPBE1029), exceeding its background value (0.79 mg/kg), its ecological criterion (0.54 mg/kg), and its human health criterion (1.1 mg/kg). Manganese was detected at concentrations of 695 mg/kg (SPBS1003) and 830 J mg/kg (SPBE1030), exceeding its background value (495 mg/kg), and its ecological criterion (59 mg/kg). The frequency and magnitude of these concentrations are not indicative of a widespread release from processes at the SPA.

Four other metals (barium, lead, nickel, and zinc) each were detected in one surface soil sample at levels exceeding their respective comparison criteria. Barium was detected at a concentration of 145 mg/kg (SPBS1003), exceeding its background value (140 mg/kg) and its ecological criterion (15 mg/kg). Lead was detected at a concentration of 50 mg/kg (P1BS01), exceeding its background value (34 mg/kg), its ecological criterion (0.013 mg/kg), and its human health criterion (16 mg/kg). Nickel was detected at a concentration of 39.6 mg/kg (SPBS1000), exceeding its background value (29 mg/kg), its ecological criterion (0.10 mg/kg), and its human health criterion (37.9 mg/kg). Zinc was detected at a concentration of 124 mg/kg (SPBS1002), exceeding its background value (110 mg/kg), and its ecological criterion (21 mg/kg) These four metals exceedances were encountered at concentrations that were mostly similar to their respective background concentrations and

appear to be spatially isolated from each other. Therefore, it appears that these metal exceedances are indicative of natural conditions at the site.

PCB Aroclors. PCB aroclors were analyzed in two surface soil samples, neither of which had a reported exceedance.

Pesticides. Organochloropesticides were analyzed in 51 surface soil samples, none of which had a reported exceedance.

SVOCs. SVOCs were analyzed at 73 surface soil sampling stations at the SPA. One PAH constituent (BaP) was detected at the SPA at concentrations exceeding its human health comparison criterion. BaP was detected at 4 surface soil samples, ranging from 18.7 J µg/kg (SPBS1029) to 270 J µg/kg (SPBS04), compared to its human health criterion of 11.4 µg/kg. The horizontal extents of BaP appear to have been addressed sufficiently, as shown in Figure 3.4-2. The vertical extents of these parameters are addressed in Section 3.4.2. Also, one additional PAH (dibenzo(a,h)anthracene) was detected at a concentration of 44 µg/kg at SPBA04, which exceeded its human health criterion of 37.75 µg/kg. The horizontal extent of dibenzo(a,h)anthracene appears to have been addressed sufficiently.

In addition to these four PAH exceedances, one additional SVOC (phenol) was detected at a concentration of 5,740 µg/kg at SPBS1032, which exceeded its ecological criterion (5,000 µg/kg). This isolated exceedance is located on the northeastern portion of the SPA, and the downgradient sample locations do not exhibit phenol exceedances. Therefore, the horizontal extent of phenol appears to have been addressed sufficiently at the SPA.

TPHs. Of the 24 surface soil samples analyzed for TPHs, 3 had reported elevated concentrations of two TPH groups. EFH group C21-C30 was encountered at SPBS1033 (142,000 µg/kg) and SPBS1039 (214,000 J µg/kg) at levels that exceeded its ecological and human health criteria of 100,000 µg/kg. EFH group C20-C30 (lubricant oil group) was detected at SPBS08 at concentrations of 130,000 J µg/kg, which exceeded its ecological and human health criteria of 100,000 µg/kg. These 3 sample locations are generally in the central portion of the SPA; there were samples located downgradient that did not indicate TPH concentration exceedances. Therefore, the horizontal extents of EFH C21-C30 and EFH C20-C30 (lubricant oil group) have been evaluated adequately.

VOCs. Of the 70 VOC surface soil sample locations, two VOC constituents (methylene chloride and chloroform) were reported at concentrations that exceeded their screening criteria in surface soils at the SPA. Methylene chloride was detected at 13 surface soil samples locations, ranging from 6.87 µg/kg (SPBS1016) to 59 µg/kg (SPA-2-58), compared to its human health criterion of 4 µg/kg. The majority of these methylene chloride exceedances were encountered in two general areas in the western and northeastern portions of the SPA. Neither of these two areas had downgradient sample locations that exhibited methylene chloride concentrations at levels exceeding the human health criterion. Therefore, the horizontal extent of methylene chloride has been evaluated adequately, as shown in Figure 3.4-3. One chloroform exceedance was encountered at SPA-1-6 at a concentration of 3 µg/kg, compared to its human health criterion of 0.77 µg/kg. This chloroform exceedance appears to be isolated, and the horizontal extent of chloroform has been addressed adequately.

3.4.2 Subsurface Soil Nature and Extent

A total of 61 subsurface samples were collected from 38 sampling stations to a maximum depth of 10 ft bgs at the site. The subsurface soil at the site was analyzed for 1 or more of the following: TAL metals, pesticides, SVOCs, TPHs, and VOCs. Table 3.4-3 lists the parameters detected in the subsurface soil samples at the SPA.

3.4.2.1 Parameters Exceeding Criteria

The nature and horizontal extent of the parameters encountered at concentrations exceeding their respective comparison criteria are described below.

Metals. Metals were detected across the 37 subsurface soil samples collected and analyzed for metals at 22 sampling locations in the SPA. Of those, 10 metal parameters spanning 4 samples were detected at concentrations that exceeded the applicable comparison criteria. The vertical nature of these metals is described below.

The majority of the subsurface soil exceedances were encountered at 1 sample location (SPBS1020 from 9.5 ft to 10 ft bgs). This subsurface soil sample contained elevated concentrations of aluminum (22,300 mg/kg, compared to its background value of 20,000 mg/kg), arsenic (18.2 mg/kg, compared to its background value of 15 mg/kg), barium (147 mg/kg, compared to its background value of 140 mg/kg), chromium (41.9 mg/kg, compared to its background value of 36.8 mg/kg), copper (36.2 mg/kg, compared to its background value of 29 mg/kg), manganese (610 mg/kg, compared to its background value of 495 mg/kg), nickel (42 mg/kg, compared to its background value of 29 mg/kg), and vanadium (78.6 mg/kg, compared to its background value of 62 mg/kg). These metals concentrations are mostly similar to their respective background concentrations and probably are representative of naturally occurring conditions at the site.

The remaining metals exceedances were encountered at 3 other sampling locations. The subsurface soil sample from SPBS1024 from 9.5 to 10 ft bgs exhibited concentrations of beryllium (1.4 mg/kg) and vanadium (78.4 mg/kg), compared to their respective background concentrations of 1.1 mg/kg and 62 mg/kg, respectively. Also, molybdenum was encountered at a concentration of 5.4 mg/kg at SPBS1035 from 4.5 to 5 ft mg/kg, compared to its background value of 5.3 mg/kg, while manganese was encountered at a concentration of 605 mg/kg at SPBS1038 from 9.5 to 10 ft mg/kg, compared to its background value of 495 mg/kg. These metal exceedances were encountered at concentrations that were mostly similar to their respective background concentrations and appear to be spatially isolated. Therefore, it appears that these metal exceedances are indicative of natural conditions at the site and the vertical extent is evaluated adequately.

Pesticides. Organochloropesticides were analyzed in 50 subsurface soil samples collected from 30 sample locations, none of which had a reported exceedance.

SVOCs. A total of 54 samples from 34 sampling stations were analyzed for 1 or more SVOC. However, no SVOC exceedances were encountered in the subsurface soil at the SPA. Therefore, the vertical extent of SVOCs at the SPA has been evaluated adequately.

TPHs. A total of 23 subsurface soil samples from 13 locations were analyzed for TPHs in the SPA. Two exceedances of the EFH (C21-C30) group ecological and human health screening criteria of 100,000 µg/kg were reported in the subsurface soil at this site. The C21-C30

exceedances were detected at concentrations of 116,000 µg/kg (SPBS1033 from 9.5 to 10 ft bgs) and 101,000 µg/kg (SPBS1038 from 4.5 to 5 ft bgs). Station SPBS1038 was sampled at a deeper interval (9.5 to 10 ft bgs), which did not have a reported exceedance of EFH (C21-C30). Additionally, the EFH (C21-C30) exceedance at SPBS1033 from 9.5 to 10 ft bgs was at or approaching bedrock, based on the general depth of bedrock encountered in the SPA. The vertical extent of EFH (C21-C30) has been addressed sufficiently at the SPA.

VOCs. A total of 60 subsurface soil samples from 37 sampling stations were analyzed for VOCs at the SPA. One parameter (methylene chloride) was detected in 10 subsurface soil samples from 6 sample locations at elevated concentrations that exceeded its comparison criteria. These methylene chloride exceedances ranged from 14 µg/kg at SPA-2-55 at 3 ft bgs to 26 µg/kg at SPA-2-55 at 5 ft bgs, compared to its human health criterion (4 µg/kg). Nine of the 10 methylene chloride exceedances occurred at sampling locations where surface soil methylene chloride exceedances were encountered. Also, the methylene chloride concentrations generally were uniform from surface soil to 5 ft bgs. All 10 of these subsurface soil exceedances occurred in the former "pond" areas in the northeastern and northwestern portions of the SPA, where bedrock is expected to be shallower than in other areas in the SPA. The deeper 5-foot-bgs subsurface samples are believed to be at or approaching bedrock, based on the general depth of bedrock encountered in the SPA. Therefore, the vertical extent of methylene chloride in subsurface soil in the SPA has been evaluated adequately. The subsurface extent of methylene chloride is shown in Figure 3.4-4.

3.4.3 Soil Gas Nature and Extent

Fifty-nine soil gas samples for VOC and PAH analyses were collected at the SPA from 41 locations to a maximum depth of 15.5 ft bgs. Figure 3.4-5 shows the locations of the soil gas samples collected as part of this RI effort. Three VOCs (1,1-DCE, methylene chloride, and TCE) were detected in the samples at levels that exceeded the screening criteria. Table 3.4-4 lists the parameters detected in the soil gas samples collected in this area. The extent of VOCs encountered via soil gas sampling at this site is described below.

Seven exceedances of 1,1-DCE were reported at this site, at concentrations ranging from an estimated 1,300 J µg/m^3 (SPSV01 at 4 ft bgs) to an estimated 21,000 J µg/m^3 (SPSV03 at 7 ft bgs), each exceeding its ecological criterion (600 µg/m^3). The 1,1-DCE exceedances are located primarily in the western portion of the SPA, with multiple exceedances encountered at SPSV01, SPSV02, and SPSV03 to a maximum of 8 ft bgs. Although no samples were collected at deeper intervals at these three stations, the sampling efforts suggest that these exceedances were encountered at depths at or near bedrock refusal. The fourth sample location that had an exceedance (SPSV05 at 5 ft bgs) had a deeper sample at 10 ft bgs; 1,1-DCE was not detected in the deeper sample. In addition, samples collected at similar intervals downgradient did not have reported 1,1-DCE exceedances. The extent of 1,1-DCE soil gases at this site has been addressed sufficiently, as shown in Figure 3.4-6.

TCE was detected in 15 soil gas samples at levels that exceeded the applicable comparison criteria. Elevated concentrations of TCE ranged from 1,700 µg/m^3 (SPSV07 at 8 ft bgs) to 28,000 µg/m^3 (SPSV03 at 7 ft bgs), each of which exceeded its human health criterion (530 µg/m^3); 7 concentrations also surpassed the ecological criterion of 6,400 µg/m^3. Most of the TCE soil gas exceedances appear to be present at or near the bedrock interface at this site. Horizontally, samples without a TCE exceedance provide an extent boundary to the

north, east, and west. A steep rock outcrop to the south provides a southern boundary of extent. The extent of TCE vapors within the SPA is shown in Figure 3.4-7.

Methylene chloride was encountered in 1 sample location (SPSV07 at 4 ft bgs) at a concentration (1,200 J µg/m^3) that exceeded its ecological criterion of 870 µg/m^3. This exceedance is bounded vertically by a non-detect methylene chloride concentration at SPSV07 at 8 ft bgs and the extent was sufficiently evaluated horizontally by non-detect methylene chloride concentrations at similar intervals to the north. Therefore, the horizontal and vertical extents of methylene chloride in soil gases in the SPA have been evaluated adequately.

3.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the SPA Area is described Section 3.8.1.4.

3.6 Fate and Transport Analysis for Chemicals Detected in Surficial Media

3.6.1 Contaminant Sources and Release Mechanisms

The primary release mechanism for contamination at the SPA is attributed to the bulk storage of hazardous materials from the tests associated with the Alfa and Bravo Test Facilities. Also, surface drainage and subsurface leaching occurred from the two surface impoundments (SPA-1 and SPA-2), which contained hazardous wastes such as those composed of TCE, petroleum, hydrazine-based fuels, DCE, VC, and MEK.

3.6.2 Potential Routes of Migration

The primary pathway for contaminant transport from the source areas at this site is the horizontal migration of potential contaminants through the drainage pathways toward the drainage ditches to the north and west of the SPA. Secondary transport mechanisms for this site include vertical migration of parameters from the surface soil to the subsurface soil and the release of surface soil to the air by wind erosion or volatilization.

3.6.3 Contaminant Persistence

Inorganics, SVOCs, TPHs, and VOCs were detected in the soil at the SPA at levels above their screening criteria. Additionally, VOCs were detected in the soil gas at concentrations above their screening criteria. This subsection describes the chemicals applicable to this area.

3.6.3.1 Parameters Exceeding Criteria

Inorganics, SVOCs, TPHs, and VOCs are described below.

Inorganics. Several metals were detected at this site at levels above the screening criteria. Most metals are naturally occurring and their reported presence may or may not indicate a contaminant release. The mobility of metals is complex and depends on several factors such

as the overall groundwater composition, pH, metal complex formation, valence state of the metal, and cation-ion exchange capacity. Metals typically are not volatile. In the water phase, the total metal concentration includes the dissolved metal concentration and the suspended metal concentration, which is sorbed to colloidal particles. Therefore, elevated metals concentrations in groundwater may be due to the suspended load and not just to the dissolved aqueous chemistry.

SVOCs. PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. HMW PAHs are more likely to be transported via particulate emissions, while LMW PAHs have a greater tendency to volatilize (ATSDR, 1995). In general, PAHs are more likely to sorb to soil or organic matter than to partition significantly to water. Photolysis and biodegradation are two common attenuation mechanisms for PAH compounds (Howard, 1991). Animals and microorganisms can metabolize PAHs to products that ultimately reach complete degradation.

TPHs. TPHs are defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. The lighter petroleum products such as gasoline contain constituents that have higher water solubility and volatility and lower sorption potential than do heavier petroleum products such as fuel oil. Data compiled from gasoline spills and laboratory studies indicate that these light-fraction hydrocarbons tend to migrate readily through soil, potentially threatening or affecting groundwater supplies. In contrast, petroleum products that have heavier molecular weight constituents, such as fuel oil, generally are more persistent in soils because of their relatively low water solubility and volatility and high sorption capacity (Stelljes and Watkin, 1991).

VOCs. VOCs are characterized by relatively high vapor pressures, Henry's Law constants, and generally high solubility in water. VOCs have a tendency to partition to the vapor phase either from soil or surface water and could be released through volatilization from contaminated soil. The sorption potential of VOCs is variable; some may persist in soil or sediment, while some are highly mobile in soil. VOCs will leach to groundwater and might persist, depending on their ability to degrade or transform in the environment.

TCE was the most prevalent VOC in the soil gas samples collected. Although TCE does not have a high soil organic carbon-water partitioning coefficient (K_{oc}), it may sorb to soil, sediment, or organic matter and persist in the environment for a long time. It also may persist in groundwater. TCE does not accumulate in plants or animal tissue and undergoes biotic and abiotic degradation via natural attenuation processes.

3.6.4 Contaminant Migration

The primary sources for contaminant migration are horizontal migration, historical leaching, and potential leaks and spills from storage units associated with the SPA.

3.6.5 Surface Soil Contaminants

Metals, SVOCs, TPHs, and VOCs have been identified in surface soil at levels above the background and/or health-based risk criteria. The following observations were made for contaminants in surface soil:

- Of the metals detected in the surface soil at the SPA, 8 metals were reported at concentrations exceeding their background values and 1 or more of their respective comparison criteria.
- Of the 74 surface soil samples analyzed for SVOCs, 4 sample locations had reported exceedances of one SVOC parameter (BaP) encountered in surface soil.
- Of the 24 surface soil samples analyzed for TPHs, 3 had reported elevated concentrations of 2 TPH groups. Each elevated concentration exceeded the chemical's ecological and human health criterion of 100,000 µg/kg.
- Of the 70 VOC surface soil sample locations, 2 VOC constituents (methylene chloride and chloroform) were reported at concentrations that exceeded their screening criteria in surface soils at the SPA. Methylene chloride exceedances were detected at 13 surface soil sample locations, while a chloroform exceedance was detected at 1 surface soil sample location.

3.6.6 Subsurface Soil Migration

The following observations were made for the contaminants in subsurface soil:

- Ten metal parameters spanning 4 subsurface samples were detected at concentrations that exceeded the applicable comparison criteria. Most of these exceedances are at concentrations mostly similar to their respective background values, which is indicative of natural occurrence.
- A total of 23 subsurface soil samples from 13 locations were analyzed for TPHs in the SPA. Two exceedances of the EFH (C21-C30) group were reported in the subsurface soil at this site. One of these 2 exceedances was sampled at a deeper interval within the same station; however, it did not have a reported exceedance of EFH (C21-C30). The second exceedance was collected at a depth interval at or approaching bedrock, based on the general depth of bedrock encountered in the SPA.
- A total of 60 subsurface soil samples from 37 sampling stations were analyzed for VOCs at the SPA. One parameter (methylene chloride) was detected in 10 subsurface soil samples from 6 sample locations at elevated concentrations that exceeded its comparison criteria. Nine of the 10 methylene chloride exceedances occurred at sampling locations where surface soil methylene chloride exceedances were encountered. Also, the methylene chloride concentrations generally were uniform from surface soil to 5 ft bgs. All 10 of these subsurface soil exceedances occurred in the former "pond" areas in the northeastern and northwestern portions of the SPA, where bedrock is expected to be shallower than in other areas in the SPA. Therefore the deeper 5-foot-bgs subsurface samples are believed to be at or approaching bedrock, based on the general depth of bedrock encountered in the SPA.

3.6.7 Soil-to-Groundwater Migration

The relationship between chemicals detected in soil, soil gas, and groundwater has been evaluated to assess whether soil chemical concentrations have affected the groundwater quality. Soil chemical concentrations were reviewed and compared with the groundwater concentrations. The evaluation was based on the chemicals detected, background concentrations, spatial distribution, and hydrogeologic conditions. The evaluation provides conclusions regarding soil sources for detected chemicals in groundwater.

The release of TCE from the SSFL operations at the SPA Area probably resulted in the entry of immiscible-phase liquid into and below the water table by the interconnected fracture network within the Chatsworth formation. SVOCs detected in the immediate study area may have resulted from site operations.

3.7 Human Health Risk Assessment for SPA

The objective of this HHRA is to assess whether the environmental media at the SPA could pose risks to human health at levels that might require remedial action, or risk at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil, soil gas, and groundwater at the SPA. The methods and guidance documents used in the preparation of this HHRA are discussed in Section 1.3.3 of this report. A discussion of the HHRA results for the SPA is presented below. The results are summarized in Section 3.9.2.

The concentration data, input parameters, and results of the HHRA for the SPA are presented in Appendix C. An index of the tables (Appendix C Human Health RA Tables Index) is provided and can be used to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated non-cancer HIs.

3.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the SPA, based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

3.7.1.1 Data Evaluation

The soil, soil gas, and groundwater sampling analytical data at the SPA were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.3.3.1. Sediment and surface water data were not collected as part of the RI site characterization activities. The locations of the soil, soil gas, and groundwater samples used in this HHRA are shown in Figures 3.4-1 and 3.4-5. The samples used in this HHRA are listed in Table C.3.1-1 by medium, sample identification (ID), sampling depth interval, and date of collection. Table C.3.1-2 lists the target receptor populations by medium. Descriptive summary statistics of these data are provided in Table C.3.1-3.

3.7.1.2 Identification of COPCs in Soil

The results of the COPC screening process for soil at 0 to 2 ft bgs and 0 to 10 ft bgs are listed in Table C.3.1-3. Detected analytes in soil at the SPA were compared to background levels.

COPCs identified in soil (0 to 2 ft bgs) included 1 inorganic (barium) and 36 organics. COPCs identified in soil (0 to 10 ft bgs) included 1 inorganic (barium) and 38 organics.

3.7.1.3 Identification of COPCs in Groundwater

The results of the COPC screening process for groundwater are listed in Table C.3.1-3. Detected analytes in groundwater at the SPA were compared to background levels. COPCs identified in groundwater included 6 inorganics (copper, dissolved molybdenum, selenium, thallium, dissolved tin, and vanadium) and 16 organics.

3.7.1.4 Identification of COPCs in Soil gas

The results of the COPC screening process for soil gas at 3 to 10 ft bgs are listed in Table C.3.1-3. The COPCs identified in soil gas included 1,1,1-TCA, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,1-DCE, methylene chloride, and TCE.

3.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the SPA may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential exposures. Figure 1.5-2 depicts the conceptual exposure model for the SPA. Table C.3.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

3.7.2.1 Identification of Receptors

The SPA recently was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the industrial worker and recreationist exposure scenarios were evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

3.7.2.2 Identification of Exposure Pathways

Future residents and industrial workers were assumed to be exposed to groundwater, soil gas (modeled for migration to indoor air and ambient air), and soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). Future recreationists were assumed to be exposed to groundwater, soil gas (modeled for migration to ambient air), and soil (0 to 2 ft bgs). Exposure pathways for groundwater included direct exposures (ingestion and dermal) and indirect exposures. Inhalation exposures were quantified for the migration of groundwater and soil gas to ambient air and indoor air. Additionally, exposures were quantified for residential receptors for inhalation of groundwater VOCs in bathroom air while showering

or bathing. Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the SPA are provided in Table C.3.1-6.

3.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs, soil at 0 to 10 ft bgs, soil gas, and groundwater at the SPA are listed in Table C.3.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts, ambient air, indoor air, and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for non-volatile COPCs. The derivation of the PEF for soil also is listed in Table C.3.1-3.

Ambient air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs to ambient air and migration from groundwater to ambient air. Parameter values used for soil gas-to-air migration and for estimating the ambient air EPCs related to soils are listed in Table C.3.1-8. Parameter values used for estimating ambient air EPCs related to groundwater also are listed in Table C.3.1-8. The estimated ambient air concentrations from the migration of volatile COPCs in soil and groundwater are listed in Tables C.3.1-9, C.3.1-10, and C.3.1-11, respectively.

Indoor air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs and from NSGW using the J-E Model (EPA, 2004e). The parameter values used in the J-E Model (EPA, 2004e) are presented in Table C.3.1-8. Soil gas data, where available, were preferentially used for indoor air modeling. The estimation of indoor air concentrations from soil gas and groundwater migration are presented in Tables C.3.1-12 through C.3.1-17.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b). COPC concentrations in edible plant tissues from soil at 0 to 2 ft bgs are presented in Table C.3.1-18.

3.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate the chemical intakes for potential adult and child residential, adult and child recreationist, and industrial worker receptors at the SPA. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix C. See the Appendix C human health RA Tables Index for the exposure parameters and chemical intakes for each exposure scenario.

3.7.3 Risk Characterization

In the risk characterization component of the HHRA process, the quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.3.

The exposure assumptions, EPCs, toxicity factors, and risk characterization results tables for this HHRA are presented in Appendix C (Appendix C human health RA Tables Index**)**. The risk calculation tables present the estimated ELCRs and non-cancer HIs for potentially exposed receptors and individual exposure routes for soil, indoor air, and groundwater at the SPA, as well as the cumulative risks and HIs across all exposure routes for the RME and CTE scenarios. Table C.3.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs and HIs are listed in Table C.3.5-2.

3.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-8} for the CTE case to 5×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 4×10^{-4} for the CTE case to 9×10^{-4} for the RME case, both of which are below the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route ranges from 7×10^{-6} for the CTE case to 1×10^{-4} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR is equal to the upper end of the regulator risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 6 for the CTE case to 36 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. The primary contributor to the HI estimate for the plant consumption pathway is formaldehyde (97 percent). The maximum concentrations of formaldehyde detected at the SPA primarily were reported from within the east and west dry ponds (Figure 3.4-1). The detected concentrations of formaldehyde also were reported from the sampling locations southeast of each of the ponds. These locations included SPA-2-CH-1 and SPBS11, which are southeast of the east pond, and SPA-1-CH-1, SPA-1-CH-4, SPA-1-CH-7, and SPBS09, which are southeast of the west pond.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-8} for the CTE case to 5×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 4×10^{-4} for the CTE case to 8×10^{-4} for the RME case, both of which are below the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-7} for the CTE case to 2×10^{-6} for the RME case. The CTE ELCR estimate is below the regulatory risk range, and the RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The HI estimates for non-cancer effects range from 0.006 for the CTE case to 0.02 for the RME case. The CTE and RME HI estimate do not exceed the regulatory threshold value of 1.

- For indoor air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-10} for the CTE case to 8×10^{-10} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 9×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-9} for the CTE case to 3×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 7×10^{-5} for the CTE case to 3×10^{-4} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-12} for the CTE case to 6×10^{-12} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 7×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to COPCs in NSGW, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to COPCs in NSGW, the HI estimates for non-cancer effects

range from 0.002 for the CTE case to 0.003 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

3.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-7} for the CTE case to 1×10^{-6} for the RME case. The CTE ELCR estimate is below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The RME ELCR estimate is equal to the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.004 for the CTE case to 0.008 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 7×10^{-6} for the CTE case to 3×10^{-5} for the RME case. The RME and CTE ELCR estimates are within the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 9 for the CTE case to 40 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. The primary contributor to the HI estimate for the plant consumption pathway is formaldehyde (97 percent). As previously mentioned, the maximum concentrations of formaldehyde detected at the SPA primarily were reported from within the east and west dry ponds (Figure 3.4-1). Detected concentrations of formaldehyde also were reported from sampling locations southeast of each of the ponds.
- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-7} for the CTE case to 1×10^{-6} for the RME case. The CTE ELCR estimate is below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The RME ELCR estimate is equal to the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.003 for the CTE case to 0.007 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-6} for the CTE case to 2×10^{-6} for the RME case.

The CTE ELCR estimate is equal to the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.03 for the CTE case to 0.06 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

- For indoor air exposure via groundwater vapor intrusion, the cumulative ELCR estimate for carcinogenic COPCs is 6×10^{-10} for the CTE and RME cases. The CTE and RME ELCR estimate is less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater vapor intrusion, the HI estimate for non-cancer effects is 5×10^{-5} for the CTE and RME scenarios. The CTE and RME HI estimate does not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-8} for the CTE case to 2×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 4×10^{-4} for the CTE case to 8×10^{-4} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimate for carcinogenic COPCs is 5×10^{-12} for the CTE and RME cases. The CTE and RME ELCR estimate is below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimate for non-cancer effects is 4×10^{-7} for the CTE and RME scenarios. The RME and CTE HI estimate does not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to COPCs in NSGW, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to COPCs in NSGW, the HI estimates for non-cancer effects range from 0.008 for the CTE case to 0.01 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

3.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-9} for the CTE case to 4×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 3×10^{-5} for the CTE case to 3×10^{-4} for the RME case, both of which are below the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-10} for the CTE case to 3×10^{-9} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 4×10^{-6} for the CTE case to 3×10^{-5} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.
- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-14} for the CTE case to 7×10^{-13} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 4×10^{-9} for the CTE case to 2×10^{-8} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

3.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. A hypothetical future recreationist child (15-kg body weight) was assumed to be exposed for 350 days per year over 6 years for the RME case and 6 years for the CTE case. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-8} for the CTE case to 3×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from

5 x 10^{-4} for the CTE case to 0.002 for the RME case, both of which are below the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1 x 10^{-9} for the CTE case to 7 x 10^{-9} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 3 x 10^{-5} for the CTE case to 2 x 10^{-4} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4 x 10^{-13} for the CTE case to 1 x 10^{-12} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 3 x 10^{-8} for the CTE case to 1 x 10^{-7} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

3.7.3.5 Hypothetical Future Industrial Worker Exposure Scenario

Potential industrial worker exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4 x 10^{-8} for the CTE case to 7 x 10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 2 x 10^{-4} for the CTE case to 0.001 for the RME case, both of which are below the regulatory threshold value of 1.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4 x 10^{-8} for the CTE case to 6 x 10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 2 x 10^{-4} for the CTE case to 0.001 for the RME case, both of which are below the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of

vapors that have migrated inside a future industrial building. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 8×10^{-8} for the CTE case to 7×10^{-7} for the RME case. The CTE ELCR estimate is less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.002 for the CTE case to 0.006 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

- For indoor air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-11} for the CTE case to 2×10^{-10} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 3×10^{-6} for the CTE case to 5×10^{-6} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-9} for the CTE case to 3×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 7×10^{-5} for the CTE case to 2×10^{-4} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-12} for the CTE case to 6×10^{-12} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 7×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

3.7.4 Uncertainty Discussion

Uncertainties associated with the results of this HHRA are a function of both the "state of the practice" of HHRAs in general and UFs specific to the SPA. Section 1.5.3 discusses the general HHRA uncertainty.

3.8 Ecological Risk Assessment for SPA

3.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to all RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the SPA are described below.

3.8.1.2 Site Background

SPA was used to store bulk quantities of hazardous materials, mostly in connection with tests conducted at the Alfa and Bravo Testing Facilities. A historical review suggested that this site was active from approximately 1956 until 2005, when the last engine test was completed. Nine buildings, 14 tanks, drum storage areas, and 2 treatment ponds are associated to and with the boundary of the SPA site. The treatment ponds were used to contain and treat hazardous wastes, such as those composed of TCE, petroleum, hydrazine-based fuels, DCE, VC, and MEK. The surface impoundments primarily were used for emergency propellant spills; however, they also were used in the drum and tank rinsing activities. A more detailed discussion of the site conditions and history is presented in Section 3.1.

The SPA Area is approximately 5 acres, of which 36 percent is developed (pavement, roads, or buildings). Habitat at the site was characterized based on a site survey conducted in April 2008. This survey indicated that the SPA consists of four habitat types, including scrub-shrub, woodland, ruderal, and rock habitat (Figure 3.8-1). Dense shrub/scrub (coast live oak, yerba santa, coyote brush, and milk thistle) covers 22.4 percent of the site. Woodland and ruderal vegetation are the next most dominant habitat types and cover 16 and 10 percent of the site, respectively. Stressed vegetation was observed over approximately 15 percent of the site. Multiple bird and mammal species (spotted towhee, western scrub-jay, house finch, Anna's hummingbird, yellow-rumped warbler, dark-eyed junco, American goldfinch, Nuttall's woodpecker, house wren, California towhee, gopher [burrows], kangaroo rat [burrows], deer [tracks], cottontail rabbit, ground squirrel, and coyote [scat]) were observed to use the site. Additionally, the western fence lizard was observed. Standing dead woody vegetation provides evidence that this site burned in the 2005 Topanga Fire.

3.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the SPA is the same as that for all Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the SPA are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 3.8-1).

- Representative species and receptor groups considered for the SPA include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

3.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the SPA is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the SPA is described below and presented in Figure 3.8-2.

The primary contaminant sources at the SPA include hazardous materials storage areas and two treatment ponds. Primary release mechanisms include spills and leakage to the ground surface or leaks to subsurface soils from the drainage areas and treatment ponds, which were gunite-lined. Soil is the secondary source of potential contaminant. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater. Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). Table 3.8-2 provides additional descriptions of potential exposure pathways for the ecological receptors at the SPA, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

3.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil and soil gas are listed in Table 3.8-3. Summary statistics for those detected analytes are listed in Table 3.8-4. A central tendency background comparison for metals and dioxins/furans in soils was conducted to assess whether the analytes were consistent with background (Table 3.8-5). The volatile organics in soil and soil gas are compared in Table 3.8-6. Non-detect analytes were evaluated by comparing the maximum SQLs against the minimum ESL and determining the exceedance frequency of the SQLs (Table 3.8-7). The CPECs identified for the SPA are summarized in Table 3.8-8. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 3.8-9, 3.8-10, and 3.8-11, respectively. EPCs for soil gas from 0 to 6 ft bgs are listed in Table 3.8-12. Calculations for extrapolating soil gas concentrations from soil concentrations are listed in Table 3.8-13.

3.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 3.8.1) with the risk characterization (Section 3.8.3) and consists of the technical evaluation of ecological and

chemical data to evaluate the potential for ecological exposure and effects. Generalized components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the SPA is presented below.

3.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this section.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the SPA. Because the SPA is strictly terrestrial, exposure is based on soil and soil gas and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

Although the SPA covers about 5 acres, the spatial extent of samples associated with the site is 11.6 acres. More than 60 percent of the land cover at this site consists of buildings, pavement, rock, and ruderal or stressed vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) and soil gas were calculated for the SPA, according to the approach outlined in Section 1.5.4.4. These values are presented in Tables 3.8-9 through 3.8-12. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 3.8.3).

3.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for receptors at the SSFL are summarized in Section 1.5.4.4. No effects data specific to the SPA are available. Consequently, the ESLs, Low TRVs, and High TRVs for terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

3.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the SPA. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the SPA. The results of these comparisons are presented below.

3.8.3.1 Risk Estimation

The risk estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 3.8-14 through 3.8-21. Table 3.8-17 presents an analysis of the depth intervals for the evaluation of burrowing animals (deer mouse). All depth intervals had the same HIs; therefore, the data from the 0- to 2-foot-bgs depth were used to evaluate the deer mouse.

3.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with any other available and appropriate lines of evidence to evaluate the potential chemical impacts on ecological receptors in SSFL's Group 3. Chemicals that had HQs exceeding 1 were further evaluated to assess the COECs. Information considered in the evaluation of the COECs includes receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.
2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.
5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.
6. No Risk–all HQs and associated HIs<1.
7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Three soil analytes (barium, 2,4-dinitrophenol, and hexachlorobenzene) were found to have one or more HQs greater than 1 under one or more scenarios (Table 3.8-22). All other soil analytes and/or analyte groups were found to pose no risk (the HQs and HIs were less than 1) to receptors under any scenario (maximum concentration for plants, invertebrates, and soil gas exposures; CTE and RME concentrations for birds and mammals) at the SPA.

Barium was the only inorganic identified as elevated relative to background, based on the non-parametric central tendency background comparisons for soil (Table 3.8-5). Although the maximum barium concentrations did not exceed the TRVs for either terrestrial plants or soil invertebrates (Tables 3.8-14 and 3.8-15, respectively), barium had HQs above 1 for at least one wildlife receptor in the refined screen. On the basis of the risk ranking discussed above, barium was found to pose a medium risk (1<HQs<2 for High TRV [RME], but HQ>10 for Low TRV [RME]).

On the basis of the RME exposure, risks from barium are predicted for the hermit thrush (high TRV-based HQ=1.1) and the deer mouse (high TRV-based HQ= 1.5), although the magnitudes of exceedance were low for both receptors. On the basis of the CTE, the high-TRV based HQ was less than 1 for the hermit thrush and was 1.4 for the deer mouse. Additionally, the incremental risk is low, indicating that almost all of the risk is a result of naturally occurring concentrations (Table 3.8-23). Therefore, on the basis of the low magnitude of exceedance and the low incremental risk, risks from barium are acceptable.

Two non-detect analytes, 2,4-dinitrophenol and hexachlorobenzene, had one or more HQs that were above 1. On the basis of the RME screen, the low TRV-based HQ for the hermit thrush was 5.4 for 2,4-dinitrophenol, although the CTE-based HQs were less than 1. On the basis of these HQs, risks for 2,4-dinitrophenol are considered medium. It should be noted, however, that risks based on the RME screen were based on the maximum SQL of 6.95 mg/kg. The remaining 54 samples had SQLs of 1.3 mg/kg or less. For hexachlorobenzene, the low and high TRV-based HQs for the deer mouse were both greater than 1, with the respective RME-based HQs of 37 and 10; the risks are considered high. However, based on the CTE screen, the high TRV-based HQ was less than 1 while the low TRV-based HQ was 1.5. It should be noted that the RME screen was based on the maximum SQL (3.47 mg/kg). The other 54 samples had SQLs of 0.5 mg/kg or less. Because these analytes were both non-detect and the RME screen was conducted using the maximum SQL, this evaluation is considered conservative and the risks are acceptable.

Soil gas CPECs were identified and evaluated as part of this ERA. Five analytes were detected in soil gas, 1 non-detect analyte was carried forward based on a comparison of SQLs to ESLs, and the concentrations of 6 analytes were modeled based on detections in soil (Table 3.8-12). Of these, 4 analytes had HQs greater than 1 (Table 3.8-16). All 3 of the detected analytes that had HQs above 1 had a low magnitude of exceedance (HQ=<5) and were considered to pose low risks (Table 3.8-24). The 1 analyte that was not detected, 1,1,2-TCA, had an HQ of 18. The TRV for this analyte is conservative and was derived from a LD50 using an uncertainty factor of 100. The application of the uncertainty factor may overestimate or underestimate a no-effect level. Additionally, this evaluation used the maximum SQLs and TRVs based on a no effect level. Consequently, risks from the evaluated VOCs are considered to be low.

Tables 5.8-24 and 5.8-25 list the chemicals of ecological concern in soil gas and soil, respectively.

3.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component in all risk assessments. Generalized uncertainties for ERAs in SSFL's Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- Samples were collected outside of the site boundary in an effort to define and evaluate potential releases from the SPA. If sample concentrations decreased with distance from the site, the inclusion of these additional data may underestimate risks in the core portion of the site when these data are integrated into the RME and CTE calculations.
- Depths were unavailable for 3 historical soil sample locations included in the SPA dataset. In an effort to be conservative and to ensure completeness, these data were

included in the 0- to 2-foot-depth interval for the purposes of risk assessment. There is some uncertainty associated with including these data in this depth interval and the risks may be overestimated. However, most analytes associated with the legacy data for the SPA were not detected and probably did not affect the overall risk conclusions.

- No screening levels were available to evaluate the TPH data; however, PAH data were available and no risks from these constituents were predicted.
- Non-detect soil gas analytes were included in the soil gas screening, per the procedure dictated by the SRAM (MWH, 2005b). Because these analytes were not detected in the 41 collected samples, basing risk off the maximum SQL is conservative; this approach probably overestimates the risks from exposure to soil gas. Additionally, other soil gas analytes were detected at concentrations posing only low risk and support the risk conclusions for 1,1,2-TCA, the one non-detect analyte that had an HQ above 1.

3.8.4 Conclusions and Recommendations

Of the soil analytes that were evaluated, no analytes were found to pose high risks to the receptors evaluated at the SPA. Barium was found to pose a medium risk, but because the magnitude of exceedance and incremental risk relative to background were low (background accounted for most of the predicted risk), the risk was acceptable. Two non-detect analytes showed a predicted risk, but based on the conservative nature of evaluation (maximum SQL) and the few SQLs that exceeded the ESL, the risks were acceptable. The remaining 36 soil analytes posed no risks. No analytes in soil gas were considered to pose risks.

3.9 Summary of Findings and Recommendations for SPA

3.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of potential contaminants at the SPA, 84 surface soil, 61 subsurface soil, and 59 soil gas samples were collected. Of the surface soil samples collected, 7 exceeded the metals' screening criteria, 4 locations had reported exceedances of SVOC parameters, 3 had reported elevated concentrations of TPH groups, and 11 had reported exceedances of VOCs. Table 3.9-1 lists the parameters that exceeded the criteria. Although the data indicate migration along the surface drainage paths (the primary surface migration pathway from the site), most of the exceedance locations are sufficiently evaluated downgradient by samples that did not have reported exceedances or that are similar to their respective background values and that probably were naturally occurring.

Of the subsurface soil samples collected, 12 metal samples, 2 TPH samples, and 10 VOCs were reported at concentrations that exceeded 1 or more of their respective screening criteria. The 12 metals exceedances were mostly similar to their respective background values. The vertical extents of the 2 TPH exceedances appear to have been investigated sufficiently, based on either deeper non-detect samples from the same station or their depth proximity to the bedrock interface. The 10 VOC exceedances of methylene chloride also were detected at the bedrock interface.

Three VOCs (1,1-DCE, methylene chloride, and TCE) were reported at levels that exceeded the screening criteria in soil gas collected at the site. TCE, which was detected in 15 soil gas samples, was the most prominent VOC in the SPA. Most of the TCE soil gas exceedances appear to be at or near the bedrock interface. Horizontally, samples without a TCE exceedance provide an extent boundary to the north, east, and west, while the topography provides an extent boundary to the south. Seven exceedances of 1,1-DCE were reported at this site. These exceedances were encountered at depths at or near bedrock refusal or the extent is sufficiently evaluated vertically by deeper, non-detect samples. In addition, samples were collected at similar intervals downgradient, which did not have reported 1,1-DCE exceedances. The lone methylene chloride exceedance is bounded vertically by a deeper non-detect concentration, and the extent is sufficiently evaluated horizontally by non-detect methylene chloride concentrations at similar intervals to the north.

3.9.2 Risk Assessment Summary

The human health and ecological risks at the SPA Area are summarized below.

3.9.2.1 Summary of Human Health Risks

The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater. The methods used to prepare the HHRA are described in Section 1.5.3. The results of the HHRA for the SPA are presented in Section 3.7.

The surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater samples collected during the RI sampling activities were evaluated for use in the HHRA. Surface water and sediment samples are not evaluated in this HHRA, because they were not present during the RI site characterization activities. The HHRA data set is listed in Table C.3.1-3 in Appendix C. The COPCs identified from the SPA HHRA data set for each exposure area are listed in Table C.3.1-4.

The potential future receptors at the SPA include recreationists, workers, and residents. The SPA and surrounding area are likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report. The assumed exposure pathways for future residents, workers, and recreationists are shown in Figure 1.5-2.

Generally, estimated cumulative cancer risks (ELCRs) less than the regulatory risk range (range of 1 in a million [1×10^{-6}] to 1 in 10,000 [1×10^{-4}]) and estimated non-cancer hazards (HIs) less than the regulatory threshold value of 1 are considered acceptable (EPA, 1993). Estimated ELCRs within the 1×10^{-6} to 1×10^{-4} range are managed on a site-specific basis. Table C.3.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are listed in Table C.3.5-2.

The following exposure scenarios for the SPA exceed or are within the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to indoor air (migration of soil gas COPCs)
- Hypothetical future child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future child residents exposed to soil (0 to 10 ft bgs)

The primary contributor to the ELCR for the soil exposure pathways is formaldehyde, which contributes 97 percent of the ELCR estimates (Table C.3.5-2). The primary contributor to the indoor air pathway is TCE (Table C.3.5-2).

The following exposure scenarios for the SPA are less than the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of soil gas and volatile groundwater COPCs) and indoor air (migration of volatile groundwater COPCs)
- Hypothetical future industrial workers exposed to indoor air (migration of soil gas COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

None of the exposure scenarios for the SPA exceed the regulatory threshold values for non-cancer COPCs.

The following exposure scenarios for the SPA are less than the regulatory threshold value for non-cancer COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)

- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of volatile groundwater and soil gas COPCs) and indoor air (migration of volatile groundwater and soil gas COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

The ELCR estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption are within the regulatory risk range. The primary contributors to the ELCR for the plant consumption route are BaP (contributing 51 percent), BAA (contributing 11 percent), and methylene chloride (contributing 10 percent). The HI estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory threshold value. The primary contributor for this scenario is formaldehyde (97 percent). The maximum concentrations of formaldehyde detected at the SPA primarily were reported from within the east and west dry ponds (Figure 3.4-1). Detected concentrations of formaldehyde also were reported from sampling locations southeast of each of the ponds. These locations included SPA-2-CH-1 and SPBS11, which are southeast of the east pond; and SPA-1-CH-1, SPA-1-CH-4, SPA-1-CH-7, and SPBS09, which are southeast of the west pond.

As described in Sections 1.5.3.6 and 3.7.4, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

3.9.2.1 Summary of Ecological Risks

Of the soil analytes that were evaluated, none were found to pose high risks to the receptors evaluated at the SPA. Barium was found to pose a medium risk, but because the magnitude of exceedance and incremental risks relative to background were low (background accounted for most of the predicted risk), the risks were acceptable. Two non-detect analytes showed predicted risks, but based on the conservative nature of evaluation (maximum SQL) and the few SQLs that exceeded the ESL, the risks were acceptable. The remaining 36 soil analytes posed no risks. No analytes in soil gas were considered to pose risks.

3.9.3 Recommendations for the SPA

The horizontal and vertical extents of the surface soil, subsurface soil, and soil gas exceedances have been evaluated adequately at the SPA. Therefore, no additional surface soil, subsurface soil, or soil gas samples are recommended at this site.

Potentially significant human health risks were identified for formaldehyde, BaP, BAA, and methylene chloride in soil (0 to 2 ft bgs) for the plant consumption pathway. Additionally, one VOC (TCE) in soil gas (3 to 10 ft bgs) contributed to the elevated human health risks. The extraction of soil gases in areas that have elevated TCE concentrations is recommended to reduce the human health risks. It is recommended that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC. The agricultural-based residential exposure scenario will be evaluated at a later date.

On the basis of the ERA results, no additional investigation or evaluation of soil or soil gas analytes is recommended in the FS.

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4. Alfa/Bravo Fuel Farm Area (ABFF)

4.1 Alfa/Bravo Fuel Farm Area Background and History

The Area II ABFF, known as Facility 2507, primarily consisted of five ASTs for fuel storage, the pipelines and pumps associated with the ASTs, and a secondary containment system with a storm water overflow basin. Fuel pipelines leading to the Alfa and Bravo testing facilities also have been considered part of the ABFF site. The site was built in 1955 to provide a bulk storage capacity for the petroleum-based fuels used in tests conducted at the Alfa and Bravo Test Stands. The Fuel Farm currently is inactive and has been designated as an Area II AOC. The potential lead-based coatings on the ASTs at the Fuel Farm had been deemed an area of potential concern (AOPC). The ABFF covers approximately 1.62 acres.

4.1.1 SWMUs and AOCs

No SWMUs have been designated in the ABFF Area; however, the Fuel Farm as a whole has been designated as an AOC. Additionally, the potential for lead-based coatings on the ASTs present has been deemed an AOPC.

4.1.2 Site History

The ABFF was acquired by NASA in 1973, along with the rest of the Area II property (known as USAF Plant 57 under ownership of the USAF). The fuel farm was active from 1955 until 2006. The ABFF ASTs include two 33,000-gallon RP-1 ASTs (Tanks 27 and 28) and three 10,000-gallon ramjet (RJ)-1 ASTs (Tanks 24, 25, and 26). The ASTs are located within an unlined secondary containment structure with walls varying in height from 2 to 5 ft. To the west of the ABFF, a fuel pumping station pumped fuel from delivery trucks into the ASTs. The pump station also pumped the fuel from the ASTs to the test stands (MWH, 2005d).

A concrete-lined storm water overflow basin doubled as a spill containment mechanism for the pumping station. Drainage from this basin flows westerly to an unlined, undeveloped drainage ravine. This ravine eventually leads to the Silvernale Reservoir. The three pole-mounted transformers are identified as Secondary Substation 2A and are located across Alfa Road from the ABFF. This elevated substation still exists. A second set of pole-mounted transformers has been identified to exist at this site, but these transformers have been removed.

Spills that occurred during the fueling activities at the ABFF were contained in a concrete-lined storm water basin immediately to the southwest of the pumping station and secondary containment berms for the ABFF. A valve-controlled drainage pipe from the storm water basin exits to an unlined drainage to the west (MWH, 2005d).

Pipelines extend from the ABFF eastward to the Alfa test stands and southward to the Bravo test stands. The pipelines run aboveground in some areas and belowground in others (MWH, 2005d). In the late 1990s, a partial removal of underground fuel lines that ran from the ABFF

to the test stands was performed (The Boeing Company, 2008a). After the last engine test that was performed at Alfa in March 2006, fuels in the ASTs and pipelines were drained and the entire system subsequently was cleaned in 2007 (The Boeing Company, 2008a).

A historical release occurred from the fuel pipeline leading from the ABFF to the Bravo test stands in the early 1970s. It was reported that during a transfer operation to one of the Bravo test stands, a large volume of fuel was released from the belowground pipeline. The exact quantity is unknown; however, it was believed to be a large volume based only on the gross volume readings from the ABFF AST fuel gauges. It was surmised at the time that the missing fuel was discharged or injected into the ground. No surface indications were observed at the time of the release. Following that incident, the Bravo fuel pipeline was abandoned and no longer used. Because the Bravo fuel pipeline was no longer operational, fuel was delivered to the Bravo test stand area during the remaining engine tests by tanker truck until July 2005, when the last engine test at Bravo was performed (The Boeing Company, 2008b).

An additional release of RP-1 occurred on February 26, 1998, along the abandoned fuel pipeline leading toward the Bravo test stands. This release occurred when an estimated 4,000 gallons of RP-1 from the Alfa 3 test stand was drained back to the ABFF through a transfer pipeline. During this procedure, the fuel inadvertently entered the abandoned pipeline that previously was used to transfer RP-1 to Bravo. The RP-1 flowed into this pipe and leaked out near the entrance to the Alfa Test Viewing Stand. The pipeline at this location is situated about 3 ft below grade and parallel to the Bravo Road. The RP-1 leaked out of the pipe at that point and rose to the surface through cracks in the asphalt. The RP-1 then flowed northward (downhill) in a storm water channel along the edge of the Bravo Road and eventually entered an unlined drainage channel that leads toward Silvernale reservoir. It was estimated that approximately 275 gallons of RP-1 entered the unlined drainage channel. No RP-1 was reported to have entered the Silvernale Reservoir. A removal action was performed in this area on February 1998 (The Boeing Company, 1998a).

A UST designated as UT-52 was once located across from the ABFF. This UST, with a 12,000-gallon capacity, was a double-walled Plasteel tank and was installed in 1988 and removed in 1993. Upon removal, 9 soil samples were collected from biased locations and analyzed for lead, gasoline range organics, and VOCs. The lead results were reported as being mostly similar to the background values, and VOCs and gasoline range organics concentrations were at levels below the laboratory detection limits. Tank UT-52 subsequently was closed by the VCEHD in February 1994.

4.1.2.1 Site Inventories

Inventories of the buildings, tanks, transformers, and chemicals used at the Bravo Area were compiled during the preparation of this RI report. This information was obtained from historical document reviews, facility drawings, and VSIs. These features are shown in Figure 4.1-1, as applicable. The inventories are included in the following tables:

- Building Inventory–Table 4.1-1
- Transformer Inventory–Table 4.1-2
- Tank Inventory–Table 4.1-3
- Chemical Inventory–Table 4.1-4

4.1.3 Site Chemical Use Areas

The Bravo and Alfa Test Stands were used to test rocket engines using petroleum-based fuels and LOX as the oxidizer. At the ABFF site, five ASTs were located with a capacity to store RP-1 and RJ-1 fuels. Fuel would be transferred to and from trucks at the pumping station, located on the western side of the AST tank farm.

4.1.4 Site Conditions

The ABFF Area is currently inactive, though the facility is mostly intact. There was a 12,000-gallon UST (UT-52) that was located north of the fuel farm, across Alfa Road, which has been removed and closed by the VCEHD. As previously stated, two of the ASTs (Tanks 27 and 28), are reported as active to support testing in the Alfa Area; however, testing activities have ceased.

4.1.5 Site Habitats/Land Cover

The ABFF Area is approximately 1.62 acres; of this acreage, more than one third is developed (paved, roadways, or buildings). Approximately 33 percent of the site is dense shrub/scrub (yerba santa and deer weed), with ruderal vegetation (red-stemmed filaree, red brome, and short-pod mustard) covering approximately 23 percent of the site. Woodland cover is limited to approximately 2.5 percent. Stressed vegetation was observed over approximately 5.5 percent of the site. Multiple bird and mammal species (house finch, spotted towhee, California towhee, house wren, Nuttall's woodpecker, hooded oriole, song sparrow, red-tailed hawk, American crow, American goldfinch, European starling, gopher [burrows], and California ground squirrel) were observed to use the site. Additionally, the western fence lizard was observed.

The habitats and land cover present at the ABFF Area are shown in Figure 4.1-2.

4.1.6 Historical Document Reviews

As described in Section 1.4.1, a historical document review was completed of documents applicable to the Group 3 RI Report. As a result of this historical document review, no new features were identified.

4.2 RI Characterization Activities

This subsection describes the sampling objectives, sampling scope, and key decision points associated with defining the nature and extent of the chemical impacts for the surface soil, subsurface soil, and groundwater at the ABFF site.

4.2.1 Sampling Objectives

To evaluate the extent of potential chemical effects on the ABFF site, soil, soil gas, and groundwater samples were collected. The objectives of the investigation were as follows:

- Evaluate the lateral and vertical extent of chemical impacts.
- Evaluate the potential gradients of chemicals.
- Develop a sufficient data set for performing a risk assessment.

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results and/or previous remediation activities
- Fate and transport characteristics of chemicals
- SSFL background concentrations of parameters
- SSFL SRAM-based (MWH, 2005b) screening concentrations for human health and ecological receptors

4.2.2 Sampling Scope

Provided in this report are the characterization results for soil matrix, soil gas, and groundwater information. The total numbers of samples collected as part of this report for soil matrix samples, soil gas samples, and groundwater samples are summarized below:

- Soil matrix: 91 samples
- Soil gas: 23 samples
- Groundwater: 1 sample

These samples were collected between 1997 and 2009 to identify the potential chemical impacts associated with the activities at the ABFF Area. Section 4.4 provides a detailed summary for these samples.

4.2.3 Key Decision Points

The site-specific decision points identified for the ABFF site represent the assumptions and/or decisions made during the sampling phase component of this RI, as follows:

- For historical sample points where the sample depth had not been recorded, it was assumed that these sample points were taken between the 0- to 2-foot-bgs range.

4.3 RI Characterization Results

The characterization results from the previous soil matrix, soil gas, groundwater, and surface water investigations at the ABFF Area are summarized below.

4.3.1 Soil Matrix and Soil Gas Findings

Surface soil samples were collected at this site from 1997 through 2009. To evaluate potential contamination related to the ABFF as a result of the 1996 WPA (Ogden, 1996a; 1996b; 1996c), surface soil, subsurface soil, and soil gas samples were collected in 1997 and 1998. Additionally, upon the completion of an aerial photography review (Lockheed, 1997), sampling plans and approaches were developed in conjunction with the DTSC, and TPHs and VOCs were sampled and analyzed. The findings indicated elevated concentrations of TPH groups in the area, primarily the diesel and kerosene range organics.

From 1998 through the present, RI characterization sampling was conducted to support the development of this RI report. Initial AOCs were recognized, and upon further investigations, additional AOCs were added. Each stage of the investigative process is

outlined in the RFI Report (MWH, 2004). To summarize, AOCs were investigated through soil, soil gas sampling, and NSGW sampling, which was followed as recently as late 2008 by rounds of step-out sampling for the nature and extent evaluation. Inorganics, TPHs, and SVOCs (PAHs) were detected at concentrations that exceeded the applicable screening criteria in the ABFF Area. Section 4.4 provides additional details regarding the analytes detected at this site as a result of the previous investigations. The HHRA and ERA of the analytes detected at this site are provided in Sections 4.7 and 4.8, respectively.

4.3.2 Groundwater Findings

4.3.2.1 Background

The ABFF (Figure 4.3-1) is an approximately 1.6-acre site in the west-central portion of Area II. The elevation varies from approximately 1,810 ft above msl to 1,830 ft msl across the site. Two piezometers located approximately 30 to 50 ft just outside the boundary of the ABFF provide information about the NSGW conditions. These wells and piezometers are listed in Table 4.3-1, along with construction summaries. The locations are shown in Figure 4.3-1.

NSGW conditions were investigated prior to this RI with the installation of one piezometer (PZ-071). PZ-071 was installed in December 2000 to aid in determining NSGW conditions on the eastern side of the SPA. However, for this report, RI activities at the ABFF included the installation of one piezometer, PZ-159 (Figure 4.3-1), in November 2008. The piezometer was installed within the weathered section of the Chatsworth formation with the screened interval constructed in potential water-bearing zones that were identified during rock coring activities. Unweathered Chatsworth formation was not encountered in either boring. Construction logs and boring logs for recently installed piezometer PZ-159 are provided in Appendix D.

PZ-159 was installed approximately 60 ft northeast of PZ-071 to evaluate whether NSGW in deeper sections of the weathered bedrock is present. On December 3, 2008, groundwater was detected at 18.55 ft below the top of casing (BTOC).

4.3.2.2 Local Geology

The ABFF is underlain by deposits of the Sandstone 2 unit of the Chatsworth formation, which consists of the Silvernale member at the base (Figure 4.3-1). All units strike southwest-northeast and dip approximately 30 degrees to the northwest.

The Silvernale member is the stratigraphically lowest member of the Sandstone 2 unit and consists almost entirely of medium- and fine-grained sandstone, although locally thin, lenticular conglomerates are present. The thickness of the Silvernale member varies from approximately 110 ft to 160 ft (MWH, 2007b).

During RI rock-coring activities at PZ-159, the materials encountered included alluvium/colluvium and weathered bedrock of the Chatsworth formation. Alluvial/colluvial material consisted of light olive brown to yellowish brown silty sand with some interbedded siltstone and sandstone.

Weathered bedrock encountered in PZ-159 consisted predominantly of weathered sandstone with some interbedded weathered siltstone and shale. Conglomerate was rarely

encountered. Colors ranged through shades of gray, brown, and yellow. The textures typically were medium grained.

4.3.2.3 Local Hydrogeologic Setting

The ABFF is bounded by the local surface water divide that serves as the Group 3 RI boundary to the north. Previous investigations have not delineated the occurrence of NSGW at the ABFF (MWH, 2003d). The depth to water in PZ-071, immediately south of the AOC, varies seasonally and yearly, as shown on the hydrograph of this piezometer in Figure 4.3-2.

The occurrence of NSGW has not been confirmed to date in piezometer (PZ-159), which was installed recently in the weathered section of the Chatsworth formation to support the Group 3 RI. Additional measurements are needed before it can be concluded that the water present at this location is actually NSGW and not water left over from recent rock coring and piezometer installation procedures. Potential seasonal variations in NSGW occurrences at these locations currently are being investigated. If NSGW is present at the ABFF, the flow direction is anticipated to be the west/southwest toward the SPA Area.

A comprehensive discussion of hydrogeologic characteristics of the Chatsworth formation is provided in the *Technical Memorandum Conceptual Site Model Movement of TCE in the Chatsworth Formation SSFL* (Montgomery Watson, 2000) and in the Geologic Characterization of the Central SSFL (MWH, 2007b).

4.3.2.4 Characterization Results

NSGW characterization is based on sampling events that have occurred from 2001 to the present. These data are termed "legacy" data. Sampling has been conducted for a variety of analytical groups (VOCs and metals), which have varied over time. The sampling results are summarized below to provide the NSGW characterization.

Near-surface Groundwater Characterization. NSGW has been sampled immediately south of the ABFF Area at PZ-071 from May 2001 through the present. A recently installed piezometer (PZ-159) was located to provide additional information about the occurrence and quality of NSGW, but the presence of NSGW has not been confirmed at this time. NSGW quality at the ABFF Area is represented by legacy data collected from 1987 to 2006.

Table 4.3-2 summarizes the historical (legacy) analytical sampling events of the NSGW for piezometer PZ-071 at the ABFF. The analytical groups that have been sampled include the following:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- Energetic parameters (explosives-related compounds)
- Hydrocarbons (fuel-related compounds)
- Organo-chlorine pesticides

The following subsections discuss the results of each analytical group in further detail. Table 4.3-3 summarizes the detections of analytes for each group and the data include available legacy data. Table 4.3-4 lists the metals concentrations over time and compares total concentrations versus dissolved concentrations by sample by location. Table 4.3-5 summarizes the most recently available data and compares the results with the screening level criteria, where available. The groundwater analytical data used to evaluate the NSGW conditions are provided in Appendix I.

Volatile Organic Compounds. VOC detections in NSGW at the ABFF Area are summarized in Table 4.3-3. PZ-071 was sampled for VOCs twice, on May 10, 2001, and on May 26, 2006. The VOCs detected in May 2001 included TCE, cis-1,2-DCE, trans-1,2-DCE, and VC. All of these parameters exceeded their screening criteria except for TCE. Time trend charts for these compounds in the samples collected from HAR-09 and RS-08 are shown in Figure 4.3-3.

Recently installed piezometer PZ-159 and other NSGW monitoring locations were not sampled for VOCs because of a lack of sufficient water for sample collection. If sufficient water is available, samples will be collected and analyzed at a later date. The results will be reported as an addendum to the RI report.

Table 4.3-5 summarizes the most recent VOC results from the available data. Screening level exceedances of cis-1,2-DCE and VC have occurred at PZ-071.

Semivolatile Organic Compounds. One SVOC (n-nitrosodimethylamine) has been detected (Table 4.3-3). The screening level criteria for n-nitrosodimethylamine have been exceeded at PZ-071.

Phthalates. No phthalates have been detected.

Polycyclic Aromatic Hydrocarbons. PAHs have not been detected in NSGW at the ABFF.

Metals. Metals detected in NSGW are summarized in Table 4.3-3. Dissolved versus total metals concentrations are compared in Table 4.3-4. PZ-071 exhibited screening level exceedances for dissolved manganese and dissolved molybdenum during each sampling event.

Energetic Parameters (Explosive Compounds). No energetic parameters have been detected.

Hydrocarbons (Fuel-related Hydrocarbons). Fuel-related hydrocarbons have been detected in NSGW at the ABFF. On May 26, 2006, PZ-071 was sampled for extractable fuel hydrocarbons. A hydrocarbon range of 8 to 30 was detected at a concentration of 77 µg/L. The result is below the 100-µg /L screening level.

Organo-chlorine Pesticides. Organo-chlorine pesticides have not been detected in NSGW at the ABFF.

4.3.2.3 Chatsworth Formation Groundwater

There are no piezometers or monitoring wells associated with the Chatsworth formation groundwater at the ABFF.

4.3.3 Surface Water Findings

Surface water samples were not collected during this RI investigation because of the seasonally dry conditions.

4.3.4 Completeness of Characterization

4.3.4.1 Near-surface Groundwater Characterization

The occurrence of NSGW at the SSFL, including the ABFF Area, is ephemeral and believed to be related to seasonal variations in precipitation. Newly installed piezometer PZ-159 has been sounded for the presence of groundwater, and if sufficient groundwater is present, samples will be analyzed and reported in an addendum to this RI report, as noted previously. Additional synoptic gauging of piezometers for the occurrence of NSGW and sampling of NSGW, when present, are planned across several seasons including late-winter and early-spring events when precipitation is anticipated to increase. Because of the ABFF's location immediately adjacent to the surface divide, the current NSGW monitoring network should provide sufficient sampling locations to characterize groundwater in the SMOU under optimum conditions.

4.3.4.2 Surface Water

No surface water samples were collected as part of this RI.

4.4 Alfa/Bravo Fuel Farm Area Nature and Extent

Surface soil, subsurface soil, soil gas, and NSGW samples were collected at the ABFF Area, per the protocol described in Section 4.2 and the data provided in Appendix D. Figure 4.4-1 shows the historical and the most recent surface and subsurface soil samples collected as part of this RI investigation. Table 4.4-1 lists the parameters analyzed in the sample media at this site. The nature and extent of potential contaminants that exceeded the comparison criteria values in the media sampled are described below.

4.4.1 Surface Soil Nature and Extent

A total of 44 surface soil samples were collected at this site and analyzed for one or more of the following: dioxins, TAL metals, PCBs (aroclors and congeners), SVOCs, TPHs, and VOCs. Table 4.4-2 lists the parameters detected in the surface soil samples at the ABFF Area.

4.4.1.1 Parameters Exceeding Criteria

The nature and horizontal extent of the parameters encountered at concentrations exceeding their respective comparison criteria are described below.

Dioxins. One surface soil sample was analyzed for dioxins in the ABFF Area. Fifteen of the 25 dioxin parameters were detected at Station BVBS0050; however, none was at a concentration that exceeded the screening criteria. This surface soil station, although located in the ABFF Area, more appropriately serves as a horizontal extent for contaminant migration along the ravine discharge from the Alfa/Bravo skim pond. Because the ABFF was a storage and transfer facility that did not house combustion or oxidation reactions, it is

unlikely that dioxins would be present. A more involved evaluation of dioxins in the ABFF Area does not appear to be warranted.

Metals. Metals were detected in the 17 surface soil samples collected and analyzed for metals. Manganese was detected at an estimated concentration of 605 J mg/kg (ABBS1007), exceeding its ecological criterion of 59 µg/kg, and was similar to its background value of 495 mg/kg. Manganese was detected at non-exceeding concentrations in each of the other samples analyzed. The nature of manganese in the ABFF is suggestive of natural occurrence rather than of historical operations at this site. The horizontal extent of manganese appears to have been evaluated adequately.

The vertical extent of metals is addressed in Section 4.4.2.

PCB Aroclors/Congeners. PCB aroclors were analyzed at 9 sampling locations, 1 of which (ABBS1003) also was analyzed for PCB-congeners. Four PCB-congeners were detected; however, the concentrations were at levels below the screening criteria. No PCB-aroclors were detected in the ABFF Area.

SVOCs. SVOCs were analyzed at 29 locations in the surface soil samples collected at the ABFF Area. One PAH constituent (BaP) was detected at ABBS1007 at an estimated concentration of 90 J µg/kg, which exceeded its human health criterion of 11.4 µg/kg. Sampling station ABBS1007 is located on the northern side of the pumping station, on the southern side of Alfa Road. This exceedance has been evaluated sufficiently through additional sampling; therefore, the horizontal extent of BaP, has been evaluated adequately. The vertical extent of SVOCs is described in the following subsection.

TPHs. TPHs were analyzed in 42 surface soil samples, 4 of which reported elevated concentrations of 1 or more TPH groups. Each elevated concentration detected was in exceedance of its ecological and human health comparison criteria of 100,000 µg/kg. At station ABBS10, both kerosene range (C11-C14) and lubricant oil range (C20-C30) organics were detected at estimated concentrations of 170,000 J µg/kg and 1,400,000 J µg/kg, respectively. Sampling station ABBS10 is located within the tank farm, where it is sufficiently evaluated horizontally by additional sampling and the secondary containment walls. The horizontal extent of kerosene range and lubricant oil range organics has been evaluated adequately.

Two exceedances of diesel range organics (DRO) (C14-C20) and the EFH (C21-C30) group were reported at this site in the surface soil. DROs were detected at estimated concentrations of 210,000 J µg/kg (ABBS05) and 17,000,000 J µg/kg (ABBS10), while elevated concentrations of EFH were reported at 109,000 µg/kg (ABBS1021) and an estimated 270,000 J µg/kg (ABBS0027). These exceedances appear to be sufficiently evaluated horizontally through additional sampling with the exception of the EFH (C21-C30) exceedance detected at ABBS1021. However, this location, situated in Bravo Road west of the ABFF, is sufficiently evaluated both upgradient and downgradient, along the road, by additional samples. The horizontal extents of these two TPH groups have been addressed sufficiently, as shown in Figure 4.4-2.

VOCs. No VOCs were reported at levels that exceeded the screening criteria in the 23 surface soil samples analyzed at the ABFF site. The vertical extents of these parameters are addressed in the following subsection.

4.4.2 Subsurface Soil Nature and Extent

A total of 47 subsurface samples were collected from 38 sampling stations to a maximum depth of 16 ft bgs at the site. The subsurface soil at the site was analyzed for one or more of the following: metals, PCB aroclors, SVOCs, TPHs, and VOCs. Table 4.4-3 lists the parameters detected in the subsurface soil samples at the ABFF Area.

Metals. Twenty-one metals were detected in 14 of the 17 subsurface soil samples collected at the ABFF Area and analyzed for metals. Of those, one parameter(chromium) was detected at an elevated concentration similar to its background value. This chromium exceedance was reported at a concentration of 40.1 mg/kg (ABBS1010, 3 to 3.5 ft bgs), compared to its background value of 36.8 mg/kg. This exceedance is probably a result of natural conditions and not related to historic operations at this site. The vertical extent of chromium at the ABFF Area has been addressed sufficiently. Additionally, the vertical extent of the manganese exceedance reported in the surface soil, along with a lack of exceedances in the subsurface soil, has been investigated sufficiently.

PCBs Aroclors. No PCB aroclors were detected in the subsurface soil in the 4 subsurface soil samples analyzed. These samples were collected in the vicinity of the pole-mounted transformers at this site. The vertical extent of PCBs has been evaluated adequately at this site.

SVOCs. Twenty-seven subsurface soil samples were collected from 22 sampling stations and analyzed for 1 or more SVOC parameters. One PAH constituent (naphthalene) was detected at elevated concentrations at this site. Elevated concentrations of naphthalene were reported at 250 J µg/kg (ABBS10, 5 ft bgs) and 1,050 J µg/kg (ABBS15, 6 to 6.5 ft bgs), each exceeding its human health criterion of 93 µg/kg. These exceedances were detected in the deepest intervals sampled at these locations; however, each station is encompassed by additional samples that did not have reported PAH exceedances in similar and deeper intervals. Additionally, these samples likely were collected at the bedrock interface. Therefore, the vertical extent of naphthalene, as well as BaP that was detected in the surface soil, have been evaluated adequately.

TPHs. A total of 48 subsurface soil samples, collected from 36 stations to a maximum depth of 16 ft bgs, were collected and analyzed for TPHs. Of those, 18 samples, spanning 13 sampling stations, had elevated concentrations reported of a combined 7 TPH groups. Each TPH exceedance surpassed the ecological and human health screening criteria of 100,000 µg/kg. Two groups, lubricant oil range (C20-C30) organics and EFH (C21-C30), reported 1 exceedance each. Lubricant oil range organics were detected at an estimated concentration of 150,000 J µg/kg (ABBS02, 10 ft bgs), and the EFH (C21-C30) group was detected at 119,000 µg/kg (ABBS1038, 15.5 to 16 ft bgs). Each exceedance was encountered at the bedrock interface of its respective location; therefore, the vertical extents of these groups have been evaluated adequately.

Kerosene range (C11-C14) organics were detected in 9 samples at levels that exceeded their comparison criteria. Elevated concentrations ranged from an estimated 120,000 J µg/kg (ABBS19, 5 ft bgs) to 4,500,000 µg/kg (ABBS10, 5 ft bgs). Most of these exceedances were detected within the tank farm area and stretch to the north. Exceedances were detected at the deepest samples analyzed at their respective locations, probably at the bedrock interface.

Additionally, these exceedances appear to have been evaluated sufficiently in the subsurface horizontally through additional sampling. The vertical extent of the kerosene range (C11-C14) organics has been investigated adequately at the SPA, as shown in Figure 4.4-3.

DROs (C14-C20) were detected in 9 subsurface soil samples at levels that exceeded their comparison criteria. Elevated concentrations ranged from an estimated 400,000 J µg/kg (ABBS19, 5 ft bgs) to an estimated 3,700,000 µg/kg (ABBS15, 5 ft bgs). This group was detected at elevated concentrations in the same samples as were the kerosene range organics. Per the same evaluation approach described above, DROs (C14-C20) in the subsurface soil at this site appear to have been evaluated adequately, as shown in Figure 4.4-4.

Eight exceedances of the EFH (C12-C14) group were detected at the SPA, with concentrations ranging from 304,000 µg/kg (ABBS1005, 8.5 to 9 ft bgs) to 10,700,000 µg/kg (ABBS1018, 9.5 to 10 ft bgs). Sampling stations that reported more than 1 exceedance indicate greater concentrations at the deeper sampling interval, which is probably the bedrock interface. Most of these exceedances were detected in and around the tank farm; the exception was a detection at ABBS1038, which is located next to a north-south running sewer line to the west, near the SPA site. These exceedances appear to be sufficiently evaluated horizontally through additional sampling and vertically by the bedrock surface. Additional sampling in the westerly direction may be required to provide the horizontal extent for subsurface exceedances encountered at ABBS1005 and ABBS1038. The vertical extent of the EFH (C12-C14) group is illustrated in Figure 4.4-5.

The EFH (C15-C20) group occurred in the same 8 samples at elevated concentrations as the EFH (C12-C14) group, with concentrations ranging from 218,000 µg/kg (ABBS1019, 4.5 to 5 ft bgs) to an estimated 2,850,000 J µg/kg (ABBS1018, 9.5 to 10 ft bgs). As noted in the previous paragraph, the sample locations for these exceedances appear to be sufficiently evaluated horizontally through additional sampling and vertically by the bedrock surface. Additional sampling in a westerly direction may be required to further evaluate the extent of exceedances detected at stations ABBS1005 and ABBS1038. The vertical extent of the EFH (C15-C20) group is shown in Figure 4.4-6.

Eleven exceedances of EFH (C8-C11) were reported at this site, at concentrations ranging from an estimated 120,000 J µg/kg (ABBS09, 5 ft bgs) to an estimated 2,420,000 J µg/kg (ABBS1018, 9.5 to 10 ft bgs). Generally, sampling stations with more than one sampling interval reported greater concentrations of this TPH group in the deeper interval. However, the deepest intervals probably were collected at the bedrock interface, so the vertical extent in the subsurface soil media has been addressed sufficiently. Additional sampling to the west, however, near station ABBS1018, may be required to further evaluate the TPH extent in the subsurface soil in that specific area. The vertical extent of the EFH (C8-C11) group is illustrated in Figure 4.4-7.

VOCs. A total of 26 samples from 20 sampling stations were analyzed for VOCs at this site. One sample location (ABBS10) had elevated concentrations of 3 VOC constituents (1,2,4-trimethylbenzene, 2-chloroethyl vinyl ether, and bromodichloromethane). 1,2,4-Trimethylbenzene was detected at ABBS10 at 5 ft bgs at a concentration of 36 J µg/kg, compared to its human health criterion of 35 µg/kg. 2-Chloroethyl vinyl ether was detected at ABBS10 at 5 ft bgs (220 J µg/kg) and from 5 ft to 5.5 ft bgs (180 µg/kg), compared to its

human health criterion of 0.00957 µg/kg. Bromodichloromethane was encountered at ABBS10 at 5 ft bgs (7 J µg/kg) and from 5 ft to 5.5 ft bgs (5 J µg/kg), compared to its human health criterion of 0.31 µg/kg. One additional sample location (ABBS03 at 10 ft bgs) had an elevated concentration of o-xylene (2,200 µg/kg), which exceeded its human health criterion of 150 µg/kg. These exceedances were reported at or near the bedrock interface and were not detected at elevated concentrations in the other samples analyzed for these parameters, including a sample collected in the 15.5- to 16-foot-bgs interval. The vertical extent of these VOC constituents in the ABFF Area has been addressed sufficiently.

4.4.3 Soil Gas Nature and Extent

Twenty-three soil gas samples were collected at the ABFF Area from 20 sampling locations to a maximum depth of 10 ft bgs (Figure 4.4-8). Two parameters, benzene and toluene, were detected once each in independent samples at concentrations that exceeded the applicable screening criteria. Benzene was detected at an estimated 37 J µg/m^3 (ABSV1021, 4.5 to 5 ft bgs), which exceeded its human health (36 µg/m^3) criterion. Toluene was detected at a concentration of 89 µg/m^3 (ABSV01, 5 ft bgs), which exceeded its ecological (84 µg/m^3) criterion. Station ABSV1021 is surrounded by three soil gas stations, sampled in the same interval, which did not have elevated benzene concentrations reported. Station ABSV01 is near sampling stations that did not have reported exceedances in similar and deeper intervals. The vertical extent of these VOCs as soil gases appears to have been evaluated adequately. The soil gas detections at the Bravo Area are listed in Table 4.4-4.

4.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the ABFF Area is described in Section 4.8.1.4.

4.6 Fate and Transport Analysis for Chemicals Detected in Surficial Media

4.6.1 Contaminant Sources and Release Mechanisms

The primary release mechanism for contamination at the ABFF Area is attributed to the transferring and handling of petroleum-based fuels that were stored in this area and potential leaks and spills from the ASTs and Universal Space Engine Flow Facility (USEFF) operations.

4.6.2 Potential Routes of Migration

The primary pathway for contaminant transport from the source areas at this site is the vertical migration of contaminants from surface soil to subsurface soil. Secondary transport mechanisms for this site include the release of surface soil to the air by wind erosion or volatilization, and horizontal migration along the surface via storm water or wind.

4.6.3 Contaminant Persistence

Inorganics, SVOCs, TPH groups, and VOCs were detected in the soil at the ABFF Area at levels above their screening criteria. Additionally, two VOCs were detected in the soil gas at concentrations above their screening criteria. This subsection describes the chemicals applicable to this area.

4.6.3.1 Parameters Exceeding Criteria

Inorganics, SVOCs, TPHs, and VOCs are described below.

Inorganics. Two metals were detected at this site at levels above the screening criteria. Many metals are naturally occurring and their reported presence may or may not indicate a contaminant release. The mobility of metals is complex and depends on several factors such as the overall groundwater composition, pH, metal complex formation, valence state of the metal, and cation-ion exchange capacity. Metals typically are not volatile. In the water phase, the total metal concentration includes the dissolved metal concentration and the suspended metal concentration, which is sorbed to colloidal particles. Therefore, elevated metals concentrations in groundwater may be due to the suspended load and not just to the dissolved aqueous chemistry.

SVOCs. PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. HMW PAHs are more likely to be transported via particulate emissions, while LMW PAHs have a greater tendency to volatilize (ATSDR, 1995). In general, PAHs are more likely to sorb to soil or organic matter than to partition significantly to water. Photolysis and biodegradation are two common attenuation mechanisms for PAH compounds (Howard, 1991). Animals and microorganisms can metabolize PAHs to products that ultimately reach complete degradation.

TPHs. TPHs are defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. The lighter petroleum products such as gasoline contain constituents with higher water solubility and volatility and lower sorption potential than do the heavier petroleum products such as fuel oil. Data compiled from gasoline spills and laboratory studies indicate that these light-fraction hydrocarbons tend to migrate readily through soil, potentially threatening or affecting groundwater supplies. In contrast, petroleum products with heavier molecular weight constituents, such as fuel oil, generally are more persistent in soils because of their relatively low water solubility and volatility and high sorption capacity (Stelljes and Watkin, 1991).

VOCs. VOCs are characterized by relatively high vapor pressures, Henry's Law constants, and generally high solubility in water. VOCs have a tendency to partition to the vapor phase from either soil or surface water and could be released through volatilization from contaminated soil. The sorption potential of VOCs is variable; some may persist in soil or sediment, while some are highly mobile in soil. VOCs will leach to groundwater and may persist, depending on their ability to degrade or transform in the environment.

4.6.4 Contaminant Migration

The primary sources for contaminant migration are historical leaching and potential leaks and spills from the ASTs and chemical transfer points associated with the ABFF Area.

4.6.5 Surface Soil Contaminants

Metals, TPHs, and SVOCs have been identified in surface soil at levels above the background and/or health-based risk criteria. The following observations were made for contaminants in surface soil:

- Of the metals detected in the surface soil at the ABFF Area, 1 metal (manganese) was reported at a concentration exceeding 1 or more of the criteria. This manganese exceedance was indicative of natural occurrence.
- Of the 29 surface soil samples analyzed for SVOCs, 1 location (ABBS1007) had a reported exceedance of BaP.
- Of the 42 surface soil samples collected and analyzed for TPHs, 4 had reported exceedances of 4 TPH groups. Sampling station ABBS10 reported 3 exceedances, as well as the highest concentration detected, 17,000,000 J µg/kg, of DROs (C14-C20).

4.6.6 Subsurface Soil Migration

The following observations were made for the exceedances in subsurface soil:

- One chromium exceedance was reported at this site at a concentration that probably is naturally occurring at SSFL.
- One PAH (naphthalene) was detected at 2 of 27 subsurface soil samples analyzed for SVOCs at concentrations greater than its screening criterion. These exceedances were detected in the deepest intervals sampled at these locations; however, each station is encompassed by additional samples that did not have reported PAH exceedances in similar and deeper intervals.
- Seven TPH groups were identified at elevated concentrations, spanning 18 of the 48 subsurface soil samples analyzed. TPH exceedances were detected to the bedrock interface and mostly are bound horizontally. There is some evidence of horizontal migration to the west through the subsurface.

4.6.7 Soil-to-Groundwater Migration

The relationship between chemicals detected in soil, soil gas, and groundwater has been evaluated to assess whether soil chemical concentrations have affected groundwater quality. Soil chemical concentrations were reviewed and compared with available groundwater concentrations immediately south of the ABFF study area. The evaluation was based on the chemicals detected, background concentrations, spatial distribution, and hydrogeologic conditions. The evaluation provides conclusions regarding soil sources for detected chemicals in groundwater.

NSGW has not yet been delineated at the ABFF; therefore, groundwater that has been affected by soil contamination in the immediate area cannot be confirmed at this time. TPH

has been detected at elevated concentrations in subsurface soil at the ABFF Area, including in the weathered bedrock, so there is a potential for local soil-to-groundwater migration to occur during rainy weather months. NSGW will be characterized in PZ-159 if sufficient water is available for sampling. Nearby Chatsworth formation wells south of the ABFF have not exhibited elevated concentrations of TPH; affected groundwater in these locations probably is related to operations at adjacent SWMUs and AOCs other than the ABFF.

4.7 Human Health Risk Assessment for Alfa/Bravo Fuel Farm Area

The objective of this HHRA is to assess whether the environmental media at the ABFF Area could pose risks to human health at levels that might require remedial action, or risks at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil, soil gas, and groundwater at the ABFF Area. The methods and guidance documents used in the preparation of this HHRA are discussed in Section 1.5.3 of this report. A discussion of the HHRA results for the ABFF Area is presented below. The results are summarized in Section 4.9.2.

The concentration data, input parameters, and results of the HHRA for the ABFF Area are presented in Appendix D. An index of the tables (Appendix D human health RA Tables Index) is provided to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated non-cancer HIs.

4.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the ABFF Area, based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

4.7.1.1 Data Evaluation

The soil, soil gas, and groundwater sampling analytical data at the ABFF Area were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.5.3.1. Sediment and surface water data were not collected as part of the RI site characterization activities. The locations of the soil, soil gas, and groundwater samples used in this HHRA are shown in Figures 4.4-1 and 4.4-8. The samples used in this HHRA are listed in Table D.4.1-1 by medium, sample ID, sampling depth interval, and date of collection. Table D.4.1-2 lists the target receptor populations by medium. Descriptive summary statistics of these data are provided in Table D.4.1-3.

4.7.1.2 Identification of COPCs in Soil

The results of the COPC screening process for soil at 0 to 2 ft bgs and 0 to 10 ft bgs are listed in Table D.4.1-3. Detected analytes in soil at the ABFF Area were compared to background levels. COPCs identified in soil (0 to 2 ft bgs) included 6 inorganics (arsenic, barium, chromium, cobalt, nickel, and vanadium) and 19 organics. COPCs identified in soil (0 to 10 ft bgs) included 6 inorganics (aluminum, arsenic, barium, chromium, nickel, and vanadium) and 31 organics.

4.7.1.3 Identification of COPCs in Groundwater

The results of the COPC screening process for NSGW are listed in Table D.4.1-3. Detected analytes in NSGW at the ABFF Area were compared to background comparison criteria. COPCs identified in NSGW included 2 inorganics (manganese [dissolved] and molybdenum [dissolved]) and 2 organics (TCE and n-nitrosodimethylamine).

4.7.1.4 Identification of COPCs in Soil Gas

The results of the COPC screening process for soil gas at 3 to 10 ft bgs are listed in Table D.4.1-3. Seven COPCs (2-butanone, acetone, benzene, ethylbenzene, tetrachloroethene, toluene, and m,p-xylenes) were identified in soil gas.

4.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the ABFF Area may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential exposures. Figure 1.5-2 depicts the conceptual exposure model for the ABFF Area. Table D.4.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

4.7.2.1 Identification of Receptors

The ABFF Area recently was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the industrial worker and recreationist exposure scenarios were evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

4.7.2.2 Identification of Exposure Pathways

Future residents and industrial workers were assumed to be exposed to groundwater, soil gas (modeled for migration to indoor air and ambient air), and soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). Future recreationists were assumed to be exposed to groundwater, soil gas (modeled for migration to ambient air), and soil (0 to 2 ft bgs). Exposure pathways for groundwater included direct exposures (ingestion and dermal) and indirect exposures. Inhalation exposures were quantified for the migration of groundwater and soil gas to ambient air and indoor air. Additionally, exposures were quantified for residential receptors for the inhalation of groundwater VOCs in bathroom air while showering or bathing. Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the ABFF Area are provided in Table D.4.1-6.

4.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs, soil at 0 to 10 ft bgs, soil gas, and groundwater at the ABFF Area are listed in Table D.4.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts, ambient air, indoor air, and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for non-volatile COPCs. The derivation of the PEF for soil is listed in Table D.4.1-5.

Ambient air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs to ambient air and migration from groundwater to ambient air. Parameter values used for soil gas-to-air migration and for estimating the ambient air EPCs related to soils are listed in Table D.4.1-8. Parameter values used for estimating ambient air EPCs related to groundwater also are listed in Table D.4.1-8. The estimated ambient air concentrations from the migration of volatile COPCs in soil and groundwater are listed in Tables D.4.1-9, D.4.1-10, and D.4.1-11, respectively.

Indoor air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs and from NSGW using the J-E Model (EPA, 2004e). The parameter values used in the J-E Model (EPA, 2004e) are listed in Table D.4.1-8. Soil gas data, where available, were preferentially used for indoor air modeling. The estimation of indoor air concentrations from soil gas and groundwater migration are presented in Tables D.4.1-12 through D.4.1-17.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b). COPC concentrations in edible plant tissues from soil at 0 to 2 ft bgs are listed in Table D.4.1-18.

4.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate chemical intakes for potential adult and child residential, adult and child recreationist, and industrial worker receptors at the ABFF Area. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix D. See the Appendix D human health RA Tables Index for a list of the tables that present the exposure parameters and chemical intakes for each exposure scenario.

4.7.3 Risk Characterization

In the risk characterization component of the HHRA process, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.5.

The exposure assumptions, EPCs, toxicity factors, and risk characterization result tables for this HHRA are presented in Appendix D (Appendix D human health RA Tables Index**)**. The risk calculation tables present the estimated ELCRs and non-cancer HIs for potentially exposed receptors and individual exposure routes for soil, indoor air, and groundwater at the ABFF Area, as well as the cumulative risks and HIs across all exposure routes for the

RME and CTE scenarios. Table D.4.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are shown in Table D.4.5-2.

4.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.02 for the CTE case to 0.04 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The cumulative ELCR and HI mentioned above do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 4×10^{-5} for the CTE case to 6×10^{-4} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 0.3 for the CTE case to 1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The elevated ELCR estimates for the plant consumption pathway are primarily due to arsenic in soil (0 to 2 ft bgs). Arsenic contributes 88 to 95 percent of the ELCR estimates for the plant consumption pathway. Arsenic was detected at concentrations slightly above the SSFL mean background level at several sample locations across the ABFF. The maximum detected concentration of arsenic in soil (0 to 2 ft bgs) was 6.1 mg/kg, compared to a mean background value of 4.5 mg/kg. Thus, it is possible that the elevated concentrations of arsenic at the ABFF are due to a natural occurrence.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.03 for the CTE case to 0.06 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-8} for the CTE case to 2×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The HI estimates for non-cancer effects range from 3×10^{-4} for the CTE case to 5×10^{-4} for the RME case. The CTE and RME HI estimate do not exceed the regulatory threshold value of 1.

- For indoor air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-12} for the CTE case to 2×10^{-11} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 2×10^{-8} for the CTE case to 4×10^{-8} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-10} for the CTE case to 2×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 3×10^{-6} for the CTE case to 6×10^{-6} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-14} for the CTE case to 1×10^{-13} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 1×10^{-10} for the CTE case to 3×10^{-10} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to COPCs in NSGW, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-9} for the CTE case to 5×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to COPCs in NSGW, the HI estimates for non-cancer effects were 0.001 for the

CTE and RME cases. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

4.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposures to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-5} for the CTE case to 5×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.2 for the CTE case to 0.4 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1. The cumulative ELCR and HI estimates mentioned above do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 4×10^{-5} for the CTE case to 2×10^{-4} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 0.4 for the CTE case to 1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The elevated ELCR estimates for the plant consumption pathway are primarily due to arsenic in soil (0 to 2 ft bgs). Arsenic contributes 88 to 95 percent of the ELCR estimates for the plant consumption pathway. As previously mentioned, arsenic was detected at concentrations slightly above the SSFL mean background level at the ABFF, and it possible that the arsenic concentrations may be due to a natural occurrence.
- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-5} for the CTE case to 6×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.3 for the CTE case to 0.6 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of

vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-7} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects are 0.002 for the CTE and RME cases. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

- For indoor air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-11} for the CTE case to 1×10^{-11} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 1×10^{-7} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-9} for the CTE case to 1×10^{-9} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 2×10^{-5} for the CTE case to 2×10^{-5} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-14} for the CTE case to 7×10^{-14} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 7×10^{-10} for the CTE case to 7×10^{-10} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to COPCs in NSGW, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-9} for the CTE case to 5×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to COPCs in NSGW, the HI estimates for non-cancer effects range from 0.003 for the CTE case to 0.006 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

4.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-7} for the CTE case to 8×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.001 for the CTE case to 0.01 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-11} for the CTE case to 2×10^{-10} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 2×10^{-7} for the CTE case to 6×10^{-7} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-15} for the CTE case to 1×10^{-14} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 7×10^{-12} for the CTE case to 3×10^{-11} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

4.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposures to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. A hypothetical future recreationist child (15-kg body weight) was assumed to be exposed for 100 days per year over 6 years for the RME case and 50 days per year over

6 years for the CTE case. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.02 for the CTE case to 0.1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-10} for the CTE case to 4×10^{-10} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 1×10^{-6} for the CTE case to 5×10^{-6} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-15} for the CTE case to 2×10^{-14} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 6×10^{-11} for the CTE case to 2×10^{-10} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

4.7.3.5 Hypothetical Future Industrial Worker Exposure Scenario

Potential industrial worker exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-6} for the CTE case to 3×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.01 for the CTE case to 0.06 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-6} for the CTE case to 4×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to

1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.02 for the CTE case to 0.09 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future industrial building. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-8} for the CTE case to 5×10^{-8} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 9×10^{-5} for the CTE case to 2×10^{-4} for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

- For indoor air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-12} for the CTE case to 5×10^{-12} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 7×10^{-9} for the CTE case to 1×10^{-8} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-10} for the CTE case to 2×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 3×10^{-6} for the CTE case to 5×10^{-6} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-14} for the CTE case to 9×10^{-14} for the RME case. The CTE and RME ELCR estimates are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 1×10^{-10} for the CTE case to 2×10^{-10} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

4.7.4 Uncertainty Discussion

Uncertainties associated with the results of this HHRA are a function of both the "state of the practice" of HHRA in general and UFs specific to the ABFF Area. A discussion of the general HHRA uncertainty is presented in Section 1.5.3.

4.8 Ecological Risk Assessment for Alfa/Bravo Fuel Farm Area

4.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to all RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the ABFF are described below.

4.8.1.2 Site Background

The ABFF, primarily used to store fuels for use in engine testing, consisted of five ASTs for fuel storage, the pipelines and pumps associated with the ASTs, and a secondary containment system with a storm water overflow basin. A 12,000-gallon gasoline UST (UT-52) was removed and clean closure was granted in 1994 by VCEHD (MWH, 2004). A more detailed discussion of the site conditions and history is presented in Section 4.1.

The ABFF contains substantial area of paved roads and buildings. Pavement, buildings, and associated developed areas constitute about 36 percent of the land cover at this site. Habitat at the site was characterized through a site survey conducted in April 2008. This survey indicated that the ABFF consists of four habitat types, including scrub-shrub, ruderal, stressed vegetation, and woodland habitat (Figure 4.8-1). Most of the site (about 33 percent) consists of scrub-shrub habitat consisting mainly of yerba santa and deer weed. The scrub-shrub habitat is distributed in patches divided by paved roadways and buildings. Ruderal habitat makes up about 23 percent of the site and is located in the central portion of the site and adjacent to paved areas. It is dominated by red-stemmed filaree, red brome, and small pod mustard. About 2 percent of the site consists of woodland habitat, divided along the northeastern, southern, and southeastern edges of the site. Evidence or actual observations of the following bird and mammal species were noted during the site visit: house wren, house finch, spotted towhee, California towhee, Nuttall's woodpecker, hooded oriole, song sparrow, red-tailed hawk, American crow, American goldfinch, European starling, gopher [burrows], and California ground squirrel. Additionally, the western fence lizard was observed. Stressed ruderal vegetation was identified, primarily adjacent to paved areas. Stressed vegetation accounted for approximately 6 percent of the habitat at the site.

4.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the ABFF is the same as that for all Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the ABFF are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 4.8-1).
- Representative species and receptor groups considered for the ABFF include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary

consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

4.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the ABFF is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the ABFF is described below and presented in Figure 4.8-2.

The primary contaminant sources at the ABFF include five ASTs for fuel storage, the pipelines and pumps associated with the ASTs, and a secondary containment system with a storm water overflow basin. Primary release mechanisms include spills and leakage to the ground surface and runoff from the storm water overflow basin. Soil is the secondary source of potential contaminant. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater.

Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). Table 4.8-2 provides additional descriptions of potential exposure pathways for the ecological receptors at the ABFF, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

4.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil and soil gas are listed in Table 4.8-3. Summary statistics for those detected analytes are listed in Table 4.8-4. A central tendency background comparison for metals and dioxins/furans in soils was conducted to assess whether the analytes were consistent with background (Table 4.8-5). The volatile organics in soil and soil gas are compared in Table 4.8-6. Non-detect analytes were evaluated by comparing the maximum SQLs against the minimum ESL and determining the exceedance frequency of the SQLs (Table 4.8-7). The CPECs identified for the ABFF are summarized in Table 4.8-8. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 4.8-9, 4.8-10, and 4.8-11, respectively. EPCs for soil gas from 0 to 6 ft bgs are listed in Table 4.8-12. Calculations for extrapolating soil gas concentrations from soil concentrations are listed in Table 4.8-13.

4.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 4.8.1) with the risk characterization (Section 4.8.3) and consists of the technical evaluation of ecological and chemical data to assess the potential for ecological exposure and effects. Generalized

components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the ABFF is presented below.

4.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this section.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the ABFF. Because the ABFF is strictly terrestrial, exposure is based on soil and soil gas and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

Although the ABFF covers 1.62 acres, the spatial extent of samples associated with the site is 3.52 acres. More than 60 percent of the land cover at this site consists of buildings, pavement, rock, and ruderal or stressed vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) and soil gas were calculated for the ABFF, according to the approach outlined in Section 1.5.4.4. These values are presented in Tables 4.8-9 through 4.8-12. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 4.8.3).

4.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for the receptors at the SSFL are summarized in Section 1.5.4.4. No effects data specific to the ABFF are available. Consequently, the ESLs, Low TRVs, and High TRVs for terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

4.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the ABFF. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the ABFF. The results of these comparisons are presented below.

4.8.3.1 Risk Estimation

The risk estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 4.8-14 through 4.8-21. Table 4.8-17 presents an analysis of the depth intervals for evaluating burrowing animals (deer mouse). The 0- to 4-foot-bgs depth interval had the greatest HI; therefore, the data from this depth were used to evaluate the deer mouse.

4.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with other available and appropriate lines of evidence, to evaluate potential chemical impacts on ecological receptors in SSFL's Group 3. Chemicals that had HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of COECs includes receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.
2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.
5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.
6. No Risk–all HQs and associated HIs<1.
7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Six soil analytes (aluminum, arsenic, barium, chromium, nickel, and vanadium) were found to have one or more HQs greater than 1 under any scenario (Table 4.8-22). The other soil analytes and/or analyte groups were found to pose no risk (all HQs and HIs were less than 1) to receptors under any scenario (maximum concentration for plants, invertebrates, and soil gas exposures; CTE and RME concentrations for birds and mammals) at the ABFF. Among receptors, no exceedances were observed for terrestrial plants, and only one analyte exceeded the screening TRVs for soil invertebrates (arsenic) and soil gas (1,1,2-TCA), respectively. HQs greater than 1 predominantly were observed for bird and mammal receptors.

Six inorganics (aluminum, arsenic, barium, chromium, nickel, and vanadium) were identified as elevated relative to background, based on the non-parametric central tendency background comparisons for soil (Table 4.8-5). Risks from arsenic were considered

medium-low (low TRV-based HQs<10 and high TRV-based HQs<1). Risks from barium and nickel were considered medium (1<high TRV-based HQs>2 but low TRV-based HQ>10). Chromium was considered to pose a high risk (high TRV-based HQ>5) and vanadium was considered to pose a medium-high risk (2<high TRV-based HQ>5). Aluminum was only considered above background in the 0- to 4-foot and 0- to 6-foot-depth intervals, and therefore was only a CPEC for the deer mouse (evaluated based on the 0- to 4-foot-depth interval). The RME background concentration for aluminum (12,800 mg/kg) is only slightly lower than the RME site concentration (13,900 mg/kg) and indicates that the incremental risk is low (Table 4.8-23). Additionally, the bioavailability of aluminum is correlated with soil pH and it is not considered bioavailable at pH levels above 5 (EPA, 2003). At the ABFF, pH ranges from 6.62 to 7.88, which suggests that aluminum is not bioavailable and is considered to pose an acceptable risk to the deer mouse. The remaining five inorganic analytes (arsenic, barium, chromium, nickel, and vanadium) were found to have incremental HQs (based on a high TRV and RME) of less than 1 (Table 4.8-23); therefore, risks from these inorganics are considered to be dominated by background and to be acceptable. The mean site concentrations for arsenic (4.71 mg/kg) and chromium (22.7 mg/kg) in the 0- to 2-foot-depth interval were only marginally greater than the mean background concentrations for arsenic (4.47 mg/kg) and chromium (19.3 mg/kg). The maximum detected arsenic site concentration (6.1 mg/kg) is also less than the background RME concentration (6.55 mg/kg) for arsenic. Both arsenic and nickel had high TRV-based HQs of less than 1 for the wildlife receptors, based on the RME. Although arsenic did have an HQ of 24 for terrestrial invertebrates, once background was accounted for, the incremental risk was less than 1. Barium and vanadium both had high TRV-based HQs for one or more receptors (based on the RME and CTE) of greater than 1 but less than 5. Consequently, none of the inorganics that were retained was considered to pose risks to receptors at the ABFF.

Ten soil gas analytes were retained and evaluated as part of this ERA. Of these, 7 were detected, 2 failed the SQL screen (Table 4.8-7), and 1 was modeled based on the soil concentration. As indicated by the soil gas screening, only one soil gas analyte, 1,1,2-TCA, had an HQ above 1. 1,1,2-TCA was not detected in the 19 samples. The TRV for this analyte is conservative and was derived from an LD50 using an uncertainty factor of 100. The application of the uncertainty factor may overestimate or underestimate a no-effect level. Additionally, this evaluation used the maximum SQL and TRVs based on a no effect level. Consequently, risks from the evaluated VOCs are acceptable.

Tables 4.8-24 and 4.8-25 list the soil COECs and the soil gas COECs, respectively.

4.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component of all risk assessments. Generalized uncertainties for ERAs in SSFL's Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- Samples were collected outside the site boundary in an effort to further evaluate potential releases from the ABFF. If sample concentrations decreased with distance from the site, the inclusion of these additional data may underestimate risk in the core portion of the site when these data are integrated into the RME and CTE calculations.

- No screening levels were available to evaluate the TPH data; however, PAH data were available and no risk from these constituents was predicted.
- Non-detect soil gas analytes were included in the soil gas screening, per the procedure dictated by the SRAM (MWH, 2005b). Because these analytes were not detected in the 19 collected samples, basing risks on the maximum SQL is conservative; this approach probably overestimates risks from exposure to soil gases. However, soil gas contamination is present at the site and may support the presence of some of the non-detect analytes that have high SQLs.

4.8.4 Conclusions and Recommendations

Of the soil analytes that were evaluated, chromium was found to pose high risks to the receptors evaluated at the ABFF. However, once background was accounted for, chromium was considered to have low incremental risk and is not considered a risk driver. Five other inorganic analytes also were retained for evaluation but background accounted for the majority of risks in all cases. Of the remaining soil analytes, 20 posed no risk and 1 did not have TRVs. No analytes in soil gas were considered to pose risks; further investigation of soil and soil gas is not recommended.

4.9 Summary of Findings and Recommendations for Alfa/Bravo Fuel Farm Area

4.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of potential contaminants at the Area II ABFF Area, 44 surface soil, 47 subsurface soil, and 23 soil gas samples were collected. Of the surface soil samples collected, 1 metal, 1 PAH, and 4 TPH groups were detected at levels that exceeded the applicable comparison criteria. Table 4.9-1 lists the parameters that exceeded the criteria. The exceedance of manganese was at concentrations indicative of natural occurrence. The PAH exceedance (BaP) was limited to one sampling station, which was bound horizontally by additional sampling and the encompassing secondary containment walls. The extent of surface soil exceedances have mostly been evaluated adequately, except for the TPHs detected at station ABBS1021. Additional surface soil sampling may be required, specifically of EFH (C21-C30) in easterly and westerly directions. Samples to the north and south of this location, along the road, did not have reported TPH exceedances.

Of the subsurface soil samples collected, 1 metal, 1 PAH, 4 VOCs, and 7 TPH groups were reported at concentrations that exceeded 1 or more of the screening criteria. Chromium was detected at a concentration indicative of natural occurrence; the vertical extent of metals has been evaluated adequately. The PAH exceedances were encountered at the deepest intervals sampled, which are at the bedrock interface. Additional samples in the same or deeper intervals surround each exceedance, suggesting that the vertical extent of PAHs has been investigated sufficiently. VOC exceedances were encountered at or near the bedrock interface in their respective sample locations and were not encountered in deeper soil samples at other nearby sample locations.

The 7 TPH groups detected at elevated concentrations were detected in samples at similar intervals. Samples that exhibited these exceedances were found down to the bedrock interface, thus completing the vertical extent. Additionally, the exceedances are sufficiently evaluated horizontally through additional subsurface soil sampling, except for the exceedances reported at ABBS1005 and ABBS1038. Additional sampling for TPHs in a westerly direction may be warranted to evaluate the extent of these parameters in the subsurface soil.

Two VOCs, benzene and toluene, were reported at levels that exceeded the screening criteria in soil gas collected at the site. Each VOC was detected once at an elevated concentration and was not encountered as an exceedance either in soil or in the NSGW samples. Additional soil gas samples in the vicinity of each exceedance provide horizontal extent boundaries for these parameters, indicating that VOCs have been addressed sufficiently as soil gases in the ABFF Area.

4.9.2 Risk Assessment Summary

The HHRA and the ERA for the ABFF Area are summarized below.

4.9.2.1 Summary of Human Health Risks

This subsection summarizes the HHRA performed for the ABFF Area. The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater. The methods used to prepare the HHRA are described in Section 1.5.3. The results of the HHRA for the ABFF Area are presented in Section 4.7.

The surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater samples collected during the RI sampling activities were evaluated for use in the HHRA. Surface water and sediment samples are not evaluated in this HHRA, because they were not present during the RI site characterization activities. The HHRA data set is listed in Table D.4.1-3 in Appendix D. The COPCs identified from the ABFF Area HHRA data set for each exposure area are listed in Table D.4.1-4.

The potential future receptors at the ABFF Area include recreationists, workers, and residents. The ABFF Area and surrounding area is likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report at a later date.

Generally, estimated cumulative cancer risks (ELCRs) less than the regulatory risk range (range of 1 in a million [1×10^{-6}] to 1 in 10,000 [1×10^{-4}]) and estimated non-cancer hazards (HIs) less than the regulatory threshold value of 1 are considered acceptable (EPA, 1993). Estimated ELCRs within the 1×10^{-6} to 1×10^{-4} range are managed on a site-specific basis. Table D.4.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are shown in Table D.4.5-2.

The following exposure scenarios for the ABFF Area exceed or are within the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)

The primary contributor to the ELCR for the soil exposure pathway is arsenic (ranging from 97 to 100 percent of the ELCR estimate) [Table D.4.5-2].

The following exposure scenarios for the ABFF Area are less than the regulatory risk range for carcinogenic COPCs:

- Hypothetical future residents, industrial workers, and recreationists exposed to indoor air (migration of soil gas and volatile groundwater COPCs) and ambient air (migration of soil gas and volatile groundwater COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

The following exposure scenarios for the ABFF Area are less than the regulatory threshold value for non-cancer COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationists exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of volatile groundwater and soil gas COPCs) and indoor air (migration of volatile groundwater and soil gas COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

The ELCR estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory risk range. The primary contributor for this scenario is arsenic (ranging from 88 to 95 percent of the ELCR estimate) [Table D.4.5-2]. The HI estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption did not exceed the regulatory threshold value [Table D.4.5-2].

As described in Sections 1.5.3.6 and 4.7.4, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

4.9.2.2 Summary of Ecological Risks

Of the soil analytes that were evaluated, chromium was found to pose high risks to the receptors evaluated at the ABFF Area. However, once background was accounted for, chromium was considered to have a low incremental risk and is not considered a risk driver. Five other inorganic analytes also were retained for evaluation, but background accounted for most of the risks in these cases. Of the remaining soil analytes, 20 posed no risk and 1 did not have TRVs. No analytes in soil gas were considered to pose risks; therefore, further investigation of soil gas is not recommended.

4.9.3 Recommendations for the Alfa/Bravo Fuel Farm Area

To complete the nature and extent evaluation in the ABFF, additional surface and subsurface soil samples for TPH analyses are recommended. Additional surface soil sampling is recommended, specifically of EFH (C21-C30) in easterly and westerly directions from ABBS1021. Additional sampling for TPHs in a westerly direction is recommended to evaluate the extent of TPH groups in the subsurface soil near ABBS1005 and ABBS1038.

Potentially significant human health risks were identified for arsenic in soil (0 to 2 ft bgs and 0 to 10 ft bgs). Arsenic was detected at concentrations slightly above the SSFL background level at several sample locations across the ABFF. The maximum detected concentrations of arsenic in soil at 0 to 2 ft bgs and 0 to 10 ft bgs were 6.1 mg/kg and 7.9 mg/kg, respectively, compared to a mean background value of 4.5 mg/kg. The slightly elevated concentrations of arsenic at the ABFF may be naturally occurring. It is recommended that the presence of arsenic at the ABFF be further evaluated following the revision of the SSFL background data set. It is important to note that the detected concentrations of arsenic at the ABFF are less than the reported background values for 12 California USAF installations (Hunter, 2001). The article, *Naturally Occurring Concentrations of Inorganic Chemicals in Groundwater and Soil at California Air Force Installations* (Hunter, 2001), reported a 95th percentile background value of 11 mg/kg for soil at a depth of less than 2.5 ft bgs and a 95th percentile background value of 14.7 mg/kg for soil at a depth of 2.5 to 10 ft bgs).

Arsenic in soil (0 to 2 ft bgs) also contributed to elevated human health risks for the plant consumption exposure pathway for a potential future residential scenario. It is recommended that that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC. The agricultural-based residential exposure scenario will be evaluated at a later date.

On the basis of the ERA results, no additional investigation of soils or soil gas at the ABFF is recommended in the FS.

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5. Bravo Area

5.1 Bravo Area Background and History

The Area II Bravo Area primarily consisted of three test stands associated with turbo pump and rocket engine testing that used petroleum-based fuels (RP-1 and/or Jet Propellant [JP-4]) and LOX as the oxidizer. This site was active from 1956 until 2005, when the last engine test was completed. Most of the activity occurred at the Bravo Area during the 1950s and 1960s. Nine buildings, two test stands, two former skim ponds, an AST waste tank area, a groundwater reclamation and remediation facility, drainage channels, and underground drainage pipes are areas associated with and within the boundary of the Bravo Area site. Some of these features are designated as SWMUs or AOCs. These features are described further below.

5.1.1 SWMUs and AOCs

A total of five SWMUs have been designated within the Bravo Area. The former Alfa/Bravo Skim Pond, which received cooling water from both the Alfa and Bravo test stands, has been designated as SWMU 5.15. The former skim pond, with an estimated 200,000-gallon capacity, most recently was used for surface water runoff and emergency spill containment. The pond also was used to prevent TCE from flowing to the Silvernale Reservoir. Closure of the Alfa/Bravo Skim Pond began in 1988 and included the excavation of soil to bedrock, backfill with clean soil, and installation of a bypass pipeline for water discharges from Alfa and Bravo testing operations. SWMU 5.13 is the designation for the three Bravo test stands. Of the three, only Bravo Test Stand 3 was dismantled (1969). The Bravo Waste Tank has been titled as SWMU 5.14. This waste tank, located below Bravo Test Stand 2, was constructed in 1972 and 1973; the secondary containment was built in 1992. There has been no documented release from this 1,000-gallon AST, which received mixtures of hydraulic oil, RP-1, and water from testing operations. SWMU 5.15 is the Bravo Skim Pond, which was the primary retention pond for spent cooling water and residual TCE from the Bravo Area testing and cleaning activities. The estimated capacity of the unlined pond is 150,000 gallons and the SWMU includes the drainage leading to the pond from the test stands and drainage leading to the Alfa/Bravo Skim Pond (SWMU 5.15). The fifth SWMU is SWMU 5.27, the Bravo Groundwater Air Stripping Tower. Since its operations began in 1987, this unit has been used in facility-wide reclamation and remediation of groundwater underlying the SSFL facility.

Three AOCs are associated with the Bravo Area. Two leach fields, one associated with Building 2213 and the other with Building 2217, have been designated as AOCs. The third AOC is the drainage piping located beneath the former Alfa/Bravo Skim Pond. This piping was installed following the excavation of the related skim pond in 1988 and was used as a bypass for the spent process water used at the Alfa and Bravo test stands.

5.1.2 Site History

The Bravo Area was acquired by NASA in 1973, along with the rest of the Area II property (known as USAF Plant 57 under ownership of the USAF). Two engine test stands are present in the Bravo Area and a third was demolished in 1969. The buildings and facilities, along with their related purposes, are described below.

Building 2213, constructed in 1956, served as a control center for Bravo Area test operations. The concrete building contained control, monitoring, and video equipment. A former leach field, associated with the control center, has been recognized south of the building and designated as an AOC.

Building 2214, constructed in 1956, was used as the Terminal House. The concrete building, located next to Building 2732, housed electronic components and wiring associated with testing activities. Adjacent to the northern side of the Terminal House is a valve pit, which consists of a grated, concrete vault.

Building 2217, which was destroyed by wildfires in 2005, was located in a paved area southwest of the test stands. Its construction date is unknown, but it was designated as the Pretest Shop. A leach field associated with this building has been observed to the north of the former building location, which is noted as an AOC. Building 2217A, also destroyed by wildfires in 2005, was an Engineering Trailer for the Pretest Shop.

Buildings 2730A and 2731A were designated as the Bravo 1 and 2 Electrical Control Shacks (ECSs), respectively. Their construction dates are unknown; however, it may be deduced that each facility was constructed along with the construction of the test stands in 1956. The buildings house electrical components and switches for the Bravo Area Test Stands 1 and 2, respectively. Buildings 2730A and 2731A are located northwest of their respective test stands, in the opposite direction from the exhaust buckets. A hydraulic tank and motor pump, located on the western side of Building 2731A, are situated within a concrete secondary containment berm.

Building 2732, positioned south of Building 2214, was used as a storage building for the Bravo Area. The building is of sheet metal siding; its construction date is unknown. During a field investigation, it was noted that the building still houses a variety of miscellaneous equipment and parts.

Building 2V was designated as the Bravo Area Entry Guard Shack. The building was destroyed by 2005 wildfires; its original construction date is unknown.

Building 2Z is the Bravo Area Pillbox. The Pillbox, constructed of reinforced concrete, was used to view engine tests in progress, providing a safe viewing angle for SSFL personnel. Its construction date is unknown.

The three test stands in the Bravo Area were numbered 1 through 3, north to south, each positioned so the exhaust buckets faced an easterly direction. Of the three, only Bravo Area Test Stand 3 has been demolished. The open-frame metal structures, built in approximately 1956, were secured by concrete foundations. These facilities were used to test a number of thrust chambers, Vernier engines, and turbo pumps. The Bravo Area was constructed to support operations at these test stands, which were active from 1956 until 2005. Petroleum-based fuels such as RP-1 and JP-4 were used as the fuel sources for combustion at these test

stands. Early testing was preceded by and followed by cleaning using TCE to remove the residual carbon deposits in the testing lines.

5.1.2.1 Site Inventories

Inventories of the buildings, tanks, transformers, and chemicals used at the Bravo Area were compiled during the preparation of this RI report. This information was obtained from historical document reviews, facility drawings, and VSIs. These features are shown in Figure 5.1-1, as applicable. The inventories are included in the following tables:

- Building Inventory–Table 5.1-1
- Transformer Inventory–Table 5.1-2
- Tank Inventory–Table 5.1-3
- Chemical Inventory–Table 5.1-4

5.1.3 Site Chemical Use Areas

The Bravo Area Test Stands were used to test rocket engines using petroleum-based fuels and LOX as the oxidizer. Five ASTs were located at this site, with a combined capacity of approximately 75,000 gallons to store RP-1 fuel.

At Building 2214, the Terminal House, a minor release (0.03-ounce) of mercury occurred in the building from a broken thermometer (Rockwell, 1991). Flammable material storage lockers were observed on the western side of Building 2214 during a 2005 VSI of the building (NASA, 2006).

At Building 2217, the former Bravo Pre-Test Shop was reported to have stored hazardous materials, including igniters used during engine testing activities. These igniters contained triethyl aluminum (TEA) and triethyl boron (TBA). Wastes stored at Building 2217 included spent igniters, waste caustic debris, waste solvent debris, waste aerosols, and waste alkaline batteries (The Boeing Company, 2007).

Test Stands 1 and 2 (Buildings 2730 and 2731, respectively) performed engine tests using JP-4, RP-1, and LOX. Hazardous materials stored and used at Test Stands 1 and 2 included RP-1, JP-4, hydraulic oil, oronite, TCE, TCA, LOX, Braycote 756, gaseous nitrogen (GN2), kerosene, waste oil and water, and kerosene fuel composite standard-waste (The Boeing Company, 2007). A 1,000-gallon Bravo Waste Tank (SWMU 5.14) located at Test Stand 2 was used to store waste RP-1, hydraulic oil, and water from testing activities. The Bravo Waste Tank was located immediately beneath Test Stand 2 in the gunite-lined drainage channel. The tank was installed in 1973 and had a secondary containment system that was built in 1992 (MWH, 2005d). During a 2005 site visit, igniters containing TEA and TEB were stored in a portable steel container located on an asphalt-paved area to the south of Building 2731 (NASA, 2006).

Originally, a cleaning process using TCE was employed after engine testing activities to remove residual fuel from engine components. The TCE waste was discharged to the spillways leading to the former Bravo Skim Pond and eventually to the former Alfa/Bravo Skim Pond. To capture the waste TCE, a TCE recycling system was implemented in 1961. The former location of the TCE system for the Bravo test stands is not documented. This TCE collection system was reported to consist of a 1,500-gallon tank, two pumps, and four

filters. Use of TCE for this purpose was discontinued in approximately 1965 when the Bravo area completed the transition from LOX kerosene engine and thrust chamber tests, which needed TCE flushing, to other components and Vernier engine testing, which did not require TCE flushing. TCA continued to be used for parts cleaning at Bravo until 1994 (NASA, 2006; MWH, 2005d).

A former solvent storage area (no building number) was located to the south of Test Stand 3. This storage area consisted of a concrete pad with an awning (MWH, 2005d).

5.1.4 Site Conditions

The Bravo Area currently is inactive. Most of the facility is still intact, the exceptions being the demolished test stand (Number 3), the buildings lost in the 2005 wildfires, and the former Alfa/Bravo Skim Pond, which has been excavated. Field investigations and interviews with current and former employees provided information that some miscellaneous process equipment has been removed after operations ceased for recycling, disposal, or use in other maintenance activities.

5.1.5 Site Habitats/Land Cover

The Bravo Area contains substantial areas of pavement and buildings, covering about 28 percent of the land cover at this site. Land cover at the Bravo Area consists of four habitat types, including scrub-shrub, ruderal, rock, and woodland habitat. Most of the site (about 39 percent) consists of scrub-shrub habitat consisting mainly of coast live oak, yerba santa, coyote brush, and laurel sumac. Ruderal habitat makes up about 20 percent of the site. Less than 0.1 percent of the site consists of woodland habitat. The following species have been observed at the site: Bewick's wren, spotted towhee, dark-eyed junco, house finch, California towhee, California quail, common raven, Anna's hummingbird, gopher [burrows], vole [runways], cottontail rabbit, and coyote [scat], western fence lizards, grasshoppers, and crickets. Stressed ruderal vegetation was identified, primarily adjacent to paved areas, and may have been due to herbicide applications. Stressed vegetation accounts for approximately 3 percent of the habitat at the site.

The habitats and land cover present at the Bravo Area are shown in Figure 5.1-2.

5.1.6 Historical Document Reviews

As described in Section 1.5.1, a historical document review was completed of documents applicable to the Group 3 RI. As a result of this historical document review, no new potential features were identified.

5.2 RI Characterization Activities

This subsection describes the sampling objectives, sampling scope, and key decision points associated with defining the nature and extent of chemical impacts for the surface soil, subsurface soil, and groundwater at the Bravo Area.

5.2.1 Sampling Objectives

To evaluate the extent of potential chemical effects on this site, soil, soil gas, and groundwater samples were collected. The objectives of the investigation were as follows:

- Evaluate the lateral and vertical extent of chemical impacts.
- Evaluate the potential gradients of chemicals.
- Develop a sufficient data set for performing a risk assessment.

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results and/or previous remediation activities
- Fate and transport characteristics of chemicals
- SSFL background concentrations of parameters
- SSFL SRAM-based screening concentrations for human health and ecological receptors

5.2.2 Sampling Scope

Provided in this report are the characterization results for soil matrix, soil gas, and groundwater information. The total numbers of historical and recent samples collected as part of this report for soil matrix samples, soil gas samples, and groundwater samples are summarized below:

- Soil matrix: 218 samples
- Soil gas: 55 samples
- Groundwater: 2 samples

These samples were collected between 1993 and 2008 to identify the potential chemical impacts associated with the activities at the Bravo Area. Section 5.4 summarizes these samples.

Note that three wells installed in the vicinity of the former incinerator were not sampled because of the seasonally dry conditions. Sampling will be completed during the next wet season.

5.2.3 Key Decision Points

The site-specific decision points identified for the Bravo Area represent the assumptions and/or decisions made during the sampling phase component of this RI, as follows:

- For historical sample points where the sample depth had not been recorded, it was assumed that these sample points were collected between the 0- to 2-foot-bgs range.

5.3 RI Characterization Results

The characterization results from the previous soil matrix, soil gas, and groundwater investigations at the Bravo Area are summarized below.

5.3.1 Soil Matrix and Soil Gas Findings

Surface soil samples were collected at this site from 1987 through 2008. Three surface soil samples were collected in 1987 in and around the discharge of the Alfa/Bravo Skim Pond for lipids, pH, and select SVOCs. No exceedances were encountered. To further evaluate this site, during subsequent soil investigations from 1993 until 1995, a total of 17 surface soil samples were collected and analyzed for dioxins, select VOCs, kerosene range organics, and general chemistry. VOCs and kerosene range organics were detected at exceeding concentrations during these sampling efforts. Data were included in the 1996 RFI WPA (Ogden, 1996a; 1996b; 1996c) and the closure reports in regard to the skim ponds present at this site.

To evaluate potential contamination related to the Bravo Area as a result of the 1996 WPA, surface soil, subsurface soil, and soil gas samples were collected in 1997 and 1998. Additionally, upon the completion of an aerial photography review (Lockheed, 1997), 10 sampling plans were developed in conjunction with the DTSC, and PCB-aroclors, metals, TPHs, and VOCs were sampled and analyzed at the site. Parameters from each category were detected at concentrations that exceeded the screening criteria.

From 1998 to the present, RI characterization sampling was conducted to support the development of this RI report. Initial AOCs were recognized, and upon further investigations, additional AOCs were added. Each stage of the investigative process is outlined in the RFI Report (MWH, 2004). To summarize, AOCs were investigated through soil, soil gas sampling, and NSGW sampling, which was followed as recently as late 2008 by rounds of step-out sampling to further evaluate the nature and extent of contamination. Dioxins, PCB-aroclors, inorganics, TPHs, SVOCs, and VOCs were detected at concentrations that exceeded the applicable screening criteria in the Bravo Area. Additional details regarding the analytes detected at the Bravo Area through the previous investigations are described in Section 5.4. The HHRA and ERA of the analytes detected at this site are provided in Sections 5.7 and 5.8, respectively.

5.3.2 Groundwater Findings

5.3.2.1 Background

The Bravo Area (Figure 5.3-1), which contains SWMUs 5.13, 5.14, and 5.15 is an approximately 8.9-acre site in the central portion of Area II. The elevation varies from approximately 1,830 ft above msl to 1,900 ft msl across the site. Ten wells and piezometers are located within the boundary of the Bravo Area and provide information regarding near-surface and Chatsworth formation groundwater conditions. These wells and piezometers are listed in Table 5.3-1, along with their construction summaries. Their locations are shown in Figure 5.3-1.

NSGW conditions were investigated prior to this RI with the installation of 2 wells (RS-08 and HAR-09) and two piezometers (PZ-059 and PZ-070). RS-08 was installed in July 1985 to investigate NSGW conditions on the northern side of a drainage feature located at the northwestern boundary of the Alfa/Bravo Skim Pond. In May 1987, HAR-09 was installed on the southern side of the same drainage feature. RS-08 and HAR-09 have, at times, contained NSGW.

PZ-059 was installed in December 2000 and PZ-070 was installed in December 2001. PZ-059 is located in a drainage that experienced stream flow during the early part of 2001 that probably was water from a leaky water line in the Bravo drainage (MWH, 2003d). Up to 3 ft of water were measured in PZ-059 during the wet season of 2001. No NSGW has been reported in PZ-059 since then. PZ-070 was installed down slope of PZ-059 along the same drainage trace and historically has been dry. PZ-070 was screened near the top of weathered bedrock, although the borehole was extended over 25 ft below the top of weathered bedrock.

RI activities at the Bravo Area included the installation of two piezometers, PZ-155 and PZ-156 (Figure 5.3-1), in November 2008. Both piezometers were installed within the weathered section of the Chatsworth formation. Screened intervals were constructed in potential water-bearing zones that were identified during rock coring activities. Unweathered Chatsworth formation was not encountered in either boring. Construction logs and boring logs for recently installed piezometers PZ-155 and PZ-156 are provided in Appendix E.

PZ-155 was installed south of PZ-070 to evaluate whether NSGW is present in deeper sections of the weathered bedrock. On January 6, 2009, 0.21 ft of water was measured in PZ-155. PZ-156 was installed to evaluate the occurrence of NSGW in the lower portion of the SFOU, to help establish the southern extent of the known alluvium in the Alfa surface water drainage, and to establish the southern extent of contamination in the SMOU within the Alfa drainage. On January 6, 2009, PZ-156 was dry.

Also as part of the RI activities, two soil borings were advanced at the southeastern boundary of the Bravo Area to evaluate the thickness of the alluvium/colluvium. BVBS-1050 and BVBS-1051 were advanced to 25.5 ft bgs and 20 ft bgs, respectively. The thickness of the overburden at BVBS-1050 was determined to be 21 ft whereas the thickness of the overburden at BVBS-1051 was determined to be 16 ft. Lithologic logs are provided in Appendix E.

Chatsworth formation monitoring wells at the Bravo Area include HAR-19, HAR-21, RD-04, and WS-09. Both RD-04 (installed in January 1986) and WS-09 (installed in 1955) have been used as groundwater extraction wells for operations at the SSFL and for treatment of contaminated water. HAR-19 and HAR-20 were installed as hydrogeologic assessment wells in June 1987.

5.3.2.2 Local Geology

The Bravo Area throughout most of its areal extent is underlain by deposits of the Upper Chatsworth Formation, Sandstone 1 Sage Member except for the northwestern section where deposits of the Shale 2 unit underlie the Bravo Area (Figure 5.3-1). The Sage Member consists predominantly of medium-grained sandstone with minor interbeds of siltstone and shale. The Shale 2 unit, which marks the boundary between the Sandstone 1 and Sandstone 2 units, consists of thin bedded shale, siltstone, and sandstone and is divided into upper and lower fine-grained units separated by sandstone. Beds strike northeast-southwest and dip between 25 and 40 degrees to the northwest. The thickness of the Shale 2 unit has been estimated to range from 150 ft to 285 ft across the SSFL property.

During RI rock-coring activities at PZ-155 and PZ-156, the materials encountered included alluvium/colluvium and weathered bedrock of the Chatsworth formation. Alluvial/ colluvial material consisted of light olive brown to yellowish brown silty sand with some interbedded siltstone and sandstone. During previous drilling activities, orange to medium-brown, silty to clayey sands were encountered. The thickness of alluvial/colluvial deposits encountered during drilling activities at the Bravo Area ranged from 0 ft to 21 ft. The thickest alluvial deposits were encountered at the southeastern boundary of the Bravo Area at BVBS-1050.

Weathered bedrock encountered in PZ-155 and PZ-156 consisted predominantly of weathered sandstone with some interbedded weathered siltstone and shale. Conglomerate rarely was encountered. Colors ranged through shades of gray, brown, and yellow. Textures typically were medium grained. Unweathered Chatsworth formation rocks were not encountered in PZ-155 (advanced to 61 ft bgs) and PZ-156 (advanced to 140 ft bgs).

Cross-sections A-A', B-B', C-C', and D-D' traverse the Bravo Area (Figures 5.3-2 through 5.3-5). Where known, the thickness of alluvial/colluvial deposits, weathered bedrock, and depth to unweathered bedrock are shown. Generally, depths to the top of unweathered Chatsworth formation rocks at the Bravo Area are speculative because of in sufficient detail in the historic lithologic logs. The most recent water level data also are posted.

5.3.2.3 Local Hydrogeologic Setting

Near-surface Groundwater. NSGW at the Bravo Test Site is characterized as neither laterally or temporally extensive (MWH, 2003d). NSGW has been found to occur in two previously installed wells (HAR-09 and RS-08) adjacent to a surface drainage feature leading from the northwestern edge of the Alfa/Bravo Skim Pond (Figure 5.3-1). Both wells are completed in weathered Chatsworth formation deposits and are depicted on cross-section B-B' (Figure 5.3-3). The depth to water in these wells varies seasonally and yearly, as shown on hydrographs of these two wells in Figure 5.3-6. Studies have indicated that the Sale 2 unit, in which HAR-09 and RS-08 are installed, represents a local aquitard with a lower hydraulic conductivity than is present in the adjacent and stratigraphically lower Sage unit, and that water present within this unit is perched (MWH, April 2007).

Two piezometers (PZ-155 and PZ-156) recently installed in the weathered section of the Chatsworth formation support the characterization of NSGW not being laterally extensive. Only PZ-155 has indicated the possible presence of NSGW (0.21 ft of water was measured on January 6, 2009). Additional measurements are needed before it can be concluded that the water present at this location is actually NSGW and not water left over from recent rock coring and piezometer installation procedures. Potential seasonal variations in NSGW occurrence at these locations currently are being investigated.

The distribution of NSGW at the Bravo Area is connected with the Alfa Test Area to the east. NSGW is believed to flow northwestwardly from the Bravo Area toward the SPA RI study area. Figure 3.3-7 is a potentiometric map of NSGW occurrence in the Group 3 study area. This map integrates NSGW levels taken during the fourth quarter of 2008 and early 2009. NSGW elevation data are sparse; however, the available data suggest that NSGW flow is to the northwest in the northern section of the Bravo Area.

Chatsworth Formation Groundwater. Chatsworth formation groundwater is regionally extensive across the Bravo Area, as it is across SSFL. Hydrographs of wells completed in the Chatsworth formation are shown in Figure 5.3-6, and, except at HAR-21, the depths to Chatsworth formation groundwater extend hundreds of feet below the surface. Groundwater in the Shale 2 unit, in which HAR-21 is constructed, is believed to be perched, as suggested by a comparison of the hydrographs of HAR-21 with other Chatsworth formation wells. Water levels in the Chatsworth formation groundwater monitoring wells are significantly deeper (with the exception of HAR-21), compared with water levels in near-surface wells HAR-09 and RS-08 (Figure 5.3-6). From approximately 1988 through 2001/2002, water levels in Chatsworth formation wells were significantly lowered because of pumping. Levels began to recover after pumping ceased and appear to continue to rise over time. The differences in elevation of Chatsworth formation groundwater levels with those of NSGW levels indicate that there is no physical connection between the two.

A comprehensive discussion of the hydrogeologic characteristics of the Chatsworth formation is provided in the *Technical Memorandum Conceptual Site Model Movement of TCE in the Chatsworth Formation SSFL* (Montgomery Watson, 2000) and the Geologic Characterization of the Central SSFL (MWH, 2007b).

5.3.2.4 NSGW Characterization Results

Both near-surface and Chatsworth formation groundwater characterization is based on sampling events that have occurred from 1985 to the present. These data are termed "legacy" data. Sampling has been conducted for a variety of analytical groups (VOCs and metals) that have varied over time and location. The following discussion of characterization results is divided into NSGW and Chatsworth formation groundwater. Although the Chatsworth formation groundwater is the subject of a separate programmatic investigation and has been designated as its own OU (the CFOU), the sampling results are summarized herein to provide a comparison with the NSGW characterization.

NSGW has been sampled at two locations (RS-08 and HAR-09) beginning in July 1987 through the present. Two recently installed piezometers (PZ-155 and PZ-156) were located to provide additional information regarding the occurrence and quality of NSGW. To date, either no NSGW or an insufficient quantity has been present at these locations, which has prevented samples from being collected. NSGW quality is represented by legacy data collected from 1987 to 2006.

Table 5.3-2 summarizes the historical (legacy) analytical sampling events of NSGW monitoring wells (RS-08 and HAR-09) at the Bravo Area. Analytical groups that have been sampled for include the following:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- PCB congeners
- Aroclors
- Dioxins

- Energetic parameters (explosives-related compounds)
- General chemistry analytes
- Hydrocarbons (fuel-related compounds)
- Organo-chlorine pesticides
- Organo-phosphate pesticides

The following subsections discuss the results of each analytical group in further detail. Table 5.3-3 summarizes the detections of the analytes for each group; the data include the available legacy data. Table 5.3-4 lists the metals concentrations over time and provides total concentrations and dissolved concentrations (when both were analyzed) by sample and by location. Table 5.3-5 summarizes the most recently available data and compares the results with available screening level criteria. The groundwater analytical data used to evaluate NSGW conditions are provided in Appendix I.

Volatile Organic Compounds. VOC detections in NSGW at the Bravo Area are summarized in Table 5.3-3. Nineteen VOCs have been detected, including 1,1,1-TCA; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,2-dichloroethane; 1,2-dichloropropane; 2-butanone (MEK); CTC; tetrachloroethene (PCE); trichlorofluoromethane; trichloromethane (chloroform); 1,2,3-trichloropropane; acetone; methylene chloride; toluene; 1,1-dichloroethane; 1,1-DCE; TCE; cis-1,2-DCE; VC; and trans-1,2-DCE.

The most frequently detected VOCs include TCE, cis-1,2-DCE, trans-1,2-DCE, and VC. All of these exceed the screening criteria except for TCE. Time trend charts for these compounds in samples collected from HAR-09 and RS-08 are shown in Figure 5.3-7.

Other detected VOCs that exceeded the screening criteria included 1,2-dichloroethane and CTC. Both compounds have been detected only once, however.

Recently installed piezometers PZ-155 and PZ-156 have not been sampled for VOCs because of a lack of sufficient or any NSGW. Once sufficient water is available, samples will be collected. The results will be reported as an addendum to the RI report.

Table 5.3-5 summarizes the most recent VOC results from the available data. Screening level exceedances of TCE, cis-1,2-DCE, and VC have occurred. Exceedances have occurred at HAR-09 and RS-08.

Semivolatile Organic Compounds. Two SVOCs have been detected, including 1,4-dioxane and n-nitrosodimethylamine (Table 5.3-3). The screening level criterion for n-nitrosodimethylamine has been exceeded at HAR-09 (both historically and most recently; Table 5.3-5), but the screening level criterion was not exceeded for 1,4-dioxane.

Polycyclic Aromatic Hydrocarbons. PAHs have not been detected in NSGW at the Bravo Area.

Phthalates. Four phthalates have been detected, including BEHP, butyl benzyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate (Table 5.3-3).

The screening level criterion for BEHP only has been exceeded at RS-08; however, no exceedances have occurred in the most recent available data (Table 5.3-5).

Metals. The metals detected in NSGW are summarized in Table 5.3-3. A comparison of dissolved versus total metals concentrations is presented in Table 5.3-4. Analyses have been performed for dissolved concentrations predominantly, and where both total and dissolved concentrations have been conducted concurrently from the same sample, both results are presented. There are an insufficient number of samples that have both total and dissolved analyses to draw conclusions regarding the relationship between turbidity and its effects on metals concentrations in groundwater.

Although exceedances of the screening levels have occurred, screening level exceedances are not frequent (concentrations of dissolved selenium exceeded the screening level most frequently).

The most-recent results indicate that 11 metals exceeded the screening level criteria. These metals are identified in Table 5.3-4.

PCB Congeners. No PCB congeners have been detected in NSGW at the Bravo Area.

Aroclors. No aroclors have been detected in NSGW at the Bravo Area.

Dioxins. Four dioxins have been detected, including 1,2,3,4,6,7,8-HpCDD, 1,2,3,4,7,8-hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF), 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF), octachlorodibenzo-*p*-dioxin (OCDD), and octachlorodibenzofuran (OCDF) (Table 5.3-3). No screening level criteria exist for the dioxins that have been detected.

Three dioxins have been detected in the most recently collected NSGW samples (Table 5.3-5). No screening criteria exist for these dioxins.

Energetic Parameters (explosive compounds). No energetic parameters have been detected in NSGW at the Bravo Area.

General Chemistry Analytes. General water quality analytes (common anions and cations) have been analyzed in NSGW. Detection and exceedances are reported in Tables 5.3-3 and 5.3-5. The most recent exceedances occurred for chloride, nitrate, sulfate, and fluoride.

Hydrocarbons (Fuel-related Hydrocarbons). Fuel-related hydrocarbons have not been detected in NSGW at the Bravo Area.

Organo-chlorine Pesticides. OC pesticides have not been detected in NSGW at the Bravo Area.

Organo-phosphate Pesticides. OP pesticides have not been detected in NSGW at the Bravo Area.

5.3.2.5 Chatsworth Formation Groundwater Characterization Results

Chatsworth formation groundwater has been sampled at four locations from 1984 through the present. As noted previously, the Chatsworth formation groundwater is under a separate regulatory program within the RCRA corrective action program at the SSFL and has been designated as its own OU (the CFOU). No investigations pertaining to Chatsworth formation groundwater were conducted during this RI. However, groundwater quality data are summarized below because of the vertical juxtaposition (albeit no direct physical connection is present at the Bravo Test Site) of the occurrences of NSGW with those of the

Chatsworth formation, and because of the potential physical connection among them in terms of contaminant transport.

Table 5.3-6 summarizes the historical (legacy) analytical sampling events of the Chatsworth formation groundwater monitoring wells (HAR-09, HAR-19, RD-04, and WS-09) at the Bravo Area. Analytical groups that have been sampled for include the following:

- VOCs
- SVOCs
- Phthalates
- Metals
- Aroclors
- Dioxins
- Energetic parameters (explosives-related compounds)
- General chemistry analytes
- Hydrocarbons (fuel-related compounds)
- Organo-chlorine pesticides
- Organo-phosphate pesticides
- PAHs

The following subsections discuss the results of each analytical group in further detail. Table 5.3-7 summarizes the detections of analytes for each group; the data include the available legacy data. Table 5.3-8 lists the metals concentrations over time and provides total concentrations and dissolved concentrations (when both were analyzed) by sample and by location. Table 5.3-9 summarizes the most recently available data and compares the results with the screening level criteria, where available. The groundwater analytical data used to evaluate the Chatsworth formation groundwater conditions are provided in Appendix I.

Volatile Organic Compounds. A total of 23 VOCs have been detected and include (in order of the most frequently detected) TCE, cis-1,2-DCE, trans-1,2-DCE, VC, toluene, methylene chloride, 1,1-DCE, formaldehyde, acetone, 1,1,2-trichloro-1,2,2-trifluoroethane, trichloromethane, 1,1,1-TCA, 1,1-dichloroethane, benzene, carbon disulfide, Freon 123, PCE, 1,1,2-TCA, 1,2-dichloro-1,2,2-trifluoroethane, CTC, chloromethane, chlorotrifluoroethylene, and trichlorofluoromethane (Table 5.3-6).

VOCs that exceeded the screening level concentrations are listed in Table 5.3-6. Time trend charts, by well, for TCE and its daughter products cis-1,2-DCE, trans-1,2-DCE, and VC are shown in Figure 5.3-8 by well. Figure 5.3-9 presents time trend charts for TCE, cis-1,2-DCE, trans-1,2-DCE, and VC across locations.

Table 5.3-9 summarizes the most recent VOC results from available data. Screening level exceedances of TCE, cis-1,2-DCE, trans-1,2-DCE and VC have occurred. Exceedances have occurred at the four Chatsworth formation groundwater monitoring locations.

Semivolatile Organic Compounds. Three SVOCs have been detected, including 1,4-dioxane, n-nitrosodimethylamine, and isopropanol (Table 5.3-7). Screening levels have been exceeded for 1,4-dioxane and n-nitrosodimethylamine and constitute exceedances in the most recent available data.

Phthalates. BEHP, the only phthalate detected, has been detected only once when it exceeded the screening level (Table 5.3-7). Subsequent analytical results for BEHP did not indicate exceedances of the screening levels.

Metals. The metals concentrations that exceeded the screening criteria in the available legacy data are summarized in Table 5.3-7. Molybdenum and potassium have exceeded the screening limits most frequently, followed by copper.

The most recent exceedances are listed in Table 5.3-9. Table 5.3-8 compares the total metals concentrations with the dissolved metals concentrations (when such analyses were conducted concurrently), by sample and by location. There are an insufficient number of samples that have both total and dissolved analyses to draw conclusions regarding the relationship between turbidity and its effects on metals concentrations in groundwater.

Aroclors. No aroclors have been detected in Chatsworth formation groundwater at the Bravo Area.

Dioxins. Six dioxins have been detected, including 1,2,3,4,6,7,8-HpCDD, 1,2,3,4,7,8-HxCDF, 1,2,3,7,8-PeCDD, 1,2,3,7,8-PeCDF, OCDD, and OCDF (Table 5.3-7). There are no screening criteria for dioxins.

Of the historic detections of dioxins, OCDD is the only dioxin that did not have occurrences in the most recent results (Table 5.3-9).

Energetic Parameters (Explosive-related Compounds). None have been detected.

General Chemistry. General water quality analytes (common anions and cations) have been analyzed in NSGW. The detections and exceedances are reported in Table 5.3-7 for the available legacy data and in Table 5.3-9 for the most recent available data. The most-recent exceedances have occurred for chloride, sulfate, fluoride, and nitrogen.

Hydrocarbons (Fuel-related Compounds). Samples were analyzed for C6-C7 hydrocarbons and kerosene. Neither analyte was detected.

Organo-chlorine Pesticides. Organo-chlorine pesticides have not been detected in Chatsworth formation groundwater at the Bravo Area.

Organo-phosphate Pesticides. Organo-phosphate pesticides have not been detected in Chatsworth formation groundwater at the Bravo Area.

Polycyclic Aromatic Hydrocarbons. No PAHs have been detected in Chatsworth formation groundwater at the Bravo Area.

5.3.3 Surface Water Findings

Surface water features at the Bravo Area consist of small drainages that trend north and west across the site and are dry throughout most of the year. Surface water releases through this drainage are monitored under an NPDES permit.

Surface water samples were not collected during this RI investigation because of the seasonally dry conditions.

5.3.4 Completeness of Characterization

Sample results in both available NSGW and CFOU samples indicate groundwater has been affected by VOCs, mainly TCE and its daughter products. These data are consistent with the soil and soil gas results. Sampling of the newly installed piezometers during rainy season conditions will provide further confirmation of affected groundwater conditions at the Bravo Area.

Chemical use areas are delineated sufficiently for risk assessment and for the support of RI recommendations .

5.3.4.1 NSGW Characterization

The occurrence of NSGW at SSFL, including the Bravo Area, is ephemeral and believed to be related to seasonal variations in precipitation. Newly installed piezometers (PZ-155 and PZ-156) have been sounded for the presence of groundwater, and when sufficient groundwater is present, sampling of the groundwater will occur and be reported in an addendum to this RI report. Additional synoptic gauging of piezometers for the occurrence of NSGW and sampling of NSGW, when present, is planned across several seasons, including late-winter and early-spring events when precipitation is anticipated to increase. The current NSGW monitoring network should provide sufficient sampling locations to evaluate groundwater in the SMOU under optimum conditions.

Legacy data provide an abundant foundation for evaluating groundwater quality, past and present. The results indicate that NSGW, albeit limited in aerial extent and thickness, primarily has been affected by a limited number of VOCs. The data also suggest potential impacts by metals. Chatsworth formation groundwater impacts are similar to those exhibited in the NSGW results; however, because the two units are separated by a considerable thickness of Chatsworth formation deposits, there appears to be no direct relationship of contamination between the two.

5.3.4.2 Surface Water

No surface water samples were collected as part of this RI.

5.4 Bravo Area Nature and Extent

Surface soil, subsurface soil, and soil gas samples were collected at the Bravo Area, per the protocol described in Section 5.2 and the data provided in Appendix E. Figure 5.4-1 shows the historical and most recent surface and subsurface soil samples collected as part of this RI investigation. Table 5.4-1 lists the parameters analyzed in the sample media at the Bravo Area. The nature and extent of contamination that exceeded the comparison criteria values in the media sampled are described below.

5.4.1 Surface Soil Nature and Extent

A total of 117 surface soil samples were collected at this site and analyzed for 1 or more of the following: dioxins, TAL metals, PCBs (aroclors and congeners), pesticides, SVOCs, TPHs, and VOCs. Table 5.4-2 lists the parameters detected in the surface soil samples in the Bravo Area.

5.4.1.1 Parameters Exceeding Criteria

The nature and horizontal extent of parameters encountered at concentrations that exceeded their respective comparison criteria are described below.

Dioxins. A total of 8 surface soil samples were analyzed for dioxins at this site, including both CDDs and CDFs. Dioxins were detected in all 8 of the surface soil samples collected. The current approach to assessing the toxicity of these mixtures is to use information regarding the toxic potency of the different congeners to convert the congener concentrations to a toxicologically equivalent concentration of the most potent congener, 2,3,7,8-TCDD. The TEQ for mammals is used in comparison to the human health criterion, while the TEQ for either birds or fish, whichever is greater, is used in comparison to the ecological comparison criterion. The samples were evaluated for nature and extent by comparing the frequency of the different CDDs and CDFs that exceeded the screening criteria at each location. The CDD and CDF exceedances were added together according to the chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD TEQ values were compared to the ecological screening criterion (4.3 pg/g) and the more conservative human health screening criterion (1.3 pg/g). The data are summarized in Table 5.4-3.

One sample location, BVBS1061, had reported a 2,3,7,8-TCDD TEQ mammal value of 2.88 pg/g, exceeding the human health screening criterion of 1.3 pg/g. The 2,3,7,8-TCDD TEQ for birds was less than the ecological comparison criterion. Station BVBS1061 is located on the western site boundary. The dioxin exceedance is evaluated sufficiently to the south and east through additional sampling, and to the west by an increase in surface elevation. Additional sampling to the north may be required to further evaluate the horizontal extent of dioxins at this site. Although station BVBS0049 to the north did not have elevated concentrations of dioxins reported, the station is located north of the pipeline coming into the site and is at a higher elevation. The vertical extent of dioxins is addressed in Section 5.4.2.

Metals. Metals were detected in all 36 surface soil samples analyzed for metals, exceeding both the human health and ecological screening risk criteria at 14 of the sample locations. Of the metals detected in the surface soil at this site, 8 metals were reported at concentrations that exceeded 1 or more of the criteria. The metals exceedances are described below.

Only 1 exceedance was reported for both nickel and silver. Nickel was detected at a concentration of 69 mg/kg (BVSS03), exceeding its ecological (0.10 mg/kg) and human health (37.9 mg/kg) screening criteria. Nickel was detected in each of the samples analyzed for the parameter, and the exceedance is encompassed by three sampling stations with non-exceeding concentrations. Silver was detected at a concentration of 1.1 mg/kg (BVBS1064), exceeding its ecological criteria of 0.54 and background level of 0.79 mg/kg. The silver exceedance, detected beneath Building 2214, is closely related to its background value. Additionally, although samples immediately to the south and east of BVBS1064 were not analyzed for silver, the lack of exceedances at BVBS1059 and BVBS1063 suggest that the elevated concentration may be indicative of natural occurrence. The horizontal extents of nickel and silver have been evaluated adequately.

Chromium and copper each were detected twice and lead was detected three times at concentrations that exceeded their respective screening criteria. Chromium was detected at concentrations of 51 mg/kg (BVSS01) and 87 mg/kg (BVSS03), exceeding its human health comparison criterion of 32 mg/kg. Each of these sampling stations was surrounded by samples depicting non-exceeding concentrations of chromium, and the downgradient Bravo Pond did not exhibit elevated concentrations of chromium. Copper was detected at 57 mg/kg (BVSS01) and an estimated 150 J mg/kg (BVBS02), each exceeding its ecological screening criteria and the latter also exceeding its human health criterion of 68.6 mg/kg. Similarly, these sampling stations are encompassed by additional surface soil samples without copper exceedances. Lead was detected ranging from 47 mg/kg (BVSS03) to 130 mg/kg (BVSS01); each detection exceeded its ecological (0.013 mg/kg), human health (16 mg/kg), and greater valued background (34 mg/kg) comparison criteria. Two of the three lead exceedances were within twice the background value. The lead exceedances additionally have been evaluated sufficiently horizontally through additional sampling. The horizontal extents of chromium, copper, and lead have been evaluated adequately at this site, as illustrated in Figure 5.4-2.

Cadmium, mercury, and zinc each were detected in several surface soil samples at levels that exceeded their respective comparison criteria. Cadmium, detected in 34 of 36 samples analyzed, exceeded the screening criteria in 11 samples at concentrations ranging from 1.1 mg/kg (BVBS1026) to an estimated 15 J mg/kg (BVSS01). Each elevated concentration exceeded its ecological (0.0045 mg/kg) screening value, with 9 of the concentrations also exceeding its human health criterion of 1.7 mg/kg. Most of these exceedances were detected on the hillside leading to the Bravo Pond, where they are bound horizontally through sampling downgradient within the pond and upgradient by the samples collected near the Bravo testing operations. Three of the 22 mercury detections exceeded its ecological (0.10 mg/kg) screening criterion, with the elevated concentrations ranging from 0.11 mg/kg (BVS08) to 0.30 mg/kg (BVSS01). Mercury exceedances were congregated just upgradient of the Bravo Pond and one was within the pond, and were evaluated sufficiently horizontally through additional sampling. Zinc was detected in all 36 samples analyzed, 8 of which exceeded its ecological (21 mg/kg) and background (110 mg/kg) comparison criteria at concentrations ranging from 121 mg/kg (BVBS1024) to an estimated 500 J mg/kg (BVSS01); the highest detection also surpassed its human health criterion of 370 mg/kg. Similar to the cadmium and mercury exceedances, most elevated concentrations of zinc were detected on the hill side between the testing areas and the Bravo Pond, with the exception of one exceedance detected near Building 2213. The zinc exceedances appear to have been evaluated sufficiently horizontally through additional surface soil sampling. The horizontal extents of cadmium, mercury, and zinc have been evaluated adequately, as illustrated in Figure 5.4-3.

Surface soil contamination of metals is expected to migrate downgradient (northwest) by means of the landscape leading to the Bravo Pond, eventually leading to the Alfa/Bravo Pond. Surface soil samples collected most downgradient in the Bravo Pond did not have reported metals exceedances; therefore, the horizontal extent of metals in the Bravo Area appears to be addressed sufficiently. Of the 9 parameters that had elevated concentrations reported in the surface soil samples collected, only 3 had a sole exceedance reported in subsurface soil samples. The vertical extent will be further discussed in the following subsection.

PCB Aroclors/Congeners. PCB congeners were analyzed in 7 surface soil samples, none of which had a reported exceedance.

PCB aroclors were analyzed at 14 locations in the surface soil within the Bravo Pond and along the main drainage line feeding that pond. Four exceedances of Aroclor-1254 and 5 of Aroclor-1260 were reported, with each exceeding its human health (89 µg/kg) and ecological (77 µg/kg) comparison criteria. Elevated concentrations of Aroclor-1254 ranged from an estimated 138 J µg/kg (BVBS1030) to 290 µg/kg (BVBS17), and elevated concentrations of Aroclor-1260 ranged from 98.8 µg/kg (BVBS1030) to 280 µg/kg (BVBS24). Although PCB aroclor exceedances are bound to the Bravo Pond, the most downgradient samples analyzed reported PCB exceedances. Additional sampling may be warranted further downgradient, toward and within the Alfa/Bravo Pond, as well as further upgradient toward the former testing areas, to further evaluate the horizontal extent of PCBs within the Bravo Area. Figure 5.4-4 shows the horizontal extents of Aroclor-1254 and Aroclor-1260 in the Bravo Area. The vertical extents of these parameters are addressed in the following subsection.

SVOCs. One or more SVOCs were analyzed at 20 surface soil sampling stations collected at the Bravo Area. One PAH, BaP, was detected twice at 144 µg/kg (BVBS1063) and 150 µg/kg (BVBS0048) compared to its human health criterion of 11.4 µg/kg. The PAH exceedances are in the vicinity of Building 2214. The other surface soil samples analyzed PAHs did not exhibit elevated concentrations of BaP, including 2 upgradient and 2 downgradient along surface drainage routes, and 2 surface soil samples in the immediate vicinity of the exceedances. Additionally, PAHs at the reported concentrations are indicative of asphalt leachate and are less likely to be related to historical operations at this site. The horizontal extent BaP appears to have been addressed sufficiently. The vertical extent of SVOC parameters is addressed in Section 5.4.2.

TPHs. Of the 68 surface soil samples analyzed for TPHs, 10 had reported elevated concentrations of a total 7 TPH groups. Three of the EFH groups, C12-C14, C15-C20, and C8-C11, were encountered once at levels that exceeded their ecological and human health criteria of 10,000 µg/kg. EFH (C12-C14) and EFH (C15-C20) were both detected at BVBS1022 at concentrations of 1,500,000 µg/kg and 541,000 µg/kg, respectively. The EFH (C8-C11) group was detected at BVBS17 at an estimated 430,000 J µg/kg. Each of these 3 exceedances has several stations surrounding it that did not have elevated concentrations reported of these parameters. Although no samples provide a horizontal extent to location BVBS1022 to the east, the terrain in that direction slopes westerly back toward the former operations, suggesting that potential contamination and migration toward the east are unlikely. The horizontal extents of EFH C12-C14, C15-C20, and C8-C11 have been evaluated adequately.

Two exceedances of both kerosene range organics (C11-C14) and kerosene (C12-C18) were reported in the Bravo Area. The C11-C14 group was detected at estimated concentrations of 110,000 J µg/kg (BVBS10) and 2,000,000 J µg/kg (BVBS17), exceeding the criterion of 100,000 µg/kg. The C12-C18 group was detected at 120,000 µg/kg (BTSC-2/3-15) and 350,000 µg/kg (BTSC-2/3-5), exceeding its human health comparison criterion of 50.4 µg/kg. The C11-C14 exceedances have been evaluated sufficiently horizontally through additional samples that did not have exceedances reported. The C12-C18

exceedances were detected within the drainage area below the former rocket exhaust buckets and have been evaluated sufficiently downgradient by samples that did not have elevated concentrations of this kerosene group reported. The horizontal extents of kerosene range organics (C11-C14) and kerosene (C12-C18) have been evaluated adequately at the Bravo Area.

Three diesel range organics (C14-C20) and 6 lubricating oil range organics (C20-C30) exceedances were detected in the Bravo Area. Group C14-C20 exceedances ranged from an estimated 150,000 J µg/kg (BVBS13) to an estimated 770,000 J µg/kg (BVBS17), and group C20-C30 exceedances ranged from an estimated 130,000 J µg/kg (BVBS11) to an estimated 1,300,000 J µg/kg (BVBS10). These 9 exceedances surpassed their ecological and human health comparison criteria of 100,000 µg/kg. Most of these exceedances were encountered in the southern portion of the area, with one C14-C20 exceedance that occurred in the southern end of the Bravo Pond. These exceedances have been evaluated sufficiently to the west and north by additional samples and to the south and southeast by elevated rock outcrops. The drainage area to the east likely provides an easterly boundary, which leads to the Bravo and, eventually, Alfa/Bravo ponds. The horizontal extents of the C14-C20, and C20-C30 groups have been evaluated adequately, as shown in Figure 5.4-5.

The horizontal extents of TPHs in the Bravo Area have been addressed sufficiently. Five of these 7 TPH groups also were detected at elevated concentrations in the subsurface soil at this site. The vertical extents of TPHs are described in the following subsection.

VOCs. Two VOCs were reported at a level exceeding the screening criteria in surface soils at the Bravo Area. Cis-1,2-DCE was detected at a concentration of 86 µg/kg at BTSC-2/3-5, exceeding its human health comparison criterion (14 µg/kg). Station BTSC-2/3-5, located downgradient of the area most likely to be affected by the engine exhaust of former Test Stand 3, was the only station analyzed for this particular parameter at this site. TCE, detected in all 8 samples analyzed, had 5 exceedances ranging from 2.26 µg/kg (BVBS1039) to an estimated 142 J µg/kg (BVBS08), compared to its human health criterion of 2.2 µg/kg. The extent of TCE in the surface soil at this site is shown in Figure 5.4-6. Additional sampling for VOC extent in the surficial soil media may be required to evaluate potential VOC contamination at this site.

5.4.2 Subsurface Soil Nature and Extent

A total of 101 subsurface samples were collected from 73 sampling stations to a maximum depth of 14.5 ft bgs at the site. The subsurface soil at the site was analyzed for 1 or more of the following: dioxins, TAL metals, PCB aroclors, pesticides, SVOCs, TPHs, and VOCs. Table 5.4-4 lists the parameters detected in the subsurface soil samples at the Bravo Area. Exceedances detected in subsurface soil samples are categorized and described below.

Dioxins. As with the dioxin investigation in the surface soils, the 11 subsurface soil samples collected from 9 locations to a maximum depth of 10 ft bgs were analyzed for both CDDs and CDFs. Dioxins were detected in 7 of the 11 subsurface soil samples collected, spanning 6 sampling stations. Likewise, the approach in subsurface soils was to assess the toxicity of these mixtures by using information regarding the toxic potency of the different congeners and converting them to 2,3,7,8-TCDD TEQs. The frequency of the different CDDs and CDFs that exceeded their respective screening criteria at each location were added according to

chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD TEQ values were compared to the screening criteria.

The mammal 2,3,7,8-TCDD TEQ values exceeded the human health (1.3 pg/g) comparison criterion at BVBS1061 (4.5 to 5 ft bgs) at a reported 1.81 pg/g. This subsurface soil sample was collected at the bedrock interface; thus, the vertical extent of the dioxin exceedance has been evaluated sufficiently . Additionally, the 2,3,7,8-TCDD TEQ detection in the subsurface soil sample is less than the exceeding concentration detected in the surface soil at this particular sampling station. Subsurface soil samples collected to the south and east of BVBS1061 at the bedrock did not have elevated TEQ values reported at this site. Table 5.4-5 summarizes the exceedances of individual dioxin parameters. The vertical extent of dioxins in subsurface soil at the site has been evaluated sufficiently.

Metals. Twenty metals were detected across the 21 subsurface soil samples collected at the Bravo Area and analyzed for metals. Of those, 5 parameters spanning 4 samples were detected at concentrations that exceeded the applicable comparison criteria. Each parameter had a sole exceedance reported. The vertical nature of these metals is described below.

Aluminum and manganese, neither of which was encountered at elevated concentrations in surface soil samples, were detected in subsurface soil at elevated concentrations similar to their respective background values. Aluminum was detected at 20,500 mg/kg (BVBS1030, 9.5 to 10 ft bgs), compared to its background value of 20,000 mg/kg. Manganese was detected at an estimated concentration of 636 J mg/kg (BVBS1060, 9.5 to 10 ft bgs), compared to its background value of 495 mg/kg. With each parameter, the background value is significantly higher than the respective action level criteria, and the reported concentrations are indicative of natural occurrence. The extents of aluminum and manganese in the subsurface soil at this site have been addressed sufficiently.

Cadmium, copper, and chromium each had reported exceedances in surface soil samples, detected once in 2 samples at elevated concentrations. Cadmium was detected at 1.8 mg/kg (BVBS1031, 4.5 to 5 ft bgs), exceeding its ecological (0.0045 mg/kg) and human health (1.7 mg/kg) criteria, but similar to its background value of 1 mg/kg. Copper was detected at 87.5 mg/kg (BVBS1031, 4.5 to 5 ft bgs), which exceeded its ecological (1.1 mg/kg), human health criteria (68.6 mg/kg) and its background value (29 mg/kg). Sampling station BVBS1031 was sampled at a deeper interval and both cadmium and copper concentrations were below their comparison values. Chromium was detected at 38.1 mg/kg (BVBS1062, 9.5 to 10 ft bgs), exceeding its human health (32 mg/kg) and similar to its background value (36.8 mg/kg). This subsurface chromium exceedance was detected a relatively great distance upgradient of the surface soil exceedances, and appears to be at a concentration indicative of natural occurrence. The vertical extents of cadmium, copper, and chromium have been evaluated adequately.

Lead, mercury, nickel, silver, and zinc each was detected at elevated concentrations in surficial soil samples; these parameters were not detected at exceeding concentrations in the subsurface soil samples collected at this site. The vertical extents of metals in the subsurface soil in the Bravo Area site have been evaluated sufficiently.

PCBs Aroclors. Three PCB aroclors were detected at elevated concentrations in the subsurface soil at this site. Aroclor-1248, which was not detected at elevated concentrations

in the surface soil samples, was detected at a concentration of 33.3 µg/kg (BVBS1030, 4.5 to 5 ft bgs), exceeding its ecological comparison criteria of 11.4 µg/kg. Sampling station BVBS1030 was sampled at a deeper interval of 9.5 to 10 ft bgs, but no exceedances of this parameter were reported. Aroclor-1260 was detected at a concentration of 109 µg/kg (BVBS1031, 4.5 to 5 ft bgs), exceeding its ecological (77 µg/kg) and human health (89 µg/kg) screening criteria. This station also was sampled at a deeper interval (6.5 to 7 ft bgs), which did not have reported elevated concentrations of Aroclor-1260. The vertical extents of Aroclor-1248 and Aroclor-1260 have been addressed sufficiently.

Aroclor-1254 was detected in 8 samples at elevated concentrations ranging from 98.9 µg/kg (BVBS1033, 6.5 to 7 ft bgs) to an estimated 570 J µg/kg (BVBS02, 6 ft bgs), each exceeding its human health (89 µg/kg) and ecological (77 µg/kg) comparison criteria. Although Aroclor-1254 was detected at levels exceeding the comparison values at some of the deepest intervals for select locations, the parameter was not detected in the deepest interval samples analyzed (10 ft bgs). However, with the potential for additional horizontal characterization of this parameter, additional vertical sampling may be warranted, as well. The vertical extent of Aroclor-1254 is shown in Figure 5.4-7.

SVOCs. A total of 48 samples from 37 sampling stations were analyzed for 1 or more SVOCs. Of those, 5 samples had reported exceedances of a total of 5 SVOCs, 4 of which are classified as PAHs.

BEHP, indeno(1,2,3-cd)pyrene, and phenanthrene each were detected once at an elevated concentration in the subsurface soil at this site. BEHP was detected at an estimated concentration of 19,000 J µg/kg (BVBS02, 5 ft bgs), exceeding its ecological (4,900 µg/kg) comparison criteria. Indeno(1,2,3-cd)pyrene was detected at 273 µg/kg (BVBS23, 6 ft bgs), exceeding its human health criterion of 114 µg/kg. Phenanthrene was detected at 3,980 µg/kg (BVBS1031, 6.5 to 7 ft bgs), exceeding its ecological (1,300 µg/kg) comparison criteria. The BEHP exceedance have been evaluated sufficiently vertically through additional sampling. The other 2 parameters were encountered at the deepest samples analyzed at their respective locations. From that interval, however, the exceedances have been evaluated sufficiently horizontally through additional sampling. The vertical extents of BEHP, indeno(1,2,3-cd)pyrene, and phenanthrene have been addressed sufficiently.

Naphthalene was encountered twice at estimated concentrations of 163 J µg/kg (BVBS15, 5 to 5.5 ft bgs) and 2,530 J µg/kg (BVBS23, 6 ft bgs), each exceeding its human health criterion of 93 µg/kg. These 2 stations are in the northwestern corner of the Bravo Pond and although the exceedances were detected in the deepest intervals analyzed, there are samples to the north, east, and south that bind the subsurface soil detections horizontally. Additionally, the bedrock surfaces as an outcrop to the west. The vertical extent of the naphthalene exceedances has been evaluated sufficiently.

Three exceedances of BaP were reported at this site. Elevated concentrations ranged from 25.6 µg/kg (BVBS1018, 4 to 5 ft bgs) to 317 µg/kg (BVBS23, 6 ft bgs), each exceeding its human health screening criterion of 11.4 µg/kg. Similar to the exceedances described in the previous paragraph, the elevated concentrations of BaP at stations BVBS15 and BVBS23 have been evaluated sufficiently vertically by the bedrock and horizontally by additional sampling and/or physically through rock outcrops. Station BVBS1018 is on the northern side of the Bravo pond and additional sampling further north may be warranted to further

evaluate the extent of BaP in subsurface soil in this area. The vertical extent of BaP in the Bravo Area is shown in Figure 5.4-8.

The subsurface soil SVOC exceedances were reported at stations differently than those reporting surface soil exceedances; hence, the surface soil PAH exceedances have been evaluated adequately vertically.

TPHs. A total of 78 subsurface soil samples from 53 locations were analyzed for TPHs in the Bravo Area. Six TPHs were reported at levels that exceeded the applicable screening criteria in the subsurface soils at the site, spanning 18 samples from 13 locations. All of the reported TPH exceedances in the subsurface soil surpassed their ecological and human health comparison criteria of 100,000 µg/kg. The vertical extents of these TPHs are described below.

Two exceedances of the EFH (C21-C30) group were reported in the subsurface soil at this site. The C21-C30 exceedances were detected at concentrations of 113,000 µg/kg (BVBS1019, 4.5 to 5 ft bgs) and 272,000 µg/kg (BVBS1062, 4.5 to 5 ft bgs). Each station was sampled at a deeper interval that did not have detections of EFH (C21-C30) reported. Additionally, EFH (C21-C30) was not detected at an elevated concentration in the surface soil samples collected from this site. The vertical extent of EFH (C21-C30) has been addressed sufficiently at the Bravo Area.

A total of 13 kerosene range organics (C11-C14) exceedances were reported in the subsurface soil at this site, with concentrations ranging from an estimated 490,000 J µg/kg (BVBS25, 6.5 ft bgs) to 15,000,000 µg/kg (BVBS23, 6 ft bgs). Kerosene range organics mostly were detected at elevated concentrations within the Bravo Pond, with exceedances also being reported on the southern boundary of this area and at 1 station along the pipeline coming from the Alfa/Bravo Fuel Farm. The C11-C14 group exceedances are evaluated sufficiently vertically by the bedrock interface and horizontally through additional sampling that did not have exceedances reported. Three locations within the former Bravo Pond area, BVBS02, BVBS15, and BVBS25, were evaluated sufficiently vertically by additional samples collected at deeper intervals. The exceedance along the southern boundary is evaluated sufficiently horizontally through additional sampling and to the south by the surfacing bedrock outcrop. The vertical extent of the kerosene range organics (C11-C14) appears to have been evaluated adequately. The extent is shown in Figure 5.4-9.

Thirteen exceedances were reported of the diesel range organics (C11-C20) group at this site, with elevated concentrations ranging from an estimated 300,000 J µg/kg (BVBS01, 5 ft bgs) to an estimated 12,000,000 J µg/kg (BVBS01, 11 ft bgs). The diesel range organic exceedances mimic the pattern of the kerosene range organics described above, with the same samples exhibiting differing elevated concentrations. As before, the vertical extent of diesel range (C14-C20) group has been sufficiently investigated, as illustrated in Figure 5.4-10.

Four EFH (C12-C14) exceedances were reported across 3 sampling stations at this site. Elevated concentrations of EFH (C12-C14) ranged from 146,000 µg/kg (BVBS1019, 4.5 to 5 ft bgs) to an estimated 2,700,000 J µg/kg (BVBS1031, 6.5 to 7 ft bgs). These exceedances are within the former Bravo Pond and reach to the deepest intervals sampled at these locations. However, the deepest intervals that had exceedances were collected at the bedrock interface.

Additionally, several sampling stations in the vicinity did not have reported elevated concentrations of the C12-C14 group, including samples collected downgradient of the exceedances, suggesting that the horizontal extent in the subsurface soil has been evaluated sufficiently. The vertical extent of EFH (C12-C14) has been evaluated adequately, as shown in Figure 5.4-11.

Four EFH (C15-C20) exceedances were detected in the same 4 samples as the 4 EFH (C12-C14) exceedances, as previously described. EFH (C15-C20) exceedances ranged in concentration from 174,000 µg/kg (BVBS1019, 4.5 to 5 ft bgs) to an estimated 1,430,000 J µg/kg (BVBS1031, 6.5 to 7 ft bgs). Similar to the preceding paragraph, these exceedances have been evaluated sufficiently vertically by the bedrock surface and horizontally through additional sampling. The extent of EFH (C15-C20) has been evaluated sufficiently, as shown in Figure 5.4-12.

The EFH (C8-C11) group was detected 14 times at exceeding concentrations, spanning 10 sampling stations. Elevated concentrations of this TPH group ranged from 134,000 µg/kg (BVBS1015, 4.5 to 5 ft bgs) to an estimated 1,700,000 J µg/kg (BVTS01S01, 3 ft bgs). EFH (C8-C11) exceedances mostly follow the same pattern as the kerosene range and diesel range organics, the exceptions being that station BVBS25 did not report C8-C11 group exceedances and stations BVBS1015 and BVBS1031 only reported C8-C11 group exceedances. However, the same approach to evaluating the extent of this TPH group applies, which was described earlier under this subheading. The vertical extent of EFH (C8-C11) has been bound by the bedrock interface, bedrock outcrops to the south, and by samples in proximity that did not have reported exceedances in similar and sometimes deeper intervals. The extent in the subsurface soil media has been evaluated adequately, as shown in Figure 5.4-13.

Lubricant oil range organics (C20-C30), analyzed for in 39 subsurface soil samples spanning 24 sampling stations, were not detected at exceeding concentrations in the subsurface soil. The vertical extent of TPHs in the Bravo Area has been investigated sufficiently.

VOCs. A total of 41 subsurface soil samples from 33 sampling stations were analyzed for VOCs at the Bravo Area. Four parameters were detected at elevated concentrations. 2-Chloroethyl vinyl ether was reported at an estimated concentration of 1,300 J µg/kg at BVBS23 (6 ft bgs), exceeding its ecological (730 µg/kg) and much lower valued human health criteria. Bromodichloromethane was detected at an estimated 9 J µg/kg (BVBS23, 6 ft bgs), exceeding its human health criterion of 0.31 µg/kg. Sampling station BVBS23 was sampled at a deeper interval (10 ft bgs), but did not have a reported detection of this parameter, thus providing a vertical extent boundary. Methylene chloride was detected at a concentration of 8 µg/kg (ABSP-334, 3 ft bgs), exceeding its human health criterion of 4 µg/kg. This exceedance was detected in the deepest interval sampled at this station, most likely at the bedrock interface, and is bound horizontally through additional subsurface sampling downgradient in the Alfa-Brave Skim Pond. The vertical extents of 2-chloroethyl vinyl ether, bromodichloromethane, and methylene chloride have been investigated sufficiently.

TCE was detected in 3 subsurface soil samples at elevated concentrations, ranging from 2.87 µg/kg (BVBS1040, 3.5 to 4 ft bgs) to an estimated 540 J µg/kg (BVBS08, 6 ft bgs), each surpassing its human health criterion of 2.2 µg/kg. The concentrations increase in the deeper intervals at these stations; however, the shallow bedrock surface and downgradient

subsurface soil samples without TCE exceedances provide a vertical boundary of extent. Figure 5.4-14 shows the extent of TCE in the subsurface soil at this site. The vertical extent of VOCs in subsurface soil in the Bravo Area has been evaluated adequately.

5.4.3 Soil Gas Nature and Extent

Fifty-five soil gas samples were collected at the Bravo Area from 50 locations to a maximum depth of 16 ft bgs. Figure 5.4-15 shows the locations of soil gas samples collected as part of this RI effort. Nine VOCs and 1 PAH, naphthalene, were detected in the samples at levels exceeding the screening criteria. Table 5.4-6 lists the parameters detected in the soil gas samples collected in this area. Naphthalene was encountered once at a concentration of 870 µg/m3 (BVPV02, 0 to 2 ft bgs), exceeding its ecological screening criterion of 380 µg/m3. None of the other 24 stations sampled for naphthalene had elevated concentrations reported, which includes several subsurface soil gas samples. The extent of naphthalene as soil gas has been evaluated adequately. The extent of VOCs encountered via soil gas sampling at this site is described below.

The VOCs 1,1,1-TCA, CTC, and VC each had reported sole soil gas exceedances at this site. 1,1,1-TCA was detected at a concentration of 172,000 µg/m^3 (SV-5.13-3, 5 ft bgs), exceeding its ecological screening criterion of 38,000 µg/m^3. CTC was detected at a concentration of 260 µg/m^3 (BVPV01, 0 to 2 ft bgs), exceeding its human health screening criterion of 25 µg/m^3. VC was detected at 98 µg/m^3 (BVSV20, 6 ft bgs), exceeding its human health criterion of 13 µg/m^3. Each of these parameters was encountered only once at an elevated concentration, and each station exhibiting these elevated concentrations is in the vicinity of other stations sampled in similar and deeper intervals, potentially providing an implied horizontal and vertical extent. The extents of 1,1,1-TCA, CTC, and VC soil gases have been evaluated adequately.

Five exceedances of 1,1-DCE were reported at this site, at concentrations ranging from 2,100 µg/m^3 (BVSV10, 3 ft bgs) to an estimated 110,000J µg/m^3 (BVSV01, 4 ft bgs), each exceeding its ecological criterion (600 µg/m^3). The 1,1-DCE exceedances appear to have been detected along a pipeline running north-south through the center of the main Bravo processing and testing area. These exceedances are evaluated sufficiently horizontally through samples located upgradient, crossgradient, and downgradient. Although no samples were collected at deeper intervals at the subject stations, the most recent sampling efforts suggest that these exceedances were encountered at the bedrock interface. In addition, samples were collected at deeper intervals downgradient, which did not have 1,1-DCE exceedances reported. The extent of 1,1-DCE soil gases at this site has been addressed sufficiently, as shown in Figure 5.4-16.

Five soil gas samples had elevated concentrations of PCE, ranging from 1,090 µg/m^3 at BVPV01 (0 to 2 ft bgs) to 4,600 µg/m^3 at BVSV19 (10 ft bgs), compared to its human health screening criterion of 180 µg/m^3. The PCE exceedances do not appear to be consolidated or formed in a particular pattern. However, PCE exceedances have been evaluated sufficiently horizontally through additional soil gas sampling. Vertically, the exceedances were encountered in the deepest intervals sampled at these five locations, suggesting that the potential PCE contamination has migrated to the bedrock interface. Figure 5.4-17 shows the extent of PCE in soil gas at the Bravo Area, which appears to have been sufficiently investigated.

TCE was detected in 27 soil gas samples and exceeded the applicable comparison criteria in 24 of those samples. Elevated concentrations of TCE ranged from 680 µg/m^3 (BVSV1025, 3 to 3.5 ft bgs) to 1,620,000 µg/m^3 (SV-5.13-3, 5 ft bgs), each exceeding its human health criterion (530 µg/m^3), with 14 concentrations also surpassing its ecological criterion of 6,400 µg/m^3. TCE soil gas exceedances appear to be present down to the bedrock interface at this site. Horizontally, samples that did not have TCE exceedances provide extent to the west and southeast. A steep rock outcrop to the south provides a southern boundary of extent, and drainage paths provide a boundary to the north. Additional sampling to the east and along the drainage path to the east and northwest may be warranted to further evaluate the extent of TCE soil gases at this site. The extent of TCE vapors in the Bravo Area is shown in Figure 5.4-18.

The VOCs cis-1,2-DCE, TCE, and VC have been detected in the shallow groundwater of the Bravo Area. The volatilization of VOCs from the groundwater may be contributing to the presence of soil gas contamination in the deeper subsurface soil samples. With evidence of VOCs in the NSGW, the vertical extent of soil gases at this site has been evaluated adequately, with the potential exception of further characterization of TCE.

5.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the ABFF Area is described Section 5.8.1.4.

5.6 Fate and Transport Analysis for Chemicals Detected in Surficial Media

5.6.1 Contaminant Sources and Release Mechanisms

The primary release mechanism for contamination at the Bravo Area is the various fuels used during rocket testing activities, solvent used during equipment cleaning, historic recorded releases from storage containers and during chemical transfer, and potential leaks and spills from the general Bravo operations.

5.6.2 Potential Routes of Migration

The primary pathway for contaminant transport from the source areas at this site is the horizontal migration of potential contaminants through the drainage pathways toward the catch pond system. Secondary transport mechanisms for this site include the vertical migration of parameters from the surface soil to the subsurface soil and the release of surface soil to the air by wind erosion or volatilization.

5.6.3 Contaminant Persistence

Dioxins, inorganics, PCBs, SVOCs, TPHs, and VOCs were detected in the soil at the Bravo Area at levels above their screening criteria. Additionally, VOCs were detected in the soil gas at concentrations above their screening criteria. This subsection describes the chemicals applicable to this area.

5.6.3.1 Parameters Exceeding Criteria

Dioxins, inorganics, PCBs, SVOCs, TPHs, and VOCs are described below.

Dioxins. Dioxins are characterized by extremely low vapor pressures, high log K_{ow}, high K_{oc}, and extremely low water solubilities. Their strong adsorption to soil, low water solubilities, and high K_{oc} values indicate that the rate of transport from unsaturated zone soils to the water table via rain infiltration would be extremely low.

Because dioxins have low vapor pressure, they are not very volatile and tend to stay bound to particles. Dioxins also have low solubility; thus, aerially deposited dioxins tend to stay adsorbed to soils in the top few millimeters in surface soil.

Inorganics. Several metals were detected at this site at levels above the screening criteria. Some metals are naturally occurring and their reported presence may or may not indicate a contaminant release. The mobility of metals is complex and depends on several factors such as the overall groundwater composition, pH, metal complex formation, valence state of the metal, and cation-ion exchange capacity. Metals typically are not volatile. In the water phase, the total metal concentration includes the dissolved metal concentration and the suspended metal concentration, which is sorbed to colloidal particles. Therefore, elevated metals concentrations in groundwater may be due to the suspended load and not just to the dissolved aqueous chemistry.

PCBs. PCBs are persistent in the environment. PCB-aroclors are characterized by low water solubility, moderate volatility, high affinity for organic matter, and high resistance to chemical or biological degradation. They will strongly sorb to soil and do not tend to leach to groundwater. In surface water, they will partition to sediment and sorb to organic matter. PCBs will bioaccumulate in aquatic organisms.

SVOCs. PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. HMW PAHs are more likely to be transported via particulate emissions, while LMW PAHs have a greater tendency to volatilize (ATSDR, 1995). In general, PAHs are more likely to sorb to soil or organic matter than to partition significantly to water. Photolysis and biodegradation are two common attenuation mechanisms for PAH compounds (Howard, 1991). Animals and microorganisms can metabolize PAHs to products that ultimately reach complete degradation.

TPHs. TPHs are defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. The lighter petroleum products such as gasoline contain constituents with higher water solubility and volatility and lower sorption potential than heavier petroleum products such as fuel oil. Data compiled from gasoline spills and laboratory studies indicate that these light-fraction hydrocarbons tend to migrate readily through soil, potentially threatening or affecting groundwater supplies. In contrast, petroleum products with heavier molecular weight constituents, such as fuel oil, generally are more persistent in soils, due to their relatively low water solubility and volatility and high sorption capacity (Stelljes and Watkin, 1991).

VOCs. VOCs are characterized by relatively high vapor pressures, Henry's Law constants, and generally high solubility in water. VOCs have a tendency to partition to the vapor

phase from either soil or surface water and could be released through volatilization from contaminated soil. The sorption potential of VOCs is variable; some may persist in soil or sediment, while some are highly mobile in soil. VOCs will leach to groundwater and may persist, depending on their ability to degrade or transform in the environment.

TCE was the most prevalent VOC in the soil gas samples collected. Although TCE does not have a high K_{oc}, it may sorb to soil, sediment, or organic matter and persist in the environment for a long time. It also may persist in groundwater. TCE does not accumulate in plants or animal tissue and undergoes biotic and abiotic degradation via natural attenuation processes.

5.6.4 Contaminant Migration

The primary source for contaminant migration is from horizontal migration, historical leaching, and potential leaks and spills from storage units and chemical transfer stations associated with the Bravo Area.

5.6.5 Surface Soil Contaminants

Dioxins, metals, PCBs, SVOCs, TPHs, and VOCs have been identified in surface soil at levels above the background and/or health-based risk criteria. The following observations were made for contaminants in surface soil:

- Dioxins were detected in all eight of the surface soil samples collected. One sample location reported a mammal 2,3,7,8-TCDD TEQ value at a level exceeding the human-health screening criterion. No calculated TEQ values exceeded the ecological screening criterion.
- Of the metals detected in the surface soil at the Bravo Area, 8 metals were reported at concentrations exceeding 1 or more of their respective comparison criteria.
- Of the 14 sample locations collected for PCBs in the surface soil at the Bravo Area, 2 PCBs (Aroclor-1254 andAroclor-1260) was reported at a cumulative 7 stations at concentrations exceeding the comparison criteria in the surface soil at the site. At BVBS17, Aroclor-1254 was detected at 290 µg/kg, the highest reported PCB concentration at this site, compared to the human health criterion of 89 µg/kg.
- Of the 20 surface soil samples analyzed for SVOCs, 2 had reported exceedances of BaP in the surface soil media.
- Of the 68 surface soil locations collected for TPHs in the surface soil samples at the Bravo Area, 10 had reported elevated concentrations of a combined 7 TPH ranged groups. Each elevated concentration exceeded its ecological and human health criteria of 100,000 µg/kg, with the exception of the kerosene (C11-C14) range, which exceeded its human health criterion of 50.4 µg/kg.
- Five of the 9 samples analyzed for VOCs at the Bravo Area exhibited concentrations of 2 parameters (cis-1,2-DCE and TCE) at levels exceeding the human health comparison criteria. The parameter cis-1,2-DCE was detected at an elevated concentration at the only location analyzed for this parameter.

5.6.6 Subsurface Soil Migration

The following observations were made for the contaminants in subsurface soil:

- Eleven subsurface soil samples collected from 9 locations to a depth of 10 ft bgs were analyzed for both CDDs and CDFs. The mammal 2,3,7,8-TCDD TEQ values exceeded the human health (1.3 pg/g) comparison criterion at BVBS1061 (4.5 to 5 ft bgs). This sampling station also reported the sole 2,3,7,8-TCDD TEQ human health exceedance in the surface soil at this site.
- Five metals were detected once at elevated concentrations in the subsurface soil samples collected at this site. Most of these sole exceedances were at concentrations similar to their respective background values, which is indicative of natural occurrence.
- Of the 48 samples collected from 37 stations and analyzed for SVOCs in the Bravo Area, 5 samples exhibited elevated concentrations of 5 SVOC parameters from depths of 4 to 7 ft bgs. BaP also was detected in surface soil at levels exceeding applicable screening criteria.
- Of the 78 subsurface soil samples collected from 53 sampling stations for TPHs at the Bravo Area 18 samples had reported elevated concentrations of a combined 6 TPH groups. Each of these parameters also was detected at elevated concentrations in the surface soil media and in the subsurface, with all parameters exceeding their ecological and human health criteria of 100,000 µg/kg. The greatest concentration was encountered at BVBS23, 6 ft bgs, with a kerosene range (C11-C14) organics concentration of 15,000,000 µg/kg.
- Of the 41 subsurface soil samples collected from 33 sampling stations for VOCs, 4 VOC parameters (2-chloroethyl vinyl ether, bromodichloromethane, methylene chloride, and TCE) were detected at levels exceeding their respective screening criteria. Of these, only TCE also was detected in the surface soil at concentrations that exceeded its screening criteria.

5.6.7 Soil-to-Groundwater Migration

The relationship between chemicals detected in soil, soil gas, and groundwater has been evaluated to assess whether soil chemical concentrations have affected groundwater quality. Soil chemical concentrations were reviewed and compared with the available groundwater concentrations immediately south of the Bravo Area. The evaluation was based on the chemicals detected, background concentrations, spatial distribution, and hydrogeologic conditions. The evaluation provides conclusions regarding soil sources for the detected chemicals in groundwater.

The release of TCE from the SSFL operations at the Bravo Area probably resulted in the entry of immiscible-phase liquid into and below the water table by the interconnected fracture network within the weathered bedrock and the Chatsworth formation. SVOCs detected in the immediate study area may have resulted from site operations. Metals detected in groundwater mostly were near background levels, suggesting there have not been impacts on groundwater from the surface operations.

5.7 Human Health Risk Assessment for Bravo Area

The objective of this HHRA is to assess whether the environmental media at the Bravo Area could pose risks to human health at levels that might require remedial action, or risk at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil, soil gas, and groundwater at the Bravo Area. The methods and guidance documents used in the preparation of this HHRA are discussed in Section 1.5.3 of this report. A discussion of the HHRA results for the Bravo Area is presented below. The results are summarized in Section 5.9.2.

The concentration data, input parameters, and results of the HHRA for the Bravo Area are presented in Appendix E. An index of the tables (Appendix E human health RA Tables Index) is provided and can be used to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated non-cancer HIs.

5.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the Bravo Area based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

5.7.1.1 Data Evaluation

The soil, soil gas, and groundwater sampling analytical data at the Bravo Area were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.5.3.1. Sediment and surface water data were not collected as part of the RI site characterization activities. The locations of the soil, soil gas, and groundwater samples used in this HHRA are shown in Figures 5.4-1 and 5.4-15. The samples used in this HHRA are listed in Table E.5.1-1 by medium, sample ID, sampling depth interval, and date of collection. Table E.5.1-2 lists the target receptor populations by medium. Descriptive summary statistics of these data are provided in Table E.5.1-3.

5.7.1.2 Identification of COPCs in Soil

The results of the COPC screening process for soil at 0 to 2 ft bgs and 0 to 10 ft bgs are listed in Table E.5.1-3. Detected analytes in soil at the Bravo Area were compared to background levels. COPCs identified in soil (0 to 2 ft bgs) included 3 inorganics (barium, cadmium, and fluoride) and 29 organics. COPCs identified in soil (0 to 10 ft bgs) included 2 inorganics (barium and fluoride) and 50 organics.

5.7.1.3 Identification of COPCs in Groundwater

The results of the COPC screening process for NSGW are listed in Table E.5.1-3. Detected analytes in NSGW at the Bravo Area were compared to background comparison criteria. COPCs identified in NSGW included 8 inorganics and 9 organics.

5.7.1.4 Identification of COPCs in Soil Gas

The results of the COPC screening process for soil gas at 3 to 10 ft bgs are presented in Table E.5.1-3. Twenty-eight COPCs were identified in soil gas.

5.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the Bravo Area may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential exposures. Figure 1.5-2 depicts the conceptual exposure model for the Bravo Area. Table E.5.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

5.7.2.1 Identification of Receptors

The Bravo Area recently was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the industrial worker and recreationist exposure scenarios were evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

5.7.2.2 Identification of Exposure Pathways

Future residents and industrial workers were assumed to be exposed to groundwater, soil gas (modeled for migration to indoor air and ambient air), and soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). Future recreationists were assumed to be exposed to groundwater, soil gas (modeled for migration to ambient air), and soil (0 to 2 ft bgs). Exposure pathways for groundwater included direct exposures (ingestion and dermal) and indirect exposures. Inhalation exposures were quantified for the migration of groundwater and soil gas to ambient air and indoor air. Additionally, exposures were quantified for residential receptors for inhalation of groundwater VOCs in bathroom air while showering or bathing. Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the Bravo Area are provided in Table E.5.1-6.

5.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs, soil at 0 to 10 ft bgs, soil gas, and groundwater at the Bravo Area are listed in Table E.5.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts, ambient air, indoor air, and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for non-volatile COPCs. The derivation of the PEF for soil is listed in Table E.5.1-5.

Ambient air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs to ambient air and migration from groundwater to ambient air. Parameter values used for soil gas-to-air migration and for estimating the ambient air EPCs related to soils are listed in Table E.5.1-8. Parameter values used for

estimating ambient air EPCs related to groundwater also are listed in Table E.5.1-8. The estimated ambient air concentrations from the migration of volatile COPCs in soil and groundwater are listed in Tables E.5.1-9, E.5.1-10, and E.5.1-11, respectively.

Indoor air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs and from NSGW using the J-E Model (EPA, 2004e). The parameter values used in the J-E Model (EPA, 2004e) are presented in Table E.5.1-8. Soil gas data, where available, were preferentially used for indoor air modeling. The estimation of indoor air concentrations from soil gas and groundwater migration are presented in Tables E.5.1-12 through E.5.1-17.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b). COPC concentrations in edible plant tissues from soil at 0 to 2 ft bgs are presented in Table E.5.1-18.

5.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate chemical intakes for potential adult and child residential, adult and child recreationist, and industrial worker receptors at the Bravo Area. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix E. See the Appendix E human health RA Tables Index for the exposure parameters and chemical intakes for each exposure scenario.

5.7.3 Risk Characterization

In the risk characterization component of the HHRA process, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.5.

The exposure assumptions, EPCs, toxicity factors, and risk characterization results tables for this HHRA are presented in Appendix E (Appendix E human health RA Tables Index**)**. The risk calculation tables present the estimated ELCRs and non-cancer HIs for potentially exposed receptors and individual exposure routes for soil, indoor air, and groundwater at the Bravo Area, as well as the cumulative risks and HIs across all exposure routes for the RME and CTE scenarios. Table E.5.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are listed in Table E.5.5-2.

5.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from

soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-7} for the CTE case to 3×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.009 for the CTE case to 0.07 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route ranges from 9×10^{-6} for the CTE case to 3×10^{-4} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 1 for the CTE case to 14 for the RME case. The CTE HI estimate is equal to the regulatory threshold value of 1 and the RME HI estimate exceeds the regulatory threshold of 1. The HI and ELCR estimates for the plant consumption pathway are primarily due to PCBs in soil (0 to 2 ft bgs). The highest concentrations of PCB TEQs are located in the northeast pond area. The maximum concentration of PCB TEQ (3.6×10^{-5} mg/kg) for soil (0 to 2 ft bgs) was estimated at sample location BVSS08. The maximum concentration for PCB TEQ is at least an order of magnitude greater than the other PCB TEQ concentrations.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-7} for the CTE case to 3×10^{-6} for the RME case. The CTE ELCR estimate does not exceed the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.0.007 for the CTE case to 0.06 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The HI estimates for non-cancer effects range from 0.04 for the CTE case to 0.3 for the RME case. The CTE and RME HI estimate do not exceed the regulatory threshold value of 1.

- For indoor air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-10} for the CTE case to 3×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater intrusion, the HI

estimates for non-cancer effects range from 0.000004 for the CTE case to 0.000007 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-8} for the CTE case to 2×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.0004 for the CTE case to 0.003 for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-12} for the CTE case to 2×10^{-11} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 2×10^{-8} for the CTE case to 3×10^{-8} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to COPCs in NSGW, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to COPCs in NSGW, the HI estimates for non-cancer effects range from 0.002 for the CTE case to 0.003 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

5.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from

soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-7} for the CTE case to 6×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.08 for the CTE case to 0.6 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 9×10^{-6} for the CTE case to 8×10^{-5} for the RME case. The RME and CTE ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 2 for the CTE case to 15 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. The HI and ELCR estimates for the plant consumption pathway primarily are due to PCBs in soil (0 to 2 ft bgs). The highest concentrations of PCB TEQs are located in the northeast pond area. The maximum concentration of PCB TEQ (3.6×10^{-5} mg/kg) for soil (0 to 2 ft bgs) was estimated at sample location BVSS08. The maximum concentration for PCB TEQ is at least an order of magnitude greater than the other PCB TEQ concentrations.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 8×10^{-7} for the CTE case to 6×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.07 for the CTE case to 0.6 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-6} for the CTE case to 2×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.2 for the CTE case to 0.9 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

- For indoor air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-9} for the CTE case to 2×10^{-9} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 0.00002 for the CTE case to 0.00002 for the

RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 8×10^{-8} for the CTE case to 2×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.002 for the CTE case to 0.01 for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-11} for the CTE case to 2×10^{-11} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 1×10^{-7} for the CTE case to 1×10^{-7} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to COPCs in NSGW, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to COPCs in NSGW, the HI estimates for non-cancer effects range from 0.008 for the CTE case to 0.01 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

5.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below.

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-8} for the CTE case to 1×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate is equal to the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 6×10^{-4} for the CTE

case to 0.02 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-9} for the CTE case to 3×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.00002 for the CTE case to 0.0004 for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-13} for the CTE case to 2×10^{-12} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 1×10^{-9} for the CTE case to 4×10^{-9} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

5.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. A hypothetical future recreationist child (15-kg body weight) was assumed to be exposed for 350 days per year over 6 years for the RME case and 6 years for the CTE case. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-7} for the CTE case to 2×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate is greater than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.01 for the CTE case to 0.2 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of

vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-9} for the CTE case to 5×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.0002 for the CTE case to 0.003 for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-12} for the CTE case to 4×10^{-12} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 8×10^{-9} for the CTE case to 3×10^{-8} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

5.7.3.5 Hypothetical Future Industrial Worker Exposure Scenario

Potential industrial worker exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-8} for the CTE case to 4×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.006 for the CTE case to 0.1 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 8×10^{-8} for the CTE case to 4×10^{-6} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.005 for the CTE case to 0.08 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of

vapors that have migrated inside a future industrial building. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-7} for the CTE case to 6×10^{-6} for the RME case. The CTE ELCR estimate is less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.01 for the CTE case to 0.09 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

- For indoor air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-10} for the CTE case to 8×10^{-10} for the RME case. The CTE and RME ELCR estimates are less than the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 1×10^{-6} for the CTE case to 2×10^{-6} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-8} for the CTE case to 2×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.0004 for the CTE case to 0.003 for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-12} for the CTE case to 2×10^{-11} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater intrusion, the HI estimates for non-cancer effects range from 2×10^{-8} for the CTE case to 3×10^{-8} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

5.7.4 Uncertainty Discussion

Uncertainties associated with the results of this HHRA are a function of both the "state of the practice" of HHRA in general and of the UFs specific to the Bravo Area. A discussion of the general HHRA uncertainty is presented in Section 1.5.3.

5.8 Ecological Risk Assessment for Bravo Area

2.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to all RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the Bravo Area are described below.

5.8.1.2 Site Background

The Area II Bravo Area primarily consisted of three test stands associated with turbo pump and rocket engine testing using petroleum-based fuels (RP-1 and/or JP-4) and LOX as the oxidizer. Test Stand 3 has been dismantled; the other two test stands remain onsite. Nine buildings, three test stands, two skim ponds, an AST waste tank area, a groundwater reclamation and remediation facility, and a channel of piping are within the boundary of, or associated with, the Bravo Area site. A more detailed discussion of the site conditions and history is presented in Section 5.1.

The Bravo Area contains substantial areas of pavement and buildings. The pavement, buildings, and associated developed areas constitute about 28 percent of the land cover at this site. Habitat at the site was characterized based on a site survey conducted in April 2008. The survey indicated that the Bravo Area is consists of four habitat types, including scrub-shrub, ruderal, rock, and woodland habitat (Figure 5.8-1). Most of the site (about 39 percent) is consists of scrub-shrub habitat consisting mainly of coast live oak, yerba santa, coyote brush, and laurel sumac. The scrub-shrub habitat is broadly distributed about the site. Ruderal habitat makes up about 20 percent of the site and is located in the north-central portion of the site and adjacent to paved areas. It is dominated by red-stemmed filaree, red brome, yerba santa, and small pod mustard. Less than 0.1 percent of the site consists of woodland habitat, which is located along the northwestern edge of the site. Evidence or actual observation of the following species was noted during the site visit: Bewick's wren, spotted towhee, dark-eyed junco, house finch, California towhee, California quail, common raven, Anna's hummingbird, gopher [burrows], vole [runways], cottontail rabbit, and coyote [scat], western fence lizards, grasshoppers, and crickets. Stressed ruderal vegetation was identified, primarily adjacent to paved areas, and may have been due to herbicide applications. Stressed vegetation accounts for approximately 3 percent of the habitat at the site.

5.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the Bravo Area is the same as that for all Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the Bravo Area are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 5.8-1).

- Representative species and receptor groups considered for the Bravo Area include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

5.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the Bravo Area is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the Bravo Area is described below and presented in Figure 5.8-2.

The primary contaminant sources at the Bravo Area include discharges as a result of rocket testing, fuel leaks, equipment cleaning activities, and disposal of liquid wastes in the skim ponds and leach fields. Primary release mechanisms include spills and leakage to the ground surface or leaks to subsurface soils from the sump. Soil is the secondary source of potential contaminant. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater.

Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). Table 5.8-2 provides additional descriptions of potential exposure pathways for the ecological receptors at the Bravo Area, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

5.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil and soil gas are listed in Table 5.8-3. Summary statistics for those detected analytes are listed in Table 5.8-4. A central tendency background comparison for metals and dioxins/furans in soils was conducted to assess whether the analytes were consistent with background (Table 5.8-5). The volatile organics in soil and soil gas are compared in Table 5.8-6. Non-detect analytes were evaluated by comparing the maximum SQLs against the minimum ESL and determining the exceedance frequency of the SQLs (Table 5.8-7). The CPECs identified for the Bravo Area are summarized in Table 5.8-8. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 5.8-9, 5.8-10, and 5.8-11, respectively. EPCs for soil gas from 0 to 6 ft bgs are listed in Table 5.8-12. Calculations for extrapolating soil gas concentrations from soil concentrations are listed in Table 5.8-13.

5.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 5.8.1) with the risk

characterization (Section 5.8.3) and consists of the technical evaluation of ecological and chemical data to evaluate the potential for ecological exposure and effects. Generalized components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the Bravo Area is presented below.

5.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this section.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the Bravo Area. Because the Bravo Area is strictly terrestrial, exposure is based on soil and soil gas and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

Although the Bravo Area is 8.9 acres, the spatial extent of samples associated with the site is 10.6 acres. More than 60 percent of the land cover at this site consists of buildings, pavement, rock, ruderal, or stressed vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) and soil gas were calculated for the Bravo Area, according to the approach outlined in Section 1.5.4.4. These values are presented in Tables 5.8-9 through 5.8-12. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 5.8.3).

5.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for the receptors at the SSFL are summarized in Section 1.5.4.4. No effects data specific to the Bravo Area are available. Consequently, the ESLs, Low TRVs, and High TRVs for terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

5.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the Bravo Area. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the Bravo Area. The results of these comparisons are presented below.

5.8.3.1 Risk Estimation

The risk estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 5.8-14 through 5.8-21. Table 5.8-17 presents an analysis of the depth intervals for evaluation of burrowing animals (deer

mouse). The 0- to 6-foot-bgs depth interval had the greatest HI; therefore, the data from this depth were used to evaluate the deer mouse.

5.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with other available and appropriate lines of evidence to evaluate potential chemical impacts on ecological receptors in SSFL's Group 3. Chemicals that had HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of COECs includes receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.
2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.
5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.
6. No Risk–all HQs and associated HIs<1.
7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Twelve soil analytes (barium, cadmium, fluoride, alpha-hexachlorocyclohexane [BHC], beta-BHC, delta-BHC, dieldrin, endrin, heptachloride epoxide, 2-chloroethyl vinyl ether, dioxin/furan, and PCB TEQs) were found to have one or more HQs greater than 1 under at least one scenario (Table 5.8-22). The other soil analytes and/or analyte groups were found to pose no risk (all HQs and HIs were less than 1) to receptors under any scenario (maximum concentration for plants, invertebrates, and soil gas exposures; CTE and RME concentrations for birds and mammals) at the Bravo Area. It also should be noted that no analytes were found to pose risks to terrestrial plants or invertebrates; risks were only identified for wildlife receptors.

Three inorganics (barium, cadmium, and fluoride) were identified as elevated relative to background, based on the non-parametric central tendency background comparisons for soil (Table 5.8-5). In addition, hexavalent chromium was retained based on the SQL screen (Table 5.8-7). However, hexavalent chromium (based on the SQL) only failed the screening for soil invertebrates with an HQ of 3.3. Because of the low magnitude of exceedance and the fact that it was non-detect, risks from hexavalent chromium are acceptable. The three other analytes had one or more HQs above 1 for at least one receptor in the refined screen. On the basis of the risk ranking discussed above, barium was found to pose a medium risk (1<HQs<2 for High TRV [RME], but HQ>10 for Low TRV [RME]); cadmium was found to pose medium-high risk (2>HQ>5 for High TRV [RME]), and fluoride was found to pose medium-low risk (HQs<1 for the High TRV (RME).

Risks from barium are predicted for hermit thrush, based on the low TRV and RME in the refined screen (HQs of 1.3), and for the deer mouse, with a high TRV-based HQ of 1.3. As listed in Table 5.8-23, the incremental risk (difference between HQs from onsite barium data and HQs based on RME background barium concentrations, as described in Section 1.5.4) is low and the predicted risk is almost exclusively a result of naturally occurring background concentrations. Therefore, risks to the hermit thrush and deer mouse from barium are acceptable.

Risks from cadmium are predicted for the hermit thrush, based on the high TRV and RME in the refined screen (HQs of 1.5), for the deer mouse, with a high TRV-based HQ of 2.9, and for the mule deer with a low TRV-based HQ of 1.5. The magnitude of exceedances based on the high TRVs is low (less than 3) for all receptors. Cadmium did not pose risks to the terrestrial plants or invertebrates, based on the maximum site concentration. Additionally, the maximum concentration for cadmium (15 mg/kg at BVSS01) is based on legacy data that have unknown depth intervals, although based on the sample ID, it is likely to be a surface sample. The next highest concentration is 6 mg/kg (BVBS02) and 16 out of 51 samples exceed the background RME. The majority of samples that contained cadmium above background were located within and near the easternmost dry pond within the site. The risks associated with this analyte are uncertain, but the overall risk on a site-wide basis is considered low and to be localized to one general area.

Fluoride was found to be greater than background (Table 5.8-5) and was retained for evaluation in this risk assessment. The low TRV-based HQs for the hermit thrush (3.5) and the deer mouse (1.4) were slightly above 1, but both of the high TRV-based HQs were less than 1. Because the magnitudes of exceedance were low and the high TRV-based HQs under the RME exposure scenario were less than 1, risks from fluoride are acceptable.

In addition, dioxin/furan and PCB congeners (based on the evaluation of total TEQs [DIOXINTEQM, PCBTEQB, and PCBTEQM]), were found to fail one or more screens for one or more wildlife receptors (Table 2.8-22). TRVs were not available for plants, but no risks were predicted for soil invertebrates. The risks from DIOXTEQ were considered medium-low (HQs<1 for the High TRV [RME], but 1<HQs<10 for the Low TRV [RME]) and the risks from PCBTEQ were considered medium-high (2<HQs<5 for the High TRV [RME]). The DIOXTEQ exceeded the low TRV for the deer mouse, based on the RME (HQ=1.7) and CTE (HQ=1.1) exposures, although all high TRV-based HQs were less than 1 for receptors under both scenarios. Additionally, none of the dioxin/furan congeners were found to be greater than background (Table 5.8-5) and the risks from dioxin/furans are acceptable. The

PCB TEQ exceeded the high TRV for the hermit thrush, based on the RME (HQ=3.0), although the high TRV-based HQ based on the CTE was less than 1. The PCB TEQ also exceeded the high TRV for the deer mouse, based on the RME (HQ=4.8), although based on the CTE, the high TRV-based HQ was less than 1. The maximum PCB TEQ was located at BVSS08, just west of the dry pond. Because the high TRV-based HQs were less than 1 based on the CTE screen, only two receptors had predicted risk, and the magnitude of exceedance based on the RME screen was generally low (HQs less than 5), risks on a sitewide basis are acceptable.

Several pesticides (4,4'-DDE; 4,4'-DDT; alpha-, beta-, and delta-BHC; endrin; heptachlor epoxide; and dieldrin) were retained based on the SQL screen (Table 5.8-7). These analytes were all non-detect, but were retained for evaluation because more than 50 percent of the SQLs exceeded the minimum ESL. None of the pesticides were identified as posing risks to terrestrial plants or invertebrates (Tables 5.8-14 and 5.8-15). On the basis of the RME exposure, high TRV-based HQs were less than 1 for alpha-, beta-, and delta-BHC and low TRV-based HQs were less than 10. Dieldrin had HQs above 1 for the hermit thrush (low TRV-based HQ= 12; no high TRV available) and for the deer mouse (high TRV-based HQ=2.4), based on the RME exposure. These HQs dropped to 3.1 (low TRV-based HQ for hermit thrush) and less than 1 (high TRV-based HQ for deer mouse) based on the CTE. 4,4-DDE and 4,4,-DDT had high TRV-based HQs above 1 for the hermit thrush, based on the CTE (11 and 15, respectively) and the RME (42 and 58, respectively). Endrin and heptachlor epoxide had high TRV-based HQs of 5.1 and 16 based on the CTE, and of 20 and 62 for the deer mouse, based on the RME. Although some of the exceedances were elevated, none of these pesticides were detected and the RME was represented by the maximum SQL. The use of the maximum SQL to predict risk is conservative and likely over estimates risks. Consequently, risks from all pesticides are uncertain but likely to be acceptable.

2,4-Dinitrophenol also was retained based on the SQL screen; however, the high TRV-based HQs (RME) were less than 1 and the risk is acceptable.

2-Chloroethyl vinyl ether was detected within the 0-6 foot depth interval and was evaluated as part of the deer mouse screen. This analyte was detected in only 1 of 62 samples (less than 5 percent), but was retained for inclusion in the VOC HI calculations. The high TRV-based HQ was less than 1 and the low TRV-based HQ was only 2.2. Because of the low detection frequency and the low magnitude of exceedance, this analyte is considered to pose an acceptable risk.

Soil gas CPECs were identified and evaluated as part of this ERA. Thirty-three analytes were detected in soil gas, 1 non-detect was retained based on the SQL screen, and concentrations of 2 analytes were modeled based on detections in soil (Table 5.8-12). Of these, 6 soil gas analytes had HQs greater than 1 based on detected concentrations (Table 5.8-16). The soil gas analytes, with the exception of 1,1-DCE and TCE, had RME-based HQs ranging from 1.6 to 6.7 (Table 5.8-24). These low HQs, coupled with generally low detection frequencies, indicate a low likelihood of risk. 1,1-DCE and TCE were the only analytes considered to pose potential risks, based on an elevated magnitude of exceedance (HQs of 183 and 85, respectively). Whereas 1,1-DCE was detected in 5 of 41 samples, TCE was detected in 23 of 47. The one non-detect analyte retained based on the soil gas screen was not considered to pose a risk, even though the HQs were greater than 1. The HQ for 1,1,2-TCA was 35; the TRV is conservative and was derived from an LD50 using an

uncertainty factor of 100. The application of the uncertainty factor may overestimate or underestimate a no-effect level. On the basis of the soil gas screen, additional investigation is recommended at this site for 1,1-DCE and TCE. Tables 5.8-24 and 5.8-25 list the COECs in soil gas and soil, respectively.

5.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component in all risk assessments. Generalized uncertainties for ERAs in SSFL's Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- Samples were collected outside of the site boundary in an effort to evaluate potential releases from the Bravo Area. If sample concentrations decreased with distance from the site, the inclusion of these additional data may underestimate risk in the core portion of the site when these data are integrated into the RME and CTE calculations.
- Depths were unavailable for several historical soil and soil gas sample locations included in the Bravo Area dataset. In an effort to be conservative and to ensure completeness, these data were included in the 0- to 2-foot-depth interval for the purposes of risk assessment. There is some uncertainty associated with including these data in this depth interval (especially for soil gas), and risks may be overestimated. However, it is likely that maximum soil concentrations would be detected at shallower depths, so inclusion with the shallowest depth interval for soil is deemed appropriate.
- Aroclor data were not evaluated in this assessment because PCB congener data were available and were used to calculate a TCDD TEQ. PCBs and dioxin/furans were evaluated based on the 2,3,7,8-TCDD TEQs. Concentrations of aroclors were low and these are not expected to be significant contaminants of concern.
- No screening levels were available to evaluate the TPH data; however, PAH data were available and no risk from these constituents was predicted.

5.8.4 Conclusions and Recommendations

Of the soil analytes that were evaluated, none were found to pose high risks to the receptors evaluated at the Bravo Area. Although cadmium and PCB congeners were found to pose potential risks to the deer mouse, elevated concentrations generally were found to be isolated to soils near the easternmost dry pond, and risks are considered acceptable on a sitewide basis. All other analytes ultimately were determined to pose acceptable or low risks, based on the qualitative and quantitative evaluations. Two analytes in soil gas (1,1-DCE and TCE) were considered to pose potential risks and are recommended for further evaluation, based on the elevated concentrations detected in shallow soil gas.

5.9 Summary of Findings and Recommendations for Bravo Area

5.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of potential contaminants at the Bravo Area, 117 surface soil, 101 subsurface soil, and 55 soil gas samples were collected. Of the surface soil samples collected, 1 sample had dioxins (compared as 2,3,7,8-TCDD TEQ) that exceeded the applicable screening criteria; 14 locations had samples that exceeded the metals screening criteria; 7 locations had 1 or more PCB aroclor exceedance; 2 locations had a PAH exceedance; and 5 locations had VOC exceedances. The parameters that exceeded the criteria are listed in Table 5.9-1. Although the data indicate migration along the former earthen drainage paths (the primary migration pathway from the site), most of the exceedance locations are evaluated sufficiently downgradient by samples that did not have reported exceedances. The exceptions to this are the reported 2,3,7,8-TCDD TEQ exceedance at BVBS1061, PCB-aroclors both upgradient and downgradient of the site, and VOCs. The calculated 2,3,7,8-TCDD TEQ exceedance does not appear to be evaluated sufficiently to the north. Both Aroclor-1254 and Aroclor-1260 may require additional information downgradient, toward and within the Alfa/Bravo retention pond, to further evaluate the nature and extent characterization. Cis-1,2-DCE was detected at an elevated concentration in the only surface soil sample analyzed for the parameter, and the TCE exceedances do not appear to be evaluated sufficiently. Therefore, additional characterization likely is warranted.

Of the subsurface soil samples collected, 1 dioxin (compared as 2,3,7,8-TCDD TEQ), 5 metals, 3 PCB-aroclors, 6 TPH groups, 5 SVOCs, and 4 VOCs were reported at concentrations that exceeded 1 or more of their respective screening criteria. The 2,3,7,8-TCDD TEQ exceeded the screening criteria in 1 subsurface soil sample analyzed for dioxins–the same location in which an exceedance in the surface soil media was reported. One PCB, Aroclor-1254, may require additional sampling to further evaluate the vertical characterization of the parameter; the vertical extents of the other two PCBs encountered at elevated concentrations have been evaluated adequately. The 5 metals each were detected once at elevated concentrations similar to their respective background values. Subsurface soil SVOC exceedances have been mostly addressed, with the exception of BaP, which may require additional sampling to further evaluate the extent of contamination. TPH exceedances are the most numerous in the subsurface soil. TPH exceedances are mostly confined to the former Bravo Pond area, and their vertical extent appears to have been sufficiently investigated. The VOC exceedances of 2-chloroethyl vinyl ether, bromodichloromethane, methylene chloride, and TCE were detected at the bedrock interface and are evaluated sufficiently further downgradient through additional samples collected at the bedrock surface.

Ten VOCs were reported at levels exceeding the screening criteria in soil gas collected at the site. TCE was the most prominent VOC that was detected at elevated concentrations, and may require additional sampling to the east and along specific drainage pathways to further evaluate the extent of contamination. The likely source of the soil gas contamination is the solvent used to clean equipment at the test stands. Toluene, TCE, and VC each was detected

at elevated concentrations as soil gases and in the NSGW at this site. Therefore, these contaminants should be further evaluated as part of the area groundwater investigation.

5.9.2 Risk Assessment Summary

The human health and ecological risks at the Bravo Area are summarized below.

5.9.2.1 Summary of Human Health Risks

This subsection summarizes the HHRA performed for the Bravo Area. The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater. The methods used to prepare the HHRA are described in Section 1.5.3. The results of the HHRA for the Bravo Area are presented in Section 5.7.

The surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater samples collected during the RI sampling activities were evaluated for use in the HHRA. Surface water and sediment samples are not evaluated in this HHRA, because they were not present during the RI site characterization activities. The HHRA data set is listed in Table E.5.1-3 in Appendix E. The COPCs identified from the Bravo Area HHRA data set for each exposure area are listed in Table E.5.1-4.

The potential future receptors at the Bravo Area include recreationists, workers, and residents. The Bravo Area and surrounding area are likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report. The assumed exposure pathways for future residents, workers, and recreationists are shown in Figure 1.5-2.

Generally, estimated cumulative cancer risks (ELCRs) less than the regulatory risk range (range of 1 in a million [1×10^{-6}] to 1 in 10,000 [1×10^{-4}]) and estimated non-cancer hazards (HIs) less than the regulatory threshold value of 1 are considered acceptable (EPA, 1993). Estimated ELCRs within the 1×10^{-6} to 1×10^{-4} range are managed on a site-specific basis. Table E.5.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are listed in Table E.5.5-2.

The following exposure scenarios for the Bravo Area exceed or are within the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)

- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents and industrial workers exposed to indoor air (migration of soil gas COPCs)

The primary contributor to the ELCR for the soil exposure pathways is PCB TEQ (ranging from 84 to 89 percent of the ELCR estimate) [Table E.5.5-2]. The primary contributors to the indoor air pathways are CTC, naphthalene, and PCE (Table E.5.5-2).

The following exposure scenarios for the Bravo Area are less than the regulatory risk range for carcinogenic COPCs:

- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of soil gas and volatile groundwater COPCs) and indoor air (migration of volatile groundwater COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

The following exposure scenarios for the Bravo Area are less than the regulatory threshold value for non-cancer COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of volatile groundwater and soil gas COPCs) and indoor air (migration of volatile groundwater and soil gas COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

The ELCR estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory risk range. The primary contributors for this scenario are PCB TEQ (ranging from 37 to 75 percent) and BaP (contributing 35 percent). The HI estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory threshold value. The primary contributors for this scenario are PCB TEQ (ranging from 20 to 40 percent), TCE (40 percent), and cadmium (ranging from 27 to 32 percent).

As described in Sections 1.5.3.6 and 5.7.4, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

5.9.2.2 Summary of Ecological Risks

Of the soil analytes that were evaluated, none were found to pose high risks to the receptors evaluated at the Bravo Area. Although cadmium and PCB congeners were found to pose potential risks to the deer mouse, elevated concentrations generally were found to be isolated to soils near the easternmost dry pond, and risks are considered to be acceptable on

a sitewide basis. All other analytes ultimately were determined to pose acceptable or low risks, based on the qualitative and quantitative evaluations. Two analytes in soil gas (1,1-DCE and TCE) were considered to pose potential risks and are recommended for further evaluation, based on the elevated concentrations detected in shallow soil gas.

5.9.3 Recommendations for the Bravo Area

To complete the nature and extent evaluation in the Bravo Area, additional surface soil samples for dioxins, 1 PCB (Aroclor-1254), and VOCs are recommended. In the subsurface soil media, additional investigation for the extent of Aroclor-1254 and BaP is recommended. It also is recommended that additional TCE soil gas samples be collected to further evaluate the extent of contamination in the soil gas at the Bravo Area.

Potentially significant human health risks were identified for PCBs (based on the PCB TEQ concentrations) in soil (0 to 2 ft bgs and 0 to 10 ft bgs). Additionally, 3 VOCs (naphthalene, CTC, and PCE) in soil gas (3 to 10 ft bgs) contributed to elevated human health risks. Elevated human health risks for the residential plant consumption pathway were primarily due to PCBs, BaP, cadmium, and TCE in soil (0 to 2 ft bgs). It is recommended that the localized extent of PCBs in soil be further evaluated. After confirmation of the extent of contamination, removal of soils that have elevated PCB concentrations and extraction of soil gases in areas that have elevated VOC concentrations are recommended at this location to reduce human health risks. It is recommended that that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC. The agricultural-based residential exposure scenario will be evaluated at a later date.

On the basis of the ERA results , 2 analytes in soil gas (1,1-DCE and TCE) were considered to pose potential risks and are recommended for further evaluation in the FS, based on the elevated concentrations detected in shallow soil gas. No soil analytes were determined to warrant additional evaluation.

6. Alfa Area

6.1 Alfa Area Background and History

The Area II Alfa Area primarily consisted of three test stands (Test Stands 1, 2, and 3) for rocket engine testing. Engines tested at this site used mostly petroleum-based fuels (kerosene) and LOX as the oxidizer. The site was built and activated in 1955. Test Stand 2 was deactivated and dismantled in 1957 and Test Stands 1 and 3 were deactivated in 2000 and March 2006, respectively. The rest of the Alfa Area facility remains mostly intact. The Alfa Testing Facility currently is inactive and has been designated as an Area II AOC. This Alfa Area site covers approximately 7.5 acres.

6.1.1 SWMUs and AOCs

A total of three SWMUs have been designated within the Alfa Area. The three Alfa Test Stands have been given the designation of SWMU 5.9. Testing of the Atlas, Thos, Navajo, Jupiter, Delta, and RS-27 engines primarily was conducted at this site. These test stands used blends of petroleum fuels, mostly in the diesel and kerosene carbon range, and solvents (TCE) to flush system piping before and after tests. SWMU 5.10 is the designation for three ASTs associated with the testing operations. Two ASTs were 1,500-gallon tanks used to store spent TCE. The third tank was a 5,000-gallon tank used to store waste RP-1 fuel. The three tanks have been empty since 1995. The third SWMU associated with the Alfa Area, SWMU 5.11, is the former Alfa skim and retention ponds, which includes the associated earthen drainage system. Cooling water that had the potential for carrying fuels and solvents was discharged to this system. Accumulated, skimmed wastes reportedly were burned.

Two AOCs are associated with the Alfa Area site. Two leach fields, one associated with Building 2208 and the other with Building 2212, have been designated as AOCs, similar to other leach fields within Area II at SSFL. Building 2208 was reported to be a recording center and Building 2212 was a pretest shop.

6.1.2 Site History

The Alfa Area was acquired by NASA in 1973, along with the remainder of the Area II property (known as USAF Plant 57 under ownership of the USAF). Two engine test stands are present in the Alfa Area; a third was active until 1957 and has since been dismantled.

The buildings and facilities and their related purposes are outlined below.

Building 2208, constructed in 1955, served as the Control Center for Alfa Area test operations. The concrete building contained control, monitoring, and video equipment. A former leach field, associated with the control center, is located west of the building and designated as an AOC. Building 2208A was an engineering trailer used for offices that was located immediately to the west of Building 2208.

Building 2209, constructed in 1955, was used as the Terminal House for Test Stand 1 (Building 2727) The concrete building is located east of Test Stand 1 and housed electronic components and wiring associated with testing activities. Adjacent to the eastern side of the Terminal House is a hazardous materials storage area that is covered by an awning. This hazardous materials storage area has a floor trench to contain releases in this area.

Building 2212 is located in a paved area northeast of the test stands. It was constructed in 1956 and designated as the Pretest Shop. Building 2212S was added as an extension to the Pretest Shop (construction date unknown). A leach field associated with these two buildings is located to the north, which is noted as an AOC.

Building 2212B was designated as the Alfa Area Entry Guard Shack. The building was located on Alfa Road and to the east of the ABFF. The construction date of this building is unknown.

Buildings 2209A, 2727A, and 2729A were designated as the Alfa 1, 2, and 3 ECS Shacks. Their construction dates are unknown; however, it may be deduced that each facility was constructed along with the construction of the test stands in approximately 1955. The buildings house electrical components and switches for the Alfa Area Test Stands 1 and 3. Two test stands currently are located in the Alfa Area, identified as Test Stand 1 and Test Stand 3 (Buildings 2727 and 2729, respectively). The open-framed metal structures with concrete foundations were built between 1955 and 1956. Test Stand 2 was active until 1957 and has since been dismantled. Test Stand 1 was deactivated in 2000 and Test Stand 3 was active until March 2006. These test stands are positioned with the exhaust buckets facing in a southerly direction. These facilities were used to test the Atlas, Thor, Navaho, Jupiter, and Delta engines. The Alfa Area was constructed to support operations at these test stands. Petroleum-based fuels including RP-1 and JP-4 were used as the fuel source for combustion at these tests stands. Early testing activities included cleaning using TCE that was flushed through the thrust chamber and the LOX dome to remove hydrocarbon deposits from the engine components.

Building 2739 was designated as the Alfa Area Talker Shack. The construction date of this building is unknown.

Building 2X is the Pillbox for Test Stand 1 (Building 2727). The Pillbox, constructed of reinforced concrete, was used to view engine tests in progress, thus providing a safe viewing angle for SSFL personnel. The construction date of this building is unknown.

Building 2Y is the Pillbox for Test Stand 3 (Building 2729). The Pillbox, constructed of reinforced concrete, was used to view engine tests in progress, thus providing a safe viewing angle for SSFL personnel. The construction date of this building is unknown.

6.1.2.1 Site Inventories

Inventories of the buildings, tanks, transformers, and chemicals used at the Bravo Area were compiled during the preparation of this RI report. This information was obtained from historical document reviews, facility drawings, and VSIs. These features are shown in Figure 6.1-1, as applicable. The inventories are included in the following tables:

- Building Inventory–Table 6.1-1
- Transformer Inventory–Table 6.1-2

- Tank Inventory–Table 6.1-3
- Chemical Inventory–Table 6.1-4

6.1.3 Site Chemical Use Areas

The Alfa Area Test Stands were used to test rocket engines using petroleum-based fuels and LOX as the oxidizer. Three ASTs were located at this site with a combined capacity of approximately 7,500 gallons of RP-1 fuel. Table 6.1-4 provides a chemical inventory of the hazardous materials used or stored at the buildings described below.

To the east of Building 2209, a hazardous material storage area stored oronite, hydraulic oil, preservative oil, and rust foil.

At Buildings 2212 and 2212S, the Alfa Pre-Test Shop was reported to have stored hazardous materials including igniters used during engine testing activities. Buildings 2727A and 2729A reportedly stored igniters, as well. These igniters contained TEA and TBA.

Test Stands 1 and 3 (Buildings 2727 and 2729, respectively) performed engine tests using petroleum-based fuels. Hazardous materials stored or used at Test Stands 1 and 2 included JP-4, RP-1, RJ-1, hydraulic oil, oronite, TCE, TCA, and waste RP-1 (The Boeing Company, 2007). Three waste ASTs, located to the south of Test Stands 1 and 3 in a concrete-lined secondary containment area, make up SWMU 5.10. These ASTs include two 1,500-gallon waste TCE tanks (Tanks V-1277 and V-1278) and one 4,775-gallon waste RP-1 tank (Tank V-57). These tanks were installed in 1983 and removed in 2008. Before these tanks were installed, a former AST, located slightly to the north, was used from the 1950s to 1983. Originally, a cleaning process using TCE was employed after engine testing activities to remove residual fuel from engine components. The TCE waste was discharged to the spillways leading to the Alfa Skim Pond, and eventually to the Alfa/Bravo Skim Pond. To capture the waste TCE, a TCE recycling system was implemented in 1961. TCE was then captured in a catch pan and contained in a storage tank after being flushed through the engines. The TCE was later sold for recycling. After TCE was no longer used, TCA was used until 1994, when the use of solvents for engine cleaning was discontinued NASA, 1993; MWH, 2005d).

6.1.4 Site Conditions

The Alfa Area currently is inactive, although the facility is mostly intact. Alfa Test Stand 2 has been demolished.

6.1.5 Site Habitats/Land Cover

The Alfa Area, approximately 7.5 acres, is predominantly open field, ruderal vegetation, with an average height of 18 inches tall. Woodland covers approximately 25 percent of the Alfa area, with evergreens (narrow-leafed willow and red willow) that are 0 to 6 inches in height. Tall (greater than 5 ft) and dense shrub/scrub habitat cover approximately 2 percent of the site. Stressed vegetation (a peach tree, laurel sumac, and dead/stressed vegetation in drainage) was observed in the Alfa area. Some of the stressed vegetation along the drainage may be a result of herbicide spraying along roads. Multiple bird and mammal species (spotted towhee, house finch, dark-eyed junco, violet-green swallow, white-crowned sparrow, western scrub-jay, American goldfinch, Anna's hummingbird, red-tailed hawk,

California quail, blue-gray gnatcatcher [in riparian area], American kestrel, California ground squirrel, gopher [burrows], coyote [scat], mule deer [tracks and scat], cottontail rabbit, bat [guano on rocks], and fox [scat]) were observed to use the site. Additionally, western fence lizards, grasshoppers, and crickets were also observed. The habitats and land cover present at the Alfa Area are shown in Figure 6.1-2.

6.1.6 Historical Document Reviews

As described in Section 1.6.1, a historical document review was completed of documents applicable to the Group 3 RI. As a result of this historical document review, no new potential feature was identified.

6.2 RI Characterization Activities

This subsection describes the sampling objectives, sampling scope, and key decision points associated with evaluating the nature and extent of chemical impacts for the surface soil, subsurface soil, soil gas, and groundwater at the Alfa site.

6.2.1 Sampling Objectives

To further evaluate the extent of potential chemical effects on the Alfa Area, soil, soil gas, and groundwater samples were collected. The objectives of the investigation were as follows:

- Evaluate the lateral and vertical extent of chemical impacts.
- Evaluate the potential gradients of chemicals.
- Develop a sufficient data set for performing a risk assessment.

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results and/or previous remediation activities
- Fate and transport characteristics of chemicals
- SSFL background concentrations of parameters
- SSFL SRAM-based screening concentrations for human health and ecological receptors

6.2.2 Sampling Scope

Provided in this report are the characterization results for soil matrix, soil gas, and groundwater information. The total numbers of historical and recent samples collected as part of this report for soil matrix samples, soil gas samples, and groundwater samples are summarized below:

- Soil matrix: 293 samples
- Soil gas: 73 samples
- Groundwater: 1 sample

These samples were collected between 1987 and 2009 to identify the potential chemical impacts associated with the activities at the Alfa Area. Section 6.6 summarizes these samples.

Note that two wells that were recently installed in this area, PZ-153 and PZ-154, were not sampled because of the seasonally dry conditions. Sampling will be attempted during an upcoming wet season.

6.2.3 Key Decision Points

The site-specific decision points identified for the Alfa Area represent the assumptions and/or decisions made during the sampling phase component of this RI, as follows:

- For historical sample points where the sample depth had not been recorded, it was assumed that these sample points were taken between the 0- to 2-foot-bgs range.

6.3 RI Characterization Results

The characterization results from the previous soil matrix, soil gas, groundwater, and surface water investigations at the Alfa Area are summarized below.

6.3.1 Soil Matrix and Soil Gas Findings

Samples were collected at the Alfa site from 1983 through 2009. Two subsurface soil stations were sampled in 1983, B-5A and B-6 in and around the eastern retention pond, for pH and VOCs. TCE was detected at an elevated concentration at the pond inlet. To further evaluate this site, subsequent soil investigations from 1993 until 1995, surface soil, subsurface soil and soil gas samples were collected and analyzed for dioxins, VOCs, pesticides, TPHs, SVOCs, and general chemistry. Data were included in the 1996 RFI WPA (Ogden, 1996a; 1996b; 1996c) and the closure reports in regard to the retention ponds present at this site.

To evaluate the potential contamination related to the Alfa Area as a result of the 1996 WPA, surface soil, subsurface soil, and soil gas samples were collected in 1997 and 1998. Additionally, upon completion of an aerial photography review (Lockheed, 1997), sampling plans and approaches were developed in conjunction with the DTSC, and dioxins, metals, SVOCs, TPHs, and VOCs were sampled and analyzed. Parameters from each category except SVOCs were detected at concentrations that exceeded the applicable screening criteria.

From 1998 through the present, RI characterization sampling was conducted to support the development of this RI report. Each stage of the investigative process is outlined in the RFI Report (MWH, 2004). To summarize, AOCs were investigated through soil, soil gas sampling, and NSGW sampling, which was followed as recently as early-2009 by rounds of step-out sampling to further evaluate the nature and extent of contamination. Dioxins, PCB-aroclors, inorganics, TPHs, SVOCs, and VOCs were all detected at concentrations that exceeded the applicable screening criteria in the Alfa Area. Additional details regarding the analytes detected at the Alfa Area as a result of the previous investigations performed are described in Section 6.4. The HHRA and ERA of the analytes detected at this site are provided in Sections 6.7 and 6.8, respectively.

6.3.2 Groundwater Findings

6.3.2.1 Background

The Alfa Test Area (Figure 6.3-1), which contains SWMUs 5.9, 5.10, and 5.11, is an approximately 6.5-acre site located in the central portion of Area II. The elevation varies from approximately 2,000 feet above msl in the eastern section of the site to 1,830 feet msl in the western section of the site. Twelve wells and piezometers are located within the boundary of the Alfa Test Area and provide information regarding near-surface and Chatsworth formation groundwater conditions. These wells and piezometers are listed in Table 6.3.-1, along with the construction summaries. The locations are shown in Figure 6.3.-1.

NSGW conditions were investigated before this RI with the installation of one well (HAR-11) and three piezometers (PZ-049, PZ-060, and PZ-061). HAR-11 was installed in May 1987 to investigate NSGW conditions on the western side of the Alfa Skim Pond (SWMU 5.11) within a drainage feature leading from the pond. PZ-049 and PZ-060 were installed in December 2000 and PZ-061 was installed in January 2001. These three piezometers were installed along the axis of a drainage that slopes from the east to the west leading away from the main test area at the Alfa Test Area. PZ-049, PZ-060, and PZ-061 have contained NSGW in the past. Measurements taken in 2008 indicate that PZ-049 and PZ-060 were dry. PZ-061, last measured in 2005, did contain NSGW. HAR-11 historically has contained NSGW.

RI activities at the Alfa Test Area included the installation of two piezometers, PZ-153 and PZ-154 (Figure 6.3-1), which were installed in November 2008. Both piezometers were installed within the weathered section of the Chatsworth formation. Screened intervals were constructed in potential water-bearing zones that were identified during rock coring activities. Unweathered Chatsworth formation was encountered at PZ-154. Construction logs and boring logs for recently installed piezometers PZ-153 and PZ-154 are provided in Appendix F.

PZ-153 was installed to evaluate site conditions near documented chemical releases from Building 2729. PZ-154 was installed adjacent to PZ-049 to investigate potentially deeper occurrences of NSGW. PZ-049 was installed relatively shallow relative to the estimated thickness of weathered bedrock, which was believed to be the reason for the lack of NSGW at that location. PZ-153 contained a trace of NSGW that was measured on January 26, 2009, while no NSGW was measured in PZ-154.

Chatsworth formation monitoring wells at the Alfa Test Area include HAR-20, RD-49A, RD-49B, and RD-49C. HAR-20 was installed in June 1987 as part of a sitewide hydrogeologic assessment program. RD-49A and RD-49B (installed in June 1993) and RD-49C (installed in July 1993) were installed specifically to evaluate water quality in the Chatsworth formation groundwater.

6.3.2.2 Local Geology

The Alfa Test Area throughout most of its areal extent is underlain by deposits of the Shale 2 unit (Figure 6.3-1). The Shale 2 unit, which marks the boundary between the Sandstone 1 and Sandstone 2 units, consists of thin bedded shale, siltstone, and sandstone and is divided

into upper and lower fine-grained units separated by sandstone. Beds strike northeast-southwest and dip between 25 and 40 degrees to the northwest. The thickness of the Shale 2 unit has been estimated to range from 150 feet to 285 ft across the SSFL property. The Alfa Test Area is bounded to the south by the Sage Member of the Sandstone 1 Unit of the Upper Chatsworth formation. The Sage Member consists predominantly of medium-grained sandstone with minor interbeds of siltstone and shale.

During RI rock-coring activities at PZ-153 and PZ-154, materials encountered included alluvium/colluvium, weathered bedrock of the Chatsworth formation, and unweathered Chatsworth formation rocks. Alluvial/colluvial material consisted of pale olive to olive brown silty sand/sandy silt with some siltstone. The thickness of alluvial/colluvial deposits encountered during drilling activities at the Alfa Test Area ranged from 0 ft to approximately 13 ft. Thickest alluvial/colluvial deposits were encountered at the western boundary of the Alfa Test Area at PZ-061.

Weathered bedrock encountered in PZ-153 and PZ-154 consisted predominantly of weathered sandstone with some interbedded weathered siltstone and shale. Conglomerate rarely was encountered. Colors ranged through shades of gray, brown, and yellow. Textures typically were medium grained.

Unweathered Chatsworth formation was encountered at PZ-154 at a depth of 60 ft bgs and consisted of medium-grained, dark gray sandstone.

Cross-sections A-A' and B-B' traverse the Alfa Test Area (Figures 6.3.-2 and 6.3-3). Where known, the thickness of alluvial/colluvial deposits, weathered bedrock and depth to unweathered bedrock are shown. Generally, depths to the top of unweathered Chatsworth formation rocks at the Alfa Test Area are speculative because of insufficient detail in historic lithologic logs. The most recent water level data also are posted.

6.3.2.3 Local Hydrogeologic Setting

Near-surface Groundwater. NSGW at the Alfa Test Area is characterized as neither laterally or temporally extensive (MWH, 2003d). NSGW has occurred in previously installed piezometers and groundwater monitoring wells, but only consistently occurs in HAR-11 at the western margin of the Alfa Test Area (Figures 6.3-1 and 6.3-3). Figure 6.3-4 presents hydrographs of the piezometers and wells for which NSGW measurements have been obtained. Studies have indicated that the Sale 2 unit, in which HAR-11, PZ-049, PZ-060, and PZ-061 are installed, represents a local aquitard with a lower hydraulic conductivity than is present in the adjacent and stratigraphically lower Sage unit, and that groundwater, when present within this unit, is perched (MWH, April 2007).

Two piezometers (PZ-155 and PZ-156) recently installed in the weathered section of the Chatsworth formation support the characterization of NSGW not being laterally extensive. Only PZ-155 has indicated the possible presence of NSGW (0.21 ft of water was measured on January 6, 2009). Additional measurements are needed before it can be concluded that the water present at this location is actually NSGW and not water left over from recent rock coring and piezometer installation procedures. Potential seasonal variations in NSGW occurrence at these locations currently are being investigated.

NSGW at the Alfa Test Area is interconnected with that at the Bravo Test Area to the west. NSGW is believed to flow northwestwardly from the Alfa Test Area toward the SPA RI study area. Figure 3.3-7 is a potentiometric map of NSGW occurrence in the Group 3 study area. This map integrates the NSGW levels taken during the fourth quarter of 2008 and early 2009. Near-surface elevation data are sparse; however, the available data indicate that where NSGW has been measured, its flow is toward the northwest (at the western end of the Alfa Area).

Chatsworth Formation Groundwater. Chatsworth formation groundwater is locally extensive across the Alfa Test Area, as it is regionally extensive across the SSFL. Hydrographs of wells completed in the Chatsworth formation are shown in Figure 6.3-4, and except at RD-49A, the depths to Chatsworth formation groundwater extend significantly below the surface. Groundwater in the Shale 2 unit is believed to be perched. Water levels in Chatsworth formation groundwater monitoring wells are significantly deeper (with the exception of RD-49A), compared with water levels in near-surface wells HAR-11, PZ-060, and PZ-061 (Figure 6.3-4). From approximately 1988 through 2001/2002, water levels in Chatsworth formation wells were significantly lowered because of pumping. Levels began to recover after pumping ceased and appear to continue to rise over time. The differences in elevation of Chatsworth formation groundwater levels with those of NSGW levels indicate that there is no physical connection between the two.

A comprehensive discussion of hydrogeologic characteristics of the Chatsworth formation is provided in the *Technical Memorandum Conceptual Site Model Movement of TCE in the Chatsworth Formation SSFL* (Montgomery Watson, 2000) and in the Geologic Characterization of the Central SSFL (MWH, 2007b).

6.3.2.4 NSGW Characterization Results

Both near-surface and Chatsworth formation groundwater characterization is based on sampling events that have occurred from 1987 to the present. These data are termed "legacy" data. Sampling has been conducted for a variety of analytical groups (VOCs and metals) that have varied over time and location. The following discussion of characterization results is divided into NSGW and Chatsworth formation groundwater. Although the Chatsworth formation groundwater is the subject of a separate programmatic investigation and has been designated as its own OU (the CFOU), the sampling results are summarized herein to provide a comparison with NSGW characterization.

NSGW has been sampled at one location (HAR-11) beginning in July 1987 through the present. Two recently installed piezometers (PZ-153 and PZ-154) were installed to provide additional information regarding the occurrence and quality of NSGW. To date, either no NSGW or an insufficient quantity has been present at these locations, which has prevented samples from being collected. NSGW quality is represented by legacy data collected over the time period of 1987 to 2006.

Table 6.3-2 summarizes the historical (legacy) analytical sampling events of NSGW monitoring well HAR-11 at the Alfa Test Area. Analytical groups that have been sampled include the following:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- Energetic parameters (explosives-related compounds)
- General chemistry analytes
- Hydrocarbons (fuel-related compounds)
- Organo-chlorine pesticides

The following subsections discuss the results of each analytical group in further detail. Table 6.3-3 summarizes the detections of analytes for each group and data include the available legacy data. Table 6.3-4 lists the metals concentrations over time (only analyses for dissolved concentrations of metals have been conducted). Table 6.3-5 summarizes the most recently available data and compares the results with the screening level criteria, where available. Groundwater analytical data used to evaluate the NSGW conditions are provided in Appendix I.

Volatile Organic Compounds. VOC detections in NSGW at the Alfa Test Area are summarized in Table 6.3-3. Eleven VOCs have been detected, including 1,1,1-TCA, 1,2-dichloroethane, acetone, benzene, dichlorodifluoromethane, methylene chloride, 1,1-dichloroethane, TCE, cis-1,2-DCE, VC, and trans-1,2-DCE.

The most frequently detected VOCs include TCE, cis-1,2-DCE, trans-1,2-DCE, and VC. All of these VOCs exceed the screening criteria except TCE. Time trend charts for these compounds in the samples collected from HAR-11 are shown in Figure 6.3-5.

1,2-Dichloroethane has exceeded the screening criteria, but has been detected only twice (Table 6.3-3).

Recently installed piezometers PZ-153 and PZ-154 have not been sampled for VOCs because of a lack of sufficient or any NSGW. Once sufficient water is available, samples will be collected. The results will be reported as an addendum to the RI report.

Table 6.3-5 summarizes the most recent VOC results from the available data. Screening level exceedances for cis-1,2-DCE have occurred.

Semivolatile Organic Compounds. No SVOCs have been detected.

Phthalates. No phthalates have been detected.

Polycyclic Aromatic Hydrocarbons. No PAHs have been detected.

Metals. Metals detected in NSGW are summarized in Table 6.3-3. A comparison of dissolved versus total metals concentrations is presented in Table 6.3-4. Although exceedances of screening levels have occurred, the screening level exceedances are not frequent.

The most recent results indicate that 3 metals exceeded the screening level criteria. These metals are identified in Table 6.3-4.

Table 6.3-4 presents the metals results for HAR-11. Analyses for dissolved concentrations only have been conducted.

Energetic Parameters (Explosive Compounds). No energetic parameters have been detected.

General Chemistry Analytes. General water quality analytes (common anions and cations) have been analyzed for in NSGW. The detections and exceedances are reported in Tables 6.3-3 and 6.3-5. Detections of fluoride, nitrate, and sulfate have exceeded the screening levels in the past. Chloride and sulfate exceeded the screening levels in the most recent samples.

Hydrocarbons (Fuel-related Hydrocarbons). Gasoline-related organics have been detected in samples from HAR-11 at levels that exceeded the screening level concentrations (Tables 6.3-3 and 6.3-5).

Organo-chlorine Pesticides. OC pesticides have not been detected in NSGW at the Alfa Test Area.

6.3.2.5 Chatsworth Formation Groundwater Characterization Results

Chatsworth formation groundwater has been sampled at 4 locations beginning in 1987 and extending to the present. The Chatsworth formation groundwater is under a separate regulatory program within the RCRA corrective action program at SSFL and has been designated its own OU (the CFOU). No investigations pertaining to Chatsworth formation groundwater were conducted during this RI. However, groundwater quality data are summarized below because of the vertical juxtaposition (albeit no direct physical connection is present at the Alfa Test Area) of the occurrences of NSGW with that of the Chatsworth formation, and because of the potential physical connection between them in terms of contaminant transport.

Table 6.3-6 summarizes the historical (legacy) analytical sampling events of the Chatsworth formation groundwater monitoring wells (HAR-20, RD-49A, RD-49B, and RD-49C) at the Alfa Test Area. Analytical groups that have been sampled include the following:

- VOCs
- SVOCs
- Phthalates
- PAHs
- Metals
- Energetic parameters (explosives-related compounds)
- General chemistry analytes
- Hydrocarbons (fuel-related compounds)
- Organo-chlorine pesticides

The following subsections discuss the results of each analytical group in further detail. Table 6.3-7 summarizes the detections of analytes for each group; the data include the available legacy data. Table 6.3-8 lists the metals concentrations over time and compares the total concentrations versus the dissolved concentrations by sample by location. Table 6.3-9

summarizes the most recently available data and compares the results with the screening level criteria, where available. The groundwater analytical data used to evaluate Chatsworth formation site conditions are provided in Appendix I.

Volatile Organic Compounds. Twenty-four VOCs have been detected and are listed in Table 6.3-6.

VOCs that exceeded the screening level concentrations include trans-1,2-DCE, cis-1,2-DCE, VC, formaldehyde, 1,1-DCE, methylene chloride, 1,1,2,2-tetrachloroethane, and 1,2-dichloroethane (Table 6.3-6). Time trend charts, by well, for TCE and its daughter products cis-1,2-DCE, trans-1,2-DCE, and VC are shown in Figure 6.3-6 by well. Figure 6.3-7 presents time trend charts for TCE, cis-1,2-DCE, trans-1,2-DCE, and VC across locations.

Table 6.3-9 summarizes the most recent VOC results from the available data. Screening level exceedances of TCE, cis-1,2-DCE, trans-1,2-DCE, VC, and formaldehyde have occurred. Exceedances have occurred at the four Chatsworth formation groundwater monitoring locations.

Semivolatile Organic Compounds. Two SVOCs have been detected–1,4-dioxane and n-nitrosodimethylamine (Table 6.3-7). The screening level for n-nitrosodimethylamine was exceeded in the most-recent available data (Table 6.3-9).

Phthalates. BEHP and di-n-butyl phthalate have been detected twice (Table 6.3-7); however, there have not been any recent detections (Table 6.3-9).

Metals. Detections exceeding the screening criteria in the available legacy data are summarized in Table 6.3-7. Fourteen metals have exceeded the screening levels over time.

The most recent exceedances are listed in Table 6.3-9. Table 6.3-8 provides a comparison of total metals concentrations with dissolved metals concentrations by sample and location. There is not enough concurrent total and dissolved analyses by sample from which to draw meaningful conclusions regarding relationships and inferences into turbidity and its effects on metals concentrations in groundwater. The concurrent dissolved and total metals analytical data from RD-49A collected on February 13, 2007, show similar dissolved and total concentrations of the same metal.

Polycyclic Aromatic Hydrocarbons. No PAHs have been detected in the Chatsworth formation groundwater at the Alfa Test Area.

Energetic Parameters (Explosive-related Compounds). None have been detected.

General Chemistry. General water quality analytes (common anions and cations) have been analyzed in NSGW. The detections and exceedances are reported in Table 6.3-7 for the available legacy data and in Table 5.3-9 for the most recent available data. The most recent exceedances have occurred for chloride, sulfate, and fluoride.

Hydrocarbons (Fuel-related Compounds). Fuel hydrocarbons have been sampled for at HAR-20 only and were detected in December 1988. No subsequent sampling has been conducted.

Organo-chlorine Pesticides. Organo-chlorine pesticides have not been detected in Chatsworth formation groundwater at the Alfa Test Area.

6.3.3 Surface Water Findings

Surface water features at the Alfa Test Area consist of small drainages that trend east to west across the site and are dry throughout most of the year. Surface water releases through this drainage are monitored under an NPDES permit.

Surface water samples were not collected during this RI investigation because of the seasonally dry conditions.

6.3.4 Completeness of Characterization

Areas of known exceedances and potential contamination at the Alfa Area were investigated further by evaluating existing data. The collection of additional groundwater samples during the rainy season will confirm NSGW conditions. The predominantly detected contaminants in NSGW in the SMOU and CFOU groundwater at the Alfa Area are VOCs, primarily TCE and its daughter products. Groundwater has been sampled and analyzed for chemicals at locations near the operational areas, and both the SMOU and CFOU analytical results indicate a relationship between the known operations and soil/soil gas data.

The chemical use areas have been delineated sufficiently for risk assessment and to support RI recommendations.

6.3.4.1 NSGW Characterization

The occurrence of NSGW at the SSFL, including the Alfa Test Area, is ephemeral and believed to be related to seasonal variations in precipitation. Newly installed piezometers (PZ-153 and PZ-154) have been sounded for the presence of groundwater, and when sufficient groundwater is present, sampling of the groundwater will occur and be reported in an addendum to this RI report. Additional synoptic gauging of piezometers for the occurrence of NSGW and sampling of NSGW, when present, is planned across several seasons to include late-winter and early-spring events when precipitation is anticipated to increase. The current NSGW monitoring network should provide sufficient sampling locations to characterize groundwater in the SMOU under optimum conditions.

Legacy data provide an abundant foundation for evaluating groundwater quality, past and present. The results indicate that NSGW, albeit limited in aerial extent and thickness, primarily has been affected by a limited number of VOCs. The data also suggest potential impacts from metals. The Chatsworth formation groundwater impacts are similar to those exhibited in the NSGW results; however, because the two units are separated by a considerable thickness of Chatsworth formation deposits, there appears to be no direct relationship of contamination between the two.

6.3.4.2 Surface Water

No surface water samples were collected as part of this RI.

6.4 Alfa Area Nature and Extent

Surface soil, subsurface soil, soil gas, and NSGW samples were collected at the Alfa Area, per the protocol described in Section 6.2 and the data provided in Appendix F. Figure 6.4-1

shows the surface and subsurface soil sample locations collected as part of this RI investigation. Table 6.4-1 lists the parameters analyzed in the sample media at this site. The nature and extent of contamination that exceeded the comparison criteria values in the media sampled are described below.

6.6.1 Surface Soil Nature and Extent

A total of 173 surface soil samples were collected at this site and analyzed for 1 or more of the following: dioxins, TAL metals, PCBs (aroclors and congeners), organochlorine pesticides, SVOCs, TPHs, and VOCs. Table 6.4-2 lists the parameters detected in the surface soil samples at the Alfa Area site.

6.6.1.1 Parameters Exceeding Criteria

The nature and horizontal extent of the parameters encountered at concentrations that exceeded their respective comparison criteria are described below.

Dioxins. A total of 24 surface soil samples were analyzed for dioxins at this site, including both CDDs and CDFs, which were detected in all of the samples collected. The current approach to assessing the toxicity of these mixtures is to use information regarding the toxic potency of the different congeners to convert the congener concentrations to a toxicologically equivalent concentration of the most potent congener, 2,3,7,8-TCDD. The samples were evaluated for nature and extent by comparing the frequency of the different CDDs and the CDFs that exceeded the screening criteria at each location. The CDD and CDF exceedances were added together according to the chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD TEQ values were compared to the ecological screening criteria (4.3 pg/g) and to the more conservative human health screening criteria (1.3 pg/g). These data are summarized in Table 6.4-3.

Ten of the sample locations had reported mammal 2,3,7,8-TCDD TEQ values at levels exceeding the human health screening criterion of 1.3 pg/g; 5 of the 2,3,7,8-TCDD TEQ for birds exceeded the ecological screening criterion of 4.3 pg/g. These samples, which represent the highest concentrations, are located within or near the site boundary. Figure 6.4-2 shows the extent of the 2,3,7,8-TCDD TEQs in surface soil at the Alfa Area. Dioxin exceedances mostly were found in a compact area north of Building 2208, while 2 more dioxin exceedances were found at the tail end of the Alfa skim and retention ponds. Exceedances north of Building 2208 have not been investigated sufficiently; horizontal boundaries have yet to be developed in this area. The 2 dioxin exceedances near the ponds have horizontal boundaries both upgradient and downgradient through additional sampling. The vertical extents of these parameters are addressed in Section 6.6.2.

Metals. Metals were detected in each of the 87 surface soil samples collected and analyzed for metals. Of the metals detected in the surface soil at this site, 16 metals were reported at concentrations exceeding 1 or more of the criteria. The metals exceedances are described below.

Five metals (aluminum, arsenic, boron, cobalt, and selenium) each were detected once at an elevated concentration mostly similar to its respective background concentration. Aluminum was detected at 20,200 mg/kg (AABS1020), compared to its background value of 20,000 mg/kg. Arsenic was detected at 19.3 mg/kg (AABS1049), compared to a background

value of 15 mg/kg. Boron was detected at 10.6 mg/kg (AABS1088), compared to its background value of 9.7 mg/kg. Cobalt was detected at 22.9 mg/kg (AABS1049), compared to its background value of 21 mg/kg. And, selenium was detected at an estimated 0.98 J mg/kg, compared to its background value of 0.655 mg/kg. These single exceedances appear to be the result of natural occurrence and probably are unrelated to operations in the Alfa Area. Therefore, their horizontal extents have been evaluated adequately.

Mercury was encountered in 2 samples at concentrations of an estimated 0.11 J mg/kg (AABS0046) and 0.12 mg/kg (AABS1008), exceeding its ecological (0.10 mg/kg) and background (0.09 mg/kg) comparison values. Each of these detections was found in the former Alfa retention pond and are sufficiently evaluated both upgradient and downgradient through additional sampling. The mercury concentrations are similar to the background comparison concentration and probably are occurring naturally in the surface soil at these concentrations. Five lead exceedances were detected at estimated concentrations, all during a 1997 investigation effort at this site. Elevated concentrations of lead ranged from 38.9 J mg/kg (AABS0066) to 231 J mg/kg (AABS0063), each exceeding its ecological (0.013 mg/kg), human health (16 mg/kg) , and background (34 mg/kg) criterion. The highest lead concentrations were detected in the vicinity of building 2209A, and additional investigation to the north of that area for lead appears warranted. The horizontal extents of mercury and lead at this site are shown in Figure 6.4-3.

Vanadium, barium, and manganese were detected at concentrations exceeding their respective screening criteria at 6, 6, and 7 sampling locations, respectively. Vanadium exceedances ranged from 64 mg/kg (AABS1050) to 79.2 mg/kg (AABD1057), exceeding its ecological and human health criteria, but similar to its background value of 62 mg/kg. Barium was detected at elevated concentrations ranging from 151 mg/kg (AABS1039) to 299 mg/kg (AABS1058), each exceeding its ecological (15 mg/kg) screening criterion; 4 also exceeded its human health (162 mg/kg) criterion. Manganese was detected at concentrations ranging from 497 mg/kg (AABS1088) to 1,040 mg/kg (AABS1019), exceeding its ecological (59 mg/kg) criteria and its background value of 495 mg/kg. The manganese exceedances have been sufficiently evaluated horizontally through additional sampling; exceedances encountered in the main drainage pathway are sufficiently evaluated downgradient through samples collected downstream. Barium exceedances mostly were sufficiently evaluated, with the exception of an exceedance detected in the northeastern portion of the site; however, this station, AABS1005, reported an exceedance mostly similar to its background value and may be the result of natural occurrence. Vanadium exceedances are mostly in the vicinity of Building 2212. Vanadium is not bound to the east through additional sampling; however, the vanadium exceedances are at concentrations suggestive of natural conditions, and these detections may not be related to processes in the area. The horizontal extents of barium, manganese, and vanadium have been evaluated adequately, as shown in Figure 6.4-4.

Cadmium, chromium, and copper each was reported at multiple stations at elevated concentrations. Cadmium, detected in 79 of 83 samples analyzed, was reported in 11 samples at elevated concentrations ranging from 1.1 mg/kg (AABS1072) to 10 mg/kg (AABS0063), each exceeding its ecological (0.0045 mg/kg) and human health (1.7 mg/kg) criteria. Chromium, detected in 82 of 83 samples analyzed, had 18 exceedances ranging from 37.1 mg/kg (AABS1052) to an estimated 58.9 J mg/kg (AABS1057), exceeding its

background (37 mg/kg) and human health (32 mg/kg) criteria. Copper was detected in all but 3 surface soil samples analyzed, and had 10 exceedances ranging from 30 mg/kg (AABS1048) to 58.4 mg/kg (AABS1088), exceeding its ecological (1.09 mg/kg) and background (29 mg/kg) comparison values. These exceedances were detected in the vicinity of the test stands and along the main drainage pathway. Samples without exceedances of these parameters appear to bind the elevated concentrations concentrically north of the testing facilities and downgradient along the drainage pathway. Figure 6.4-5 illustrates the horizontal extents of cadmium, chromium, and copper, which appear to have been evaluated adequately.

Silver and zinc were detected in 8 and 23 samples, respectively, at concentrations exceeding their comparison criteria. Silver exceedances ranged from 1.2 mg/kg (AABS0046 and 1091) to 14.2 mg/kg (AABS1073), each exceeding its ecological (0.54 mg/kg) and human health (1.1 mg/kg) screening criteria. Elevated concentrations of zinc ranged from 112 mg/kg (AABS1017, 1025, and 1058) to 635 mg/kg (AABS0063), each exceeding its ecological (21 mg/kg) comparison criterion;, 2 also surpassed its human health criterion of 370 mg/kg. Eighteen of the 23 zinc exceedances were within twice the background value of 110 mg/kg, suggesting that some of these exceedances may be naturally related. These exceedances appear to be sufficiently evaluated through additional sampling to the south and west by samples taken downgradient along the main drainage pathway. Additional sampling may be warranted further north of sampling station AABS0063 and east of the Buildings 2212 and 2729A areas to further evaluate the horizontal extents of silver and zinc in the Alfa Area. Figure 6.4-6 depicts the extents of these parameters in the surface soil.

Nickel was detected at elevated concentrations in 27 samples. Nickel exceedances ranged in concentration from an estimated 29.4 J mg/kg (AASB0060) to 82 mg/kg (AABS1069), each exceeding its ecological screening criterion of 0.1 mg/kg; 16 of those also exceeded its human health comparison criterion of 37.9 mg/kg. A total of 22 of these 27 exceedances were within twice the background value of 29 mg/kg, suggesting that some of these exceedances might be due to natural occurrence as opposed to historical operations. This parameter appears to be horizontally sufficiently evaluated to the north and south at this site. Nickel is sufficiently evaluated downgradient along the main drainage line; however, additional samples to the east may be required to further evaluate the nickel exceedances. The horizontal extent of nickel is shown in Figure 6.4-7.

Nine of the metals discussed here also were encountered in subsurface soil samples; their vertical extents will be addressed in the following subsections. Arsenic, cadmium, cobalt, lead, mercury, selenium, silver, and zinc were not detected at elevated concentrations in the subsurface soil samples at this site; therefore, their vertical natures and extents have been evaluated adequately.

PCB Aroclors/Congeners. PCB congeners were analyzed for in 26 surface soil samples at this site, none of which reported PCB congener exceedances.

PCB aroclors were analyzed at 61 locations in the surface soil at the Alfa Area. Two PCBs, Aroclor-1254 and Aroclor-1260, were detected at concentrations exceeding their common human health (89 µg/kg) and ecological (77 µg/kg) screening values. Aroclor-1254 was detected at twice at concentrations of 189 J µg/kg (AABS0064) and 642 µg/kg (AABS1037), and Aroclor-1260 had 3 exceedances ranging from 288 µg/kg (AABS1037) to 350 µg/kg

(AABS0067). Sampling stations that had PCB exceedances are mostly bound by additional samples concentrically. The exceedances found at AABS1042 are sufficiently evaluated upgradient and downgradient along the drainage pathway by additional samples. PCB exceedances at AABS0063 and AABS0064 are not directly bound to the north by nearby samples; however, they are sufficiently evaluated both up and down gradient and the extent of PCBs in this area may be inferred. The horizontal extents of Aroclor-1254 and Aroclor-1260 are illustrated in Figure 6.4-8; their horizontal extents have been evaluated adequately.

Neither PCB-1254 nor PCB-1260 was detected at elevated concentrations in the subsurface soil media, so their extent evaluation appears to have been addressed sufficiently. Other PCB-aroclor exceedances in the subsurface soil will be addressed in the following subsection.

Pesticides. Thirty-two surface soil samples were analyzed for organochlorine pesticides at this site, none of which had reported concentrations exceeding the applicable screening criteria. The vertical extent of pesticides in the Alfa Area will be addressed in a later subsection.

SVOCs. One or more SVOC parameter was analyzed at 122 locations in the surface soil samples collected at the Alfa Area. Of those, 9 had reported elevated concentrations of 2 SVOCs (BaP and BEHP). BEHP was detected at AABS1033 at a concentration of 5,830 µg/kg, exceeding its ecological (4,900 µg/kg) screening criterion. Station AABA1033 was the location of the only surface soil collected along the northern trench leading from Test Stand 3; however, this exceedance sufficiently has been evaluated upgradient at the trench inlet and downgradient outside of the trench outlet by additional samples that did not have a reported phthalate exceedance. The horizontal extent of BEHP has been evaluated adequately.

Eight BaP exceedances were detected out of the 122 samples collected and analyzed for this parameter. Elevated concentrations ranged from an estimated 13.1 J µg/kg (AABS0058) to 150 µg/kg (AABS1088), exceeding its human health screening criterion of 11.4 µg/kg. BaP exceedances mostly are sufficiently evaluated through additional sampling, with the exception of the detection at AABS1068. This exceedance, located on the northwestern side of Building 2212, was sufficiently evaluated in the northwesterly direction by a higher elevation landscape. The horizontal extent of BaP has been evaluated adequately, as shown in Figure 6.4-9.

SVOCs have been investigated sufficiently in the surface soil in the Alfa Area. The vertical extent will be addressed in the following subsection.

TPHs. A total of 117 surface soil samples were collected and analyzed for TPHs in the Alfa Area. Of those, 18 stations had elevated concentrations of a combined 6 TPH groups. Three groups, DROs (C14-C20) and (C15-C20) and EFH (C15-C20), each were detected once at an exceeding concentration. The difference in the DROs is related to the analysis dates; more current analytical data is reported in the C15-C20 range. The DRO groups were detected at an estimated concentration of 240,000 J µg/kg (C14-C20, AABS08) and 1,720,000 µg/kg (C15-C20, AABS0063), and the EFH (C15-C20) group was detected at 221,000 µg/kg (AABS1025), each exceeding its ecological and human health criteria of 100,000 µg/kg. Two

of the 3 exceedances are sufficiently evaluated horizontally by samples that did not have elevated concentrations of these TPH groups. The exceedance exhibited at AABS0063 is not sufficiently evaluated directly to the north in the cross-gradient direction; however, additional sampling up and down gradient provide suitable boundaries for this exceedance in the Alfa Area. Therefore, the extents of the DROs and the EFH (C15-C20) group have been evaluated adequately.

Lubricant oil range (C20-C30) organics and the EFH (C21-C30) group each were detected in 4 and 6 surface soil samples, respectively, at concentrations exceeding their ecological and human health criteria of 100,000 µg/kg. Lubricant oil range organics were detected at estimated concentrations ranging from 140,000 J µg/kg (AABS12) to 200,000J µg/kg (AABS19), and the EFH (C21-C30) TPH exceedances ranged from 121,000 µg/kg (AABS0064) to 2,960,000 µg/kg (AABS0063). Exceedances have been investigated adequately, in that additional samples without exceedances encompass the samples that had elevated concentrations, except for the exceedances detected at AABS0063 and AABS14. As aforementioned, station AABS0063 is only indirectly bound to the north through additional sampling; however, there are sampling both up and down gradient that provide adequate horizontal extent for this sampling station. Location AABS14 is the most downgradient sample collected along the main drainage path at this site; however, samples collected in the Bravo Area to the west provide horizontal extent outside of the Alfa Area. Figure 6.4-10 illustrates the horizontal extents of the lubricant oil range (C20-C30) organics and the EFH (C21-C30) group.

Ten exceedances of the kerosene (C12-C18) group were reported out of the 14 surface soil samples analyzed in the Alfa Area. Exceedances ranged from 10,000 µg/kg (ARPC-22) to 5,900,000 µg/kg (ATSC-2-15), surpassing its human health criterion of 50.4 µg/kg. These exceedances mostly were detected in the southerly facing drainage paths coming from each test stand in this area. Samples that did not have kerosene exceedances reported line the main drainage pathway, thus providing a downgradient boundary for the elevated concentrations. One exceedance, at ARPC-22, was sufficiently evaluated downgradient by analytical results from ARPC-20. The horizontal extent of the kerosene (C12-C18) group appears to have been evaluated adequately, as shown in Figure 6.4-11.

VOCs. Twenty-seven of the 120 surface soil samples analyzed for VOCs had elevated concentrations of a combined 4 VOC parameters in the Alfa Area. PCE was detected once at an estimated concentration of 0.943 J µg/kg (AABS1025), exceeding its human health criterion of 0.43 µg/kg. This exceedance, detected just east of Building 2209, has been evaluated sufficiently horizontally through additional sampling. The horizontal extents of the other three VOC parameters are described below.

Cis-1,2-DCE and methylene chloride were detected in 8 and 11 samples, respectively, at concentrations exceeding their applicable screening criteria. Elevated concentrations of cis-1,2-DCE ranged from an estimated 18 J µg/kg (AABS09) to an estimated 2,600 J µg/kg (AABS34), exceeding its human health criterion of 14 µg/kg. Cis-1,2-DCE exceedances were detected mostly in the washout basins leading from Alfa Test Stands 1 and 2; these exceedances are sufficiently evaluated downgradient though additional sampling. The cis-1,2-DCE exceedance detected at station AABS11, just west of former Test Stand 2, is bound horizontally through additional sampling. Methylene chloride exceedances ranged from an estimated 4.93 J µg/kg (AABS1021) to 790 µg/kg (ATSC-1-20), surpassing its

human health comparison criterion of 4 µg/kg. These concentrations of methylene chloride were detected in the washout from Test Stand 1 and the series of ponds lying downgradient, with two detections being encountered near Test Stand 2. Samples from upgradient provide a horizontal boundary in that direction. The most downgradient surface soil sample along the main drainage path had an exceedance of methylene chloride; however, the samples collected further downgradient in the Bravo Area provide horizontal extent. The extents of cis-1,2-DCE and methylene chloride have been evaluated sufficiently at this site, as shown in Figure 6.4-12.

TCE was the most prominent VOC encountered at elevated concentrations at this site, having been detected as an exceedance in 33 samples, from 31 stations, of the 93 samples analyzed. Elevated concentrations of TCE ranged from an estimated 3.44 J µg/kg (AABS0057) to 75,000 µg/kg (ATSC-1-21), each exceeding its human health (2.2 µg/kg) comparison criterion. Six of these exceedances also exceeded its ecological (3,000 µg/kg) screening criterion. TCE exceedances primarily are congregated around the washout basins leading from Test Stands 1 and 2. This portion of the Alfa Area has been sufficiently evaluated horizontally through additional sampling, primarily downgradient along the earthen drainage and retention ponds. The extent of TCE in the surface soil at this site has been evaluated adequately, as shown in Figure 6.4-13.

Cis-1,2-DCE, methylene chloride, and TCE also were detected at elevated concentrations in the subsurface soil collected at this site, as described in a later subsection.

6.6.2 Subsurface Soil Nature and Extent

A total of 120 subsurface samples were collected from 74 sampling stations to a maximum depth of 59 ft bgs at the site. The subsurface soil at the site was analyzed for 1 or more of the following: dioxins, inorganics (metals), PCB aroclors, organochlorine pesticides, SVOCs, TPHs, and VOCs. Table 6.4-4 lists the parameters detected in the subsurface soil samples at the Alfa Area.

Dioxins. As with the dioxin investigation in the surface soils, the 5 subsurface soil samples collected from 4 locations to a maximum depth of 10 ft bgs were analyzed for both CDDs and CDFs. Likewise, the approach in subsurface soils is to assess the toxicity of these mixtures by using the information regarding the toxic potency of the different congeners and converting them to 2,3,7,8-TCDD TEQs. The frequency of the different CDDs and CDFs that exceeded their respective screening criteria at each location were added according to the chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD TEQ values were compared to the screening criteria, as summarized in Table 6.4-5.

The 2,3,7,8-TCDD TEQ value exceeded the human health (1.3 µg/kg) comparison criterion at AABS0046 (2 to 2.5 ft bgs) at a reported 2.6 pg/g. This sample was collected at the bedrock interface in the central area of the easternmost retention pond. Two stations located further downgradient along the drainage pathway did not exhibit exceeding TEQ values at similar and deeper sampling intervals. The vertical extent of dioxins in subsurface soil at the site has been evaluated sufficiently.

Metals. Twenty-one samples collected from 17 sampling stations were analyzed for metals in the Alfa Area. Twenty-two metals were detected at this site, 9 of which were detected at

concentrations exceeding the applicable screening criteria. The vertical extents of these metals are described below.

Aluminum, beryllium, boron, and vanadium were detected at elevated concentrations mostly similar to their respective background values. Aluminum was detected at a concentration of 21,600 mg/kg (AABS1004, 4 to 4.5 ft bgs), compared to its background value of 20,000 mg/kg. Beryllium was detected at 2.0 mg/kg (AABS1003, 4.5 to 5 ft bgs), compared to its background value of 1.1 mg/kg. Boron was detected at 11.6 mg/kg (AABS1056, 7.5 to 8 ft bgs), compared to its background value of 9.7 mg/kg. Vanadium was detected at 63.3 mg/kg (AABS1003, 4.5 to 5 ft bgs), compared to its background value of 62 mg/kg. These parameters at these concentrations are more likely to be related to natural occurrence than to processes in the Alfa Area. The vertical extents of aluminum, beryllium, boron, and vanadium have been evaluated adequately.

Copper and manganese each were detected twice at elevated concentrations at this site. Copper exceedances were a reported 31.1 mg/kg (AABS1003, 4.5 to 5 ft bgs) and 40 mg/kg (AABS0046, 2 to 2.5 ft bgs), surpassing its ecological screening criteria, but is similar to its background value of 29 mg/kg. Manganese was detected at concentrations of 496 mg/kg (AABS1048, 9.5 to 10 ft bgs) and 691 mg/kg (AABS1003, 4.5 to 5 ft bgs), also exceeding its ecological screening criteria, but is similar to its background value of 495 mg/kg. Each of these exceedances was encountered at the deepest interval sampled at its respective stations, which is at the bedrock interface. Horizontally, these subsurface samples are sufficiently evaluated by additional sampling in similar or deeper intervals downgradient. The vertical extents of copper and manganese have been addressed sufficiently at this site.

Three barium exceedances were detected in this area at concentrations ranging from 149 mg/kg (AABS1004, 4 to 4.5 ft bgs) to 228 mg/kg (AABS1056, 7.5 to 8). These exceedances surpassed its ecological screening criteria (15 mg/kg); two of them also exceeded its human health criterion of 162 mg/kg. Each exceedance was detected at the deepest interval sampled at its respective station, probably at the bedrock interface. Two of the 3 exceedances were encountered in the main operations area; the third station, AABS1004, is in the northernmost area of this site. Station AABS1004 is sufficiently evaluated to the west horizontally through station AABS42; the subsurface horizontal extent is unavailable in the other directions for this detection. However, the exceedance at AABS1004 is most likely a result of natural occurrence, and additional sampling for barium in this area does not appear to be warranted. Figure 6.4-14 illustrates the vertical extent of barium in the Alfa Area.

Seven chromium exceedances were detected in the subsurface soil at this site, at concentrations ranging from 38.8 mg/kg (AABS1056, 7.5 to 8) to 45.9 mg/kg (AABS1004, 4.5 to 5 ft bgs). These detections exceeded its human health (32 mg/kg) criterion and background value (36.8 mg/kg); however, each was significantly less than the ecological comparison criterion of 930 mg/kg. The extent characterization appears to be incomplete horizontally in the northern portion of this site, where the highest concentrations of chromium were encountered. Additional sampling may be warranted to further evaluate the horizontal extent of chromium in the subsurface soil. The vertical extent of this parameter is shown in Figure 6.4-15.

Nickel, found in each sample analyzed, was detected at elevated concentrations in 6 subsurface soil samples. Exceedances ranged in concentration from 29.7 mg/kg (AABS1048, 4.5 to 5 ft bgs) to 63.2 mg/kg (AABS1078, 9.5 to 10 ft bgs), each surpassing its ecological criterion of 0.1 mg/kg, with two also exceeding its human health criterion of 37.9 mg/kg. The background value for nickel is 29 mg/kg, and 4 of the 6 exceedances were encountered at concentrations mostly similar to this background value. These exceedances were encountered in the deepest intervals sampled at each station, except for AABS1048, where a deeper sample provides a vertical boundary at that station. Stations exhibiting nickel exceedances are in proximity to other stations that did not report elevated metals concentrations in similar sampling intervals; therefore, the extent of nickel has been evaluated sufficiently. Figure 6.4-16 illustrates the vertical extent of nickel in the subsurface soil at this site.

Arsenic, cadmium, cobalt, mercury, selenium, silver, and zinc were not detected at elevated concentrations in subsurface soil samples at this site; therefore, their vertical natures and extents have been evaluated adequately.

PCBs Aroclors. Fifteen subsurface soil samples from 12 sampling locations were analyzed for PCBs. Of those, one (AABS1003, 4.5 to 5 ft bgs) had a reported exceedance of Aroclor-1248 at a concentration of 45.1 µg/kg, exceeding its ecological screening criterion of 11.4 µg/kg. Aroclor-1248 was not detected at elevated concentrations in surface soil samples at this site. Additionally, station AABS1002, which is in proximity to AABS1003, did not have a PCB detection in the same sampling interval. The vertical extent of PCBs appears to have been evaluated adequately. The vertical extents of Aroclor-1254 and Aroclor-1260 also appear to have been evaluated sufficiently.

Pesticides. Six subsurface soil samples were analyzed for hexachlorobenzene, but none had a reported detection. The vertical extent of pesticides, which were not known to be used in processes at the Alfa Area, has been evaluated adequately.

SVOCs. One PAHs, BaP, was detected at an elevated concentration of 110 µg/kg at AABS0046, 2 to 2.5 ft bgs, out of the 47 subsurface soil samples analyzed for SVOCs. This concentration exceeded the BaP human health criteria of 11.4 µg/kg. This station is located in the eastern retention pond, and although no deeper samples were collected at this station, there were subsurface soil samples collected at both the inlet and outfall of the pond that did not report a PAH exceedance. The vertical extent of PAHs has been addressed sufficiently at this site.

TPHs. Seventy-six subsurface soil samples collected from 60 stations were analyzed for TPHs in the Alfa Area. Of those, 14 samples had reported elevated concentrations of a combined 6 TPH parameter groups, each in exceedance of its ecological and human health criteria of 100,000 µg/kg. The TPH exceedances are described below.

The EFH (C15-C20) group was detected once at an elevated concentration of 212,000 µg/kg (AABS1031, 9.5 to 10 ft bgs), and the EFH (C12-C14) group was detected twice at concentrations of 102,000 µg/kg (AABS1029, 4.5 to 5 ft bgs) and 139,000 µg/kg (AABS1031, 9.5 to 10 ft bgs). These exceedances were detected in the deepest intervals samples at their respective stations and probably were collected from the bedrock interface. Sampling station AABS1031 is the most downgradient station sampled in the Alfa Area, along the

drainage path; however, samples collected in the Alfa-Bravo skim pond provide subsurface horizontal extent. The vertical extents of these two EFH groups have been evaluated adequately.

Three exceedances of the EFH (C8-C11) TPH group were reported in this area. The elevated concentrations ranged from an estimated 220,000 J µg/kg (AABS06, 12 ft bgs) to an estimated 270,000 J µg/kg (AABS34, 10 ft bgs). Each of these stations was sampled at deeper internals, none of which reported EFH (C8-C11) exceedances. The vertical extent of the EFH (C8-C11) group has been evaluated adequately, as shown in Figure 6.4-17.

Seven exceedances of the kerosene range (C11-C14) organics were reported in the subsurface soil samples at the Alfa Area. Elevated concentrations, each an estimated value, ranged from 190,000 J µg/kg (AABS06, 5 ft bgs) to 2,900,000 J µg/kg (AABS34, 10 ft bgs). Exceedances detected at AABS15 (downgradient retention pond) and AABS34 (Test Stand 1 washout) were found in the deepest intervals sampled, probably at the bedrock interface. Both stations AABS06 and AABS14 were sampled at deeper intervals that did not have elevated concentrations of kerosene range organics; this is particularly noted at station AABS14, which is the most downgradient sample collected in the Alfa Area. The vertical extent of kerosene range organics appears to have been investigated sufficiently. Figure 6.4-18 illustrates the extent of this parameter in the subsurface soil.

DROs (C14-C20) also were detected at concentrations exceeding the universal ecological and human health criteria of 100,000 µg/kg. Nine exceedances were detected, each reported as an estimated value, ranging in concentration from 260,000 J µg/kg (AABS14, 10 ft bgs) to 7,900,000 J µg/kg (AABS34, 10 ft bgs). The DROs group was only sufficiently evaluated vertically through additional sampling at 1 station, AABS06. The other 4 stations that had elevated concentrations of this group reported exceedances in the deepest intervals samples, probably at the bedrock interface. Although additional vertical sampling may not be required, additional subsurface soil samples, primarily downgradient of station AABS14, may be warranted to establish the horizontal characterization of DROs in the subsurface media at this site. The extent of DROs (C14-C20) in subsurface soil at this site is shown in Figure 6.4-19.

Lubricant oil range (C20-C30) organics also were detected at exceeding concentrations in 9 samples, ranging in estimated concentrations from 110,000 J µg/kg (AABS09, 7 ft bgs) to 1,100,000 J µg/kg (AABS34, 10 ft bgs). Most of these exceedances were detected at the deepest intervals sampled, probably at the bedrock interface. However, lubricant oil range organics were sufficiently evaluated vertically through additional sampling at station AABS14, the most downgradient sample at this site. These exceedances are sufficiently evaluated horizontally through additional subsurface soil samples taken in this area, and as stated, vertically in the most downgradient sampling station at this site. The extent of lubricant oil range (C20-C30) organics has been addressed adequately in the Alfa Area subsurface soil, as shown in Figure 6.4-20.

VOCs. Eighty-two subsurface soil samples, collected from 48 sampling stations, were analyzed for VOCs at this site. Of those, 21 stations had elevated concentrations of 4 VOCs (chloroform, methylene chloride, cis-1,2-DCE, and TCE.) Chloroform was detected once at an estimated concentration of 0.785 J µg/kg (AABS1021, 4 to 4.5 ft bgs), exceeding its human health criterion of 0.77 µg/kg. This sample was collected at the bedrock interface.

Vertically, the extent of chloroform has been evaluated adequately, and horizontally, this exceedance is bound through additional sampling. The remaining VOC exceedances are described below.

Three exceedances of methylene chloride were detected in the subsurface soil at concentrations ranging from an estimated 136 J µg/kg (AABS19, 5 ft bgs) to 520 µg/kg (AABS17, 5 ft bgs), each exceeding its human health criterion of 4 µg/kg. These exceedances were encountered in the two former retention ponds, in the only subsurface soil samples collected at these stations. There are, however, additional samples at similar or deeper intervals that did not have reported exceedances near the elevated concentrations, notably in both the upgradient and downgradient directions. The vertical extent of methylene chloride appears to have been addressed sufficiently in the Alfa Area, as shown in Figure 6.4-21.

Cis-1,2-DCE was detected at estimated concentrations exceeding its human health (14 µg/kg) screening criteria in 13 samples. Elevated concentrations of cis-1,2-DCE ranged from 16 J µg/kg (AABS02, 15 ft bgs) to 16,800 J µg/kg (AABS06, 13 ft bgs), which are stations near Test Stands 1 and 2. Although these exceedances probably were detected down to the bedrock interface, this area appears to be sufficiently evaluated horizontally by additional samples collected in similar and deeper intervals. The vertical characterization of cis-1,2-DCE has been evaluated sufficiently . Figure 6.4-22 shows the vertical extent of this parameter in the Alfa Area.

A total of 26 TCE exceedances were detected in the subsurface soil at this site, with concentrations ranging from 2.85 µg/kg (AABS1083, 4.5 to 5 ft bgs) to an estimated 1,820,000 J µg/kg (AABS06, 13 ft bgs). Each exceedance was in excess of the TCE human health criterion of 2.2 µg/kg, with 2 exceedances also surpassing the ecological screening criterion of 3,000 µg/kg. The elevated concentrations of TCE ranged across 17 sampling stations to a maximum depth of 54 ft bgs, with the deepest being vertically bound through additional sampling. Many of these exceedances were detected near Test Stands 1 and 2, and in the deepest intervals sampled. This area mostly has been evaluated sufficiently horizontally through additional subsurface soil samples, primarily in the downgradient direction and along the main drainage ditch. Vertically, TCE appears to have migrated to the bedrock interface below the Alfa Area; however, its migration horizontally along the bedrock surface may require additional sampling to further evaluate the extent of contamination.. The vertical extent of TCE at this site is shown in Figure 6.4-23.

The vertical extent of VOCs in the Alfa Area has been evaluated adequately. The analytical results suggest that VOCs have migrated to the bedrock surface, and that these VOCs are not migrating horizontally along the bedrock surface horizontally.

6.6.3 Soil Gas Nature and Extent

Seventy-three soil gas samples were collected at the Alfa Area from 61 locations to a maximum depth of 20 ft bgs. Ten VOCs were detected in the samples at levels exceeding the screening criteria. Figure 6.4-24 shows the soil gas locations sampled in the Alfa Area. Table 6.4-6 lists the parameters detected in the soil gas samples collected in this area. The extent of VOCs encountered via soil gas sampling at this site is described below.

1,1,1-TCA and benzene each were detected once at a concentration exceeding its applicable criteria. 1,1,1-TCA was detected at a concentration of 83,900 µg/m^3 (SV-5.10-1, 7 ft bgs), exceeding its ecological screening criterion of 38,000 µg/m^3. Benzene was detected at 2,210 µg/m^3 (SV-5.11-4, 4.5 ft bgs), exceeding its human health criterion of 36 µg/m^3. The 1,1,1-TCA exceedance is sufficiently evaluated concentrically through additional sampling, and the benzene exceedance, detected along the drainage path, is sufficiently evaluated both upgradient and downgradient through additional sampling. The extents of 1,1,1-TCA and benzene soil gases have been evaluated adequately.

PCE and toluene each were detected twice at elevated concentrations. PCE was detected at estimated concentrations of 2,700 J µg/m^3 (AASV04, 3 ft bgs) and 4,400 J µg/m^3 (AASV07, 12 ft bgs), exceeding its human health criterion (180 µg/m^3). Toluene was detected at an estimated 90 J µg/m^3 (AASV1035, 9.5 to 10 ft bgs) and 9,040 µg/m^3 (SV-5.9-3, 2 ft bgs), exceeding its ecological screening criteria of 84 µg/m^3. These exceedances, detected in the deepest intervals sampled at their respective stations, are sufficiently evaluated horizontally by additional samples collected in similar or deeper sampling intervals. The extents of PCE and toluene as soil gases have been evaluated adequately.

1,1-DCE was detected in 7 samples at elevated concentrations ranging from 1,700 µg/m^3 (AASV01, 10 ft bgs) to 9,500 µg/m^3 (AASV08, 6 ft bgs), each exceeding its ecological screening criteria of 600 µg/m^3. Most of these exceedances were detected in the vicinity of Test Stand 1, except for the detection at AASV10, which is located near the entrance of Test Stand 3. The 1,1-DCE exceedances are sufficiently evaluated concentrically through additional sampling. The extent of 1,1-DCE as a soil gas is illustrated in Figure 6.4-25.

Four exceedances of 1,2-DCE (total) were reported at this site in 1993. These exceedances were evaluated more completely in 1997, when samples were analyzed for cis-1,2-DCE and trans-1,2-DCE independently. These parameters are described below.

Thirteen exceedances of cis-1,2-DCE were reported at this site, at concentrations ranging from 3,100 µg/m^3 (AASV13, 10 ft bgs) to an estimated 27,000,000 J µg/m^3 (AASV07, 4 ft bgs). Each detection exceeded its ecological screening criterion (1,900 µg/m^3); 11 detections also exceeded its human health criterion of 16,000 µg/m^3. The highest value exceedances were detected in the washout basin at Test Stand 1, with each of the cis-1,2-DCE exceedances being within the same vicinity. Soil gas exceedances were detected in the deepest intervals sampled; however, the vicinity of Test Stand 1 is sufficiently evaluated horizontally through additional sampling. The extent of cis-1,2-DCE as a soil gas has been evaluated adequately, as shown in Figure 6.4-26.

Three exceedances of trans-1,2-DCE were encountered at this site. Elevated concentrations ranged from 1,900 µg/m^3 (AASV05, 20 ft bgs) to an estimated 2,800 J µg/m^3 (AASV01, 15 ft bgs). The trans-1,2-DCE soil gas exceedances were detected to the southwest of Test Stand 1, where additional sampling provided a horizontal extent boundary. Exceedances increased in value at deeper intervals at station AASV01; however, these exceedances probably are sufficiently evaluated vertically by the bedrock surface. The extent of trans-1,2-DCE as a soil gas has been addressed sufficiently, as shown in Figure 6.4-27.

The three VC exceedances ranged in concentration from an estimated 28 J µg/m^3 (AASV1029, 9.5-10 ft bgs) to an estimated 2,800 J µg/m^3 (AASV07, 12 ft bgs), each exceeding

its human health criterion (13 µg/m^3); the latter two exceedances also surpassed its ecological screening criterion (560 µg/m^3). Two of these exceedances were detected in the washout basin from Test Stand 1; the lowest concentration in exceedance of the criteria was found at the outfall of the easternmost retention pond. These areas are sufficiently evaluated both upgradient and downgradient through additional sampling. Figure 6.4-28 illustrates the extent of the VC soil gases.

TCE was the most prominent VOC detected at elevated concentrations, with reported exceedances in 32 samples. Elevated concentrations of TCE ranged from an estimated 680 J µg/m^3 (AASV1019, 4.5 to 5 ft bgs) to an estimated 65,000,000 J µg/m^3 (AASV07, 8 ft bgs). TCE soil gas exceedances at this site are localized around the test stands. The analytical results suggest that TCE soil gases exist at exceeding concentrations down to the bedrock interface. Sampling to the north, east, and south appears to be adequate to provide horizontal extent, but additional sampling in a westerly direction may be warranted to further evaluate TCE. The extent of the TCE soil gases in the Alfa Area is shown in Figure 6.4-29.

Potential soil gas contamination in the Alfa Area appears to have been adequately evaluated, with the exception of TCE in a westerly direction.

6.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the Alfa Area is described Section 5.8.1.4.

6.6 Fate and Transport Analysis for Chemicals Detected in Surficial Media

6.6.1 Contaminant Sources and Release Mechanisms

The primary release mechanism for contamination in the Alfa Area is the testing of rocket engines and the cleaning of testing components with solvent thereafter. Secondary release mechanisms may be related to the storage of small quantities of fuel and solvent in the area, as well as chemical transfer points.

6.6.2 Potential Routes of Migration

The primary pathway for contaminant transport from the source areas at this site is the vertical migration of contaminants from the surface soil to subsurface soil. A secondary transport mechanism for this site includes the horizontal migration of potential contaminants to the main drainage pathway and on to the skim ponds, and the release of surface soil to the air by wind erosion or volatilization.

6.6.3 Contaminant Persistence

Dioxins, inorganics, PCBs, SVOCs, TPHs, and VOCs were detected in the soil at this site at levels above their screening criteria. Additionally, VOCs were detected in the soil gas at

concentrations above their screening criteria. This subsection describes the chemicals applicable to this area.

6.6.3.1 Parameters Exceeding Criteria

Dioxins, inorganics, PCBs, SVOCs, TPHs, and VOCs are described below.

Dioxins. Dioxins are characterized by extremely low vapor pressures, high log K_{ow}, high K_{oc}, and extremely low water solubilities. Their strong adsorption to soil, low water solubilities, and high K_{oc} values indicate that the rate of transport from unsaturated zone soils to the water table via rain infiltration would be extremely low.

Because dioxins have low vapor pressure, they are not very volatile and tend to stay bound to particles. Dioxins also have low solubility; thus, aerially deposited dioxins tend to stay adsorbed to soils in the top few millimeters in surface soil.

Inorganics. Several metals were detected at this site at levels above the screening criteria. Many metals are naturally occurring and their reported presence may or may not indicate a contaminant release. The mobility of metals is complex and depends on several factors such as the overall groundwater composition, pH, metal complex formation, valence state of the metal, and cation-ion exchange capacity. Metals typically are not volatile. In the water phase, the total metal concentration includes the dissolved metal concentration and the suspended metal concentration, which is sorbed to colloidal particles. Therefore, elevated metals concentrations in groundwater may be due to the suspended load and not just to the dissolved aqueous chemistry.

PCBs. PCBs are persistent in the environment. Aroclor-1254 and Aroclor-1260 are characterized by low water solubility, moderate volatility, high affinity for organic matter, and high resistance to chemical or biological degradation. They will strongly sorb to soil and do not tend to leach to groundwater. In surface water, they will partition to sediment and sorb to organic matter. PCBs will bioaccumulate in aquatic organisms.

SVOCs. PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. HMW PAHs are more likely to be transported via particulate emissions, while LMW PAHs have a greater tendency to volatilize (ATSDR, 1995). In general, PAHs are more likely to sorb to soil or organic matter than to partition significantly to water. Photolysis and biodegradation are two common attenuation mechanisms for PAH compounds (Howard, 1991). Animals and microorganisms can metabolize PAHs to products that ultimately reach complete degradation.

TPHs. TPHs are defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. The lighter petroleum products such as gasoline contain constituents that have higher water solubility and volatility and lower sorption potential than do heavier petroleum products such as fuel oil. Data compiled from gasoline spills and laboratory studies indicate that these light-fraction hydrocarbons tend to migrate readily through soil, potentially threatening or affecting groundwater supplies. In contrast, petroleum products that have heavier molecular weight constituents, such as fuel oil, generally are more persistent in soils, due to their relatively low water solubility and volatility and high sorption capacity (Stelljes and Watkin 1991).

VOCs. VOCs are characterized by relatively high vapor pressures, Henry's Law constants, and generally high solubility in water. VOCs have a tendency to partition to the vapor phase from either soil or surface water and could be released through volatilization from contaminated soil. The sorption potential of VOCs is variable; some may persist in soil or sediment, while some are highly mobile in soil. VOCs will leach to groundwater and may persist, depending on their ability to degrade or transform in the environment.

TCE was the most prevalent VOC in the soil gas samples collected. Although TCE does not have a high K_{oc}, it may sorb to soil, sediment, or organic matter and persist in the environment for a long time. It also may persist in groundwater. TCE does not accumulate in plants or animal tissue and undergoes biotic and abiotic degradation via natural attenuation processes.

6.6.4 Contaminant Migration

The primary source for contaminant migration is from historical engine testing and cleaning of testing lines and equipment associated with the Alfa Area.

6.6.5 Surface Soil Contaminants

Dioxins, metals, PCBs, SVOCs, TPHs, and VOCs have been identified in surface soil at levels above the background and/or health-based risk criteria. The following observations were made for contaminants in surface soil:

- Dioxins were detected in all 24 of the surface soil samples collected. Ten of the sample locations reported 2,3,7,8-TCDD TEQ values at levels exceeding the human-health screening criterion. Six of those also exceeded the ecological screening criterion.
- Of the metals detected in the surface soil at the Alfa Area, 16 metals were reported at concentrations exceeding 1 or more of the criteria.
- Of the 61 sample locations collected for PCBs in the surface soil at the Alfa Area, 2 PCBs (Aroclors-1254 and 1260) were reported at 3 locations at concentrations exceeding the comparison criteria in the surface soil. The highest PCB concentration reported was Aroclor-1254 at AABS1037, at a concentration of 642 µg/kg, compared to the human health screening criterion of 89 µg/kg.
- Of the 122 surface soil samples analyzed for SVOCs, 9 had reported exceedances of a combined 2 SVOC parameters, BaP (8 exceedances) and BEHP (1 exceedance).
- Six TPH groups were detected across 20 sampling stations at elevated concentrations. The horizontal extent of the exceedances detected at AABS14 stretch to the eastern portions of the neighboring Bravo Area.
- Four VOCs (cis-1,2-DCE, methylene chloride, PCE, and TCE) were detected at exceeding concentrations and appear to have migrated to the bedrock surface. The horizontal extent of VOCs appears to have been investigated sufficiently.

6.6.6 Subsurface Soil Migration

The following observations were made for the contaminants in subsurface soil:

- Five subsurface soil samples collected from 5 locations to a depth of 10 ft bgs were analyzed for both CDDs and CDFs. The 2,3,7,8-TCDD TEQ value exceeded the human health (1.3 pg/g) screening criterion at AABS0046 (2 to 2.5 ft bgs).
- Nine metals were detected at levels exceeding their respective screening criteria at this site. Chromium is the sole inorganic parameter that appears to require additional sampling to further evaluate the extent of contamination.
- Aroclor-1248 was the only PCB detected at an elevated concentration in the subsurface soil; however, it was not detected at exceeding levels in the surficial soil media.
- Six TPH groups were detected at exceeding concentrations in subsurface soil at this site. The DROs group may require additional sampling to further evaluate the extent of contamination in a westerly direction and to evaluate the extent of horizontal migration along the bedrock surface.
- One PAH, BaP, was detected at an exceeding concentration in both surficial and subsurface soil media. This subsurface exceedance appears to be limited within the boundary of the easternmost retention pond.
- Four VOCs (chloroform, cis-1,2-DCE, methylene chloride, and TCE) were detected at exceeding concentrations and appear to have migrated to the bedrock surface. Additional sampling for TCE may be warranted to adequately evaluate the horizontal migration through the subsurface soil.

6.6.7 Soil-to-Groundwater Migration

The relationship among the chemicals detected in soil, soil gas, and groundwater has been evaluated to assess whether soil chemical concentrations have affected groundwater quality. Soil chemical concentrations were reviewed and compared with the available groundwater concentrations immediately south of the Alfa Area. The evaluation was based on the chemicals detected, background concentrations, spatial distribution, and hydrogeologic conditions. The evaluation provides conclusions regarding the soil sources for the detected chemicals in groundwater.

The release of TCE from SSFL operations at the Bravo Area probably resulted in the entry of immiscible-phase liquid into and below the water table by the interconnected fracture network within the weathered bedrock and the Chatsworth formation.

6.7 Human Health Risk Assessment for Alfa Area

The objective of this HHRA is to assess whether the environmental media at the Alfa Area could pose risks to human health at levels that might require remedial action, or risks at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil, soil gas, and groundwater at the Alfa Area. The methods and guidance documents used in the preparation of this HHRA are discussed in

Section 1.5.3 of this report. A discussion of the HHRA results for the Alfa Area is presented below. The results are summarized in Section 6.9.2.

The concentration data, input parameters, and results of the HHRA for the Alfa Area are presented in Appendix F. An index of the tables (Appendix F human health RA Tables Index) is provided and can be used to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated non-cancer HIs.

6.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the Alfa Area, based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

6.7.1.1 Data Evaluation

The soil, soil gas, and groundwater sampling analytical data at the Alfa Area were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.5.3.1. Sediment and surface water data were not collected as part of the RI site characterization activities. The locations of the soil, soil gas, and groundwater samples used in this HHRA are shown in Figures 6.4-1 and 6.4-24. The samples used in this HHRA are listed in Table F.6.1-1 by medium, sample ID, sampling depth interval, and date of collection. Table F.6.1-2 lists the target receptor populations by medium. Descriptive summary statistics of these data are provided in Table F.6.1-3.

6.7.1.2 Identification of COPCs in Soil

The results of the COPC screening process for soil at 0 to 2 ft bgs and 0 to 10 ft bgs are listed in Table F.6.1-3. Detected analytes in soil at the Alfa Area were compared to background levels. COPCs identified in soil (0 to 2 ft bgs) included 9 inorganics and 40 organics. COPCs identified in soil (0 to 10 ft bgs) included 9 inorganics and 43 organics.

6.7.1.3 Identification of COPCs in Groundwater

The results of the COPC screening process for NSGW are listed in Table F.6.1-3. Detected analytes in NSGW at the Alfa Area were compared to the background comparison criteria. COPCs identified in NSGW included 2 inorganics (dissolved manganese and dissolved selenium) and 1 organic (cis-1,2-DCE).

6.7.1.4 Identification of COPCs in Soil Gas

The results of the COPC screening process for soil gas at 3 to 10 ft bgs are listed in Table F.6.1-3. Ten COPCs were identified in soil gas.

6.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the Alfa Area may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential

exposures. Figure 1.5-2 depicts the conceptual exposure model for the Alfa Area. Table F.6.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

6.7.2.1 Identification of Receptors

The Alfa Area recently was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the industrial worker and recreationist exposure scenarios were evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

6.7.2.2 Identification of Exposure Pathways

Future residents and industrial workers were assumed to be exposed to groundwater, soil gas (modeled for migration to indoor air and ambient air), and soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). Future recreationists were assumed to be exposed to groundwater, soil gas (modeled for migration to ambient air), and soil (0 to 2 ft bgs). Exposure pathways for groundwater included direct exposures (ingestion and dermal) and indirect exposures. Inhalation exposures were quantified for the migration of groundwater and soil gas to ambient air and indoor air. Additionally, exposures were quantified for residential receptors for inhalation of groundwater VOCs in bathroom air while showering or bathing. Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the Alfa Area are provided in Table F.6.1-6.

6.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs, soil at 0 to 10 ft bgs, soil gas, and groundwater at the Alfa Area are listed in Table F.6.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts, ambient air, indoor air, and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for non-volatile COPCs. The derivation of the PEF for soil is listed in Table F.6.1-5.

Ambient air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs to ambient air and migration from groundwater to ambient air. Parameter values used for soil gas-to-air migration and for estimating the ambient air EPCs related to soils are listed in Table F.6.1-8. Parameter values used for estimating ambient air EPCs related to groundwater also are listed in Table F.6.1-8. The estimated ambient air concentrations from the migration of volatile COPCs in soil and groundwater are listed in Tables F.6.1-9, F.6.1-10, and F.6.1-11, respectively.

Indoor air COPC concentrations were estimated for volatile COPCs by modeling migration from soil gas at 3 to 10 ft bgs and from NSGW using the J-E Model (EPA, 2004e). The parameter values used in the J-E Model (EPA, 2004e) are presented in Table F.6.1-8. Soil gas data, where available, were used preferentially for indoor air modeling. The estimations of

indoor air concentrations from soil gas and groundwater migration are presented in Tables F.6.1-12 through F.6.1-17.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b). COPC concentrations in edible plant tissues from soil at 0 to 2 ft bgs are listed in Table F.6.1-18.

6.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate chemical intakes for potential adult and child residential, adult and child recreationist, and industrial worker receptors at the Alfa Area. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix F. The Appendix F human health RA Tables Index provides a list of the tables that present the exposure parameters and chemical intakes for each exposure scenario.

6.7.3 Risk Characterization

In the risk characterization component of the HHRA process, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.5.

The exposure assumptions, EPCs, toxicity factors, and risk characterization result tables for this HHRA are presented in Appendix F (Appendix F human health RA Tables Index**)**. The risk calculation tables present the estimated ELCRs and non-cancer HIs for potentially exposed receptors and individual exposure routes for soil, indoor air, and groundwater at the Alfa Area, as well as the cumulative risks and HIs across all exposure routes for the RME and CTE scenarios. Table F.6.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are shown in Table F.6.5-2.

6.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-6} for the CTE case to 4×10^{-5} for the RME case. The CTE and RME estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.05 for the CTE case to 0.3 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1. The cumulative ELCR and HI mentioned

above do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 1×10^{-4} for the CTE case to 3×10^{-3} for the RME case. The CTE ELCR estimate is equal to the upper end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 61 for the CTE case to 1,206 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. TCE, PCBs, and arsenic are the primary contributors to the ELCR for the plant consumption route. TCE contributes 28 to 49 percent, PCB contributes 7 to 20 percent, and arsenic contributes 26 to 57 percent of the total ELCR. TCE is also the primary contributor (98 percent) to the HI for the plant consumption exposure route. The highest concentrations of TCE in soil (0 to 2 ft bgs) were detected at sample locations ATSC-1-20 and ATSC-1-21, both of which are located south of Building 2727. TCE was detected at 75 mg/kg at ATSC-1-21 and 38 mg/kg at ATSC-1-20. The highest PCB TEQ in soil (0 to 2 ft bgs) was noted at sample location AABS0063 at a concentration of 0.2 µg/kg. The next highest PCB TEQ (0.06 µg/kg at AABS0067) was an order of magnitude below the maximum detected concentration. Arsenic was detected at concentrations above the SSFL mean background level at several sample locations across the Alfa area. The maximum detected concentration of arsenic in soil (0 to 2 ft bgs) was 19.3 mg/kg, compared to a mean background value of 4.5 mg/kg. The maximum detected concentration for arsenic was at sample location AABS1049. Fifty-three of the 71 surface soil samples had detected concentrations of arsenic that were greater than the mean background value of 4.5 mg/kg.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 6×10^{-6} for the CTE case to 4×10^{-5} for the RME case. The CTE and RME estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.05 for the CTE case to 0.3 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-4} for the CTE case to 7×10^{-3} for the RME case. The CTE and RME ELCR estimates exceed the upper end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The HI estimates for non-cancer effects range from 18 for the CTE case to 260 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. The primary contributor to the ELCR estimates for the indoor air exposure route is TCE detected in soil gas. TCE contributes 100 percent of the ELCR estimates. The primary contributor to the HI estimates is cis-1,2-DCE (contributing 86 to 93 percent). Sample location AASV07 has the 3 highest detected TCE concentrations in soil gas (65,000,000 µg/m^3, 31,000,000 µg/m^3, zinc 22,000,000 µg/m^3) and the 2 highest

detected cis-1,2-DCE concentrations (27,000,000 µg/m^3 and 18,000,000 µg/m^3). Sample location AASV07 is south of Building 2727.

- For indoor air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 6 x 10^{-8} for the CTE case to 1 x 10^{-7} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 5 x 10^{-6} for the CTE case to 1 x 10^{-4} for the RME case. The CTE ELCR estimate exceeds the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4} and the RME ELCR estimate is equal to the upper end of the regulatory risk range. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.2 for the CTE case to 4 for the RME case. The CTE HI is less than the regulatory threshold of 1 and the RME HI estimate exceeds the regulatory threshold value of 1. The primary contributor to the ELCR estimates for the ambient air exposure route is TCE detected in soil gas. TCE contributes 99 to 100 percent of the ELCR estimate. The primary contributor to the HI estimates is cis-1,2-DCE (contributing 93 percent). As previously mentioned, sample location AASV07 (south of Building 2727) has the highest detected concentrations of TCE and cis-1,2-DCE in soil gas.

- For ambient air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 4 x 10^{-10} for the CTE case to 7 x 10^{-10} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to COPCs in NSGW, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 3 x 10^{-4} for the CTE case to 4 x $10^{-4}$for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

6.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-5} for the CTE case to 9×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.5 for the CTE case to 3 for the RME case. The CTE HI estimate does not exceed the regulatory threshold value of 1, but the RME HI estimate does. The cumulative ELCR and HI estimates mentioned above do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogencic COPCs for exposure to 0- to 2-foot-bgs soil from the plant consumption exposure route range from 1×10^{-4} for the CTE case to 8×10^{-4} for the RME case. The CTE ELCR estimate is equal to the upper end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME estimate exceeds the upper end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 92 for the CTE case to 1,334 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. TCE, PCBs, and arsenic are the primary contributors to the ELCR for the plant consumption route. TCE contributes 33 to 49 percent, PCB contributes 7 to 20 percent, and arsenic contributes 26 to 57 percent of the total ELCR. TCE also is the primary contributor (contributing 98 percent) to the HI for the plant consumption exposure route. As previously mentioned, the highest concentrations of TCE in soil (0 to 2 ft bgs) were detected at sample locations ATSC-1-20 and ATSC-1-21, which are both south of Building 2727. The highest concentration of PCBs was found at sample location AABS0063 and was an order of magnitude greater than the next highest TEQ. Also as mentioned previously, arsenic was detected in 53 of the 71 surface soil samples at concentrations above the SSFL mean background level.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-5} for the CTE case to 9×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.4 for the CTE case to 2 for the RME case. The CTE HI estimate does not exceed the regulatory threshold value of 1, but the RME HI estimate does.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated inside a future residence. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-3} for the CTE case to 5×10^{-3} for the RME case. The CTE and RME ELCR exceed the upper end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer

effects range from 101 for the CTE case to 771 for the RME case. The CTE and RME HI estimates are greater than the regulatory threshold value of 1. The primary contributor to the ELCR estimates for the indoor air exposure route is TCE detected in soil gas. TCE contributes 100 percent of the ELCR estimates. The primary contributor to the HI estimates is cis-1,2-DCE (contributing 86 to 93 percent). As previously mentioned, sample location AASV07 (south of Building 2727) has the highest detected concentrations of TCE and cis-1,2-DCE in soil gas.

- For indoor air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 3×10^{-7} for the CTE case to 3×10^{-7} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-5} for the CTE case to 7×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 1 for the CTE case to 11 for the RME case. The CTE HI estimate is equal to the regulatory threshold of 1 and the RME estimate exceeds the regulatory threshold value of 1. The primary contributor to the ELCR estimates for the ambient air exposure route is TCE detected in soil gas. TCE contributes 99 to 100 percent of the ELCR estimate. The primary contributor to the HI estimates is cis-1,2-DCE (contributing 93 percent). As previously mentioned, sample location AASV07 (south of Building 2727) has the highest detected concentrations of TCE and cis-1,2-DCE in soil gas.

- For ambient air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 2×10^{-9} for the CTE case to 2×10^{-9} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Groundwater. Potential routes of exposure to COPCs in groundwater include ingestion, dermal contact, and the inhalation of vapors during assumed hypothetical domestic use. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to COPCs in NSGW, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 0.001 for the CTE case to 0.002 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold value of 1.

6.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and the inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below.

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-7} for the CTE case to 1×10^{-5} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.004 for the CTE case to 0.1 for the RME case. The CTE and RME HI estimates are less than the regulatory threshold of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is the inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-7} for the CTE case to 1×10^{-5} for the RME case. The CTE ELCR estimate is less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.01 for the CTE case to 0.4 for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.
- For ambient air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 2×10^{-11} for the CTE case to 8×10^{-11} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

6.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and the inhalation of vapors and fugitive dust in ambient air. A hypothetical future recreationist child (15-kg body weight) was assumed to be exposed for 100 days per year over 6 years for the RME case and 50 days per year over 6 years for the CTE case. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 5 x 10^{-6} for the CTE case to 3 x 10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.07 for the CTE case to 0.7 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1 x 10^{-6} for the CTE case to 2 x 10^{-5} for the RME case. The CTE ELCR estimate is equal to the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4} and the RME ELCR estimate exceeds the lower end of the regulatory risk range. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 0.1 for the CTE case to 3 for the RME case. The CTE HI estimate does not exceed the regulatory threshold value of 1 and the RME HI does exceed the regulatory threshold.

- For ambient air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 2 x 10^{-10} for the CTE case to 7 x 10^{-10} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

6.7.3.5 Hypothetical Future Industrial Worker Exposure Scenario

Potential industrial worker exposure to COPCs in soil, soil gas, and groundwater were evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and the inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For exposure to 0- to 2-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4 x 10^{-6} for the CTE case to 6 x 10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects range from 0.03 for the CTE case to 0.4 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 3 x 10^{-6} for the CTE case to 6 x 10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1 x 10^{-6} to 1 x 10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 0.03 for the CTE case to 0.3 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Indoor Air. For the indoor air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated inside a future industrial building. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For indoor air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-4} for the CTE case to 2×10^{-3} for the RME case. The CTE ELCR estimate is equal to the upper end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}, and the RME ELCR estimate exceeds the upper end of the regulatory risk range. For indoor air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 5 for the CTE case to 73 for the RME case. The CTE and RME HI estimates exceed the regulatory threshold value of 1. The primary contributor to the ELCR estimates for the indoor air exposure route is TCE detected in soil gas. TCE contributes 100 percent of the ELCR estimate. The primary contributor to the HI estimates is cis-1,2-DCE (contributing 86 to 93 percent). As previously mentioned, sample location AASV07 (south of Building 2727) has the highest detected concentrations of TCE and cis-1,2-DCE in soil gas.

- For indoor air exposure via groundwater vapor intrusion, a cumulative ELCR was not estimated because no carcinogenic constituents were identified as COPCs in groundwater. The HI estimates for non-cancer effects range from 2×10^{-8} for the CTE case to 3×10^{-8} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

Estimated Risks/Hazard Indexes for COPCs in Ambient Air. For the ambient air pathway, the potential route of exposure to COPCs detected in soil gas and groundwater is inhalation of vapors that have migrated to ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For ambient air exposure via soil gas intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-6} for the CTE case to 9×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via soil gas intrusion, the HI estimates for non-cancer effects range from 3×10^{-6} for the CTE case to 5×10^{-6} for the RME case. The RME and CTE HI estimates do not exceed the regulatory threshold value of 1.

- For ambient air exposure via groundwater vapor intrusion, the cumulative ELCR estimates for carcinogenic COPCs range from 5×10^{-6} for the CTE case to 9×10^{-5} for the RME case. The CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For ambient air exposure via groundwater vapor intrusion, the HI estimates for non-cancer effects range from 0.2 for the CTE case to 3 for the RME case. The CTE estimate is less than the regulatory threshold of 1 and the RME estimate exceeds the regulatory threshold value of 1.

6.7.4 Uncertainty Discussion

Uncertainties associated with the results of this HHRA are a function of both the "state of the practice" of HHRA in general and of UFs specific to the Alfa Area. A discussion of the general HHRA uncertainty is presented in Section 1.5.3.

6.8 Ecological Risk Assessment for Alfa Area

6.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to all RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the Alfa Area are described below.

6.8.1.2 Site Background

The Alfa Area is 7.54 acres] and consists of three test stands for rocket engine testing. Engines tested at this site used mostly petroleum-based fuels (kerosene) and LOX as the oxidizer. The site was built in and activated in 1955, with the last of the three test stands being decommissioned in March 2006. A more detailed discussion of the site conditions and history is presented in Section 6.1.

Habitat at the site was characterized based on a site survey conducted in April 2008. This survey indicated that the Alfa Area consists of several habitat types, including ruderal, rock, scrub shrub, and woodland habitat (Figure 6.8-1). The Alfa Area is predominantly open field, ruderal vegetation, with an average height of 18 inches tall. Woodland covers approximately 25 percent of the Alfa area with evergreens (narrow-leafed willow and red willow) that are 0 to 6 inches in height. Tall (greater than 5 ft) and dense shrub/scrub habitat cover approximately 3 percent of the site. Stressed vegetation (a peach tree, laurel sumac, and dead and stressed vegetation in drainage) was observed across 24 percent of the Alfa area. Some of the stressed vegetation along the drainage may be a result of herbicide spraying along roads. Multiple bird and mammal species (spotted towhee, house finch, dark-eyed junco, violet-green swallow, white-crowned sparrow, western scrub-jay, American goldfinch, Anna's hummingbird, red-tailed hawk, California quail, blue-gray gnatcatcher [in riparian area], American kestrel, California ground squirrel, gopher [burrows], coyote [scat], mule deer [tracks and scat], cottontail rabbit, bat [guano on rocks], and fox [scat]) were observed to use the site. Additionally, western fence lizards, grasshoppers, and crickets also were observed.

6.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the Alfa Area is the same as that for all Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the Alfa Area are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 6.8-1).
- Representative species and receptor groups considered for the Alfa Area include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary

consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

6.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the Alfa Area is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the Alfa Area is described below and presented in Figure 6.8-2.

The primary contaminant sources at the Alfa Area include engine testing at this site that used mostly petroleum-based fuels (kerosene) and LOX as the oxidizer. Primary release mechanisms include spills and leakage to the ground surface, and releases of exhaust and other materials during engine tests. Soil is the secondary source of potential contaminant. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater.

Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). Table 6.8-2 provides additional descriptions of the potential exposure pathways for the ecological receptors at the Alfa Area, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

6.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil and soil gas are listed in Table 6.8-3. Summary statistics for those detected analytes are listed in Table 6.8-4. A central tendency background comparison for metals and dioxins/furans in soils was conducted to assess whether the analytes were consistent with background (Table 6.8-5). The volatile organics in soil and soil gas are compared in Table 6.8-6. Non-detect analytes were evaluated by comparing the maximum SQLs against the minimum ESL and determining the exceedance frequency of the SQLs (Table 6.8-7). The CPECs identified for the Alfa Area are summarized in Table 6.8-8. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 6.8-9, 6.8-10, and 6.8-11, respectively. EPCs for soil gas from 0 to 6 ft bgs are listed in Table 6.8-12. Calculations for extrapolating soil gas concentrations from soil concentrations are listed in Table 6.8-13.

6.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 6.8.1) with the risk characterization (Section 6.8.3) and consists of the technical evaluation of ecological and chemical data to evaluate the potential for ecological exposure and effects. Generalized

components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the Alfa Area is presented below.

6.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this section.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the Alfa Area. Because the Alfa Area is strictly terrestrial, exposure is based on soil and soil gas and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

Although the Alfa Area is 7.5 acres, the spatial extent of samples associated with the site is 32.7 acres. More than half of the land cover at this site consists of buildings, pavement, rock, ruderal or stressed vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) and soil gas were calculated for the Alfa Area, according to the approach outlined in Section 1.5.4.4. These values are listed in Tables 6.8-9 through 6.8-12. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 6.8.3).

6.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for the receptors at the SSFL are summarized in Section 1.5.4.4. No effects data specific to the Alfa Area are available. Consequently, the ESLs, Low TRVs, and High TRVs for terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

6.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the Alfa Area. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the Alfa Area. The results of these comparisons are presented below.

6.8.3.1 Risk Estimation

The risk estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 6.8-14 through 6.8-21. Table 6.8-17 presents an analysis of the depth intervals for the evaluation of burrowing animals (deer mouse). The 0- to 6-foot-bgs depth interval had the greatest HI; therefore, the data from this depth were used to evaluate the deer mouse.

6.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with other available and appropriate lines of evidence to evaluate the potential chemical impacts on ecological receptors in SSFL's Group 3. Chemicals that had HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of COECs includes the receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.
2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.
4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.
5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.
6. No Risk–all HQs and associated HIs<1.
7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Twenty-five soil analytes were found to have one or more HQs greater than 1 under any scenario (Table 6.8-22). All other soil analytes and/or analyte groups were found to pose no risk (all HQs and HIs were less than 1) to receptors under any scenario (maximum concentration for plants, invertebrates, and soil gas exposures; CTE and RME concentrations for birds and mammals) at the Alfa Area.

Ten inorganics (aluminum, arsenic, barium, chromium, cobalt, copper, nickel, sodium, vanadium, and zinc) were identified as elevated relative to background, based on the non-parametric central tendency background comparisons for soil (Table 6.8-5). All of these analytes had HQs above 1 for at least one receptor in the refined screen, except for sodium, which generally did not have TRVs. On the basis of the risk ranking discussed above, aluminum and chromium were found to pose high risks (HQs>5 for High TRV [RME], or HQs>100 for any EPC/TRV combination); vanadium was found to pose medium-high risks

(2<HQs<5 for the High TRV [RME]); barium and nickel were found to pose medium risks (1<HQs<2 for High TRV [RME], but HQ>10 for Low TRV [RME]); and arsenic, cobalt, copper, and zinc were found to pose medium-low risks (HQs<1 for the High TRV [RME], but 1<HQs<10 for the Low TRV [RME]).

Although the predicted risks from inorganic CPECs ranged from medium-low to high, the incremental risks (Table 6.8-23) generally were low for wildlife receptors. All analytes, except for aluminum and chromium, had high TRV-based incremental HQs (RME) of less than 1 for the wildlife receptors, suggesting that predicted risk is almost entirely due to background concentrations. Although high risk was predicted for deer mice from aluminum, the bioavailability of aluminum is correlated with soil pH and aluminum is not considered bioavailable at pHs above 5.5 (EPA, 2003). At Alfa, the average pH in soils from 0 to 6 ft bgs is 7.69, based on 43 samples. This pH levels suggests that aluminum is not bioavailable and is considered to pose a acceptable risk to terrestrial plant, invertebrate, and wildlife receptors. Chromium had a high TRV-based HQ of 7 for the hermit thrush, based on the RME (Table 6.8-18) and a high TRV-based HQ of 6.6 based on the CTE (Table 6.8-20). When accounting for background risk, the high TRV-based RME HQ for the hermit thrush is 2.3 (Table 6.8-23). Risks were not predicted for other receptors based on chromium exposure. However, risks from chromium to the hermit thrush are considered possible.

For terrestrial plants and invertebrates, which are evaluated using maximum detections or SQLs, although 5 inorganics resulted in HQs greater than 1, only aluminum had an HQ above 5. As discussed above, based on the soil pH at the site, aluminum is not anticipated to affect plants or invertebrates.

Dioxin/furan and PCB congener data were used to calculate 2,3,7,8-TCDD TEQs. On the basis of these TEQs, only PCBs had a high TRV-based HQ above 1 in the RME screen (HQ=13 for the deer mouse). The high TRV-based HQ for the deer mouse under the CTE screen was 1.8. Based on the TEQ, dioxin/furans had a low TRV-based HQ of 5.3 but a high TRV-based HQ of less than 1. On the basis of these predicted risks, risks from dioxin/ furans are considered low, while risks from PCBs are possible. The maximum PCB TEQ for mammals was located at station ID AABS0063. PCB TEQ concentrations at 21 of 26 sampling locations were at least two orders of magnitude lower than the maximum TEQ, and risk probably is driven by four hot spots (AABS0060, AABS0063, AABS0064, and AABS0067).

Eleven non-detect soil analytes (9 pesticides, 2-chloroethyl vinyl ether, and 2,4-dinitrophenol) were retained based on the SQL screen (Table 6.8-7). These analytes were evaluated based on the maximum SQL in the RME screen and the mean SQL in the CTE screen. The maximum SQL for the 9 pesticides was 3.3 mg/kg, although only 1 sample had an SQL that high. The other samples had SQLs of 0.33 mg/kg or less. Similarly, for 2,4-dinitrophenol, the maximum SQL was 16 mg/kg, but only 1 of 40 samples had an SQL this high. The other SQLs were 1.6 mg/kg or less. In addition, 2,4-dinitrophenol only had one high TRV-based HQ above 1, based on the RME (HQ=1.7 for the hermit thrush), and all HQs based on the CTE were less than 1. Under the RME screen, the hermit thrush was the only receptor with a high TRV-based HQ above 1 (HQ=1.3) for alpha-, beta-, and delta-BHC and under the CTE screen, all high TRV-based HQs were less than 1. Dieldrin also had high TRV-based HQs above 1 for the deer mouse, based on the RME screen (HQs of 12), although it was less than 1 under the CTE screen. Gamma-BHC had high TRV-HQs of less than 1 for

all receptors (including plants; TRVs were unavailable for invertebrates) under both scenarios. Endrin and heptachlor epoxide had high TRV-based HQs above 1 for the deer mouse under the RME (HQs of 98 and 310) and CTE (HQs of 7.7 and 24, respectively) scenarios. Heptachlor epoxide also had a high TRV-based HQ of 3.4 for the mule deer. 4,4-DDT and 4,4'-DDE had HQs above 1 for terrestrial plants (4.7), and both high and low TRV-based HQs above 1 (RME) for the hermit thrush. The red-tailed hawk and deer mouse also had low TRV-based HQs above 1 for both pesticides based on the RME screen. Although risks from some of these analytes (including 4,4'-DDT, 4,4'-DDE, endrin, and heptachlor epoxide) were predicted, these analytes were not detected in the 16 samples analyzed, and no other pesticides were detected at this site. Consequently, the overall risk is uncertain, but is considered acceptable.

Of the detected organic analytes, BEHP and TCE both had one or more HQs above 1. However, only the low TRV-based HQ (1.4) for the hermit thrush (RME) exceeded 1 for BEHP. No other plants, invertebrates, or wildlife receptors had HQs above 1, and all HQs under the CTE screen were less than 1. Consequently, the risk from BEHP is considered acceptable. TCE had an HQ above 1 for terrestrial plants (HQ=25) and soil invertebrates (HQ=25), as well as the deer mouse under the RME screen (low TRV-based HQ=2.4). However, only 6 sample locations of 106 soil samples collected in the 0- to 2-foot interval (5.6 percent) contained TCE at concentrations above the terrestrial plant and invertebrate TRV of 3 mg/kg. The maximum concentration of 75 mg/kg was detected at an unknown depth from ATSC-1-21. Three of the 6 sample locations that exceeded the TRV were legacy data and had unknown depths. Because such a small percentage of samples were found to contain TCE at concentrations greater than TRVs and risks to wildlife receptors appear to be low, the overall sitewide risk is considered to be acceptable, based on TCE in soils; however, as discussed below, additional evaluation of TCE in soil gas should be conducted.

Soil gas CPECs were identified and evaluated as part of this ERA. Ten analytes were detected in soil gas, 1 non-detect was carried forward based on a comparison of SQLs to ESLs, and concentrations of 8 analytes were modeled based on detections in soil (Table 6.8-13). Of these, 5 analytes had HQs greater than 1 (Table 6.8-16). VC was the only analyte considered to pose a low risk, based on the low magnitude of exceedance (HQ = 2.) and low detection frequency (2.2 percent). The one non-detect soil gas analyte, 1,1,2-TCA, had an HQ above 1 (HQ=18). 1,1,2-TCA was not detected in any of the 44 samples analyzed for this parameter. The TRV for this analyte is conservative and was derived from an LD50 using an uncertainty factor of 100. The application of the uncertainty factor may overestimate or underestimate a no-effect level. 1,1-DCE had an HQ of 16; however, it was only detected in 4 of 45 samples and, if based on the CTE or RME, the respective HQs would be 1 and 5. Cis-1,2-DCE had a high magnitude of exceedance with an HQ of 14,000. Cis-1,2-DCE was only detected in 7 of 45 samples, and 5 of 45 samples exceeded the low TRV. The maximum concentration (27,000 parts per million by volume [ppmv]) was detected at 4 ft bgs at AASV07. The next highest concentration was detected at 3 ft bgs at AASV04. TCE also had an elevated HQ of 1,200 and was detected in 20 of 38 samples. The highest concentrations were co-located with elevated cis-1,2-DCE at AASV07 and AASV04. Eight locations contained TCE at concentrations above 10 ppmv. Because localized hot spots appear to exist for several VOCs, additional investigation of soil gases is recommended at this site.

Tables 6.8-24 and 6.8-25 list the soil and the soil gas COECs, respectively.

6.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component in all risk assessments. Generalized uncertainties for ERAs in SSFL's Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- Samples were collected outside of the site boundary in an effort to further evaluate potential releases from the Alfa Area. If sample concentrations decreased with distance from the site, the inclusion of these additional data may underestimate risk in the core portion of the site when these data are integrated into the RME and CTE calculations.
- Depths were unavailable for several historical soil and soil gas sample locations included in the Alfa Area dataset. The maximum concentration of TCE in soil was associated with these "legacy" data. In an effort to be conservative and to ensure completeness, these data were included in the 0- to 2-foot-depth interval for the purposes of risk assessment. There is some uncertainty associated with including these data in this depth interval (especially for soil gas), and the risks may be overestimated. However, it is likely that maximum soil concentrations would be detected at shallower depths, so inclusion with the shallowest depth interval for soil is deemed appropriate.
- Aroclor data were not evaluated in this assessment because PCB congener data were available and were used to calculate a TCDD TEQ. PCBs and dioxin/furans were evaluated based on the 2,3,7,8-TCDD TEQs. Concentrations of aroclors were low, and these are not expected to be significant COCs.
- No screening levels were available to evaluate the TPH data; however, PAH data were available and no risk from these constituents was predicted.
- Non-detect soil gas analytes were included in the soil gas screening, per the procedure dictated by the SRAM (MWH, 2005b). Because these analytes were not detected in any of the 187 collected samples, basing the risk on the maximum SQL is conservative; this approach probably overestimates risk from exposure to soil gas. However, soil gas contamination is present at the site and may support the presence of some of the non-detect analytes that have high SQLs.

6.8.4 Conclusions and Recommendations

Of the soil analytes that were evaluated, only PCBs and chromium were determined to pose potential risks subsequent to the quantitative and qualitative evaluations. PCBs were found to pose potential risks to the deer mouse; the risks probably are driven by 4 sample locations. Several inorganics were found to pose risk ranging from medium-low to high. However, except for the chromium exposure to the hermit thrush, because the magnitude of exceedance and incremental risk relative to background were low, then the risks from inorganics were considered acceptable. Chromium was retained because after accounting for background, CTE estimate exposure was more than twice the high TRV. Several non-detect analytes also were predicted to pose risks, but because the evaluation was based on non-detects, risks from these analytes were considered acceptable. Of the remaining soil analytes, 57 posed no risk and 1 lacked TRVs. Two analytes in soil gas were considered to

pose risks and are recommended for further evaluation, based on the elevated concentrations detected in shallow soil gas.

On the basis of the isolated hot spots, the presence of legacy data, and the predicted risk, PCBs and chromium in soil and cis-1,2-DCE and TCE in soil gas are recommended for evaluation in the FS.

6.9 Summary of Findings and Recommendations for Alfa Area

6.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of potential contaminants at the Area II Alfa Area, 173 surface soil, 120 subsurface soil, and 73 soil gas samples were collected. Of the surface soil samples collected, 10 dioxins (compared as 2,3,7,8-TCDD TEQ), 17 metals, two PCB aroclors, 5 SVOCs, 6 TPH groups, and 4 VOCs exceeded 1 or more of their applicable screening criteria. The parameters that exceeded the criteria are listed in Table 6.9-1. Although the analytical results suggest that some potential contaminants are migrating along the main drainage pathway, most of the exceedances are sufficiently evaluated downgradient by samples that did not have reported exceedances. Additional sampling, primarily in the northeastern portion of the site, may be warranted to further evaluate 4 metals (lead, nickel, silver, and zinc) at this site.

Of the subsurface soil samples collected, 1 dioxin (compared as 2,3,7,8-TCDD TEQ), 9 metals, 1 PCB, 1 PAH, 6 TPH groups, and 4 VOCs were reported at concentrations that exceeded 1 or more of the comparison criterion. Exceedances were mostly detected in the deepest sampling interval of a given station, and most were likely bound vertically by the bedrock surface and horizontally through additional sampling. Chromium, DROs, and TCE may require additional sampling at this site to further evaluate the potential migration along the bedrock surface horizontally.

Ten VOCs were reported at levels exceeding the screening criteria in soil gas collected at the site, including 2 that were detected at elevated concentrations in the soil media: cis-1,2-DCE and TCE. VOC exceedances were mostly found in the vicinity of Test Stands 1 and 2 and were evaluated adequately. Additional soil gas samples for TCE may be warranted to further evaluate its potential to migrate horizontally in a westerly direction. The likely source of the soil gas contamination is the groundwater; these contaminants should be further evaluated as part of the area groundwater investigation.

6.9.2 Risk Assessment Summary

The HHRA and the ERA for the Alfa Area are summarized below.

6.9.2.1 Summary of Human Health Risks

This subsection summarizes the HHRA performed for the Alfa Area. The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater. The methods used to prepare the HHRA are described in Section 1.5.3. The results of the HHRA for the Alfa Area are presented in Section 6.7.

The surface soil (0 to 2 ft bgs), subsurface soil (0 to 10 ft bgs), soil gas, and groundwater samples collected during the RI sampling activities were evaluated for use in the HHRA. Surface water and sediment samples are not evaluated in this HHRA, because they were not present during the RI site characterization activities. The HHRA data set is listed in Table F.6.1-3 in Appendix F. The COPCs identified from the Alfa Area HHRA data set for each exposure area are listed in Table F.6.1-4.

The potential future receptors at the Alfa Area include recreationists, workers, and residents. The Alfa Area and surrounding area are likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report at a later date.

Generally, estimated cumulative cancer risks (ELCRs) less than the regulatory risk range (range of 1 in a million [1×10^{-6}] to 1 in 10,000 [1×10^{-4}]) and estimated non-cancer hazards (HIs) less than the regulatory threshold value of 1 are considered acceptable (EPA, 1993). Estimated ELCRs within the 1×10^{-6} to 1×10^{-4} range are managed on a site-specific basis. Table F.6.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are shown in Table F.6.5-2.

The following exposure scenarios for the Alfa Area exceed or are within the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationist exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents, industrial workers, and recreationists exposed to indoor air (migration of soil gas COPCs) and ambient air (migration of soil gas COPCs)

The primary contributor to the ELCR for the soil exposure pathways is arsenic (ranging from 96 to 97 percent of the ELCR estimate) [Table F.6.5-2]. The primary contributor to the ELCR for the indoor air and ambient air exposure pathways is TCE (ranging from 99 to 100 percent of the ELCR estimate). Sample location AASV07 has the 3 highest detected TCE concentrations in soil gas (65,000,000 $\mu g/m^3$, 31,000,000 $\mu g/m^3$, and 22,000,000 $\mu g/m^3$). Sample location AASV07 is to the south of Building 2727.

The following exposure scenarios for the Alfa Area exceed the regulatory threshold values for non-cancer COPCs:

- Hypothetical future child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future residents, industrial workers, and child recreationists exposed to ambient air (migration of soil gas COPCs) and indoor air (migration of soil gas COPCs)

The primary contributor to the HI for the child residential soil exposure scenario is TCE (ranging from 53 to 58 percent). The primary contributor to the HI for the indoor air and ambient air exposure pathways is cis-1,2-DCE (ranging from 86 to 93 percent of the HI estimate). Sample location AASV07 has the two highest detected cis-1,2-DCE concentrations (27,000,000 µg/m^3 and 18,000,000 µg/m^3). Sample location AASV07 is to the south of Building 2727.

The following exposure scenarios for the Alfa Area are less than the regulatory threshold value for non-cancer COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationists exposed to soil (0 to 2 ft bgs)
- Hypothetical future residents, industrial workers, and recreationists exposed to ambient air (migration of volatile groundwater COPCs) and indoor air (migration of volatile groundwater COPCs)
- Hypothetical future adult recreationists exposed to ambient air (migration of soil gas COPCs)
- Hypothetical future adult and child residents exposed to NSGW (domestic use)

The ELCR estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory risk range. The primary contributors for this scenario are arsenic (ranging from 26 to 57 percent of the ELCR estimate) and TCE (ranging from 28 to 49 percent) [Table F.6.5-2]. The HI estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory threshold value. The primary contributor for this scenario is TCE (contributing 98 percent of the HI estimate) [Table F.6.5-2]. The highest concentrations of TCE in soil (0 to 2 ft bgs) were detected at sample locations ATSC-1-20 and ATSC-1-21, which are both south of Building 2727. TCE was detected at 75 mg/kg at ATSC-1-21 and 38 mg/kg at ATSC-1-20.

As described in Sections 1.5.3.6 and 6.7.4, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

6.9.2.2 Summary of Ecological Risks

Of the soil analytes that were evaluated, only PCBs and chromium were determined to pose potential risks subsequent to the quantitative and qualitative evaluations. PCBs were found to pose potential risks to the deer mouse; the risks probably are driven by 4 sample locations. Several inorganics were found to pose risks ranging from medium-low to high. However, except for the chromium exposure to the hermit thrush, because the magnitude of exceedances and incremental risks relative to background were low, then the risks from inorganics were considered acceptable. Chromium was retained because after accounting for background, the CTE estimate exposure was more than twice the high TRV. Several non-detect analytes also were predicted to pose risks, but because the evaluation was based on non-detects, the risks from these analytes were considered acceptable. Of the remaining soil analytes, 57posed no risk and 1 lacked TRVs. Two analytes in soil gas were considered to pose risks and are recommended for further evaluation, based on the elevated concentrations detected in shallow soil gas.

6.9.3 Recommendations for the Alfa Area

To complete the nature and extent evaluation in the Alfa Area, additional surface soil samples for dioxins and 4 metals (lead, nickel, silver, and zinc) are recommended for collection. In the subsurface soil media, additional investigation for the extent of chromium, DROs, and TCE is recommended. It also is recommended that additional TCE soil gas samples be collected to further evaluate its extent in a westerly direction.

Potentially significant human health risks were identified for arsenic in soil (0 to 2 ft bgs and 0 to 10 ft bgs) for direct exposure pathways. Significant human health risks also were identified for TCE and cis-1,2-DCE in soil gas (3 to 10 ft bgs). It is recommended that the presence of arsenic at the Alfa Area be further evaluated following the revision of the SSFL background data set. The extraction of soil gases in areas that have elevated TCE and cis-1,2-DCE concentrations are recommended at the Alfa Area to reduce human health risks.

TCE and arsenic in soil (0 to 2 ft bgs) also contributed to the elevated human health risks for the plant consumption exposure pathway for a potential future residential scenario. It is recommended that that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC. The agricultural-based residential exposure scenario will be evaluated at a later date.

On the basis of the ERA, PCBs and chromium in soil were found to pose risks to the deer mouse and hermit thrush, respectively, while 2 analytes in soil gas were found to pose potential risks to the deer mouse. On the basis of the isolated hot spots, the presence of the legacy data, and the predicted risks, PCBs and chromium in soil and cis-1,2-DCE and TCE in soil gas are recommended for evaluation in the FS. Additional surface soil sampling to further evaluate the extent of contamination for lead, nickel, silver, and zinc may be recommended for the FS. In addition, subsurface soil samples for chromium, TCE, and DROs along with TCE soil gas samples are recommended to further evaluate the extent of contamination at this site.

7. Skyline Road Area

7.1 Skyline Road Area Background and History

The Area II Skyline Road Area primarily consisted of two distinct features: a set of ASTs used to hold potable process water and a power pole holding a set of elevated transformers. The area covered approximately 5.6 acres. Skyline Road, in this area, generally runs east and west and lies to the south of the Bravo Area testing facilities. The Skyline Road Area is described further below.

7.1.1 SWMUs and AOCs

There are no SWMUs or AOCs associated with the Skyline Road Area.

7.1.2 Site History

Process water was stored in a series of ASTs in the eastern portion of the Skyline Road Area. The process water was obtained through a number of methods, including recycling process water, purchasing fresh potable water, collecting storm water, and using treated sanitary water. The water was gravity fed to both the Alfa and Bravo testing facilities and used as cooling water and/or fire protection water during testing operations. The process water storage tanks included, eight 100,000-gallon ASTs, one 470,000-gallon AST, and a 1,000,000-gallon tank. The historical document review indicated that these tanks also were used to house process cooling water, some of which was directed to the Coca Testing Facility to the south.

The other area of interest within the Skyline Road Area consists of the three pole-mounted transformers located in the western portion of the site. The transformers, SSFL-identified as numbers 144, 145, and 146, still exist and do not show signs of leaking or corrosion.

Building 2614, the only building within this area, is a pillbox that was used to observe engine tests conducted at the Coca Testing Facility, which is not part of the Group 3 RI. The 135-square-foot building was constructed in 1965 and currently is inactive.

7.1.2.1 Site Inventories

Inventories of the buildings, tanks, transformers, and chemicals used at the Skyline Road Area were compiled during the preparation of this RI report. This information was obtained from historical document reviews, facility drawings, and VSIs. These features are shown in Figure 7.1-1, as applicable. The inventories are included in the following tables:

- Building Inventory–Table 7.1-1
- Transformer Inventory–Table 7.1-2
- Tank Inventory–Table 7.1.3

7.1.3 Site Chemical Use Areas

There were no chemical use areas within the Skyline Road Area.

7.1.4 Site Conditions

The Skyline Road Area currently is inactive. The pole-mounted transformers are still in place and a VSI did not report signs of leaking or corrosion. The process water ASTs in the western portion of the area are still intact, although as mentioned previously, are inactive.

7.1.5 Site Habitats/Land Cover

The Skyline Road Area primarily consists of a roadway and property immediately adjacent to the road. The road, buildings, and associated developed areas constitute about 23 percent of the land cover at this site. Habitat at the site was characterized based on a site survey conducted in January 2009. This survey indicated that, aside from the developed areas, the Skyline Road Area consists of five habitat types–annual grassland, scrub-shrub, ruderal, rock, and riparian woodland habitat. Although extensive woodland does not occur within the site, several coast live oaks were documented along drainages away from the project area. This woodland habitat covers 1.5 percent of the site. Bird species observed during the site visit include American crow, Anna's hummingbird, black phoebe, bushtit, California quail, house finch, house and white-crowned sparrow, Lesser goldfinch, mourning dove, red-tailed hawk, rock pigeon, spotted towhee, turkey vulture, and western meadowlark. Mammals observed onsite include desert cottontail, California ground squirrel, and coyote.

The habitats and land cover present at the Skyline Road Area are shown in Figure 7.1-2.

7.1.6 Historical Document Reviews

As described in Section 1.7.1, a historical document review was completed of documents applicable to the Group 3 RI. No new potential features were identified as a result of this historical document review.

7.2 RI Characterization Activities

This subsection describes the sampling objectives, sampling scope, and key decision points associated with defining the nature and extent of chemical impacts for the surface soil and subsurface soil at the Skyline Road Area.

7.2.1 Sampling Objectives

To evaluate the extent of potential chemical effects on Skyline Road Area, soil samples were collected. The objectives of the investigation were as follows:

- Evaluate the lateral and vertical extent of chemical impacts.
- Evaluate the potential gradients of chemicals.
- Develop a sufficient data set for performing a risk assessment.

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results and/or previous remediation activities
- Fate and transport characteristics of chemicals
- SSFL background concentrations of parameters
- SSFL SRAM-based screening concentrations for human health and ecological receptors

7.2.2 Sampling Scope

Provided in this report are the characterization results for soil matrix information. The total number of soil matrix samples collected during historical and recent sampling events, and used as part of this report, are summarized below:

- Soil matrix: 10 samples

These samples were collected between 1993 and 2009 to identify the potential chemical impacts associated with the activities at this area. Section 7.4 summarizes these samples.

7.2.3 Key Decision Points

The site-specific decision points identified for this area represent the assumptions and/or decisions made during the sampling phase component of this RI, as follows:

- For historical sample points where the sample depth had not been recorded, it was assumed that these sample points were taken between the 0- to 2-foot-bgs range.

7.3 RI Characterization Results

The characterization results from the previous soil media investigations at the Skyline Road Area are summarized below.

7.3.1 Soil Matrix Findings

Surface soil samples were collected from the Skyline Road Area from 1993 through 2009. One surface soil sample was collected in 1993 and analyzed for metals, pesticides, SVOCs, TPHs, and VOCs, which yielded elevated concentrations of 2 metals parameters. In 2006, another sample was collected and analyzed for dioxins and PCBs; 6 dioxin parameters were identified as exceeding the applicable comparison criterion. Five more surface soil samples were collected in 2008 and 2009 and analyzed for metals, PCB-aroclors, and dioxins to further investigate potential releases from the transformers and degradation from the ASTs. Two metals and several dioxins were identified as exceedances during the most recent sampling effort.

To further evaluate this area, 3 subsurface soil samples were collected in 2008 and 2009 at the bedrock interface and analyzed for dioxins, metals, and PCB-aroclors. Only 10 individual dioxins were detected at elevated concentrations during this sampling event. Surface soil metals exceedances were evaluated sufficiently with this sampling effort, which is described in Section 7.4.2.

7.3.2 Groundwater Findings

No near-surface or Chatsworth formation groundwater monitoring locations are associated with this site. The nearest near-surface and Chatsworth formation groundwater monitoring wells and piezometers are located north of the Skyline Area at the Bravo Area (see Section 5.3.2).

7.4 Skyline Road Area Nature and Extent

Surface soil and subsurface soil samples were collected at the Skyline Road Area, per the protocol described in Section 7.2 and the data provided in Appendix G. Figure 7.4-1 shows the historical and most recent surface and subsurface soil samples collected as part of this RI investigation. Table 7.4-1 lists the parameters analyzed in the sample media at this area. The nature and extent of contamination that exceeded the comparison criteria values in the media sampled are described below.

7.4.1 Surface Soil Nature and Extent

A total of 7 surface soil samples were collected at this site and analyzed for 1 or more of the following: dioxins, TAL metals, PCBs (aroclors and congeners), pesticides, SVOCs, TPHs, and VOCs. Table 7.4-2 lists the parameters detected in the surface soil samples in the Skyline Road Area.

7.4.1.1 Parameters Exceeding Criteria

The nature and horizontal extent of the parameters encountered at concentrations exceeding their respective comparison criteria are described below.

Dioxins. A total of 6 surface soil samples were analyzed for dioxins at this site, including both CDDs and CDFs. Dioxins were detected in all 6 of the surface soil samples collected. The current approach to assessing the toxicity of these mixtures is to use information regarding the toxic potency of the different congeners to convert the congener concentrations to a toxicologically equivalent concentration of the most potent congener, 2,3,7,8-TCDD. The 2,3,7,8-TCDD TEQs were reported by the laboratory for the surface soil dioxin samples. The samples were evaluated for nature and extent by comparing the frequency of the different CDDs and the CDFs that exceeded the screening criteria at each location. The TEQ for mammals is used in comparison to the human health criterion, while the TEQ for either birds or fish, whichever is greater, is used in comparison to the ecological comparison criterion. The CDD and CDF exceedances were added together according to the chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD TEQ values were compared to the ecological screening criteria (4.3 pg/g) and the more conservative human health screening criteria (1.3 pg/g). These data are summarized in Table 7.4-3.

Two sample locations, BVBS1054 and BVBS1055, had reported mammal 2,3,7,8-TCDD TEQ values of 1.93 pg/g and 1.44 pg/g, respectively, each of which exceeded the human health screening criterion (1.3 pg/g). These surface soil samples, which represent the highest concentrations, are located near the power pole with elevated transformers. Figure 7.4-2 shows the extent of the mammal 2,3,7,8-TCDD TEQs in surface soil in the Skyline Road

Area. Dioxin exceedances have been evaluated sufficiently to the east through additional sampling; however, additional sampling may be required to further evaluate the extent of dioxins at this area. The vertical extent of these parameters is addressed in Section 7.4.2.

Metals. Metals were detected in all 4 surface soil samples analyzed for metals, exceeding the applicable human health and ecological screening criteria at 2 locations. A total of 4 metals reported sole exceedances in this area, mostly at concentrations indicative of natural occurrence.

At sampling station BVBS1056, manganese was detected at an estimated concentration of 509 J mg/kg, compared to its background value of 495; zinc was detected at 122 mg/kg, compared to its background value of 110 mg/kg. Copper was detected at an elevated concentration of 33 mg/kg at SB_TTF_BG-3, compared to its background value of 29 mg/kg. These 3 metals were encountered at concentrations similar to their respective background values. Cadmium was detected at a concentration of 8 mg/kg (SB_TTF_BG-3), exceeding its ecological (0.0045 mg/kg), human health (1.7 mg/kg), and background (1 mg/kg) comparison values. Cadmium was detected in the nearby surface soil samples at concentrations below its background value; the horizontal extent of cadmium, as well as of the other 3 metals parameters, has been evaluated adequately. The vertical extent of metals in this area will be addressed in the following subsection.

PCB Aroclors/Congeners. PCB aroclors and congeners were analyzed for in 6 and 2 surface soil samples, respectively. If there had been a release from the elevated transformers in this area, PCB detections could be expected at elevated concentrations. No PCBs were detected above the applicable comparison criteria in the Skyline Road Area; thus, it is unlikely that a release has occurred.

SVOCs. SVOCs were analyzed at sampling station SB_TTF_BG-3, which is closest to the ASTs in the eastern portion of this area. SVOCs were not known to be used in this area, and as could be expected, no SVOCs were detected at this area in the surface soil.

TPHs. TPHs were analyzed at sampling station SB_TTF_BG-3, which is closest to the ASTs in the eastern portion of this area. Similar to the SVOCs result, no TPHs were detected in this area in the surface soil.

VOCs. VOCs were analyzed at sampling station SB_TTF_BG-3; no VOC parameters were detected at this site in the surface soil.

7.4.2 Subsurface Soil Nature and Extent

A total of 3 subsurface samples were collected from 3 sampling stations to a maximum depth of 5 ft bgs in the Skyline Road Area. In consideration of potential release mechanisms in this area, each subsurface soil was analyzed for dioxins, metals, and PCB aroclors. Table 7.4-4 lists the parameters detected in the subsurface soil samples at the Skyline Road Area. The exceedances detected in subsurface soil samples are categorized and described below.

Dioxins. As with the dioxin investigation in the surface soils, the 3 subsurface soil samples were analyzed for both CDDs and CDFs. Dioxins were detected in all 3 of the subsurface soil samples collected. Likewise, the approach in subsurface soils is to assess the toxicity of

these mixtures by using the information regarding the toxic potency of the different congeners and converting them to 2,3,7,8-TCDD TEQs. The frequency of the different CDDs and CDFs that exceeded their respective screening criteria at each location were added according to the chlorine designation (tetra-, penta-, hexa-, hepta-, and octa-), and the 2,3,7,8-TCDD TEQ values were compared to the screening criteria, as summarized in Table 7.4-5.

The mammal 2,3,7,8-TCDD TEQ values were elevated at 1 location, BVBS1055 (2.7 to 3.2 ft bgs), at a calculated potency of 1.37 pg/g. This value exceeds the human health comparison criterion of 1.3 pg/g. This sampling station is located near the power pole that has the elevated transformers. The reported exceedance was collected from the bedrock interface; however, there are no other subsurface samples in the immediate vicinity by which to evaluate the horizontal extent in the subsurface media. Similar to surface soil dioxins, additional sampling near the power pole may be warranted to further evaluate the dioxin exceedances in the subsurface soil in this area. Table 7.4-5 summarizes the subsurface soil dioxin exceedances.

Metals. Metals were detected in both of the subsurface soil samples collected and analyzed for metals–BVBS1056 and BVBS1058. However, no metals parameters were encountered at concentrations that exceeded the applicable screening criteria. Therefore, the 4 metals detected at elevated concentrations in the surface soil, which probably were indicative of natural occurrence, have been evaluated adequately for vertical extent.

PCBs Aroclors. Similar to the surface soil findings, no PCB aroclors were detected in the subsurface soil in the Skyline Road Area.

7.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the Skyline Road Area is described Section 7.8.1.4.

7.6 Fate and Transport Analysis for Chemicals Detected in Surficial Media

7.6.1 Contaminant Sources and Release Mechanisms

The primary release mechanism for contamination at the Skyline Road Area is the potential degradation of the pole-mounted transformers , as well as the coatings on the currently inactive ASTs.

7.6.2 Potential Routes of Migration

The primary pathway for contaminant transport from the source areas at this site is the vertical migration of contaminants from the surface soil to subsurface soil. A secondary transport mechanism for this site includes the release of surface soil to the air by wind erosion or volatilization.

7.6.3 Contaminant Persistence

Dioxins and inorganics were detected in the soil at this site at levels above their respective screening criteria. This subsection describes the chemicals applicable to this area.

7.6.3.1 Parameters Exceeding Criteria

Dioxins and inorganics are described below.

Dioxins. Dioxins are characterized by extremely low vapor pressures, high log K_{ow}, high K_{oc}, and extremely low water solubilities. Their strong adsorption to soil, low water solubilities, and high K_{oc} values indicate that the rate of transport from unsaturated zone soils to the water table via rain infiltration would be extremely low.

Because dioxins have low vapor pressure, they are not very volatile and tend to stay bound to particles. Dioxins also have low solubility; thus, aerially deposited dioxins tend to stay adsorbed to soils in the top few millimeters in surface soil.

Inorganics. Several metals were detected at this site at levels above the screening criteria. Many metals are naturally occurring and their reported presence may or may not indicate a contaminant release. The mobility of metals is complex and depends on several factors such as the overall groundwater composition, pH, metal complex formation, valence state of the metal, and cation-ion exchange capacity. Metals typically are not volatile.

7.6.4 Contaminant Migration

The primary potential sources for contaminant migration are the pole-mounted transformers, corrosion of the ASTs, and the coatings covering the ASTs in the Skyline Road Area.

7.6.5 Surface Soil Contaminants

Dioxins and metals have been identified in surface soil at levels above the background and/or health-based risk criteria. The following observations were made for contaminants in surface soil:

- Dioxins were detected in all 6 of the surface soil samples collected. Two of the sample locations had reported 2,3,7,8-TCDD TEQ values at levels exceeding the human-health screening criterion.
- Two of the 4 surface soil samples analyzed for metals had reported exceedances of a combined 4 metals parameters. These 4 metals were detected at concentrations mostly indicative of natural occurrence and unrelated to the operations at this area.

7.6.6 Subsurface Soil Migration

The following observations were made for the contaminants in subsurface soil:

- Three subsurface soil samples collected from 3 locations to a maximum depth of 5 ft bgs were analyzed for both CDDs and CDFs. The 2,3,7,8-TCDD TEQ values exceeded the human health (1.3 pg/g) comparison criterion at BVBS1055 (2.7 to 3.2 ft bgs). This sample was collected at the bedrock interface; there were not other subsurface soil samples collected in the immediate vicinity.

- Eighteen metals were detected in the subsurface soil samples collected at this area, none of which were at concentrations exceeding their respective screening criteria and background values.

7.6.7 Soil-to-Groundwater Migration

The relationship among chemicals detected in soil, soil gas, and groundwater has been evaluated to assess whether soil chemical concentrations have affected groundwater quality. Soil chemical concentrations were reviewed and compared with the available groundwater concentrations in the vicinity if the Skyline Road Area. The evaluation was based on the chemicals detected, background concentrations, spatial distributions, and hydrogeologic conditions. This evaluation provides conclusions regarding soil sources for the detected chemicals in groundwater.

NSGW has not been delineated at the Skyline Road Area; therefore, no affected groundwater in the SMOU within the immediate study area is expected. Soil and soil gas results do not indicate potential source areas for constituents in groundwater, including the CFOU.

7.7 Human Health Risk Assessment for Skyline Road Area

The objective of this HHRA is to assess whether the environmental media at the Skyline Road Area could pose risks to human health at levels that might require remedial action, or risks at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil, soil gas, and groundwater at the Skyline Road Area. The methods and guidance documents used in the preparation of this HHRA are discussed in Section 1.5.3 of this report. A discussion of the HHRA results for the Skyline Road Area is presented below. The results are summarized in Section 7.9.2.

The concentration data, input parameters, and results of the HHRA for the Skyline Road Area are presented in Appendix G. An index of the tables (Appendix G human health RA Tables Index) is provided and can be used to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated non-cancer HIs.

7.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the Skyline Road Area, based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

7.7.1.1 Data Evaluation

The soil, soil gas, and groundwater sampling analytical data at the Skyline Road Area were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.5.3.1. Groundwater, soil gas, sediment, and surface water data were not collected as part of the RI site characterization activities. The locations of the soil samples used in this HHRA are shown in Figure 7.4-1. The samples used in this HHRA are listed in Table G.7.1-1 by medium, sample ID, sampling depth interval, and date of collection. Table G.7.1-2 lists the target receptor populations by medium. Descriptive summary statistics of this data are provided in Table G.7.1-3.

7.7.1.2 Identification of COPCs in Soil

The results of the COPC screening process for soil at 0 to 2 ft bgs and 0 to 10 ft bgs are listed in Table G.7.1-3. The detected analytes in soil at the Skyline Road Area were compared to background levels. COPCs identified in soil (0 to 2 ft bgs) included 1 inorganic (fluoride) and 2 organics (2,3,7,8-TCDD TEQ and PCB TEQ). COPCs identified in soil (0 to 10 ft bgs) included 1 inorganic (fluoride) and 1 organic (PCB TEQ).

7.7.1.3 Identification of COPCs in Groundwater

NSGW data are not available for the Skyline Road Area; therefore, COPCs are not identified for groundwater.

7.7.1.4 Identification of COPCs in Soil Gas

Soil gas data are not available for the Skyline Road Area; therefore, COPCs are not identified for soil gas.

7.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the Skyline Road Area may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential exposures. Figure 1.5-2 depicts the conceptual exposure model for the Skyline Road Area. Table G.7.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

7.7.2.1 Identification of Receptors

The Skyline Road Area recently was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the industrial worker and recreationist exposure scenarios were evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

7.7.2.2 Identification of Exposure Pathways

Future residents and industrial workers were assumed to be exposed to soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). Future recreationists were assumed to be exposed to soil (0 to 2 ft bgs). Exposure pathways for soil included direct exposures (ingestion and dermal) and indirect exposure (inhalation of airborne fugitive dusts). Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the Skyline Road Area are provided in Table G.7.1-6.

7.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs and soil at 0 to 10 ft bgs at the Skyline Road Area are listed in Table G.7.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for non-volatile COPCs. The derivation of the PEF for soil is listed in Table G.7.1-5.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b). COPC concentrations in edible plant tissues from soil at 0 to 2 ft bgs are listed in Table G.7.1-8.

7.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate chemical intakes for potential adult and child residential, adult and child recreationist, and industrial worker receptors at the Skyline Road Area. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix G. See the Appendix G human health RA Tables Index for the exposure parameters and chemical intakes for each exposure scenario.

7.7.3 Risk Characterization

In the risk characterization component of the HHRA process, the quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential non-cancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.5.

The exposure assumptions, EPCs, toxicity factors, and risk characterization results tables for this HHRA are presented in Appendix G (Appendix G human health RA Tables Index**)**. The risk calculation tables present the estimated ELCRs and non-cancer HIs for potentially exposed receptors and individual exposure routes for soil at the Skyline Road Area, as well as the cumulative risks and HIs across all exposure routes for the RME and CTE scenarios. Table G.7.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are listed in Table G.7.5-2.

7.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil was evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from

soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-8} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for non-cancer effects range from 9×10^{-4} for the CTE case to 0.003 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogencic COPCs for exposure to 0- to 2-ft-bgs soil from the plant consumption exposure route range from 5×10^{-7} for the CTE case to 1×10^{-5} for the RME case. The RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-foot-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 0.03 for the CTE case to 0.2 for the RME case. The RME and CTE HI estimates are below the regulatory threshold value of 1.

- For exposure to 0- to 10-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-9} for the CTE case to 7×10^{-9} for the RME case. The CTE and RME ELCR estimates are below the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-ft-bgs soil, the HI estimates for non-cancer effects range from 2×10^{-4} for the CTE case to 3×10^{-4} [for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1.

7.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposure to COPCs in soil was evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of vapors and fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 8×10^{-8} for the CTE case to 2×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for non-cancer effects range from 0.008 for the CTE case to 0.02 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route. The ELCR estimates for carcinogencic COPCs for exposure to 0- to 2-ft-bgs soil from the plant consumption exposure route range from 5×10^{-7} for the CTE case to 3×10^{-6} for the RME case. The RME ELCR estimate exceeds the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for non-cancer effects from the plant consumption exposure route range from 0.05 for the CTE case to 0.3 for the

RME case. The RME and CTE HI estimates are below the regulatory threshold value of 1.

- For exposure to 0- to 10-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 7×10^{-9} for the CTE case to 2×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-ft-bgs soil, the HI estimates for non-cancer effects range from 0.001 for the CTE case to 0.003 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1.

7.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposure to COPCs in soil was evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 9×10^{-10} for the CTE case to 3×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for non-cancer effects range from 6×10^{-5} for the CTE case to 8×10^{-4} for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

7.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposure to COPCs in soil was evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. A hypothetical future recreationist child (15-kg body weight) was assumed to be exposed for 100 days per year over 6 years for the RME case and 50 days per year over 6 years for the CTE case. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 1×10^{-8} for the CTE case to 7×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to $1 \times 10\text{-}^{4}$. For exposure to 0- to 2-ft-bgs soil, the HI estimates for non-cancer effects range from 0.001 for the CTE case to 0.007 for the RME case. The RME and CTE HI estimates are below the regulatory threshold value of 1.

7.7.3.5 Hypothetical Future Industrial Worker Exposure Scenario

Potential industrial worker exposure to COPCs in soil was evaluated under this hypothetical scenario.

Estimated Risks/Hazard Indexes for COPCs in Soil. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust in ambient air. The ELCR and HI estimates for the future industrial worker exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 8×10^{-9} for the CTE case to 1×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for non-cancer effects range from 5×10^{-4} for the CTE case to 0.004 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1.
- For exposure to 0- to 10-foot-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from $7x\ 10^{-10}$ for the CTE case to 1×10^{-8} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 10-foot-bgs soil, the HI estimates for non-cancer effects range from 9×10^{-5} for the CTE case to 4×10^{-4} [for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1.

7.7.4 Uncertainty Discussion

Uncertainties associated with the results of this HHRA are a function of both the "state of the practice" of HHRA in general and of UFs specific to the Skyline Road Area. A discussion of the general HHRA uncertainty is presented in Section 1.5.3.

7.8 Ecological Risk Assessment for Skyline Road Area

7.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to all RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the Skyline Road Area are described below.

7.8.1.2 Site Background

The Skyline Road Area primarily consists of a roadway and property immediately adjacent to the road. A more detailed discussion of the site conditions and history is presented in Section 7.1.

The Skyline Road Area contains a substantial number of cleared areas, roadway corridors, and areas currently supporting structures, facilities, or other developments.

The road, buildings, and associated developed areas constitute about 23 percent of the land cover at this site. Habitat at the site was characterized based on a site survey conducted in January 2009. This survey indicated that, aside from developed areas, the Skyline Road Area is consists of five habitat types–annual grassland, scrub-shrub, ruderal, rock, and riparian woodland habitat (Figure 7.8-1). Although extensive woodland does not occur within the site, several coast live oaks were documented along drainages away from the

project area. This woodland habitat covers 1.5 percent of the site. Venturan coastal sage scrub (29.3 percent), annual grassland (13.1 percent), and ruderal vegetation (7.3 percent) are the most common vegetation types throughout the site. Areas at elevations where disturbance has been limited support well-developed Venturan Coastal Sage Scrub (Holland, 1986), dominated by California sagebrush, thick leaf yerba santa, California buckwheat, black sage, California encelia, and some coyote brush. The annual grassland community on the site is dominated by grasses such as ripgut brome, red brome, slender wild oat, and foxtail barley. Ruderal habitat occurs along the road and adjacent to the water tanks and associated parking lot and pipelines. Bird species observed during the site visit include American crow, Anna's hummingbird, black phoebe, bushtit, California quail, house finch, house and white-crowned sparrow, Lesser goldfinch, mourning dove, red-tailed hawk, rock pigeon, spotted towhee, turkey vulture, and western meadowlark. Mammals observed onsite include desert cottontail, California ground squirrel, and coyote.

7.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the Skyline Road Area is the same as that for all of the Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the Skyline Road Area are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 7.8-1).
- Representative species and receptor groups considered for the Skyline Road Area include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

7.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the Skyline Road Area is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the Skyline Road Area is described below and presented in Figure 7.8-2.

Skyline Road Area does not include a listed SWMU or AOC, but samples were collected near a set of ASTs used to hold potable process water and also adjacent to a power pole holding a set of elevated transformers. The primary contaminant sources at the Skyline Road Area include the ASTs and the transformers. Primary release mechanisms include leakage to the ground surface from the ASTs and transformers. Soil is the secondary source of potential contaminant. Secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater.

Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the sites. Burrowing mammals (deer mice) may be exposed to soil gases via inhalation. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles,

may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and prey animals to omnivores, etc.). Table 7.8-2 provides additional descriptions of the potential exposure pathways for the ecological receptors at the Skyline Road Area, along with the rationale for inclusion or exclusion in the quantitative and qualitative evaluations.

7.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil are listed in Table 7.8-3. Summary statistics for those detected analytes are listed in Table 7.8-4. A central tendency background comparison for metals and dioxins/furans in soils was conducted to assess whether the analytes were consistent with background (Table 7.8-5). Non-detect analytes were evaluated by comparing the maximum SQLs against the minimum ESL and determining the exceedance frequency of the SQLs (Table 7.8-6). The CPECs identified for the Skyline Road Area are summarized in Table 7.8-7. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 7.8-8, 7.8-9, and 7.8-10, respectively.

7.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 7.8.1) with the risk characterization (Section 7.8.3) and consists of the technical evaluation of ecological and chemical data to further evaluate the potential for ecological exposure and effects. Generalized components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the Skyline Road Area is presented below.

7.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this subsection.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the Skyline Road Area. Because the Skyline Road Area is strictly terrestrial, exposure is based on soil and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

The Skyline Road Area is approximately 5.6 acres, and more than 56 percent of the land cover at this site consists of buildings, pavement, rock, and ruderal or stressed vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) were calculated for the Skyline Road Area, according to the approach outlined in Section 1.5.4.4. These values are listed in Tables 7.8-8 through 7.8-10. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 7.8.3).

7.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for the receptors at SSFL are summarized in Section 1.5.4.4. No effects data specific to the Skyline Road Area are available. Consequently, the ESLs, Low TRVs, and High TRVs for the terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

7.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the Skyline Road Area. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the Skyline Road Area. The results of these comparisons are presented below.

7.8.3.1 Risk Estimation

The risk estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 7.8-11 through 7.8-17. Table 7.8-13 presents an analysis of the depth intervals for the evaluation of burrowing animals (deer mouse). The depth intervals had the same HI; therefore, the data from the 0- to 2-foot-depth interval were used to evaluate the deer mouse.

7.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with other available and appropriate lines of evidence to evaluate the potential chemical impacts on ecological receptors in SSFL's Group 3. Chemicals that had HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of the COECs includes receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (ESL, Low TRV, or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.

2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.

3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.

4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.

5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.

6. No Risk–all HQs and associated HIs<1.

7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Three soil analytes (selenium, benzidine, and dioxin/furans [based on DIOXTEQ]) were found to have one or more HQs greater than 1 under any scenario (Table 7.8-18). The other soil analytes and/or analyte groups were found to pose no risk (all HQs and HIs were less than 1) to receptors under any scenario (maximum concentration for plants, invertebrates; CTE and RME concentrations for birds and mammals) at the Skyline Road Area. All of the HQs greater than 1 were observed for bird and mammal receptors. No risks were identified either for terrestrial plants or for soil invertebrates.

One inorganic, fluoride, was identified as elevated relative to background, based on the non-parametric central tendency background comparisons for soil (Table 7.8-5). In addition, selenium was retained based on the SQL screen (Table 7.8-6). Although it was elevated relative to background, fluoride had HQs less than 1 for all receptors, and therefore, is not considered to pose a risk. Selenium had a low TRV-based HQ for deer mice based on the RME scenario above 1 and was considered to pose medium risk (HQs<2 for High TRV [RME], but HQ>10 for Low TRV [RME]). However, none of the high TRV-based HQs were greater than 1 and all of the CTE HQs were less than 1. It also should be noted that selenium was not detected in the 6 samples collected. Consequently, risks from selenium are acceptable. An evaluation of the incremental risks (Table 7.8-19) indicated that initial exceedances for both fluroride and selenium probably are due to background concentrations.

Benzidine was retained based on the SQL screen (Table 7.8-6). The RME screen used the maximum SQL and resulted in a low TRV-based HQ above 1 (HQ=2.8) (Table 7.8-16). On the basis of the CTE screen, the low TRV-based HQ for deer mice was 1.4 (Table 7.8-14). No other receptors had HQs greater than 1. Because benzidine was not detected and the high TRV-based HQs were less than 1, the risks are acceptable.

Dioxin/furans (based on congener data and resulting TEQs) had a low TRV-based HQ above 1 for the deer mouse, based on the RME (HQ=2) and CTE (HQ=1.3) screens and was considered to pose a medium-low risk (HQs<1 for the High TRV [RME], but 1<HQs<10 for the Low TRV [RME])). All of the high TRV-based HQs for all receptors (RME and CTE screens) were less than 1. Six samples were analyzed for dioxin/furans, and the sample size is considered to be adequate. Consequently, the risks were acceptable and additional investigation is not recommended.

Table 7.8-20 lists the soil chemicals that have one or more HQs above 1, along with the resulting soil COECs, if any.

7.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component in all risk assessments. Generalized uncertainties for ERAs in SSFL's Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- Aroclor data were not evaluated in this assessment because PCB congener data were available and were used to calculate a TEQ. PCBs and dioxin/furans were evaluated based on the 2,3,7,8-TCDD TEQs. However, because only 2 samples were analyzed for PCBs, there is some uncertainty in the risk results for PCBs.
- No screening levels were available to evaluate the TPH data; however, PAH data were available and no risk from these constituents was predicted.

7.8.4 Conclusions and Recommendations

Of the soil analytes that were evaluated, no risks were identified for fluoride. Selenium was found to pose a medium risk, but because selenium was not detected and the magnitude of exceedance and the incremental risk were low, the risk was acceptable. Risks from benzidine and dioxin/furans also were acceptable. Consequently, no additional ecological investigation is recommended for the Skyline Road Area.

7.9 Summary of Findings and Recommendations for Skyline Road Area

7.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of potential contaminants at the Skyline Road Area, 7 surface soil and 3 subsurface soil samples were collected. Of the surface soil samples collected, 2 dioxins (compared as 2,3,7,8-TCDD TEQ) and 4 metals exceeded the applicable screening criteria. The parameters that exceeded the criteria are listed in Table 7.9-1. Additional dioxin sampling may be required to further evaluate the horizontal extent of contamination, because the extent appears to be evaluated sufficiently only to the east. The metals exceedances were detected at concentrations mostly indicative of natural occurrence, and the horizontal extent of metals at this area has been evaluated adequately. Of the subsurface soil samples collected, 1 calculated dioxin TEQ value exceeded the screening criterion. Similar to the surface soil exceedances, additional dioxin sampling in the vicinity of the power pole may be required to further evaluate the extent of contamination. No metals were detected at elevated concentrations in the subsurface soil; therefore, the vertical extent of surface soil metals exceedances has been addressed sufficiently.

7.9.2 Risk Assessment Summary

Human health and ecological risks at the Skyline Road Area are summarized below.

7.9.2.1 Summary of Human Health Risks

This subsection summarizes the HHRA performed for the Skyline Road Area. The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs) and subsurface soil (0 to 10 ft bgs). The methods used to prepare the HHRA are described

in Section 1.5.3. The results of the HHRA for the Skyline Road Area are presented in Section 7.7.

The surface soil (0 to 2 ft bgs) and subsurface soil (0 to 10 ft bgs) samples collected during the RI sampling activities were evaluated for use in the HHRA. Surface water and sediment samples are not evaluated in this HHRA, because they were not present during the RI site characterization activities. The HHRA data set is listed in Table G.7.1-3 in Appendix G. The COPCs identified from the Skyline Road Area HHRA data set for each exposure area are listed in Table G.7.1-4.

The potential future receptors at the Skyline Road Area include recreationists, workers, and residents. The Skyline Road Area and surrounding area is likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report at a later date. The assumed exposure pathways for future residents, workers, and recreationists are shown in Figure 1.5-2.

Generally, estimated cumulative cancer risks (ELCRs) were less than the regulatory risk range (range of 1 in a million [1×10^{-6}] to 1 in 10,000 [1×10^{-4}]) and estimated non-cancer hazards (HIs) were less than the regulatory threshold value of 1 and are considered acceptable (EPA, 1993). Estimated ELCRs within the 1×10^{-6} to 1×10^{-4} range are managed on a site-specific basis. Table G.7.5-1 summarizes the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs and HIs are listed in Table G.7.5-2.

The following exposure scenario for the Skyline Road Area exceeds or is within the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption

The primary contributor to the ELCR for the soil exposure pathways is 2,3,7,8-TCDD TEQ (93 percent of the ELCR estimate) [Table G.7.5-2].

No exposure scenarios for the Skyline Road Area exceed the regulatory threshold values for non-cancer COPCs.

The following exposure scenarios for the Skyline Road Area are less than the regulatory risk range for carcinogenic COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationists exposed to soil (0 to 2 ft bgs)

The following exposure scenarios for the Skyline Road Area are less than the regulatory threshold value for non-cancer COPCs:

- Hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult and child residents exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 2 ft bgs)
- Hypothetical future adult industrial worker exposed to soil (0 to 10 ft bgs)
- Hypothetical future adult and child recreationists exposed to soil (0 to 2 ft bgs)

As described in Sections 1.5.3.6 and 7.7.4, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

7.9.2.2 Summary of Ecological Risks

Of the soil analytes that were evaluated, no risks were identified for fluoride. Selenium was found to pose a medium risk; however, because selenium was not detected and the magnitude of exceedance and the incremental risk were low, the risk was acceptable. The risks from benzidine and dioxin/furans also were acceptable. Consequently, no additional ecological investigation is recommended for the Skyline Road Area.

7.9.3 Recommendations for the Skyline Road Area

To complete the nature and extent evaluation in the Skyline Road Area, it is recommended that additional samples be collected for dioxin analysis in both the surface and subsurface soil media.

The estimated cumulative ELCR and HI for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4} with 2,3,7,8-TCDD TEQ as the primary contributor. It is recommended that that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC.

On the basis of the results of the ERA, additional investigation within the Skyline Road Area is not recommended in the FS; however, additional dioxin samples may be warranted to further characterize the extent of dioxins in the surface and subsurface soil.

8. Hazardous Waste Coolant Tank (WCT)

8.1 WCT Area Background and History

The WCT area comprises approximately 0.1 acre in the central portion of Area II at SSFL. The only feature present onsite was a 600-gallon AST. This tank, which was used from 1987 to 1990, is further described below.

8.1.1 SWMUs and AOCs

The WCT Area contains one SWMU and no AOCs. The former WCT has been designated as SWMU 5.7.

8.1.2 Site History

The Area II portion of property at SSFL was acquired by NASA in 1973 from the USAF. Although the WCT Area is situated on NASA property, the former WCT was owned and operated by Boeing. The tank was a 600-gallon capacity AST used to contain non-RCRA hazardous waste cutting oil. The tank was installed in 1987 and was removed from service in 1990. The waste cutting oil was generated by various onsite tooling shops at SSFL, which used the oil as a coolant. The tank was situated on a concrete pad with an 18-inch-high concrete secondary containment berm (Ogden, 2000a). The tank and secondary containment structure were removed in the early 1990s (Banaga, 2009). Figure 8.1-1 shows the location of the tank in the WCT Area.

Directly north of the WCT is the former HWSA. The HWSA (SWMU 5.8) was a permitted RCRA unit and was operated jointly by NASA and Boeing; this SWMU was clean-closed by DTSC in 1999. Although the HWSA and WCT Area were close to each other, the WCT Area was not regulated as a permitted unit because it only contained non-RCRA waste and, as such, was not included in the HWSA closure.

8.1.3 Site Chemical Use Areas

The former AST is the only chemical use area present at the WCT Area. The tank was used to contain waste cutting oil generated by various tooling shops at SSFL. No other substances were contained by the tank. Although the tank capacity was 600 gallons, observations by onsite workers indicate that the tank contained less than an estimated 150 gallons of oil during its operational period (Banaga, 2009). There were no reported chemical releases from the tank or at the WCT Area. The chemical use area is shown in Figure 8.1-1. Table 8.1-1 summarizes chemical use at the WCT Area.

8.1.4 Site Conditions

The WCT was removed from service in 1990. There are no structures or pavement remaining onsite. There are no surface water features such as drainage ditches, ponds, lakes, and streams at the site.

8.1.5 Site Habitats/Land Cover

The WCT Area measures approximately 0.1 acre in size. The dominant land cover types include ruderal vegetation (73 percent) and scrub-shrub (16 percent). Unpaved roadways cover the remaining approximately 11 percent of the area. Although dehydration-stressed vegetation was observed immediately adjacent to the WCT, none was observed within this site. Multiple bird and mammal species (California towhee, red-tailed hawk, spotted towhee, American goldfinch, common raven, coyote [scat], cottontail rabbit, western fence lizard) were observed to use the site area.

8.1.6 Historical Document Reviews

On the basis of the historical document review, no new features, COPCs, or release areas were identified in the WCT Area (SWMU 5.7).

8.2 RI Characterization Activities

This subsection describes the sampling objective, sampling scope, and key decision points associated with defining the nature and extent of chemical effects for the surface soil, subsurface soil, and groundwater at the WCT Area.

8.2.1 Sampling Objectives

To characterize the extent of potential chemical effects at the WCT Area, soil and soil gas samples were collected. The objectives of the investigation were as follows:

- Define the lateral and vertical extent of chemical impacts
- Define the potential gradients of chemicals
- Develop a sufficient data set for performing a risk assessment

These objectives contributed to the selection of sampling locations, analytical methods, and depths, while incorporating site-specific information such as the following:

- Site conditions observed at the location of proposed sampling
- Historical sampling results
- Fate and transport characteristics of chemicals
- SSFL background concentrations of chemicals
- SSFL SRAM-based screening concentrations for human health and ecological receptors

8.2.2 Sampling Scope

Provided in this report are all of the characterization results for soil matrix and soil gas investigations. The total numbers of historical and 2009 RI samples (excluding field

duplicate and split samples) collected as part of this report for soil matrix and soil gas are summarized below.

- Soil matrix: 9 samples
- Soil gas: 1 sample

These samples were collected between 2000 and 2009 to assess potential chemical impacts associated with historic activities at the WCT Area. These sample result are described further in Section 8.4.

8.2.3 Key Decision Points

The site-specific decision points identified for the WCT Area represent the assumptions and/or decisions made during the sampling phase component of this RI.

8.3 RI Characterization Results

The characterization results from soil matrix and soil gas investigations that occurred prior to 2009 at the WCT Area are summarized below.

8.3.1 Soil Matrix and Soil Gas Findings

In June 2000, shallow soil samples were collected from two locations and analyzed for TPH. One sample was collected beneath the former tank secondary containment unit (WTBS01; 0 to 0.5 ft bgs) and a second sample was collected approximately 40 ft to the southeast (WTBS02; 2 to 2.5 ft bgs).

The analytical results included detectable concentrations of longer carbon chain petroleum hydrocarbons in both samples. Diesel-range hydrocarbons (C14-C20) were detected at 3.3 J mg/kg (J is an estimated value) at WTBS02 (southeast of tank location), but were not detected at WTBS01 (beneath tank secondary containment unit) adjacent to tank location); the detected value is less than the ecological and human health screening levels (100 mg/kg for both). For lubricant oil range hydrocarbons (C20-C30), reported concentrations were 200 mg/kg at WTBS02 and 31 mg/kg at WTBS01; the concentration at WTBS02 is greater the 100-mg/kg screening level for ecological and residential exposures.

To further evaluate the TPH concentrations observed at the WTBS02 sampling location described above, supplemental soil gas and soil sampling was performed in January 2007. These supplemental samples were co-located with WTBS02. One soil gas sample (WTSV0001) was collected and analyzed for VOCs. The soil gas sample was collected at 4 ft bgs (maximum depth achieved due to shallow bedrock). No VOCs were detected in the soil gas sample. One surface soil sample and a field duplicate sample were collected

(WTBS0003) and were analyzed for SVOCs and metals. A summary of the findings for these soil samples is presented below:

- Trace concentrations of various SVOCs were detected in the soil sample, including phthalates and PAHs. None of the detected concentrations exceeded the ecological or human health screening criteria.
- Boron was detected at concentrations above the background (9.7 mg/kg) and ecological screening criteria (6.76 mg/kg) in both the primary (14 mg/kg) and duplicate (12 mg/kg) samples collected at this location.
- Cadmium was detected at a concentration of 0.44 mg/kg in the primary sample at WTBS0003, which is less than the background screening level of 1 mg/kg. In the duplicate sample collected at this location, the cadmium concentration (2.6 mg/kg) exceeded the background, ecological (0.0045 mg/kg), and human health screening levels (1.7 mg/kg).

8.3.2 Local Geology and Hydrogeology

The WCT Area measures approximately 0.1 acre and is located in the central portion of Area II. The topography onsite is fairly flat with a gentle slope to the northwest in the western portion of the site. The elevation onsite is approximately 1,850 ft above msl.

There is a limited extent of alluvial material onsite. Based on observations during drilling, the alluvium thickness onsite is generally less than 1 ft bgs at the former tank location. A soil gas probe was installed to a reported depth of approximately 4 ft bgs east of the former tank location, but weathered bedrock was encountered within approximately 0.5 ft bgs at lateral step-out borings. The soil type onsite is grayish-brown silty sand. Figure 8.3.2-2 presents a cross-section developed for the WCT Area (Surficial Cross Section A-A'), detailing topography and locations and depths of alluvium. The location of the cross-section is shown in Figure 8.3.2-1.

Although there are no near-surface or Chatsworth formation groundwater wells in the WCT Area, data for nearby groundwater wells indicate that NSGW exists in the vicinity of the WCT, ranging from 6 to 12 ft bgs. The depth to the Chatsworth formation groundwater in the area ranges from 8 to 33 ft bgs. Chatsworth formation groundwater has a gradient of 0.23 ft/ft south-southeast. These groundwater levels are based on the 2008 annual groundwater report (Haley & Aldrich, 2009). Figure 8.3.2-3 shows groundwater monitoring wells locations and the Chatsworth formation groundwater elevations in the vicinity of the WCT Area.

8.3.3 Completeness of Characterization

On the basis of the previous sampling performed at the WCT Area, supplemental soil sampling was performed in 2009 to further assess the presence of boron and cadmium in surface soil to the east of the former tank location, and to provide additional geographic sampling coverage to assess the potential presence of metals, PCBs, SVOCs, and TPH. The historical and the current 2009 RI sampling results are discussed in Section 8.4.

8.4 WCT Area Nature and Extent

During the 2009 RI field activities, surface soil samples were collected at the WCT Area per the protocol described in Section 8.2 and the data are provided in Appendix H. Figure 8.4-1 shows the locations of historical samples and the most recent soil samples collected as part of this RI. Table 8.4-1 lists the parameters analyzed in the sample media at the WCT Area. The nature and extent of chemicals that exceeded the comparison criteria values in the media sampled are described in this section.

8.4.1 Surface Soil Nature and Extent

To evaluate the nature and extent of potential contaminants in the WCT Area, 9 surface soil samples and 3 field duplicate and split samples were collected at the site and analyzed for one or more of the following: metals, PCBs, SVOCs, and TPH. A summary of the sampling performed is provided in Table 8.4-1, and the sample locations are presented in Figure 8.4-1.

8.4.1.1 Parameters above Comparison Criteria

This section describes the chemical parameters with detected concentrations that exceeded one or more comparison criterion. Surface soil detections at the WCT Area are presented in Table 8.4-2.

Metals. Surface soil samples were collected at two locations and analyzed for total metals, and three additional surface soil samples were collected and analyzed for boron and cadmium. These parameters were generally encountered at concentrations similar to their respective background values, and are likely indicative of natural occurrence. Those metals with concentrations exceeding their respective background level, and their ecological and/or human health screening levels, are described below. Locations of metals detected above background and ecological and/or human health comparison criteria are presented in Figure 8.4-2.

At previous investigation location WTBS0003, situated approximately 40 ft southeast of the former WCT, boron and cadmium concentrations exceeded their respective background levels and ecological and/or human health screening levels in surface soil. Based on these observed exceedances, supplemental sampling was performed during the 2009 RI activities. A surface soil sample (and duplicate sample) (WTBS1004) were collected at the previous WTBS0003 location to confirm the previous investigation detections. Three lateral step-out surface soil samples were also collected approximately 15 ft from WTBS0003 (WTBS1005, WTBS1006, and WTBS1007 shown in Figure 8.4-2) to assess the lateral extent of boron and cadmium. A summary of the sampling results for boron and cadmium are provided below:

- Boron was detected at a maximum concentration of 14 mg/kg in a surface soil sample collected at previous investigation location WTBS0003. The duplicate sample at this location had a boron concentration of 12 mg/kg. These concentrations exceed the background level of 9.7 mg/kg and the ecological screening level of 6.76 mg/kg, but are significantly less than the human health screening level of 1,500 mg/kg. In the supplemental samples collected in 2009, none of the boron concentrations exceeded the background level (maximum detected boron concentration was 1.73 J mg/kg), including in the sample that was co-located with the previous investigation location WTBS0003. In addition, the boron concentration in the surface soil sample collected at the former WCT

location (1.6 J mg/kg at WTBS1008) did not exceed the background level. These sample results indicate the elevated boron concentrations observed in the previous samples collected at location WTBS003 were isolated detections. Boron concentrations at the WCT Area are considered to be similar to naturally occurring conditions.

- Cadmium was detected at a concentration of 2.6 mg/kg in the duplicate surface soil sample collected at previous investigation location WTBS0003. This concentration is greater than the background level of 1 mg/kg, and the ecological (0.0045 mg/kg) and human health (1.7 mg/kg) screening levels. The cadmium concentration in the primary sample collected at this location (0.63 mg/kg) was less than the background level. In the supplemental samples collected in 2009, the cadmium concentration exceeded background in one (1.5 mg/kg) of two samples that were co-located with previous location WTBS0003. The cadmium concentrations in the lateral step-out samples were less than background. Similar to the results for boron described above, background exceedances for cadmium were isolated detections limited to a single location.

Beryllium, chromium, and iron were detected above their respective background and human health screening levels from a sample collected at WTBS1008. Beryllium was detected at a concentration of 1.4 J mg/kg compared to its background level of 1.1 mg/kg and its human health screening level of 0.9 mg/kg. Chromium was detected at a concentration of 39 mg/kg compared to its background level of 37 mg/kg and its human health screening level of 32 mg/kg. Iron was detected at a concentration of 32,000 mg/kg compared to its background level of 28,000 mg/kg and its human health screening level of 23,500 mg/kg. The beryllium and chromium concentrations at the other WCT Area sample locations analyzed for total metals (primary and duplicate samples at WTBS0003) did not exceed their respective background levels. Iron was not analyzed in these samples. The beryllium, chromium, and iron concentrations observed at WTBS1008 are only slightly higher than their respective background levels, suggesting that these metals concentrations are consistent with naturally occurring conditions.

Nickel and selenium were detected above their respective background levels and ecological screening levels at WTBS1008, which was positioned at the former WCT location. Nickel was detected at a concentration of 30 mg/kg compared to its background level of 29 mg/kg and its ecological screening level of 0.1 mg/kg. Selenium was detected at a concentration of 0.68 J mg/kg compared to its background level of 0.66 mg/kg and its ecological screening level of 0.17 mg/kg. The detected concentrations for these metals in the other surface soil samples collected at the WCT Area (primary and duplicate samples at WTBS0003) did not exceed their respective background levels. The nickel and selenium concentrations observed at WTBS1008 are only slightly higher than their respective background levels, suggesting that these metals concentrations are considered consistent with naturally occurring conditions.

PCBs. No detectable PCB concentrations were reported in the soil samples collected at the WCT Area.

SVOCs. Trace levels of various phthalates and PAHs were reported in the soil samples collected at the WCT Area. However, none of the detected concentrations exceeded the screening levels.

TPHs. Surface soil samples were collected and analyzed for TPHs at three locations (WTBS01, WTBS02, and WTBS1008). Locations of TPHs detected at levels above the ecological and human health comparison criteria are presented in Figure 8.4-3.The analytical results included detectable concentrations of longer carbon chain petroleum hydrocarbons in samples collected at WTBSS01 and WTBS02 only. Lubricant oil range hydrocarbons (C20-C30) were reported at concentrations of 200 mg/kg at WTBS02 (approximately 40 ft southeast of the former WCT location) and 31 mg/kg at WTBS01 (beneath tank secondary containment unit). The concentration observed at WTBS02 is greater than the 100-mg/kg screening level for ecological and residential exposures. However, as described above, no elevated SVOCs were observed and no PCBs were detected at this location. Additionally, as described below, no VOCs were detected in soil gas at this location. Furthermore, there are no individual constituent risk drivers for TPH, as discussed in Sections 8.7 and 8.8 of this report. Therefore, no further evaluation of petroleum hydrocarbons appears to be warranted.

8.4.2 Soil Gas Nature and Extent

One soil gas sample was collected at the WCT Area. The soil gas probe (WTSV0001) was co-located with WTBS02, where the maximum lubricant oil range hydrocarbons (C20-C30) concentration (200 mg/kg) was observed during a previous sampling event. The purpose of the soil gas sampling at this location was to assess the potential presence of fuel-related VOCs. No detectable levels of VOCs were reported in soil gas at this location; therefore, no additional soil gas sampling was performed.

8.5 Conceptual Site Exposure Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. The ecological CSM specific to the WCT Area is described Section 8.8.1.4.

8.6 Fate and Transport Analysis for Chemicals Detected in Groundwater in Surficial Media at the WCT Area

8.6.1 Contaminant Sources and Release Mechanisms

The primary potential release mechanism at the WCT Area was potential leaks from the WCT and potential spills of waste coolant oil during transfer and handling activities.

8.6.2 Potential Routes of Migration

The primary potential pathways for contaminant transport for this site include the release of contaminants in surface soil to the air by wind erosion and horizontal migration of contaminants along the surface via storm water. Based on the small size of the site (approximately 0.1 acre), the potential for wind erosion of chemicals in surface soil is considered insignificant. Significant migration via surface water run-off is also unlikely due to the relatively flat topography at the WCT Area.

Vertical migration of contaminants from surface soil to subsurface soil is unlikely due to the shallow depth of bedrock. Soil borings at the site were advanced to a maximum depth of 4 ft bgs to the southeast of the former tank location, although the depth of bedrock was typically less than 1 ft bgs at other portions of the area. In addition, detected parameters above screening levels (metals and long chain hydrocarbons) have very low mobility and are likely to be bound to soil.

8.6.3 Contaminant Persistence

The concentrations of several metals and lubricant oil range hydrocarbons were detected in surface soil at concentrations above their respective screening criteria. A general discussion of the persistence of these types of chemicals is described below.

8.6.3.1 Parameters Exceeding Criteria

Metals and petroleum hydrocarbons are described below.

Metals. Several metals were detected at the site at levels above the screening criteria. Many metals are naturally occurring, and their reported presence may or may not indicate a past chemical release. Metals generally persist in soil due to their high affinity for soil. In addition, metals typically are not volatile.

TPHs. Heavy range petroleum hydrocarbons (C20-C30 lubricant oil range) were detected at this site at levels above ecological and human health comparison criteria. Heavier petroleum products such as fuel oil have lower volatility and higher sorption potential than lighter petroleum products such as gasoline. Data compiled from gasoline spills and laboratory studies indicate that petroleum products with heavier molecular weight constituents generally are more persistent in soils because of their relatively low water solubility and volatility, and high sorption capacity (Stelljes and Watkin, 1991).

8.6.4 Contaminant Migration

The primary sources for contaminant migration are leaching of chemicals that may have been historically released at the WCT Area. The WCT was operational for only a short time period (1987 to 1990), the tank was located within a concrete secondary containment unit, and there are no records of releases. Therefore, it does not appear that any significant releases occurred at the site and, if releases occurred, they were properly controlled. The results of soil and soil gas sampling also indicate that no significant releases occurred onsite.

8.6.5 Surface Soil Contaminants

Metals have been identified in surface soil at levels above background and human health and/or ecological screening criteria. Of the metals detected in the surface soil at the WCT Area, seven were reported at concentrations exceeding one or more of the criteria. However, the metals with detected concentrations that exceeded the background levels (that is, beryllium, boron, cadmium, chromium, iron, nickel, and selenium) were generally comparable to the background levels and, as such, are considered to be indicative of natural occurrence.

TPH (C20-C30 lubricant oil range) was detected above ecological and human health comparison criteria in a surface soil sample at the WCT Area. However, no elevated SVOCs

or PCBs were detected at the same location. Furthermore, VOCs were not detected during soil gas sampling at the same location.

8.6.6 Subsurface Soil Migration

The presence of alluvial materials is limited at the WCT Area. The depth to weathered bedrock at the site is typically less than 1 ft bgs. Soil samples collected onsite were limited to surface soil. Given these onsite geologic conditions, vertical migration in soil would be limited.

8.6.7 Soil-to-Groundwater Migration

The potential threat of chemicals detected in soil at the WCT Area to migrate to groundwater is considered low. NSGW has not been delineated at the WCT Area; therefore, no affected groundwater in the SMOU within the immediate study area is expected. The types of chemicals detected at concentrations exceeding screening levels in onsite soil (metals and long-chain hydrocarbons) could migrate to groundwater, but given their low mobility, they are more likely to be bound to soil. VOCs, which have higher mobility potential, have not been detected at the WCT Area.

8.7 Human Health Risk Assessment for the WCT Area

The objective of this HHRA is to assess whether the environmental media at the WCT Area could pose risks to human health at levels that might require remedial action, or risks at levels that are eligible for an NFA designation. This HHRA assesses the potential current and future exposures to chemicals in soil at the WCT Area. The methods and guidance documents used in the preparation of this HHRA are discussed in Section 1.5.3 of this report. A discussion of the HHRA results for the WCT Area is presented below. The results are summarized in Section 8.9.2.

The concentration data, input parameters, and results of the HHRA for the WCT Area are presented in Appendix H. An index of the tables (Appendix H human health RA Tables Index) is provided and can be used to locate tables that contain information regarding the HHRA data set, EPCs, exposure parameters, toxicity factors, estimated chemical intakes, estimated ELCRs, and estimated noncancer HIs.

8.7.1 Identification of Chemicals of Potential Concern

Chemicals were selected as COPCs at the WCT Area, based on the protocol presented in Sections 1.5.3.1 and 1.5.3.2.

8.7.1.1 Data Evaluation

The soil sampling analytical data at the WCT Area were evaluated to assess their suitability for use in the risk assessment following the procedures presented in Section 1.5.3.1. Groundwater, sediment, and surface water data were not collected as part of the RI site characterization activities. One soil gas sample was collected (location WTSV0001); however, no VOCs were detected, indicating that vapor intrusion and ambient air pathways are incomplete at WCT. The locations of the soil samples used in this HHRA are shown in Figure 8.4-1. The soil samples used in this HHRA are listed in Table H.8.1-1 by sample ID,

sampling depth interval, and date of collection. Table H.8.1-2 lists the target receptor populations by medium. Descriptive summary statistics of these data are provided in Table H.8.1-3.

8.7.1.2 Identification of COPCs in Soil

The process for the selection of COPCs is described in Section 1.5.4.4. Constituents that were analyzed for but not detected were not selected as COPCs for soil. Summary statistics for those detected analytes are listed in Table H.8.1-3. A statistical comparison of site metal data to background was not possible due to the small number of samples collected from this site. The background comparison was conducted using both the maximum detected site and background concentrations. The COPCs identified for the WCT Area are summarized in Table H.8.1-4.

8.7.2 Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals at or near the WCT Area may come into contact with constituents in exposure media. It addresses current exposures and those that may result in the future under reasonably anticipated potential uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed; the routes by which individuals may become exposed; and the magnitude, frequency, and duration of potential exposures. Figure H.1.5-1 depicts the conceptual exposure model for the WCT Area. Table H.8.1-2 summarizes the exposure scenarios. The methods and assumptions used in the exposure assessment are discussed in Section 1.5.3.3.

8.7.2.1 Identification of Receptors

The WCT Area was used for industrial purposes and is most likely to have a future industrial or recreational land use; however, a hypothetical future residential scenario also was included in the exposure assessment. Future residents are expected to have the greatest level of exposure. Therefore, the hypothetical future residential scenario, assuming adult and child receptors, was the most conservative scenario in the HHRA. In addition to the residential scenario, the recreationist exposure scenario was evaluated.

As stated in Section 1.5.3.3, an agricultural-based residential exposure scenario will be evaluated once the protocol to evaluate this exposure has been developed in consultation with DTSC.

8.7.2.2 Identification of Exposure Pathways

Future residents were assumed to be exposed to soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). In accordance with the SRAM (MWH, 2005b), the 0- to 2-ft-bgs or 0- to 10-ft-bgs soil interval resulting in the highest risk estimates was used and reported here. For the WCT area, the 0- to 2-ft-bgs interval was used. Future recreationists were assumed to be exposed to soil (0 to 2 ft bgs). Exposure pathways for soil included direct exposures (ingestion and dermal) and indirect exposure (inhalation of airborne fugitive dusts). Residential receptors also were assumed to ingest edible plants and homegrown produce. The exposure pathways and exposure assumptions included in the HHRA for the WCT Area are provided in Table H.8.1-6.

8.7.2.3 Exposure Point Concentrations

EPCs for soil at 0 to 2 ft bgs and soil at 0 to 10 ft bgs at the WCT Area are listed in Table H.8.1-3. EPCs were estimated for indirect exposures for the following media: airborne fugitive dusts and edible plants (homegrown consumption). Airborne particulate COPC concentrations were estimated for nonvolatile COPCs. The derivation of the PEF for soil is listed in Table H.8.1-5.

The derivation of edible plant concentrations is calculated using soil-to-plant uptake factors, as described in the SRAM (MWH, 2005b).

8.7.2.4 Intake Estimates

EPCs were applied to human intake equations, as presented in the SRAM (MWH, 2005b), to calculate chemical intakes for potential adult and child residential, adult and child recreationist and at the WCT. The chemical-specific intakes were estimated based on an RME scenario and a CTE scenario. The exposure assumptions and the chemical intakes for soil are presented in Appendix H. See the Appendix H human health RA Tables Index for the exposure parameters and chemical intakes for each exposure scenario.

8.7.3 Risk Characterization

In the risk characterization component of the HHRA process, the quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment, see Section 1.5.3.4) to provide numerical estimates of potential health risks. The quantification approach differs for potential noncancer and cancer effects. The methods used in the risk characterization are discussed in Section 1.5.3.5.

The exposure assumptions, EPCs, toxicity factors, and risk characterization results tables for this HHRA are presented in Appendix H (Appendix H human health RA Tables Index). The risk calculation tables present the estimated ELCRs and noncancer HIs for potentially exposed receptors and individual exposure routes for soil at the WCT Area, as well as the cumulative risks and HIs across all relevant exposure routes for the RME and CTE scenarios. Tables H.8.4-1 and H.8.4-2 summarize the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are also listed in those tables.

8.7.3.1 Hypothetical Future Adult Residential Exposure Scenario

Potential residential adult exposure to COPCs in soil was evaluated under this hypothetical scenario. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident adult exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-8} for the CTE case to 2×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for noncancer effects range from 0.03 for the CTE case to 0.07 for the RME case. The CTE and RME HI estimates are below the

regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route.

- The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-ft-bgs soil from the plant consumption exposure route range from 2×10^{-6} for the CTE case to 2×10^{-5} for the RME case. Both the CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for noncancer effects from the plant consumption exposure route range from 0.4 for the CTE case to 2.0 for the RME case. The RME HI estimate exceeds the regulatory threshold value of 1. The primary contributor to the adult RME HI is cadmium (64 percent contribution; HQ=1.3). Although the HI associated with the plant consumption pathway was above the regulatory threshold value of 1, no COCs are identified for this pathway because of the high uncertainties associated with plant uptake modeling (MWH, 2005b).

8.7.3.2 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Residential Exposure Scenario

Potential residential child exposure to COPCs in soil was evaluated under this hypothetical scenario. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, inhalation of fugitive dust in ambient air, and consumption of homegrown produce that has accumulated COPCs from soil. The ELCR and HI estimates for the future resident child exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 2×10^{-7} for the CTE case to 3×10^{-7} for the RME case. The CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for noncancer effects range from 0.3 for the CTE case to 0.6 for the RME case. The CTE and RME HI estimates are below the regulatory threshold value of 1. The cumulative ELCR and HI do not include the ELCR and HI estimates from the plant consumption exposure route.

- The ELCR estimates for carcinogenic COPCs for exposure to 0- to 2-ft-bgs soil from the plant consumption exposure route range from 2×10^{-6} for the CTE case to 6×10^{-6} for the RME case. Both the CTE and RME ELCR estimates exceed the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for noncancer effects from the plant consumption exposure route range from 0.6 for the CTE case to 2.0 for the RME case. The RME HI estimate exceeds the regulatory threshold value of 1. The primary contributor to the adult RME HI is cadmium (64 percent contribution; HQ=1.4). Although the HI associated with the plant consumption pathway was above the regulatory threshold value of 1, no COCs are identified for this pathway because of the high uncertainties associated with plant uptake modeling (MWH, 2005b).

8.7.3.3 Hypothetical Future Adult Recreational Exposure Scenario

Potential adult recreationist exposure to COPCs in soil was evaluated under this hypothetical scenario. Potential routes of exposure to COPCs in soil include incidental

ingestion, dermal contact, and inhalation of fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist adult exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 3×10^{-8} for the CTE case to 1×10^{-7} for the RME case. Both the CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for noncancer effects range from 0.002 for the CTE case to 0.01 for the RME case. The CTE and RME HI estimates do not exceed the regulatory threshold value of 1.

8.7.3.4 Estimated Risks/Hazard Indexes for the Hypothetical Future Child Recreational Exposure Scenario

Potential child recreationist exposure to COPCs in soil was evaluated under this hypothetical scenario. Potential routes of exposure to COPCs in soil include incidental ingestion, dermal contact, and inhalation of fugitive dust in ambient air. The ELCR and HI estimates for the future recreationist child exposure scenario are discussed below:

- For exposure to 0- to 2-ft-bgs soil, the cumulative ELCR estimates for carcinogenic COPCs range from 4×10^{-8} for the CTE case to 1×10^{-7} for the RME case. Both the CTE and RME ELCR estimates are below the regulatory risk range of 1×10^{-6} to 1×10^{-4}. For exposure to 0- to 2-ft-bgs soil, the HI estimates for noncancer effects range from 0.05 for the CTE case to 0.2 for the RME case. The RME and CTE HI estimates are below the regulatory threshold value of 1.

8.7.4 Uncertainty Discussion

Uncertainties associated with the results of the HHRA are a function of both the "state of the practice" of risk assessment in general and uncertainty factors specific to an RI Site. The nature and magnitude of uncertainties depend on the amount and quality of the data available, the degree of knowledge concerning site conditions, and the assumptions made to perform the HRA.

The uncertainties associated with the Group 3 RI Sites in general are discussed in Section 1.5.3.

8.8 Ecological Risk Assessment for the WCT Area

8.8.1 Problem Formulation

The problem formulation describes the site to be assessed, specifies the assumptions and data to be employed, and is generally the foundation of the ERA. Generalized components of the problem formulation, applicable to all RI sites in Group 3, are described in Section 1.5.4.1. Problem formulation components specific to the WCT are described below.

8.8.1.2 Site Background

A discussion of the site conditions and history of the WCT Area is presented in Section 8.1.

Habitat at the site was determined based on a site survey conducted on April 7, 2008. This survey indicated that the WCT Area is made up of four habitat types, including

scrub-shrub, ruderal, and bare ground (barren areas and rocky hill slopes) (Figure 8.8-1). A large portion of the site (about 73 percent) is made up of ruderal habitat consisting mainly of coyote brush and deerweed. The ruderal habitat is located in the north-central portion of the site and adjacent to paved areas. Patchy scrub-shrub habitat makes up about 16 percent of the site and is located around the perimeter of the site and in the western portion. It is dominated by yerba santa and deerweed. The site also contains areas of bare ground (about 11 percent). These areas are comprised of bare areas and barren, rocky hill slopes and unpaved roadways. Evidence or actual observation of the following species was noted during the site visit: California towhee, red-tailed hawk, spotted towhee, American goldfinch, common raven, cottontail rabbit, coyote [scat], and western fence lizard. Dehydration-stressed vegetation was observed immediately adjacent to the WCT, but none was observed within the site.

8.8.1.3 Ecological Management Goals, Assessment Endpoints, and Measures

The ecological management goal for the WCT Area is the same as that for all Group 3 RI sites, as follows:

- Maintenance of soil, sediment, water quality, food source, and habitat conditions capable of supporting ecological receptors, including special-status species, likely to be found in the area.
- Habitats present at the WCT Area are exclusively terrestrial. Consequently, only terrestrial assessment endpoints and measures were identified for this site (Table 8.8-1).
- Representative species and receptor groups considered for the WCT Area include the terrestrial plant community (primary producers), soil invertebrate community (primary consumers), hermit thrush (primary and secondary consumer), red-tailed hawk (tertiary consumer), deer mouse (primary and secondary consumer), mule deer (primary consumer), and bobcat (secondary and tertiary consumer).

8.8.1.4 Ecological Conceptual Site Model

The generalized ecological CSM for Group 3 is presented in Section 1.5.4.4. Because the WCT Area is strictly a terrestrial location, only the terrestrial pathways are relevant. The CSM specific to the WCT Area is described below and presented in Figure 8.8-2.

The primary contaminant source at the WCT Area is the former waste cutting oil tank. Primary release mechanisms include spills or leaks from the WCT to the ground surface. Soil is the secondary source of potential contaminant. Potential secondary release mechanisms include volatilization and wind erosion, bioaccumulation from soil, and leaching from soil into groundwater.

Complete or potentially complete exposure pathways from contaminated soil and biota to ecological receptors exist at the site. Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, and small mammals resident in and associated with the site soils. Terrestrial wildlife (herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in soil by incidental ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial invertebrates and wildlife (reptiles, birds, and mammals) also may receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (plants to herbivores, plants and

prey animals to omnivores, etc.). Burrowing mammals (deer mice) may also be exposed to soil gases via inhalation. Table 8.8-2 provides a summary of the potential exposure pathways for the ecological receptors at the WCT Area.

8.8.1.5 Selection of Chemicals of Potential Ecological Concern

The process for the selection of CPECs is described in Section 1.5.4.4. Detected analytes in soil are listed in Table 8.8-3. Summary statistics for those detected analytes are listed in Table 8.8-4. A statistical comparison of site metal data to background was not possible due to the small number of samples collected from this site. The background comparison was conducted using the maximum detected site and background concentrations (Table 8.8-5). Non-detected analytes were evaluated by comparing the maximum SQLs against the minimum environmental screening level (ESL) and determining the exceedance frequency of the SQLs (Table 8.8-6). The CPECs identified for the WCT Area are summarized in Table 8.8-7. EPCs for each depth interval (0 to 2 ft, 0 to 4 ft, and 0 to 6 ft bgs) are provided in Tables 8.8-8, 8.8-9, and 8.8-10, respectively. EPCs for soil gas from 0 to 6 ft bgs are listed in Table 8.8-11.

8.8.2 Analysis

The analysis phase, which consists of the exposure characterization and the ecological effects characterization, links the problem formulation (Section 8.8.1) with the risk characterization (Section 8.8.3) and consists of the technical evaluation of ecological and chemical data to determine the potential for ecological exposure and effects. Generalized components of the exposure and ecological effects characterizations are presented in Section 1.5.4. Exposure and effects information specific to the WCT Area is presented below.

8.8.2.1 Exposure Characterization

The exposure characterization is used to evaluate the relationship between receptors at the site and potential stressors (CPECs). The methods used to estimate exposure, including receptor-specific exposure models, exposure factors, and assumptions; exposure areas; and calculation of EPCs, are described in this section.

The receptor-specific exposure models, exposure factors, and assumptions presented in Section 1.5.4.4 are used for receptors at the WCT Area. Because the WCT Area is strictly terrestrial, exposure is based on soil and soil gas and was evaluated only for terrestrial receptors (plants, soil invertebrates, birds, and mammals).

The exposure area for the WCT area is 0.1 acre. More than 80 percent of the land cover at this site consists of bare ground, rock, or ruderal vegetation. Consequently, most of the site represents habitat of poor or limited quality.

Summary statistics and EPCs for CPECs in soil at various depths (up to 6 ft bgs) and soil gas were calculated for the WCT Area, according to the approach outlined in Section 1.5.4.4. These values are presented in Tables 8.8-8 through 8.8-11. Modeled exposure estimates for bird and mammal receptors are presented as part of the risk characterization (Section 8.8.3).

8.8.2.2 Ecological Effects Characterization

The ecological effects characterization consists of an evaluation of available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effects. Generalized effects data for all receptors at the SSFL are summarized in Section 1.5.4.4. No effects data specific to the WCT Area are available. Consequently, the ESLs, Low TRVs, and High TRVs for terrestrial receptors described in Section 1.5.4.5 were used to evaluate the effects associated with the estimated exposures.

8.8.3 Risk Characterization

The risk characterization integrates estimated CPEC exposures with their potential ecological effects on the assessment endpoints for the WCT Area. The sequential processes for performing the risk characterization, described in Section 1.5.4.4, were applied to the WCT Area. The results of these comparisons are presented below.

8.8.3.1 Risk Estimation

The Risk Estimation focuses primarily on quantitative methods to evaluate the potential for risk. The results of the quantitative risk estimation are presented as HQs and HIs. HQs and HIs for evaluated receptors are provided in Tables 8.8-12 through 8.8-19. Table 8.8-15 presents an analysis of the depth intervals for evaluation of burrowing animals (deer mouse). The 0- to 6-ft-bgs depth interval had the greatest HI; therefore, the data from this depth interval were used to evaluate the deer mouse.

8.8.3.2 Risk Description

The risk description incorporates the results of the risk estimates, along with any other available and appropriate lines of evidence to evaluate potential chemical impacts on ecological receptors in Group 3. Chemicals that had HQs exceeding 1 were further evaluated to determine the COECs. Information considered in the determination of COECs includes receptor groups potentially affected, exceedance of Low and/or High TRVs, magnitude of exceedance, bioavailability, and habitat quality at the site.

To facilitate the interpretation of TRV exceedances, chemicals that exceeded one of the TRVs (Low TRV or High TRV) were assigned into seven general risk groups (1 through 7, described below). These groups were created as an additional tool to assist risk managers in making remedial decisions. The groupings are subjective, based on professional judgment, and the placement of a chemical within a given group is not an absolute indicator of the potential risk:

1. High Risk–HQs>5 for High TRV (RME), or HQs>100 for any EPC/TRV combination. Chemical classes with HIs>10 at High TRV (RME). Four or more receptors showing estimated risks.

2. Medium-High Risk–2<HQs<5 for the High TRV (RME). Chemical classes with 2<HIs<10 at the High TRV (RME) or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.

3. Medium Risk–1<HQs<2 for High TRV (RME), but HQ>10 for Low TRV (RME). Chemical classes with 1<HIs<2 at the High TRV or HIs>10 at the Low TRV. Three or more (of six) receptors showing estimated risks.

4. Medium-Low Risk–HQs<1 for the High TRV (RME), but 1<HQs<10 for the Low TRV (RME). Chemical classes with HIs<1 at the High TRV or 2<HIs<10 at the Low TRV. No more than two of six receptors showing estimated risks.
5. Low Risk–HQs<1 for the Low TRV (RME). Chemical classes with HIs<1 at the Low TRV.
6. No Risk–all HQs and associated HIs<1.
7. Uncertain–TRVs unavailable to calculate either HQs or HIs.

Seven soil analytes (boron, cadmium, chromium, iron, nickel, selenium, and Aroclor-1248) were found to have 1 or more HQs greater than 1 under any scenario (Table 8.8-20). All other soil analytes and/or analyte groups were found to pose no risk (all HQs and HIs were less than 1) to any receptor under any scenario (maximum concentration for plants, invertebrates, and soil gas exposures; CTE and RME concentrations for birds and mammals) at the WCT Area.

The estimation of incremental risks (risk in excess of background) is presented in Table 8.8-21. (Note: while incremental risks are presented, they are not used as a basis for exclusion of a chemical as a COEC.) The identification of COECs in soil is presented in Table 8.8-22.

Boron, cadmium, chromium, iron, nickel, and selenium were not retained as COECs. Estimated risks for boron exceeded one for the deer mouse only (Low TRV). Much of the estimated risk was due to background concentrations, and the maximum detected site concentration was less than 1.5 times the background concentration.

Cadmium was not retained as a COEC. Estimated risks were in the Low risk range for all receptors with the exception of the hermit thrush (Low TRV) and deer mouse (Low and High TRV). Soil samples were collected at five locations and analyzed for cadmium. The cadmium concentrations at one location exceeded the background level in two of four surface soil samples. The cadmium concentrations in surface soil samples collected at three lateral step-out locations (15-ft spacing) were all less than the background level. The sampling results indicate the exceedances, which are similar to background, are limited to isolated detections at a single location.

Chromium was not retained as a COEC. Estimated risks exceeded one for the hermit thrush (Low and High TRV), but estimated risks for all other receptors were less than one. Two samples were collected for chromium at the WCT Area with detected concentrations of 37 and 39 mg/kg. These were within 1.5 times background. Additionally, the chromium concentration in the paired duplicate sample at one location was 30 mg/kg, which is less than the background level.

Iron was not retained as a COEC. Estimated risks exceeded one for soil invertebrates (High TRV) and deer mouse (Low and High TRV). Estimated risks for all other receptors were less than one. One sample was collected for iron (32,000 mg/kg), which was less than 1.5 times background (28,000 mg/kg).

Nickel was not retained as a COEC. Estimated risks exceeded one for hermit thrush (Low TRV) and deer mouse (Low and High TRV). Estimated risks for all other receptors were

less than one. Of the two samples collected for nickel, one (26 mg/kg) was less than background (29 mg/kg); and the other (30 mg/kg) was very similar to background.

Selenium was not retained as a COEC. Estimated risks exceeded one deer mouse (Low TRV) only. Estimated risks for all other receptors were less than one. Of the two samples collected for selenium (0.36 and 0.68 mg/kg), one was less than background; and the other was similar to background (0.655 mg/kg).

In each case, estimated risks exceeded one for one or two receptors. Only a limited number of detections were greater than background, and all were less than 1.5 times background.

Aroclor-1248 was not retained as a COEC. It was never detected. Per general guidance in the SRAM (MWH, 2005b), chemicals with SQLs exceeding ESLs are retained as CPECs for evaluation in the risk assessment. The presence/actual concentration of Aroclor-1248 is uncertain and potential ecological risks are most likely over-estimated. Aroclor-1248 was not retained as a COEC because none of the other aroclors were detected.

The identification of soil gas COECs is presented in Table 8.8-23. All soil gas CPECs evaluated in this ERA were never detected. Eight non-detections were carried forward based on a comparison of SQLs to ESLs (Table 8.8-6). Five of these (1,1,2-TCA, 1,1-DCE, CTC, trichloromethane, and VC) had HQs greater than 1 (Table 8.8-14). Potential ecological risks from these analytes are considered low and are most likely over estimated.

8.8.3.3 Uncertainty Analysis

Uncertainty is an implicit component in all risk assessments. Generalized uncertainties for ERAs in Group 3 are summarized in Section 1.5.4.5. Additional uncertainties include the following:

- No screening levels were available to evaluate the TPH data. However, PAH data were available; and no risk from these constituents was predicted.
- One nondetected soil analyte (Aroclor-1248) was included in the soil screening, per the procedure dictated by the SRAM (MWH, 2005b). Because this analyte was not detected in the collected sample, basing risk off the maximum SQL is conservative; this approach probably overestimates risk from exposure to soil.
- Eight nondetected soil gas analytes were included in the soil gas screening (1,1,2-TCA, 1,1-DCE, benzene, CTC, methylene chloride, trichloromethane, and VC), per the procedure dictated by the SRAM (MWH, 2005b). Because these analytes were not detected in the collected sample, basing risk off the maximum SQL is conservative; this approach probably overestimates risk from exposure to soil gas.

8.8.4 Conclusions and Recommendations

Data available for the WCT area included a limited number of samples collected for metals, general chemistry parameters, hydrocarbons, PCBs, PAHs, and SVOCs in soil. In addition, one sample was collected from soil gas and analyzed for VOCs.

Potential risks were estimated for terrestrial plants, soil invertebrates, and terrestrial birds and mammals. Results of the risk characterization indicated the following:

- Soil–Boron, cadmium, chromium, iron, nickel, and selenium were not retained as COECs. These analytes had estimated risks to the hermit thrush and/or deer mouse, but detected concentrations were either below or similar to background concentrations. Aroclor-1248 was not retained as a COEC. It was retained for evaluation in the risk assessment because the SQL exceeded the ESL; however, estimated risks exceeded one for a single receptor at the Low TRV only. In addition, there were no detections of any other aroclors.
- Soil gas–1,1,2-TCA, 1,1-DCE, CTC, trichloromethane, and VC were not retained as COECs. None of these analytes were detected. Potential ecological risks from these analytes are considered low and are most likely over estimated.

8.9 Summary of Findings and Recommendations for the WCT Area

8.9.1 Nature and Extent of Contamination Summary

To evaluate the nature and extent of chemical constituents at the WCT Area, nine surface soil samples and one soil gas sample were collected (totals exclude field duplicate and split samples). Of the surface soil samples collected, several metals (boron, cadmium, beryllium, chromium, iron, nickel, and selenium) and lubricant-range petroleum hydrocarbons (C20-C30) were detected at levels that exceeded their respective background (for metals) and human health or ecological screening levels. Table 8.9-1 lists the parameters that exceeded the criteria.

The metals (beryllium, chromium, iron, nickel, and selenium) with detected concentrations above their respective background levels are generally considered to be similar to naturally occurring conditions, within 1.5 times background levels. Boron and cadmium exceeded their respective background and ecological and/or human health screening levels in surface soil samples collected at one location. However, two co-located surface soil samples and three lateral step-out samples exhibited no elevated boron or cadmium concentrations. Therefore, no additional evaluation of these metals appears warranted.

8.9.2 Risk Assessment Summary

The HHRA and the ERA for the WCT Area are summarized below.

8.9.2.1 Summary of Human Health Risks

This subsection summarizes the HHRA performed for the WCT Area. The HHRA assesses the potential current and future exposures to chemicals in surface soil (0 to 2 ft bgs) and soil gas. The methods used to prepare the HHRA are described in Section 1.5.3. The results of the HHRA for the WCT Area are presented in Section 8.7.

The surface soil (0 to 2 ft bgs) and soil gas samples collected during the RI sampling activities were evaluated for use in the HHRA. Subsurface soil, groundwater, surface water,

and sediment samples are not evaluated in this HHRA because they were not present during the RI site characterization activities. The HHRA data set is listed in Table H.8.1-3 in Appendix H. The COPCs identified from the WCT Area HHRA data set for each exposure area are listed in Table H.8.1-4.

The potential future receptors at the WCT Area include recreationists, workers, and residents. The WCT Area and surrounding area are likely to have a future recreational or industrial land use; however, a hypothetical future residential scenario was assessed in the HHRA, along with recreational and industrial exposure scenarios. The residential scenario consists of conservative exposure assumptions, and residents are expected to have the greatest level of exposure. The residential exposure scenario evaluated in this report assumes that exposure can occur through consuming fruits and vegetables from a garden. The agricultural residential exposure scenario evaluation will be included in a separate report at a later date.

Generally, estimated cumulative ELCRs less than the regulatory risk range (range of 1 in a million [1 x 10-6] to 1 in 10,000 [1 x 10-4]) and estimated noncancer hazards (HIs) less than the regulatory threshold value of 1 are considered acceptable (EPA, 1993). Estimated ELCRs within the 1 x 10-6 to 1 x 10-4 range are managed on a site-specific basis. Tables H.8.7-3 and H.8.7-4 summarize the ELCRs and HIs. The chemicals that are the primary contributors to the estimated ELCRs are shown in Tables H.8.4-1 and H.8.4-2.

The ELCR estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the lower end of the regulatory risk range. The HI estimates for the hypothetical future adult and child residents exposed to soil (0 to 2 ft bgs) from plant consumption exceeded the regulatory threshold value (Table H.8.7-3). The primary contributor for this scenario is cadmium (64 percent contribution; HQ=1.4), which was detected above the background level in surface soil at one location onsite. For the plant consumption pathway, although the ELCR exceeded the lower end of the regulatory risk range and the HI exceeded the regulatory threshold value of 1, no COCs are identified for this pathway because of the high uncertainties associated with plant uptake modeling (MWH, 2005b).

As described in Section 1.5.3.6, there is a degree of uncertainty associated with these risk estimates that should be considered before risk management decisions are made.

8.9.2.2 Summary of Ecological Risks

No analytes were retained as COECs at the WCT Area. Boron, cadmium, chromium, iron, nickel, and selenium had estimated risks above an HI of 1 to the hermit thrush and/or deer mouse. They were not retained as COECs because detected concentrations of these analytes were either below or similar to background concentrations. In addition, Aroclor-1248 had estimated risks to the deer mouse but was not retained because it was not detected in surface soil. No VOCs were detected in soil gas; therefore, further investigation of soil gas is not recommended.

8.9.3 Recommendations for the WCT Area

Based on the HHRA, the ELCR and HI estimates for the soil exposure pathway are less than the regulatory thresholds for the exposure scenarios evaluated. For the plant consumption pathway, ELCR values were in the lower end of the regulatory risk range of 1 x 10-6 to 1 x 10-4; and HI values were slightly greater than 1. No action is currently recommended based on the results for the plant consumption pathway. It is recommended that that the plant consumption pathway be further evaluated with the agricultural-based residential exposure scenario once the protocol to evaluate this exposure has been developed in consultation with DTSC.

The ERA did not identify any COECs for the WCT Area. Therefore, no additional investigation or evaluation of soil or soil gas analytes is recommended in the FS.

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9. Group 3 RI Summary

9.1 Summary of RI Findings for Group 3

The data presented in this document from the historical review, nature and extent of contamination, human health, and risk evaluations have provided sufficient information to gather the necessary data to support the FS. Additional data are recommended to further evaluate the extent of contamination, as well as the human health and ecological risk factors, to support FS evaluations. Furthermore, additional groundwater sampling during the wet season, sampling from within Group 3 buildings, sampling at debris areas, and sampling associated with the sewer in Group 3 are planned.

9.2 Recommendations for Consideration during FS, Human Health Risk Summary and COCs by Media and Receptors

Several chemicals significantly contribute to the estimated human health risks and hazards for the exposure areas in the Group 3 Reporting Area. The identified chemical risk drivers (COCs), and their associated risks and hazards, are used as the basis for the FS site action recommendations. The HHRA COCs for the Group 3 Reporting Area are summarized in Table 9.2-1.

Note that the HHRA included an evaluation of the plant consumption pathway for a hypothetical future residential exposure scenario. Although elevated human health risks were estimated for some of the Group 3 sites for this pathway, no site action recommendations are identified based on this pathway because of the high uncertainties associated with plant uptake modeling. It is recommended that the plant consumption pathway be further evaluated with the agricultural residential exposure scenario once the protocol for evaluating this exposure has been established in consultation with DTSC.

9.2.1 Building 204 Area

To complete the nature and extent evaluation in the Building 204 Area, additional surface soil samples for dioxins, 8 metals (antimony, cadmium, chromium VI, copper, lead, mercury, silver, and zinc), 2 PCBs (Aroclor-1254 and Aroclor-1260a), and 1 PAH (BaP) are recommended. In the subsurface soil media, additional investigation for the extent of BaP is recommended. In addition, as noted, additional subsurface soil sampling for PCBs may be warranted based on the results of potential step-out sampling for PCBs in the surface soil media.

On the basis of the results of the HHRA, the Building 204 area requires further evaluation in the FS. The total ELCR is within or exceeds the regulatory risk range (1×10^{-6} to 1×10^{-4}) for one or more exposure scenarios for soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). The total HI also exceeds the regulatory threshold of 1 for one or more exposure scenarios for soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). The primary COCs

for the Building 204 area are dioxins/furans (based on 2,3,7,8-TCDD TEQ concentrations) and 2,4-dimethylphenol in soil (0 to 2 ft bgs) and dioxins/furans in soil (0 to 10 ft bgs).

Dioxins/furans exceed the lower end of the regulatory risk range (1×10^{-6}) for the direct exposure soil (0-2 ft bgs) pathways for the residential, industrial, and recreational exposure scenarios. Dioxins/furans also contribute to an HI greater than the threshold of 1 for the residential and recreational exposure scenarios for surface soil (0 to 2 ft bgs). For the residential plant consumption pathway, dioxins/furans exceed the upper end of the regulatory risk range (1×10^{-4}). 2,4-Dimethylphenol and dioxins/furans exceed the HI threshold of 1 for the residential plant consumption pathway. For subsurface soil (0 to 10 ft bgs), dioxins/furans exceed the lower end of the regulatory risk range (1×10^{-6}) for one or more of the residential and industrial exposure scenarios. Dioxins/furans in soil (0 to 10 ft bgs) also exceed the HI threshold of 1 for the at least one of the residential scenarios. The ELCRs for the soil gas exposure pathways were less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the HIs for the soil gas pathways were less than the threshold of 1.

9.2.2 SPA Area

On the basis of the results of the nature and extent evaluation, the horizontal and vertical extents of the surface soil, subsurface soil, and soil gas exceedances have been evaluated adequately at the SPA. Therefore, no additional surface soil, subsurface soil, or soil gas samples are recommended at this site.

On the basis of the results of the HHRA, the SPA area requires further evaluation in the FS. The total ELCR exceeds the lower end of the regulatory risk range (1×10^{-6} to 1×10^{-4}) for the residential plant consumption pathway and the residential indoor air pathway (migration of soil gas COPCs). Additionally, the total HI exceeds the regulatory threshold of 1 for the residential plant consumption pathway. For the plant consumption pathway, benzo(a)pyrene, benzo(a)anthracene, and methylene chloride in soil (0 to 2 ft bgs) contribute to an ELCR that exceeds the lower end of the regulatory risk range (1×10^{-6}). Formaldehyde in soil (0 to 2 ft bgs) contributes to a HI greater than the threshold of 1 for the plant consumption pathway. The ELCR for TCE in soil gas exceeds the lower end of the regulatory risk range (1×10^{-6}) for the residential indoor air pathway. The ELCRs for the 0 to 10 ft bgs soil depth interval and the groundwater exposure pathways were less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the HIs were less than the threshold of 1.

9.2.3 ABFF Area

To complete the nature and extent evaluation in the ABFF, additional surface and subsurface soil samples for TPH analyses are recommended. Additional surface soil sampling is recommended, specifically of EFH (C21-C30) in the easterly and westerly directions from ABBS1021. Additional sampling for TPHs in a westerly direction is recommended to evaluate the extent of TPH groups in the subsurface soil near ABBS1005 and ABBS1038.

On the basis of the results of the HHRA, the ABFF area requires further evaluation in the FS. The total ELCR is within or exceeds the regulatory risk range (1×10^{-6} to 1×10^{-4}) for one or more exposure scenarios for soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs). The

primary carcinogenic COC for the ABFF area is arsenic in soil (0 to 2 ft bgs and 0 to 10 ft bgs).

For surface soil (0 to 2 ft bgs), arsenic exceeds the lower end of the regulatory risk range (1×10^{-6}) for the direct exposure pathways for the residential, industrial, and recreational exposure scenarios. For the residential plant consumption pathway, arsenic exceeds the upper end of the regulatory risk range (1×10^{-4}). For subsurface soil (0 to 10 ft bgs), arsenic exceeds the lower end of the regulatory risk range (1×10^{-6}) for the residential and industrial exposure scenarios. The ELCRs for the soil gas exposure pathways and the groundwater exposure pathways are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. The total HIs are less than threshold of 1 for all exposure scenarios evaluated at the ABFF area.

9.2.4 Bravo Area

To complete the nature and extent evaluation in the Bravo Area, collecting additional surface soil samples for dioxins, 1 PCB (Aroclor-1254), and VOCs is recommended. In the subsurface soil media, additional investigation for the extent of Aroclor-1254 and BaP is recommended. It also is recommended that additional TCE soil gas samples be collected to further evaluate the extent of contamination in the soil gas at the Bravo Area.

On the basis of the results of the HHRA, the Bravo area requires further evaluation in the FS. The total ELCR is within or exceeds the regulatory risk range (1×10^{-6} to 1×10^{-4}) for one or more exposure scenarios for soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs) and for soil gas. Additionally, the total HI exceeds the regulatory threshold of 1 for the residential plant consumption pathways for soil (0 to 2 ft bgs). The primary COCs for the Bravo area are PCBs (based on PCB TEQ concentrations), cadmium, and TCE in surface soil (0 to 2 ft bgs); PCBs in subsurface soil (0 to 10 ft bgs); and carbon tetrachloride, naphthalene, and PCE in soil gas (3 to 10 ft bgs).

For surface soil (0 to 2 ft bgs), PCBs exceed the lower end of the regulatory risk range (1×10^{-6}) for direct exposure pathways for the residential, industrial, and recreational exposure scenarios. For the residential plant consumption pathway, PCBs exceed the upper end of the regulatory risk range (1×10^{-4}). PCBs, cadmium, and TCE exceed the HI threshold of 1 for the residential plant consumption pathway. For subsurface soil (0 to 10 ft bgs), PCBs exceed the lower end of the regulatory risk range (1×10^{-6}) for the residential and industrial exposure scenarios. For soil gas, carbon tetrachloride, naphthalene, and PCE exceed the lower end of the regulatory risk range (1×10^{-6}) for the residential exposure scenario and naphthalene and PCE exceed the lower end of the regulatory risk range (1×10^{-6}) for the industrial worker exposure scenario. HIs evaluated in subsurface soil (0 to 10 ft bgs) and soil gas were all below the regulatory threshold of 1.

9.2.5 Alfa Area

To complete the nature and extent evaluation in the Alfa Area, collecting additional surface soil samples for dioxins and 4 metals (lead, nickel, silver, and zinc) is recommended. In the subsurface soil media, additional investigation for the extent of chromium, diesel range organics, and TCE is recommended. It also is recommended that additional TCE soil gas samples be collected to further evaluate its extent in a westerly direction.

The HHRA results indicate that the Alfa Area requires further evaluation in the FS. The total ELCR is within or exceeds the regulatory risk range (1×10^{-6} to 1×10^{-4}) for one or more exposure scenarios for soil at two depth intervals (0 to 2 ft bgs and 0 to 10 ft bgs) and soil gas (3 to 10 ft bgs). Additionally, the total HI exceeds the regulatory threshold of 1 for the residential plant consumption pathways and the soil gas (3 to 10 ft bgs) pathways. The primary COCs for the Alfa area are arsenic and TCE in soil (0 to 2 ft bgs) and TCE and cis-1,2-dichloroethene in soil gas (3 to 10 ft bgs).

For surface soil (0 to 2 ft bgs), arsenic exceeds the lower end of the regulatory risk range (1×10^{-6}) for direct exposure pathways for the residential, industrial, and recreational exposure scenarios. For the residential plant consumption pathway, arsenic and TCE exceed the upper end of the regulatory risk range (1×10^{-4}). TCE also exceeds the HI threshold of 1 for the residential plant consumption pathway. For subsurface soil (0 to 10 ft bgs), arsenic exceeds the lower end of the regulatory risk range (1×10^{-6}) for the residential and industrial exposure scenarios. For soil gas, TCE exceeds the upper end of the regulatory risk range (1×10^{-4}) for the residential and industrial worker exposure scenarios and exceeds the lower end of the regulatory risk range for the recreational exposure scenarios. Cis-1,2-dichloroethene in soil gas exceeds the regulatory threshold of 1 for the residential, industrial, and recreational exposure scenarios The ELCRs for the groundwater exposure pathways are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4} and the HIs for the groundwater exposure pathways are less than the threshold of 1.

9.2.6 Skyline Road Area

To complete the nature and extent evaluation in the Skyline Road Area, it is recommended that additional samples be collected for dioxin analyses in both the surface and subsurface soil media.

The HHRA results indicate that the Skyline Road area requires further evaluation in the FS. The total ELCR exceeds the lower end of the regulatory risk range (1×10^{-6}) for the residential plant consumption pathway for soil (0 to 2 ft bgs). The primary carcinogenic COCs for the Skyline Road area are dioxins/furans (based on 2,3,7,8-TCDD TEQ concentrations) in soil (0 to 2 ft bgs).

For the plant consumption pathway, dioxins/furans exceed the lower end of the regulatory risk range (1×10^{-6}). The ELCRs for the direct exposure pathways for soil (0 to 2 ft bgs and 0 to 10 ft bgs) are less than the regulatory risk range of 1×10^{-6} to 1×10^{-4}. Additionally, the total HIs are less than threshold of 1 for all exposure scenarios evaluated at the Skyline Road area.

9.2.7 WCT Area

The nature and extent evaluation for the WCT Area has been adequately completed. The ELCR and HI estimates for the soil exposure pathway for this site are less than the regulatory thresholds for the exposure scenarios evaluated. Therefore, no further investigation of chemicals in soil or soil gas at the WCT Area is recommended in the FS.

For the plant consumption pathway, ELCR values were in the lower end of the regulatory risk range of 1×10^{-6} to 1×10^{-4}; and HI values were only slightly greater than 1. No action currently is recommended, based on the results for the plant consumption pathway.

9.3 Ecological Risk Summary and COCs by Media

A combination of literature-based and site-specific data were used to evaluate risks to ecological receptors at the seven sites located in Group 3. Because no aquatic habitat is present at any site in Group 3, only terrestrial receptors were evaluated. Receptor groups included terrestrial plants (evaluated quantitatively if field observations indicated the presence of stressed plants), soil invertebrates, birds (hermit thrush and red-tailed hawks), and mammals (deer mouse, bobcat, and mule deer). All receptor groups were evaluated based on direct or indirect (through food-web transfer) exposure to soil. In addition, inhalation exposure of deer mice (as a representative burrowing animal) to contaminants in soil gas was evaluated. The results of the ecological risk evaluation for Group 3 are summarized in Table 9.3-1.

Initial screens identified 12 inorganics (aluminum, arsenic, barium, chromium, cobalt, copper, fluoride, hexavalent chromium, iron, nickel, selenium, and zinc), one phthalate (BEHP), dioxin/furan and PCB congeners, 10 pesticides (4,4-DDT; 4,4-DDE; alpha-, beta-, delta-, and gamma-BHC; dieldrin; endrin; heptachlor epoxide; and hexachlorobenzene); 2,4-dinitrophenol, and 2 VOCs (TCE and 2-chloroethyl vinyl ether), as potential risk drivers in soil (Table 9.3-1). Eight VOCs (1,1,2-TCA; 1,1-DCE; 1,1,2-trichloro-1,2,2-trifluoroethane; cis-1,2-DCE; 2-chloroethyl vinyl ether; total naphthalenes; TCE; and VC) were identified as potential risk drivers in soil gas. This initial list of analytes was reduced through consideration of detection limits, frequency and magnitude of TRV exceedances, refined exposure estimates, and incremental risks relative to background (for inorganics only). At the conclusion of the refinements to the risk evaluations at each site, significant risk drivers (those that present unacceptable risks) were reduced to chromium and dioxin/furan and PCB congeners in soil, and three VOCs (1,1-DCE; cis-1,2-DCE; TCE) in soil gas. These were generally retained based on a high magnitude of exceedance. These significant risk drivers should be carried forward for additional evaluation as part of the FS.

Only three Group 3 RI sites had unacceptable risks identified for at least one receptor from at least one COC. Unacceptable risks from chromium in soil to the hermit thrush were identified at the Alfa site. Dioxin/furan congeners in soil present a risk to hermit thrush and deer mouse at the Building 204 Area. PCB congeners in soil also present a risk to deer mice at the Alfa site. Only two sites, the Bravo and Alfa sites, had significant risks from VOCs in soil gas. Two VOCs at each site present a significant inhalation risk (Table 9.3-1).

9.4 Cross Media Transfer

Cross media transfer in SMOU groundwater in the Group 3 RI study area has been confirmed at one location and is likely at two others. Contaminant mass was verified in both the SMOU and CFOU in the vicinity of the spillway as a large input area at the Alfa Test Area. The cumulative TCE profile delineated by rock core porewater results indicates that approximately 10 percent of the contaminant mass resides in the unlithified upper 25 feet of the SMOU, which corresponds to alluvium. Core results show approximately 50 percent of the TCE mass extends downward through the alluvium and weathered bedrock section into the unweathered bedrock above the water table near 200 ft bgs. Contaminant mass at Alfa Test Area continues beneath the water table to approximately

375 ft bgs, which provides evidence of cross media transfer at this study area. Cross media transfer of VOCs in the vicinity of the spillway and catch pond system also is possible at the Bravo Test Area, based on increasing downward soil concentrations along with soil gas flux and groundwater results in both the SMOU and CFOU. The elevated TPH concentrations detected in the weathered bedrock downgradient of the ABFF Fuel Farm suggest that cross media transfer may be possible; however, the contamination delineated is localized and the occurrence of NSGW at the SWMU has not yet been verified. The migration of constituents downward to the CFOU at all known or anticipated input areas is possible via the subsurface interconnected fracture network, even though the CFOU water table is nearly 200 ft bgs throughout most of the Group 3 RI study area.

9.5 FS Recommendations for Group 3

On the basis of the evaluations presented in this document and the risk summaries presented in Sections 9.2 and 9.3, further sampling is recommended in the FS evaluations for all Group 3 sites except the WCT Area to further evaluate the extent of contamination, as well as the human health and/or ecological risk factors.

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