STANDARDIZED RISK ASSESSMENT METHODOLOGY (SRAM) WORK PLAN
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
REVISION 2 - FINAL

Prepared for:

THE BOEING COMPANY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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LIST OF ACRONYMS AND ABBREVIATIONS

ABSP	Alfa/Bravo Skim Pond
ACR	acute to chronic ratio
ADD	average daily dosage
AOC	Areas of Concern
APTF	Advanced Propulsion Test Facility
AST	aboveground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BAF	biota sediment/soil accumulation factor
BCR	Biological Conditions Report
bgs	below ground surface
Boeing	The Boeing Company
BTAG	Biological Technical Advisory Group
BTEX	benzene, toluene, ethylbenzene, xylenes
Cal-EPA	California Environmental Protection Agency
CDC	Center for Disease Control
CDD	chlorinated dibenzo-p-dioxin
CDF	chlorinated dibenzofuran
CFOU	Chatsworth Formation Operable Unit
CLP	Contract Laboratory Program
CMI	corrective measures implementation
CMS	corrective measures study
COPC	Chemical of Potential Concern
CPEC	Chemical of Potential Ecological Concern
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency exposure
CTL-III	Component Test Laboratory III
DHS	Department of Health Services
DHS-RHB	Department of Health Services - Radiologic Health Branch
DOE	U.S. Department of Energy
DTSC	Department of Toxic Substance Control
EC50	median effective concentration
ECAO	Environmental Criteria and Assessment Office
ECL	Engineering Chemistry Lab
ED50	median effective dose
EPC	exposure point concentration
EPV	exposure point values
ESL	ecological screening level
ETEC	Energy Technology Engineering Center
FSDF	Former Sodium Disposal Facility
GC/MS	Gas Chromatograph/Mass Spectrometer
GIS	geographic information system
GWTS	groundwater treatment systems

LIST OF ACRONYMS AND ABBREVIATIONS

ha	alternative hypothesis
HCPC	high-carbon petroleum constituents
HEAST	Health Effects Assessment Summary Table
HERD	Health and Ecological Risk Division
HI	hazard index
h_o	null hypothesis
HQ	hazard quotient
HWSA	Hazardous Waste Storage Area
ICF	ICF Kaiser Engineers
ICP	inductively coupled plasma
IEL	Instrument and Equipment Laboratories
IRIS	Integrated Risk Information System
LADD	lifetime average daily dosage
LC50	median lethal concentration
LCPC	low-carbon petroleum constituents
LCV	lowest chronic value
LD50	median lethal dose
LOAEL	lowest observable adverse effect level
LOEC	lowest observable effect concentration
LOEL	lowest observable effect level
LOX	liquid oxygen
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mm Hg	millimeters of mercury
MMH	monomethyl hydrazine
NASA	National Aeronautics and space Administration
NOAEL	no observable adverse effect level
NOEC	no observable effect concentration
NOEL	no observable effect level
NPDES	National Pollutant Discharge Elimination System
OEHHA	Office of Environmental Health Hazard Assessment
Ogden	Ogden Environmental and Energy Services Co., Inc.
ORNL	Oak Ridge National Laboratory
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEF	particulate emission factor
PLF	Propellant Load Facility
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RDL	reportable detection limit
RFA	RCRA facility assessment
RfC	reference concentration

LIST OF ACRONYMS AND ABBREVIATIONS

RfD	reference dose
RFI	RCRA facility investigation
RME	reasonable maximum exposure
RMHF	Radioactive Materials Handling Facility
RWQCB	Regional Water Quality Control Board
SAIC	Science Applications International Corporation
SF	scaling factor
SMMC	Santa Monica Mountains Conservancy
SPA	Storable Propellant Area
SQG	sediment quality guideline
SQL	sample quantitation limit
SRAM	Standardized Risk Assessment Methodology
SSFL	Santa Susana Field Laboratory
STL-IV	Systems Test Laboratory IV
Surficial OU	Surficial Media Operable Unit
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit
SWRCB	State Water Resources Control Board
TCA	1,1,1-trichloroethane
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCE	trichloroethylene
TEF	toxicity equivalency factor
TEQ	toxicity equivalent
TIC	Tentatively Identified Compound
TOC	total organic carbon
TPH	Total Petroleum Hydrocarbons
TRV	toxicity reference value
TTF	Thermal Treatment Facility
UCL	upper confidence limit
UDMH	unsymmetrical dimethyl hydrazine
UF	uncertainty factor
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VCAPCD	Ventura County Air Pollution Control District
VCEHD	Ventura County Environmental Health Division
VF	volatilization factor
VOC	volatile organic compound
WDR	Waste Discharge Requirement
WHO	World Health Organization
WRS Test	Wilcoxon Rank Sum Test
µg/dL	micrograms per deciliter

SECTION 1

1 INTRODUCTION

The Standardized Risk Assessment Methodology (SRAM) Revision 2 describes the methods to be used to conduct human health and ecological risk assessments for chemical contamination of the Surficial Media Operable Unit (Surficial OU) and Chatsworth Formation OU (CFOU) at the Santa Susana Field Laboratory (SSFL). This document supercedes the original SRAM (Ogden 2000a) approved by the Human and Ecological Risk Division (HERD) of the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC) during June 2000. This revision to the SRAM was requested by DTSC because it includes, expands on, and provides additional information to supplement the original SRAM.

This document has been prepared on behalf of The Boeing Company (Boeing); the National Aeronautics and Space Administration (NASA); and the U.S. Department of Energy (DOE) as part of the Resource Conservation and Recovery Act (RCRA) Corrective Action Program at the SSFL. The RCRA Corrective Action Program at the SSFL is being conducted as required by three Hazardous Waste Facility Permits issued to Boeing, NASA, and DOE by DTSC. The three permits governing the RCRA Corrective Action Program at the SSFL include (1) the Areas I and III Post-Closure Permit issued in 1995, (2) the Area II Post-Closure Permit issued in 1995, and (3) the Area IV Hazardous Waste Management Facility Operating Permit issued in 1993.

The SRAM Revision 2, hereafter referred to as the SRAM, expands upon the methods presented in the original SRAM and SRAM Revision 1 and incorporates several additional methods at the request of the DTSC. This revision of the SRAM (Revision 2) also incorporates comments made by DTSC on the draft version of this document published in June 2005. The purpose of the SRAM is to establish a standardized, regulatory-approved approach to assess the human health and ecological risk of chemicals that are present in the various environmental media (*e.g.*, air, soil, water) at the SSFL. Because risk assessment science and regulatory policy change with time, provisions are presented in this work plan that allow the proposed approach to be "evergreen" through time (see definitions provided in Section 1.7).

After the risk assessments are completed, the risk assessments will be used to help identify areas at any investigational unit that are determined to need remediation. Both wide-area and SSFL-site wide risks may need to be addressed in addition to investigation unit risks for some receptors. Area wide risks may be addressed in bundled reports which are inclusive of a large reporting area. SSFL risks may be addressed in a limited and specific site-wide risk assessment.

1.1 OBJECTIVE AND SCOPE OF THE SRAM

The objective of the SRAM is to provide a consistent approach for risk assessment at the investigational units at the SSFL. Although each investigational unit is unique, many have similar potential contaminants, exposure pathways, and receptors. As such, a consistent technical approach for all investigational units at the SSFL is proposed as the first step in the risk assessment process. The methodology will be applied to each investigational unit to determine the potential human and ecological risks due to exposures to chemicals present in various media at the SSFL.

The scope of the SRAM includes both human and ecological risk assessments and describes the following:

- establish the requirements for data to be used for the risk assessment
- identify the criteria for selection of chemicals of potential concern for the human health and ecological risk assessments
- establish a conceptual model to identify human health and ecological receptors, exposure pathways, exposure points, and exposure mechanisms
- establish the procedure for human health and ecological toxicity assessments
- develop the procedure to characterize human and ecological risk

These general tasks are common to the assessment of both human health and ecological risk. However, the specific steps recommended by the regulatory risk assessment guidance for the SSFL (see Section 1.5) sometimes overlap and sometimes diverge for the two assessments. The relationship of human health and ecological risk assessment steps, as driven by the prevailing regulatory guidance, is shown on Figure 1-1. Where the specific steps are similar, this work plan describes an approach common to both human health and ecological assessment. Where there are divergent techniques, human health and ecological assessment methods are described separately. This is reflected in the subject of subsequent sections of this work plan, which are summarized in Section 1.6.

1.2 FACILITY BACKGROUND

The SSFL is approximately 29 miles northwest of downtown Los Angeles, California, in the southeast corner of Ventura County. The SSFL occupies approximately 2,850 acres of hilly terrain, with approximately 1,100 feet of topographic relief near the crest of the Simi Hills. The Simi Hills are bordered to the east by the San Fernando Valley and to the north by the Simi

Valley. Figure 1-2 shows the general geographic location, property lines, and topography of the site.

1.2.1 History and Land Use

Table 1-1 outlines the history of property ownership at the SSFL, and Figure 1-3 identifies the location of the acquired properties. Prior to use as a rocket engine testing facility, the land at the SSFL was used for ranching and grazing. North American Aviation (a predecessor to Boeing) began using (by lease) what is now known as the northeastern portion of Area I during 1947/1948. The majority of the SSFL was acquired as part of the Silvernale property in 1954, and development of the western portion of the SSFL began soon after. Undeveloped land parcels to the south of the SSFL were acquired during 1968 and 1976, and to the north during 1998. These undeveloped portions of the SSFL were primarily used for historical ranching and grazing, and motion picture film-making. No site-related operations were conducted in these undeveloped areas.

The SSFL is jointly owned by The Boeing Company and NASA. A portion of the SSFL includes facilities owned by DOE.

The site is divided into four administrative areas (Areas I, II, III, and IV) and undeveloped land to both the north and south (Figure 1-2). The areas are owned and operated as follows (Science Applications International Corporation [SAIC] 1994):

- Area I (U.S. Environmental Protection Agency [USEPA] ID Number CAD 093365435) consists of 713 acres located in the northeast portion of the site. Boeing owns 671 acres, and the remaining 42 acres are owned by NASA. Boeing operates the entire Area I, including the NASA portion. The 42-acre NASA property in Area I was formerly owned by the U.S. Air Force.

- Area II (USEPA ID Number CA 1800090010) consists of 410 acres located in the north-central portion of the site. Area II is owned by NASA and operated by Boeing.

- Area III (USEPA ID Number CAD 093365435) consists of 114 acres in the northwest portion of the SSFL and is owned and operated by Boeing.

- Area IV (USEPA ID Number CAD 000629972 and CA 3890090001) consists of 290 acres located in the extreme northwest section of the site, which are owned and operated by

Boeing. A portion of Area IV (consisting of 90 acres that house the Energy Technology Engineering Center [ETEC]) was leased to DOE, and operated by Boeing.

- Southern Undeveloped Area in the southern portion of the SSFL is an undeveloped, open-space area that consists of approximately 1,200 acres along the southern boundary of the site. This naturally vegetated area is owned by Boeing. Industrial activities have never been conducted in this area.

- Northern Undeveloped Area in the northern portion of the SSFL, adjacent to Areas II, III, and IV, is an undeveloped open space area consisting of about 180 acres. This area is naturally vegetated and has not been used for industrial activity. It is owned by Boeing.

The SSFL has been active since 1948. Site activities have included research, development, and testing of rocket engines, water jet pumps, lasers, liquid metal heat exchanger components, nuclear energy, and related technologies. The principal activity has been large rocket engine testing by Boeing and NASA in Areas I, II, and III, and energy technology research for DOE in Area IV. Laboratory research, rocket engine assembly, and rocket engine testing are ongoing activities at the site, along with site use supporting these activities (maintenance, site engineering, environment, health and safety, and security).

1.2.2 Surrounding Land Use

Most of the land adjacent to the site property is undeveloped and mountainous. About 75 percent of the area within a five-mile radius of the site is undeveloped. Surrounding land use and the boundaries of adjacent properties in Ventura County are shown on Figure 1-4. A brief description of the land use of each of the adjacent properties is presented below.

Northern Adjacent Properties - Two properties are situated adjacent to the north of the SSFL. The adjacent property located to the northwest is occupied by the Brandeis-Bardin Institute and the adjacent property located to the northeast is occupied by the Santa Monica Mountains Conservancy (SMMC). The Brandeis-Bardin Institute 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 Brandeis-Bardin Institute indicate that this property contains religious, teaching, and camping facilities, and a cemetery. The SMMC is zoned as open space.

Eastern Adjacent Properties - The properties situated immediately adjacent to the east of the SSFL are zoned light agricultural, with variances that permit higher density use (*e.g.*, mobile

home parks). An existing residential community occurs approximately ¼ mile east of the SSFL boundary in Woolsey Canyon.

Southern Adjacent Properties - The properties situated adjacent to the south of the SSFL are used for residential purposes. While residential properties abut the southern border of the SSFL, the southern portion of the site consists of an undeveloped area lying between the active portions of the SSFL and residential areas. Dense residential development begins in the San Fernando Valley about five miles to the south of the SSFL.

Western Adjacent Properties - The properties situated adjacent to the west of the SSFL are designated by the Ventura County Planning Department as Open Space, with the exception of a 2,800 acre section of Ahmanson Ranch which is zoned Specific Plan (Rincon Consultants 2002; D. Hawkins 2003). This Open Space zoning category indicates that the purpose of the open space zoning designation is to provide for the conservation of renewable and nonrenewable natural resources, to preserve and enhance environmental quality and to provide for the retention of the maximum number of future land use options while allowing reasonable and compatible uses on open lands in the County which have not been altered to any great extent by human activities.

1.2.3 Facility Operations and Chemical Use

Operational activities at the SSFL began in 1948 and have primarily included research, development, and testing of liquid-propellant rocket engines and associated components (pumps, valves, etc.) (SAIC 1994). Liquid-propellant rocket engine testing activities have been conducted at six major rocket engine test areas: Bowl, Canyon, Alfa, Bravo, Coca, and Delta. These areas were in operation simultaneously in the late 1950s and early 1960s. The Bowl, Canyon, and Delta test areas were phased out of operation in the late 1960s and 1970s. The Coca test area was shut down in May 1988. The Alfa and Bravo test areas are currently in operation. Engine testing at these areas primarily used petroleum-based compounds as the “fuel” and liquid oxygen (LOX) as the “oxidizer.” Solvents, primarily trichloroethene (TCE), were used for cleaning of engine components. In 1961, a TCE recycling system was installed in active testing areas to capture and reuse this solvent. After 1977, TCE was only used (and reclaimed) at one test stand location (Alfa) (ICF Kaiser Engineers [ICF] 1993a,b, c). TCE use at the SSFL was discontinued in the early 1990s. In addition to the primary facility operation for testing liquid-propelled rocket engines, the SSFL was used for research, development, and testing of water jet pumps, and lasers.

From the mid 1950s until the mid 1990s, DOE and its predecessor agencies sponsored nuclear energy research and energy development projects within Area IV of the SSFL. Today, the research center is referred to as the ETEC. The research and energy development activities included nuclear energy operations (development, fabrication, disassembly, and examination of nuclear reactors, reactor fuel, and other radioactive materials) and large-scale liquid sodium metal experiments for testing liquid metal fast breeder reactor components. All nuclear energy operations ended in 1988 and included 10 nuclear research reactors, seven critical facilities, the Hot Laboratory, the Nuclear Materials Development Facility (SWMU 7.2), the Radioactive Materials Handling Facility (RMHF) (SWMU 7.6), and various test and nuclear material storage areas at ETEC. Area IV nuclear energy research and other energy development operations and facility status are summarized in a recent Environmental Assessment Report prepared in anticipation of ETEC closure activities (DOE 2003).

Laboratories, chemical storage areas, equipment assembly, and maintenance facilities have supported operations at the SSFL. Laboratories were used to supply chemicals for testing operations, or to conduct small-scale testing of materials (*e.g.*, metals). Liquid chemicals were historically stored in various types of containers and vessels including drums, aboveground storage tanks (ASTs), and underground storage tanks (USTs). Solid or powdered chemicals used at the SSFL were stored in drums or small containers and often kept in buildings or above-grade storage pads. Equipment assembly was typically performed inside buildings and only involved minimal chemical use.

A summary of the types of chemicals used for SSFL operations is provided in Table 1-2. Petroleum fuel hydrocarbons and chlorinated solvents have been used at the SSFL in the largest volumes. Petroleum hydrocarbons were used as fuel for many of the liquid-propellant rocket engine tests performed there. Chlorinated solvents, primarily TCE, were used following engine tests to clean elements of the rocket engines (*e.g.*, thrust chambers) and for other equipment degreasing operations at the SSFL. Another solvent used in lesser quantities, 1,1,1-trichloroethane (TCA), contained 1,4-dioxane as a stabilizer to increase the longevity and usefulness of the solvent. Based on facility records, 1,4-dioxane was not added to TCE as a stabilizer for rocket engine testing operations at the SSFL because it also caused an undesirable residue on engine components that did not meet specifications. Solid propellants, including perchlorate compounds, were used at the SSFL for research and testing operations. Perchlorate was used in relatively small quantities as an oxidizer for the production of turbine spinners and igniters; for research, development, and production of flares; and for small-scale solid-propellant rocket motors research, development, and testing (MWH 2003a). Polychlorinated biphenyls

(PCBs) were present in some waste oils, and oils within pre-1980 electrical transformers at various sites within the SSFL.

Other chemicals may have entered the environment as by-products of operations at the SSFL. The periodic burning of off-spec fuels in ponds may have produced polychlorinated dibenzodioxins and dibenzofurans (collectively referred to in this document as "dioxins"). N-nitrosodimethylamine may have been produced by the environmental breakdown of unsymmetrical dimethyl hydrazine (UDMH). UDMH and monomethyl hydrazine (MMH) were used as a fuel in testing certain rocket engines for research and development at a few limited locations within the SSFL. Various metals may have used in machining operations, or stored or disposed as construction debris.

Chemical and solid wastes created from facility operations have been managed through various methods. Three landfills were used at the SSFL primarily for disposal of nonhazardous, inert construction debris (*e.g.*, concrete, asphalt, rock, soil, etc.). Liquid wastes from engine testing were managed until the 1980s in a series of both flow-through and retention ponds. Ten of these ponds (impoundments) have undergone closure; one was clean-closed, and nine were closed as RCRA-regulated investigational units, managed under the Post-Closure Permit (described further in Section 1.2, below). After closure of these impoundments, wastes were managed for offsite recycling, treatment, or disposal. Extensive efforts at waste reduction and minimization over the last 20 years have greatly reduced the volume and types of wastes produced at the SSFL. Waste management at the SSFL has been performed consistent with standard practices of the time throughout the SSFL's history and is performed in compliance with applicable laws and regulations.

1.3 REGULATORY PROGRAMS AND OVERSIGHT

A comprehensive environmental program is conducted at the SSFL under the jurisdiction of several federal, state, and county regulatory agencies. Because it is an active facility, five environmental programs at the SSFL are being conducted under the authority of RCRA. However, other federal, state, and county environmental programs are also being performed at the SSFL. These programs are designed so that facility operations are conducted in an environmentally protective manner, and that investigation and cleanup are performed to meet regulatory standards. Both RCRA- and non-RCRA-related programs are described in the following sections.

1.3.1 RCRA Programs

The RCRA-related activities at the SSFL include five major environmental programs, all under the oversight and jurisdiction of the DTSC. These programs include (1) RCRA Corrective Action, (2) Closure of inactive RCRA units, (3) Compliance/permitting of RCRA units, (4) Groundwater Characterization and Remediation, and (5) Interim Measures. In some instances these programs overlap (*e.g.*, closed RCRA investigational units within RCRA Facility Investigation (RFI) sites are investigated as part of Corrective Action). Although related under RCRA, each program has separate process requirements and guidelines. Collectively, these programs represent a comprehensive program for the handling and cleanup of hazardous chemicals. Investigation and cleanup of radioactive constituents are under oversight of DOE and the Department of Health Services (DHS) as described in Section 1.3.2 below.

RCRA Corrective Action

This program includes the RCRA facility assessment (RFA), RFI, corrective measures study (CMS), and corrective measures implementation (CMI) phases. Corrective Action at the SSFL is being conducted as required by the Stipulated Enforcement Order issued by DTSC in 1992. Specifications regarding the ongoing Corrective Action Program were subsequently provided in three Hazardous Waste Facility Permits issued to Boeing, NASA, and DOE by DTSC. The three permits governing the RCRA Corrective Action Program at the SSFL include (1) the Areas I and III Post-Closure Permit issued in 1995, (2) the Area II Post-Closure Permit issued in 1995, and (3) the Area IV Hazardous Waste Management Facility Operating Permit issued in 1993.

The first phase of the RCRA Corrective Action, the RFA, was conducted for USEPA in 1989 identified 122 Solid Waste Managements (SWMUs) and Areas of Concern (AOCs) at the SSFL (SAIC 1991). These include any units at the SSFL that have used, stored, or handled various hazardous materials. When finalized in 1994, the RFA included three additional sites for a total of 125 SWMUs and AOCs at the SSFL (SAIC 1994). During the subsequent RFI phase of Corrective Action, 10 additional AOCs have been identified at the SSFL. All 135 SWMUs and AOCs currently identified at the SSFL are listed in Table 1-3 and shown on Figure 1-5 and, either individually or as combined groups, represent investigational units that will be among the subjects of the risk assessment process. Because of the association of most leach fields with RFI Sites, these are not shown individually on Figure 1-5 except where they are independent units (Area IV).

The SSFL RCRA Corrective Action program is currently in the RFI phase. Identified SWMUs and AOCs undergoing closure as part of the RFI program have been grouped by location for investigation and are called "RFI sites." Fifty-one RFI sites have been identified for investigation and are shown on Figure 1-6 and listed in Table 1-4. Both surficial media and groundwater characterization are ongoing as part of the RFI. The scope and approach for the overall RFI program are further described in Sections 1.3 and 2 of this document. Site investigation is being conducted under DTSC-approved work plans (Ogden 1996, 2000b, 2000c; Montgomery Watson 2000; MWH 2001). Since 1984, over 17,500 laboratory analyses have been performed on more than 10,000 samples collected from surficial media during this program. As part of the groundwater characterization effort since 1990, over 5,000 feet of bedrock core have been drilled and more than 4,000 samples have been collected and analyzed.

Closure of Inactive RCRA Regulated Units

This program includes the closure of 12 units used to store RCRA-regulated wastes. These units include 10 former surface impoundments, a PCB storage area and a Hazardous Waste Storage Area (HWSA). These closed RCRA units are:

- Advanced Propulsion Test Facility (APTF) Impoundments 1 and 2 (SWMUs 4.9, 4.10)
- Alfa/Bravo Skim Pond (ABSP) (SWMU 5.12)
- Storable Propellant Area (SPA) Impoundments 1 and 2 (SWMUs 5.16, 5.17)
- Propellant Load Facility (PLF) Impoundment (SWMU 5.22)
- Delta Skim Pond (SWMU 5.24)
- Engineering Chemistry Lab (ECL) Pond (SWMU 6.2)
- Systems Test Laboratory IV (STL-IV) Impoundments 1 and 2 (SWMUs 6.6, 6.7)
- Building 231 PCB Storage Facility (SWMU 5.2)
- HWSA Container Storage Area (SWMU 5.8)

Nine of the closed surface impoundments are being managed and monitored according to the Post-Closure Permits administered by DTSC. The first permit applies to five Boeing impoundments in Areas I and III, and the second applies to four NASA impoundments in Area II. These Post-Closure Permits were finalized and issued to Boeing and NASA in May 1995. The PLF impoundment was clean-closed by the DHS because it was never used. The two remaining units (PCB Storage Facility and HWSA Container Storage) were sampled and closed by DTSC in 1998, since no contamination was identified.

Compliance/Permitting of RCRA Units

This program includes the permitting and compliance of active and inactive RCRA-regulated units at the SSFL, including storage areas and waste disposal practices. The three current permits issued by DTSC for active RCRA facilities at the SSFL include the Areas I and III Post-Closure Permit, the Area II Post-Closure Permits for groundwater treatment system operations, and the Operating Permit for the Area IV Hazardous Waste Management Facility (SWMU 7.2). Closure of the Area IV Hazardous Waste Management Facility began in 1998 and is ongoing at the time this report was prepared. Interim status authorization has also been issued to Boeing by DTSC to operate the DOE-owned Area IV RMHF.

In addition, this program also includes ongoing or future closure activities for other sites under RCRA Permits issued by DTSC: the Thermal Treatment Facility (TTF) (SWMU 4.8), the Hazardous Waste Management Facility (SWMU 7.2), the RMHF (SWMU 7.6), and the Building 029 Reactive Metal Storage Yard (SWMU 7.11).

Groundwater Monitoring and Remediation

SSFL groundwater characterization began in the early 1980s and continues as part of a monitoring program under DTSC oversight. This ongoing program consists of continuing groundwater monitoring and groundwater remediation. To date, over 14,000 chemical analyses have been performed on more than 8,000 samples collected from groundwater wells during this program. Groundwater monitoring and remediation are also performed in support of the surface impoundment Post-Closure Permits described above. In addition to regular monitoring and characterization activities, the groundwater RFI being conducted includes several additional, comprehensive tasks. Further information regarding the groundwater RFI characterization program is provided in Sections 2 and 3 of the *RCRA Facility Investigation Program Report* (MWH 2004a).

Thirty-two extraction wells supply water to the eight RCRA-permitted groundwater treatment systems (GWTS) at the SSFL. Currently, three of the GWTS are not being operated but remain on stand-by. Sampling of effluent at the GWTS locations has been conducted since 1986. To date, over 6,900 samples have been collected during this program. These samples are all regularly analyzed for volatile organic compounds (VOCs). Perchlorate is also monitored at four of the treatment systems.

Interim Measures

Interim measures have been conducted under DTSC oversight as part of the RCRA Corrective Action Program. Interim measures are cleanup activities that address a specific contamination issue that requires immediate cleanup. Sites where interim measures have been completed are still subject to the RCRA Corrective Action Program and will be evaluated as part of the RFI and, as appropriate, during the CMS and CMI. To date, interim measures for soil cleanup have been completed at the Happy Valley site in Area I (MWH 2004b) and the Former Sodium Disposal Facility (FSDF) site in Area IV (IT 2002). Building 203). Interim measures for groundwater contamination were initiated in the late 1980s under Los Angeles Regional Water Quality Control Board (RWQCB) oversight. The ongoing groundwater pump and treatment systems described above, now under DTSC permit, is a continuation of this interim measure.

1.3.2 Non-RCRA Environmental Programs

Environmental programs not related to RCRA include environmental permitting (including air and surface water discharges), other types of site investigation, and closure activities. These programs, under the jurisdiction of various agencies, include the activities described below.

Fuel Storage Tanks

Two types of storage tank programs are being conducted at the SSFL. The UST program includes soil investigation and cleanup associated with fuel USTs historically used at the site. This program was under the jurisdiction of the Ventura County Environmental Health Division (VCEHD). However, based on review of previous data and discussions with the RWQCB and VCEHD, DTSC assumed oversight of ongoing UST investigations at the Instrument and Equipment Laboratories (IEL) and B-1 Area investigational units. Soil investigation and cleanup associated with fuel and solvent ASTs historically used at the site is included in the RFI program under the oversight of DTSC.

Environmental Permitting

The SSFL is an active industrial facility with several types of environmental permits. Current environmental permits include those for surface water and air discharges.

Historically, waste discharges from the SSFL have been regulated since 1959. Waste Discharge Requirements (WDR) were issued by the RWQCB to regulate sewage and industrial waste discharge onsite (*i.e.*, nonhazardous leach fields). There are no longer any active leach fields at

the SSFL, and the WDR permit was rescinded by the RWQCB in 1994. Sewage treatment plants are inactive (standby status), and all sanitary waste is disposed to the municipal sewer system.

Surface water discharge from the SSFL is regulated under an National Pollutant Discharge Elimination System (NPDES) permit issued by the RWQCB, beginning in 1984. Surface water discharges from the site are regularly monitored at 18 NPDES locations, shown on Figure 1-6, as per the NPDES permit (effective August 2004). Since 1998, over 2,400 laboratory analyses have been performed on more than 200 samples collected from the eight sampling locations routinely monitored in this program.

Air emissions at the SSFL are regulated and permitted by Ventura County Air Pollution Control District (VCAPCD). Emissions of carbon monoxide, nitrogen and sulfur oxides, reactive organic compounds, and particulate matter are managed in accordance with all applicable rules, regulations, and permit conditions. In addition, lead and asbestos abatement work performed at the facility is managed as required by applicable local, state, and federal regulations. When required, notifications are prepared and submitted to the appropriate regulatory agencies.

Landfills

Nonhazardous solid waste landfills are regulated by the RWQCB and VCEHD. Currently, the SSFL has two inactive nonhazardous landfills, which are inspected quarterly by VCEHD (Area I and Area II Landfills, SWMUs 4.2 and 5.1, respectively). These landfills are being investigated as part of the RCRA Corrective Action Program under oversight of the DTSC, RWQCB, and VCEHD. A third landfill, the Building 56 Landfill (SWMU 7.1), is located in Area IV and is also being investigated under DTSC oversight as part of the RFI. Locations of these three sites are shown on Figure 1-6. There are no designated hazardous waste landfills at the SSFL.

Mixed and Radioactive Waste Monitoring and Closure Activities

Radioactive materials have been used in Area IV of the SSFL. The only remaining nuclear-related activity at the SSFL is decontamination and decommissioning of former nuclear facilities. DOE owns some buildings and equipment in Area IV and has primary jurisdiction of monitoring radioactive materials in this area. The DHS Radiologic Health Branch (DHS-RHB) oversees the Boeing-owned Radioactive Materials License, conducts facility verification surveys, concurs with the radioactive facility cleanup, and conducts environmental monitoring. SWMUs or AOCs identified in the RFA with potential radioactive contamination (SAIC 1994) are being addressed by the DOE site closure programs. Potential chemicals at these sites are being addressed by the

RFI under DTSC oversight, after DOE has approved each site for unrestricted use. The process followed when former radioactive facilities are also RCRA RFI sites is that radiological characterization, cleanup (if necessary), and closure are completed first. This is then followed by RCRA Correction Action to address any chemical contamination.

1.4 RCRA CORRECTIVE ACTION AND OPERABLE UNITS

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 OUs (DTSC 1999a). As defined by USEPA, an OU is a discrete entity that may comprise various attributes including the characteristics of the impacted media, geographical location, vertical and aerial considerations, specific site problems, potential exposure pathways. An OU may also consider various phases of an action, any set of actions performed over time, or any actions that are concurrent but located in different parts of a site. The cleanup of a site can be divided into a number of OUs, depending on the complexity of the problems associated with the site.

The OUs identified at the 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 the SSFL through discussion with 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 1999a). The OUs at the SSFL are:

- the CFOU, comprised of the Chatsworth formation aquifer, and both saturated and unsaturated unweathered (competent) bedrock; and,
- the Surficial OU, comprised of saturated and unsaturated soil, sediment, surface water, near-surface groundwater, air, biota, and weathered bedrock. Near-surface groundwater is groundwater that occurs within the alluvium or weathered bedrock.

The boundary between these two OUs is the boundary between weathered and unweathered bedrock. A brief description of each OU is provided below and depicted graphically on Figure 1-7.

It should be noted that one of the goals of the RFI program is to characterize contamination in all environmental media at the SSFL – this goal will be achieved by combining and integrating site

data from the characterization programs for both OUs. Similarly, the goal of the RFI risk assessment program is to evaluate risks from all environmental media at the SSFL. This will be accomplished by combining the estimated risk associated with exposure pathways for both OUs. Reporting and evaluation aspects of the OU delineation are further described below. This revision of the SRAM (Revision 2) incorporates the CFOU. Further discussion of the exposure pathways for the SSFL is provided in Section 4 of this work plan.

1.4.1 Chatsworth Formation OU

The CFOU consists of the groundwater and associated unweathered, competent bedrock of the Chatsworth formation. Approximately 170 groundwater wells associated with the Chatsworth formation are sampled and analyzed on a regular basis. As described above, Chatsworth formation groundwater is currently being extracted and treated onsite at the GWTS.

Chatsworth formation bedrock is comprised of thickly bedded sandstone with interbeds of siltstone and shale and is unweathered and competent within the CFOU. This investigational unit has been impacted by downward flow of chlorinated solvents (primarily TCE) from surficial spills and/or by dissolved contaminants transported by Chatsworth formation groundwater. However, due to its nature and depth, it is unlikely human or ecological receptors would be exposed to chemicals in the unweathered, deeper bedrock (surficial impacts to weathered bedrock are addressed in the Surficial OU). Direct exposures to Chatsworth formation groundwater could only occur through the installation of a drinking water well, or at a surface seep or spring supplied by Chatsworth formation groundwater.

1.4.2 Surficial Media OU

The Surficial OU consists primarily of soil, sediment, and surface water, which are potentially impacted by spills or waste management practices at the SSFL. Also included in this OU are near-surface groundwater, 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 and potentially be transferred to near-surface groundwater, air, biota, and weathered bedrock.

Soil and surface sediment are typically comprised of fine-grained silty sands, with occasional silts and clays. Surface water is present in ponds, intermittent streams, and surface seeps across the site. Near-surface groundwater is present only in selected locations at the SSFL; its occurrence generally follows topographic constraints and coincides with alluvial deposits. Biota

has been included in the Surficial OU because organisms may take up chemicals from surficial media.

Migration between OUs

Several possible pathways of migration of chemicals across or between OUs have been identified. These are:

Migration from the CFOU to the Surficial OU

- Migration of volatile chemicals (via vapor transport) from Chatsworth formation groundwater or deep, unweathered bedrock to surficial media (soils, weathered bedrock, near-surface groundwater, and air). When available, direct measurement data will be used to evaluate this migration. However, when direct measurement of surficial soil vapor cannot be collected, field validated vapor flux model calculations will be used to evaluate this migration.

- Migration of nonvolatile chemicals (via mass transport) from Chatsworth formation groundwater to surficial media (soils, weathered bedrock, seeps, springs, surface water, near-surface groundwater). This occurs when the level of Chatsworth formation groundwater either rises within surficial media (*i.e.*, then defined as near-surface groundwater), or discharges at the surface as a spring or seep. Direct measurement of Chatsworth formation groundwater at existing wells and spring/seep monitoring data will be used to evaluate this migration pathway.

Migration from the Surficial OU to the CFOU

- Migration of chemicals (via mass transport or leaching) from surficial media (soil, weathered bedrock, surface water, near-surface groundwater) to Chatsworth formation groundwater or deeper bedrock. This pathway will be evaluated on a case by case basis with respect to potential sources in the Surficial OU and relative chemical concentrations measured in Surficial OU media and Chatsworth formation groundwater or deep bedrock.

This SRAM describes procedures for assessing the risks associated with the possible migration of chemicals from the CFOU to the Surficial OU. These pathways are further described in Section 4. Characterization of the CFOU and evaluation of its associated pathways are in progress. Where Chatsworth formation groundwater exists at near-surface depths in direct communication with the near-surface groundwater zone, or where near-surface and Chatsworth

formation groundwater cannot be differentiated, groundwater data from wells at or near the investigational unit will be evaluated as part of the Surficial OU risk assessment (see Section 2.6).

Based on this approach, risks from all media at the SSFL will be considered for corrective action decisions although the timing of those decisions will vary for the media assessed. Corrective actions based on risk management decisions for the Surficial OU will therefore be sufficient to protect all media within the Surficial OU. Possible impacts of residual chemicals within the Surficial OU on CFOU media will be evaluated in the risk assessment(s) for the CFOU.

1.5 GUIDANCE AND AUTHORITIES

While there are several regulatory authorities with jurisdiction for environmental compliance at the SSFL, the organization with primary authority for applying risk-based decisions is the DTSC of Cal-EPA. Thus, the primary source of guidance for this work plan comes from DTSC.

In the case of human health risk assessment, this guidance is the *Supplemental Guidance for Human Health Multimedia Risk Assessment of Hazardous Waste Sites and Permitted Facilities* (DTSC 1992). For ecological risk assessment, DTSC guidance is contained in *Guidance for Ecological Risk Assessment of Hazardous Waste Sites and Permitted Facilities* (DTSC 1996). In each of these documents, DTSC references specific guidance documents from USEPA. These guidance documents served as secondary sources for development of the present work plan and include the following:

- Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A) (USEPA 1989a)
- Exposure Factors Handbook, Volume I. General Factors (USEPA 1997a)
- Guidelines for Ecological Risk Assessment (USEPA 1998)

In addition, risk assessment guidance from the California Office of Environmental Health Hazard Assessment (OEHHA) was also used where appropriate. Other appropriate guidance and relevant published literature was used in the development of the work plan and is cited throughout the document.

1.6 WORK PLAN ORGANIZATION

This SRAM work plan is organized into the following sections:

- Section 1 describes the SSFL and the scope, objectives, and approach of the SRAM and other ongoing environmental programs at SSFL
- Section 2 presents the data requirements for use in the human health and ecological risk assessments.
- Section 3 describes the hazard identification process and identification of chemicals of potential concern (COPCs) for human health and chemicals of potential environmental concern (CPECs) for ecological risk assessments, including a discussion of background.
- Section 4 describes the conceptual site model approach for human receptors.
- Section 5 presents human exposure models.
- Section 6 presents methods for estimating exposure point concentrations for the human health assessment.
- Section 7 presents the human toxicity assessment procedure.
- Section 8 describes the human risk characterization procedure.
- Section 9 presents the ecological problem formulation with selection of ecological receptors, identification of exposure pathways, and the ecological conceptual site model.
- Section 10 describes the ecological exposure assessment procedure.
- Section 11 presents the ecological toxicity criteria.
- Section 12 describes the ecological risk characterization procedure.
- Section 13 lists references cited in this document.

The following are included as appendices to this document:

- Appendix A Derivation of Polychlorinated Biphenyl Extrapolation Factors
- Appendix B Derivation of Total Petroleum Hydrocarbon Extrapolation Factors
- Appendix C Ecological Screening Level Calculations
- Appendix D Soil Background Report
- Appendix E Groundwater Comparison Data Set Report
- Appendix F SSFL Physical Parameters Tables
- Appendix G Vapor Migration Modeling Methodology
- Appendix H Example Human Health Risk Summary Tables
- Appendix I Biological Conditions Report (March 2005 Update)
- Appendix J Large Home Range Species Exposure
- Appendix K Bioaccumulation Factor Calculations

1.7 DEFINITIONS

Terms are used in this methodology that have specific meaning with respect to the SSFL or the processes described. The following are definitions of special or important terms:

1. The entirety of the SSFL, including Areas I through IV as described in earlier work plans and work plan addenda for environmental investigations (ICF Kaiser 1993a,b,c; Ogden 1996) and the undeveloped land along the southern boundary, will hereinafter be referred to as the "site."

2. Individual portions of the site subject to environmental investigations, such as SWMUs and AOCs under the Corrective Action requirements of RCRA, will be referred to as "investigational units" or simply "units."

3. "Reporting Areas" are either an investigational unit or a group of investigational units.

4. An "operable unit" (OU) is a discrete action that comprises an incremental step toward comprehensively addressing site issues. An OU may be a portion of a remedial response, a geographical portion of a site, or any actions that are concurrent but located in different parts of a site. At the SSFL, OUs are specific media or groups of media that will be characterized together and include (1) Chatsworth Formation OU (CFOU): Chatsworth formation groundwater and inaccessible, unweathered (competent) bedrock and (2) Surficial OU: near-surface groundwater, soil, sediment, surface water, air, biota, and accessible weathered bedrock.

5. A "Chemical of Potential Concern" (COPC) is a potentially site-related chemical with data of sufficient quality for use in quantitative human health risk assessment.

6. A "Chemical of Potential Ecological Concern" (CPEC) is a potentially site-related chemical with data of sufficient quality for use in quantitative ecological risk assessment.

7. "Pristine conditions" are concentrations of metals in soils naturally occurring in locations unaffected by human activity (DTSC 1997).

8. "Ambient conditions" are concentrations of compounds in soils in the vicinity of a site that are unaffected by site-related activities. Ambient conditions are sometimes referred to as "local background" (DTSC 1997).

9. "Type I error" is rejecting the null hypothesis when it is true. Type I error is often called a "false positive." An example of Type I error would be identifying a metal as a COPC when its concentrations are within the range of ambient conditions.

10. "Type II error" is accepting the null hypothesis when it is false. Type II error is often called a "false negative." An example of Type II error would be identifying concentrations of a metal as within the range of ambient conditions, and thus not a COPC, when contamination is actually present.

11. "Dioxins" refers to the family of polychlorinated dibenzo-p-dioxin and dibenzofuran compounds.

12. "Toxicity equivalency factor" (TEF) is a normalizing factor used to relate the relative contribution to total exposure and risk of the various dioxin and furan congeners.

13. "Coplaner PCBs" refer to the 12 PCB congeners for which the World Health Organization (WHO), as published in Van den Berg *et al*. (1998), has developed TEFs.

14. "Toxicity equivalent" (TEQ) is the total dioxin and furan concentration of a sample expressed as the sum of the product of the individual congener concentrations and their TEF.

15. An "exposure area" is the minimum area that will sustain an assumed exposure in humans or ecological receptors. An exposure area may be larger or smaller than an investigational unit or may encompass several investigational units. Boeing recognizes that specification of exposure areas larger or smaller than investigational units is subject to DTSC approval and may provide proposals on a study-by-study basis.

16. A "human receptor" is a hypothetical individual who may be exposed to compounds in the environment. Receptors are often identified by the behaviors that determine how or with what intensity they may be exposed, such as "workers" or "residential receptors."

17. An "ecological receptor" is an organism that occurs onsite that may be exposed to compounds in the environment.

18. An "exposure route" is a mechanism of uptake. Environmentally relevant exposure routes for both human and ecological receptors typically include inhalation, ingestion, and absorption through the skin.

19. USEPA (1989a) defines an "exposure pathway" as consisting of four elements: (a) source and mechanism of chemical release; (b) retention or transport mechanism through an environmental medium; (c) point of potential contact with the impacted medium (*i.e.*, an exposure point); and (d) exposure route at the exposure point. If any of these elements is missing, the exposure pathway is considered "incomplete," and compound uptake via the pathway would not occur.

20. An "exposure point concentration" (EPC) is the concentration of a COPC in a medium at the location where a receptor is assumed to make contact with that medium. Depending on the nature of the exposure, an EPC may be estimated at a specific point (*e.g.*, a wellhead), or may need to be averaged about an "exposure area" (*e.g.*, the soil surface). It may also be necessary to take account of the potential for the EPC to change in time.

21. DTSC (1996) defines an "assessment endpoint" as the environmental attributes that are considered critical to the function of the biological community or population. The assessment endpoint is the ultimate focus of the ecological risk assessment.

22. DTSC (1996) defines a "measurement endpoint" as the measurable observable change that is used to evaluate the effects of chemicals of concern on the selected assessment endpoints. Measurement endpoints are specific qualities of an ecosystem that can be measured and that relate to the general ecosystem to be protected.

23. The term "evergreen" refers to the concept that the methods and assumptions described in the SRAM may be modified in the future based on scientific advancements or changes in regulatory guidance or policies.

SECTION 2

2 DATA REQUIREMENTS AND SELECTION CRITERIA

All sample analytical results will be evaluated to determine their suitability for use in the risk assessment. The data quality assessment performed on the sampling results will follow the criteria provided by USEPA in the *Guidance for Data Usability in Risk Assessment (Part A), Final* (USEPA 1992a). The criteria specified by USEPA will be met for sampling data results used in any risk assessment of investigational units at the SSFL. The data assessment will be based on the five criteria described in Sections 2.1 through 2.5. Findings of the data quality assessment will be presented in the RFI reports.

Although USEPA provides a comprehensive framework for risk assessment data requirements, specific data requirements for any particular data point will be established based on how that data point will be used during the risk assessment (*e.g.*, what decision is to be made based on that data) (USEPA 1992a). The establishment of any alternative data requirements will be approved by DTSC prior to use in any risk assessment.

In addition to the data requirements described above, methods for selecting representative data sets for groundwater, PCBs, and total petroleum hydrocarbon (TPH) constituent concentrations are presented in this section. The data selection criteria and methodologies described herein are common to all risk assessments for the SSFL, and have been developed in conjunction with DTSC.

2.1 DATA SOURCE REVIEW

The data source review evaluates the analytical methods performed on the sample with respect to site use information. The objective of the review is to ensure that appropriate analytical methods are used to identify all potential COPCs for each environmental medium of interest.

2.2 DOCUMENTATION

The documentation review evaluates the manner in which samples were managed by the field sampling teams and receiving laboratories. The objective of this review is to ensure that each analytical result can be associated with a sampling location and that appropriate procedures were used to collect the environmental sample. The three types of documentation that will be used to trace samples and analytical methods are chain-of-custody forms, standard operating procedures, and field sampling and analytical records.

Data obtained from previous reports will be appropriately reviewed. The criteria used to evaluate information contained in the previous reports include:

- 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
- a description of the data review
- a description of the field conditions and physical parameters

2.3 ANALYTICAL METHODS AND DETECTION LIMITS

For an analytical result to be usable for assessing risk, 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 (*e.g.*, benchmark). The significance of detection limits greater than benchmark levels will be evaluated on a case-by-case basis in the discussion of uncertainty. Typical sample analytical suites and the chemical compounds detected are summarized in Table 2-1. The analytical methods listed in Table 2-1 include both historical and current laboratory procedures used for sample analysis at investigational units at the SSFL. This table summarizes the analytical methods for any sample collected at an investigational unit that may be used in the risk assessment; sampling at any investigational unit will be performed according to an agency-approved sampling plan specifying the appropriate analytical methods to be used.

Where a chemical species (*e.g.*, trivalent versus hexavalent chromium) is not specified, a conservative assumption—considering the following information; site use, media of concern, and environmental chemistry—relative to the potential for the most toxic form to be present will be applied as appropriate.

2.4 DATA REVIEW AND VALIDATION

All sample data utilized in the risk assessment will be reviewed and validated. The data will be validated following the guidance set forth in USEPA's *Contract Laboratory Program National*

Functional Guidelines for Organic Data Review (1994a), and USEPA's *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (1994b).

Soil matrix, soil vapor, and water sample data will be 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 results, surrogate recoveries, matrix spike/matrix spike duplicate recoveries and precision, reporting limits, and field quality control (QC) sample results (equipment rinsate blanks, field blanks, and field duplicates).

A more detailed validation may be performed on selected data according to requirements specified in the relevant work plan for field studies for the investigational unit in question. The additional review may include, but is not limited to, evaluation of calibration data; gas chromatography/mass spectrometry (GC/MS) tuning; internal standards; confirmation analyses; inductively coupled plasma (ICP) interference checks; post digestion spikes; all raw data (quantitation sheets, extraction benchsheets, chromatograms, and analysts log sheets); and all information pertinent to the collection, extraction, and analysis of the samples.

The data validation procedures are designed to meet overall project data quality objectives. Data qualifiers will be assigned to data with associated qualification codes, which denote the specific reason for the qualification. The data qualifiers that may be assigned to a sample with a qualification code are shown in Table 2-2. A list of qualification codes that explain the reason for the data qualifier is provided in Table 2-3. Section 6 presents specifications for the use of qualified data.

2.5 DATA QUALITY INDICATORS - REPRESENTATIVENESS AND COMPLETENESS

Data will be evaluated to determine how well the chemicals are characterized. Data representativeness is an evaluation of site characterization, *i.e.*, how well the samples describe investigational unit conditions (*e.g.*, are samples appropriately placed to reveal potential releases and have all compounds potentially related to activities at the investigational unit been analyzed). Completeness relates to whether enough sample results are retained after validation to adequately characterize the investigational unit. Additionally, the data will be reviewed to determine if the variability of chemical concentrations in time and space are adequately characterized.

2.6 GROUNDWATER DATA SELECTION CRITERIA

Groundwater that occurs within the alluvium or weathered bedrock is defined as near-surface groundwater, while groundwater in unweathered, competent bedrock of the Chatsworth formation is defined as Chatsworth formation groundwater. As such, these groundwaters may represent potentially complete exposure pathways for human and ecological receptors (see Section 4.1.2). At the SSFL, near-surface groundwater is primarily monitored by wells and piezometers constructed with open intervals within the alluvium and/or weathered bedrock. However, some near-surface groundwater at the site is also monitored by deeper wells constructed with open intervals within both the overlying weathered bedrock and deeper unweathered (competent) bedrock. Depending on groundwater levels, water quality data from these deeper wells could represent near-surface groundwater conditions and should be considered near surface groundwater. During 2000, discrete depth interval monitoring systems were installed in some deep wells to provide additional understanding of the chemical distribution within the Chatsworth formation groundwater system. Recent monitoring data (water levels and water quality information) have been collected from the weathered bedrock portion of these wells and should also be considered near surface groundwater.

Because of the complexity of the data available for the SSFL risk assessments, selection criteria have been established to maintain consistency of groundwater data used. These criteria include the definition of and identification of CFOU and near-surface groundwater monitoring wells and the selection of the water quality data set, as described below:

1. Definition of Near-Surface Groundwater 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 an open interval exposed to the alluvium/weathered bedrock, and historical water levels that have risen to within that alluvium/weathered bedrock interval.

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 three year period will be evaluated to determine whether the adequately reflects water concentrations to which potential receptors will be exposed. All historical groundwater monitoring data will be evaluated to assure representativeness for the three-year period used. In addition, groundwater data from upgradient monitoring wells will be evaluated to determine what chemicals may migrate resulting in future exposures.

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

c) Compare the analytes represented in the CFOU or near-surface groundwater data set with those mobile chemicals (*e.g.*, VOCs, perchlorate) selected as COPCs in soil and soil vapor and determine the need for inclusion of certain mobile soil or soil vapor COPCs as CFOU or near-surface groundwater COPCs.

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

2.7 PCB EXTRAPOLATION METHODOLOGY

Historically, PCB samples collected at SSFL investigational units have been analyzed using USEPA Method 8082, with PCBs reported as Aroclor mixtures (*e.g.*, Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260). To date, only Aroclors 1254 and 1260 have been detected at the SSFL using this analytical method. Aroclor 1254 is the predominant Aroclor mixture detected at the SSFL; Aroclor 1260 has only been detected in a few soil samples (Ogden 1999).

Recent developments in risk science have prompted DTSC to request an evaluation of potential risks based on both Aroclor mixture analytical results and PCB congener analytical results. The impetus for DTSC's request is the fact that certain coplanar PCB congeners act through similar mechanisms and exhibit similar toxic responses to that of dioxins (Van den Berg *et al*. 1998). Therefore, risks should be assessed using the dioxin toxicity equivalency approach described in Section 7.4. Furthermore, PCB congeners may be measured at much lower concentrations using USEPA Method 1668 than Aroclor mixtures using USEPA Method 8082. The availability of

USEPA- and DTSC-approved analytical methods for PCB congeners, as well as the development of methods for assessing risks associated with PCB congeners, are relatively recent developments with respect to the RFI program. Therefore, because PCB congener data are not available for many of the sites for which Aroclor data are available, data were collected specifically for the purpose of evaluating the relationship between Aroclor concentrations and PCB concentrations in order to develop a method for estimating PCB concentrations from Aroclor results specific for the site.

This section describes the evaluation of the relationship between detected concentrations of Aroclors and detected concentrations of PCB congeners in soil. The purpose of this evaluation was to develop a method for estimating PCB congener concentrations, using Aroclor sampling results, for use in site-specific risk assessments at the SSFL. This approach allows use of all the PCB data collected at an investigational unit and provides a more complete evaluation of potential site risks.

As requested by DTSC, potential risks associated with PCBs will be 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.* 1998), and (2) risks associated with a total Aroclor mixture (USEPA 1996a). Potential risks associated with the 12 PCB congeners and potential risks associated with Aroclor mixtures will be presented separately in the risk assessments. The PCB extrapolation methods described in this section will be used to estimate the concentrations of each of the 12 PCB congeners in samples for which only Aroclors have historically been detected.

The sampling and analytical program for this PCB extrapolation methodology was developed in conjunction with DTSC based on previous Aroclor results at the SSFL investigational units. Seven samples for both Aroclor and congener analysis were colocated with previous samples with elevated Aroclor results. Table 2-4 presents the site locations, samples, and analyses for samples collected during this program. Field, laboratory, and validation procedures used for this sampling event followed DTSC-approved RFI protocols (Ogden 2000b). Analytical results and data validation reports for these samples are presented in Appendix A. Data review indicated all data were useable for risk assessment. Field, laboratory, and validation procedures for this sampling event are further described in the RFI Program Report (MWH 2004a). All site-specific PCB data will be used in the RFI site reports.

Only the 12 PCB congeners applicable to risk assessment, as described by Van den Berg *et al*. (1998), were evaluated to develop a method for extrapolating Aroclor concentrations to PCB congener concentrations. Each of these 12 congeners was detected in each of the seven soil samples, with the exception of PCB 169, which was only detected in two duplicate samples. Aroclor 1254 was detected in all seven soil samples; Aroclor 1260 was only detected in two samples.

To develop Aroclor-specific extrapolation factors, Aroclor 1254 and 1260 were evaluated separately. Only pairs of detected data (Aroclor and congener) were included in the evaluation. Due to small sample size, regression analysis was not considered appropriate for relating Aroclor concentrations to congener concentrations. Rather, the ratio of congener concentration to Aroclor concentration was determined for each set of paired results. For non detect PCB 169 results, the concentrations were estimated at one-half the sample quantitation limit (SQL). The maximum ratio of PCB congener to Aroclor concentration was conservatively selected as the extrapolation factor to be used for predicting congener concentrations in risk assessments at the SSFL. Use of the maximum ratio gives the maximum degree of confidence (based on this data set), that the predicted PCB congener concentrations will be greater than actual congener concentrations. Its use, therefore, tends to over-predict, rather than under-predict, actual congener concentrations. This uncertainty will be discussed in each of the investigational unit risk assessments for which the method is employed. The calculations used to derive Aroclor to PCB extrapolation factors are also presented in Appendix A. The extrapolation factors that will be used in risk assessments at the SSFL are summarized in Table 2-5.

Aroclor to congener extrapolation factors will be used to predict PCB congener concentrations as described in Equation 2-1.

$$C_{congener} = EF \times C_{Aroclor} \quad (2\text{-}1)$$

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])

Note that all data used to derive Aroclor to PCB congener extrapolation factors were reported on a dry weight basis, and therefore, extrapolation factors can only be applied to soil samples in

which Aroclor concentrations were reported on a dry weight basis. If data are not reported on a dry weight basis, then the sample-specific percent moisture content report by the laboratory will be used to convert Aroclor concentrations to a dry weight basis.

The application of PCB extrapolation factors requires that during COPC and CPEC selection, assumptions are made regarding the presence of PCB congeners based on the presence of Aroclors. This requirement is described in detail in Section 3.1. The specific methods for applying PCB extrapolation factors during the process of calculating EPCs are described in Section 6.2.

2.8 TOTAL PETROLEUM HYDROCARBON EXTRAPOLATION METHODOLOGY

Risks associated with TPH impacts are commonly included in risk assessments based on the petroleum constituent concentrations rather than the TPH results because toxicity criteria for TPH are not well established or approved within the regulatory community. For the purpose of evaluation in this SRAM, petroleum chemical constituents include: benzene, toluene, ethylbenzene, and xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), 2-methylnaphthalene, and naphthalene (collectively, "petroleum constituents"). The petroleum constituents and their molecular formulas are presented in Table 2-6.

As required by the RFI work plans and site reviews by DTSC, TPH data are used to determine the nature and extent of a petroleum release at an investigational unit, and typically greatly outnumber the petroleum constituent data. 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 the petroleum constituent concentration.

This section describes the evaluation of the relationship TPH fraction and petroleum constituent concentrations. The purpose of this evaluation was to develop a method for estimating petroleum constituent using TPH fraction sampling results for use in site-specific risk assessments at the SSFL. This approach allows use of all the TPH data collected at an investigational unit and provides a more complete evaluation of potential site risks. The TPH extrapolation methods described in this section are applicable only to soil media, and cannot be used for other media or for extrapolation between different media.

The sampling and analytical program for this TPH extrapolation methodology was based on previous TPH results at the SSFL investigational units. Sixteen soil samples were colocated near previous soil samples with elevated TPH fraction results. Each colocated sample was analyzed

for TPH, VOCs (including BTEX), and/or PAHs. Because different types of petroleum constituents are associated with different carbon ranges of TPH fractions, the sampling program differed depending on previous TPH fraction results. BTEX, naphthalene, and 2-methyl-naphthalene are associated with the lighter, "low-carbon" (C08-C11) petroleum constituents (hereafter designated LCPC) whereas PAHs are associated with the heavier, "high-carbon" (C11-C14, C14-C20, C20-C30) petroleum constituents (hereafter designated HCPC).

The initial premise for this sampling and analysis approach was that any individual petroleum constituent would only occur within one of the four TPH fractions based on the number of carbons comprising the compound. For example, acenaphthene has 12 carbons, and therefore, would only occur within the C11-C14 TPH fraction. In the case of benzene and toluene, which have six and seven carbons, respectively, it was assumed that the C08-C11 fraction may be an indicator of their presence. Although benzene and toluene contain less carbons than the low-carbon TPH fraction (C08-C11), they were included in this evaluation because they are commonly associated with petroleum mixtures that contain the C08-C11 TPH fraction.

Table 2-7 presents the site locations, samples, and analyses for samples collected during this program. Sixteen samples were collected and analyzed for this evaluation at previous locations with elevated high-carbon TPH fraction results, and eight samples at previous locations with elevated low-carbon TPH fraction results. Field, laboratory, and validation procedures used for this sampling event followed DTSC-approved RFI protocols (Ogden 1996, 2000b), or augmented them to allow for low-level detection limit methodologies. Analytical results and data validation reports for these samples are presented in Appendix B. Data review indicated all data were useable for risk assessment. Field, laboratory, and validation procedures for this sampling event are further described in the RFI Program Report (MWH 2004a). All site-specific TPH and petroleum constituent data will be used in the RFI site reports.

In most cases, linear regression analysis of individual petroleum constituents against the applicable TPH fractions did not produce correlations between petroleum constituents and TPH fractions that were adequate for extrapolation purposes. An attempt to correlate PAHs to the sum of the high-end fractions (*i.e.*, C11-C30) also failed to produce good correlations (Appendix B, Attachment 1). In most cases correlations were either negative or had low regression coefficients (*i.e.*, $r^2 < 0.5$). Further, comparison of some historical TPH data with more recent TPH data found a systematic error in the reporting of historical TPH data from one laboratory during a specific time frame (Columbia Analytical Services [CAS], between 1997 and 2000). The concentrations of C11-C14 fraction reported by CAS during this period were consistently biased

low and the concentrations of C14-C20 were consistently biased high (Appendix B, Attachment 2). The historical TPH fraction C08-C11 data and C08-C11 data collected for this evaluation were found to be comparable.

Because of the discrepancy between recent and historical high-carbon fraction TPH data, and the lack of good correlation between petroleum constituents and individual TPH fractions, the following approach was developed for estimating petroleum constituent concentrations in soil from historical TPH data.

1. The C08-C11 TPH fraction will be used for estimating BTEX, 2-methylnaphthalene, and naphthalene concentrations by application of TPH C08-C11 to LCPC extrapolation factors to RFI site TPH C08-C11 soil sample data.

2. The sum of the concentrations of the C11-C14, C14-C20, and C20-C30 TPH fractions, equivalent to C11-C30, will be used for estimating PAH concentrations by application of TPH C11-C30 to HCPC extrapolation factors to RFI site TPH C11-C30 soil sample data.

3. The maximum ratio of individual petroleum constituent concentrations to TPH concentrations from the data sets of paired TPH and petroleum constituent samples will serve as chemical-specific extrapolation factors in the SSFL risk assessments.

4. The data used to calculate extrapolation factors include only detected TPH data, but include both detect and non detect petroleum constituent data. Non detect petroleum constituent data were not included in the calculations because these data would result in ratios that are neither conservative nor meaningful.

The maximum ratios of individual petroleum constituent concentrations to TPH concentrations were determined by first calculating the individual chemical- and sample-specific ratios for each set of paired petroleum constituent and TPH data. For each petroleum constituent, the maximum ratio was then selected as an extrapolation factor for use in SSFL risk assessments. Both detect and non detect TPH data were used in the above calculations because petroleum constituents were generally detected in all samples (with the exception of benzene) regardless of whether TPH fractions were detected. Use of non detect TPH data and detect petroleum constituent data result in maximum possible ratios.

The spreadsheet presenting all data and calculations of maximum ratios is presented in Appendix B, Attachment 3. Use of the maximum ratio gives the maximum degree of confidence

that the predicted petroleum constituent concentrations will be greater than actual petroleum constituent concentrations. Its use, therefore, tends to over-predict, rather than under-predict, actual concentrations.

The TPH extrapolation factors that will be used in risk assessments at the SSFL are summarized in Table 2-8.

TPH extrapolation factors will be used to predict LCPC and HCPC concentrations as described in Equations 2-2 and 2-3, respectively.

$$C_{LCPC} = EF \times C_{C08\text{-}C11} \quad (2\text{-}2)$$

Where,

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

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

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

$$C_{HCPC} = EF \times C_{C11\text{-}C30} \quad (2\text{-}3)$$

Where,

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

$C_{C11\text{-}C30}$ = 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])

All data used to derive extrapolation factors were reported on a dry weight basis, and therefore, extrapolation factors can only be applied to soil samples in which TPH concentrations were reported on a dry weight basis. In cases where TPH data are reported on a wet weight basis, then sample-specific moisture content data reported by the laboratory will be used to adjust the data to a dry weight basis. As noted previously, the TPH extrapolation methods described in this section are applicable only to soil media, and cannot be used for other media or for extrapolation between different media.

The application of TPH extrapolation factors requires that during COPC and CPEC selection, assumptions are made regarding the presence of individual petroleum constituents based on the presence of specific TPH fractions. This requirement is described in detail in Section 3.1. TPH

extrapolations will only be applied at investigational units where no combustion is known or suspected to have taken place—at sites where combustion is known or is evident, direct measurements of PAHs in soils will be made. The specific methods for applying TPH extrapolation factors during the process of calculating EPCs are described in Section 6.2.

This extrapolation methodology for evaluating TPH in risk assessment is similar to the 'fraction-ation' method developed by the TPH Criteria Working Group (TPHCWG, 1997a,b; 1998a,b; 1999). In both procedures, TPH data are represented by fraction-specific toxicity criteria. Both methods are similar in that the toxicity of the specific hydrocarbon fraction is represented by a specific compound. For example, both methods use benzene and carcinogenic PAHs as indicator compounds to evaluate cancer risk. Differences between the two methods include:

1. The TPHCWG uses toxicity criteria representative of both aliphatic and aromatic fractions of LCPCs. The SRAM TPH extrapolation methodology uses only toxicity criteria for the aromatic constituents of LCPCs. However, as mentioned by the TPHCWG (1997b), aromatic fractions are considered to be at least an order of magnitude more toxic than the aliphatic fractions. Therefore, the use of the toxicity criteria for aromatics is conservative.

2. The TPHCWG uses toxicity criteria representative of both aliphatic and aromatic fractions of HCPCs. The SRAM TPH extrapolation methodology uses only toxicity criteria for the aromatic constituents of HPCPs. However, this is conservative because the aromatic fractions are considered to be at least an order of magnitude more toxic than the aliphatic fractions.

3. The TPHCWG divides both aromatic and aliphatic constituents into three groups. The SRAM TPH extrapolation methodology uses two groups for aromatic constituents.

4. The TPHCWG considers all the toxicity of a given hydrocarbon fraction to be equal to a specific chemical. In the SRAM, specific hydrocarbon fractions are assumed to contain numerous chemicals and each of those are assumed to be present for purposes of the risk assessment. In many cases, the same chemicals assumed to be present by the SRAM methodology are those used in the TPHCWG methodology to be representative of the entire fraction.

The SRAM TPH extrapolation methodology is considered appropriate for estimating exposures and risks at SSFL. The methodology is similar to other published methods (*e.g.*, TPHCWG) and uses petroleum constituents generally considered the more toxic components of TPH (*i.e.*,

BTEX, PAHs). The SRAM TPH extrapolation methodology conservatively estimates the risks associated with exposures to TPH.

SECTION 3

3 HAZARD IDENTIFICATION

A large number of individual analytes will be considered for inclusion in the risk assessment. It is neither appropriate nor necessary to carry every chemical compound through the risk assessment process in order to quantify site-related risks. DTSC (1992) and USEPA (1989a) provide guidance on methods for selecting COPCs for purposes of risk assessment.

Section 3.1 describes the process for selecting COPCs for evaluation within risk assessments conducted at the SSFL. The selection of COPCs relies on a multi-step process of screening data from each unit subject to environmental investigation. This method will be applied to select COPCs for human health risk assessment.

The steps included in the selection of human health COPCs are generally applicable to selecting CPECs. However, further review of data may be required to determine if additional compounds need to be addressed based on special effects in nonhuman species. Additional steps in the CPEC selection process that are specific to the ecological risk assessment are discussed in Section 3.2.

Among the criteria discussed below is an evaluation of whether unit-related compounds are consistent with soil background or groundwater comparison concentrations. Section 3.3 provides a detailed description of the methodology for making this comparison.

Methods for extrapolating soil Aroclor concentrations to soil PCB congener concentrations, and soil TPH concentrations to soil petroleum constituent concentrations, were described in Section 2.7 and 2.8, respectively. These methods require certain assumptions about the presence of TPH constituents when a TPH fraction is selected as a COPC or CPEC, and about the presence of PCB congeners when an Aroclor is selected as a COPC or CPEC. Following the methods described in Section 3.1, when TPH fraction C8-C11 is selected as a COPC or CPEC, then benzene, toluene, ethylbenzene, xylenes, naphthalene, and 2-methylnaphthalene will be selected as COPCs and/or CPECs. When either TPH fraction C11-C14, C14-C20, or C20-C30 is selected as a COPC or CPEC, then PAHs will be selected as COPCs and/or CPECs. When any Aroclor is selected as a COPC or CPEC, then all 12 PCB congeners described in Section 2.7 will also be selected as COPCs and/or CPECs.

3.1 COPC SELECTION CRITERIA

The goal of the risk assessment is to estimate the potential risks to human and ecological receptors from site-related chemicals under reasonable exposure scenarios (USEPA 1989a,b). To ensure that the focus of the risk assessment is on site-related chemicals, COPCs are selected using several criteria. The criteria used to select COPCs ensure that site-related chemicals that may pose a human health or ecological risk are included in the evaluation and, if risks are above acceptable levels, subsequently in remedial response actions. The following sequential criteria will be applied to select COPCs in the human health evaluation:

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

A decision flow diagram for selecting human health COPCs is shown on Figure 3-1. All excluded data will be documented in the investigational unit risk assessments, including the rationale for the removal.

3.1.1 Candidate Compounds

The first step in the COPC selection process is the evaluation of candidate COPCs. Candidate COPCs are selected from chemicals that have been detected at an investigational unit and meet acceptable data quality requirements (USEPA 1989a, 1992a). Any compound detected in a useable data set will be a candidate COPC.

3.1.1.1 Data Validation

For those analytes that meet the quality assurance/quality control (QA/QC) requirements, the data will be sorted by environmental media (*i.e.*, soil, sediment and groundwater) and the SQL will be evaluated. Those compounds detected in the validated samples will be included as candidate COPCs. It may also be necessary to retain undetected compounds as candidate COPCs if the chemical may be site-related, and if SQLs in one or more samples are too high to adequately evaluate the presence or absence of the compound. For purposes of the SRAM, a high

SQL is defined as being inconsistent with reportable detection limits (RDLs). RDLs are the laboratory's estimate of what the SQL will be, based on optimal analytical conditions and theoretical sample weight. Table 3-1 presents RDLs for analytical procedures specified by USEPA in the Contract Laboratory Program (CLP).

High SQLs will be evaluated on a case-by-case basis using best professional judgment and knowledge of the investigational unit. Possible outcomes include:

- requesting additional sampling
- retaining the compound on the COPC list
- determining that the higher SQL does not alter the decision to remove the compound from the COPC list

When a high SQL is used to remove a compound from the COPC list, justification will be provided to DTSC in the Hazard Identification section of the risk assessment report.

3.1.1.2 Tentatively Identified Compounds

A Tentatively Identified Compound (TIC) is reported based on an analytical pattern that approximately fits the mass and retention time pattern of a particular chemical. However, "approximate" is the operative word. By definition, the pattern diverges sufficiently from the pattern in the analytical library that neither the identity nor reported concentration can be confirmed. TICs will not generally be considered as COPCs for the following reasons:

- The identity of a TIC is not as certain as compounds identified in the analyte list. Thus, it is not clear whether the compound is actually present.
- TICs are frequently general compound classes (*e.g.*, "C-8 compounds") for which specific toxicity data are not available.
- TICs are frequently compounds for which no toxicity data are available.

When TICs are encountered, the risk assessor may include the compound as a COPC for purposes of "screening" the compound in the risk assessment. However, the assessor may also offer a justification based on (1) probability of the compound identity (*i.e.*, demonstrate that an attempt to identify the unknown, based on judgment by an analyst, was not possible) or (2) infeasibility of doing a risk assessment to eliminate the TIC from the COPC list. If a TIC is eliminated from the list of COPCs, it will be discussed in the uncertainty assessment of the risk assessment report.

3.1.2 Screening Candidate Compounds

Candidate compounds may be screened to determine whether they will be included as COPCs in the quantitative risk assessment. A serial multi-step screening process will be used to evaluate candidate compounds[i], including comparison of detected site concentrations to comparison concentrations, evaluation of frequency of detection, and consideration of blank contamination. Each of these steps is described in the following subsections.

3.1.2.1 Soil Background and Groundwater Comparison Concentrations

Soil and groundwater samples collected from individual units or from appropriately scaled exposure areas will be evaluated using the two-tiered approach described in DTSC (1997) guidance *Selecting Inorganic Constituents as Chemicals of Potential Concern for Risk Assessments at Hazardous Waste Sites and Permitted Facilities.* This approach is described in Section 3.3. Inorganic analytes and dioxins, whose concentrations at units are determined to not be representative of concentrations in the soil background and groundwater comparison concentration data sets, will be identified as candidate COPCs.

Since the goal of a risk assessment is to evaluate site-related risks, the elimination of chemicals as COPCs can appropriately be applied to either inorganic chemicals or dioxins determined to be present in the local ambient environment and not related to the site (USEPA 1989a,b, 1994c). If a chemical is present in soil or groundwater as part of ambient conditions, defined as concentrations in the vicinity of a site or local background, that chemical should be fully considered in the background evaluation (USEPA 1989a). Although DTSC policy specifically addresses the issue of background levels of inorganic chemicals, DTSC has agreed that this policy may be extended to dioxins since they are widespread throughout the environment, and because background levels of dioxins have been well characterized by USEPA (1994c) and others in the scientific literature.

Both naturally occurring chemicals and anthropogenic chemicals meet the criteria for background chemicals, as specified by USEPA (1989a, 1994c). USEPA defines the two sources of background chemicals that are considered in the risk assessment process as follows (USEPA 1989a, p. 4-5):

[i] It is noted that the selection of COPCs is a serial process. That is, each criterion is applied to the candidate compounds that remain after application of the previous selection criterion. For instance, the frequency of detection criterion will only be applied to compounds that have been selected from the candidate COPC list because they are in excess of site-specific soil background or groundwater comparison concentrations.

> naturally occurring levels, which are ambient concentrations of chemicals present in the environment that have not been influenced by humans … [and] anthropogenic levels, which are concentrations of chemicals that are present in the environment due to human-made, nonsite sources.

Therefore, the USEPA definition of background is fully aligned with their definition of a COPC to the extent that only site-related chemicals are evaluated in the risk assessment, and those chemicals detected in site media that are not site related are present due to natural sources or offsite anthropogenic sources.

DTSC (1997) further differentiates between pristine and ambient conditions as described in the following definitions:

> "Pristine conditions" are concentrations of metals in soils naturally occurring in locations unaffected by human activity. "Ambient conditions" are concentrations of metals in soils in the vicinity of a site but which are unaffected by site-related activities (also referred to as local background).

Background levels of metals and dioxins are the result of both natural and anthropogenic sources. Both can be characterized in the context of "pristine conditions" and "ambient conditions." Metals occur naturally within the geologic matrix and as a result of atmospheric deposition and other nonpoint sources (USGS 1984). Dioxins are also present in the environment due to natural sources (*i.e.*, forest fires, volcanoes) and atmospheric deposition, primarily related to various combustion processes (USEPA 1994c). Therefore, background levels of metals and dioxins will be evaluated in the risk assessments conducted at the SSFL.

The proposed protocols, described in Sections 3.3 are consistent with both state and federal regulatory guidance (DTSC 1992; USEPA 1989a,b,c, 1992a,b, 1994c).

3.1.2.2 Frequency of Detection

Analytes that are infrequently detected may be artifacts in the data due to sampling, analytical, or other errors. Analytes will be identified as COPCs if they are detected in greater than five percent of the samples at a site (USEPA 1989a; DTSC 1992) or when use of a chemical at the site is historically documented. Application of the selection criterion necessarily requires that 20 or more samples be in the candidate data set. Therefore, the frequency of detection step in the screening process will not be applied at sites with fewer than 20 samples.

Professional judgment must be applied to findings with a frequency of detection between zero percent and five percent. Thus, this step in the selection process will review data on a case-by-case basis and retain infrequently detected compounds as COPCs if:

- The compound was historically present in processes associated with the investigational unit.
- The compound is potentially a breakdown product of other compounds detected at the investigational unit.
- The compound is present in other media within the investigational unit.
- The compound is present in the same or other media in areas that may impact the investigational unit (*e.g.*, upgradient or adjacent areas).
- The compound is detected in a concentration high enough relative to its toxicity to be cause for concern, even if its presence is limited[ii].
- Samples with detections are grouped spatially.
- Other judgments make it difficult to rule out the possibility that a compound is present at an environmentally relevant concentration.

This evaluation will be discussed in an appropriate section of the risk assessment report.

3.1.2.3 Blank Contamination

In the event of blank contamination of samples, if a compound is not associated with past activities at the investigational unit and the analyte is a common laboratory contaminant, it will only be identified as a COPC if the concentration in any sample from the candidate data set is greater than ten times the concentration observed in the corresponding blank. If an analyte detected in the blank is not a common laboratory contaminant, it will be included as a COPC unless the observed concentrations are less than five times the corresponding blank. “Common” laboratory contaminants are:

- acetone
- 2-butanone (also know as methyl ethyl ketone, MEK)
- methylene chloride
- toluene
- any common phthalate ester

[ii] The potential presence of a compound in a “hot spot” such as described here may potentially impact health based on chronic and/or acute exposure assessment. Such evaluations require separate exposure assumptions and will be developed as needed.

As a practical matter, the validation procedures for many data sets (as described in Section 2) call for ranking a compound as "non detect" if observed concentrations are less than tenfold or fivefold higher than observations of common laboratory contaminants or other compounds, respectively. Thus, the evaluation of compounds based on blank contamination may actually be applied within the data validation step.

If a compound encountered in the blank does not meet the specifications for proportionally greater concentrations than the blank, but was associated with former unit activities, Boeing will either resample and/or reanalyze for the compound or include the compound as a COPC regardless of the blank contamination. Additionally, the compound found in the blank will be included as a COPC if any of the following conditions is true:

- The compound is present in other media within the investigational unit.
- The compound is present in media upslope, upgradient, or in areas adjacent to the investigational unit onsite.
- The compound is a breakdown product of other compounds detected at or adjacent to the investigational unit.

Where a portion of the samples of the compound in question have concentrations greater than the corresponding blank criterion, but other samples have detectable levels above the criterion, the compound will be identified as a COPC. However, if all samples without blank contamination are non detect, the compound will not be identified as a COPC.

3.1.2.4 Special Mixtures

Certain compounds that typically exist as mixtures, specifically PCB and TPH, have or will be evaluated at many of the investigational sites using analytical methods that account for the whole mixture, as opposed to individual chemical compounds. Thus, an additional "rule" for including all or a portion of the individual compounds making up a mixture in the list of COPCs and/or CPECs is required. The general approach applied to hazard identification for the mixtures will be to apply the selection criteria described above to the analytical results for the mixture (*i.e.*, Aroclor for PCBs or TPH fractions as a representation of the various compounds that may exist in a petroleum based product). Where criteria indicate inclusion is appropriate, individual compounds present in the mixture will be included in the COPC/CPEC list. Methods for extrapolating soil Aroclor concentrations to soil PCB congener concentrations, and soil TPH concentrations to soil petroleum constituent concentrations, were described in Section 2.7 and 2.8, respectively, and indicate that the following assumptions are appropriate:

- When TPH fraction C8-C11 is selected as a COPC or CPEC, then benzene, toluene, ethylbenzene, xylenes, naphthalene, and 2-methylnaphthalene will be selected as COPCs and/or CPECs.

- When either TPH fraction C11-C14, C14-C20, or C20-C30 is selected as a COPC or CPEC, then PAHs will be selected as COPCs and/or CPECs.

- When any Aroclor is selected as a COPC or CPEC, then all 12 PCB congeners described in Section 2.7 will also be selected as COPCs and/or CPECs.

3.2 ADDITIONAL CRITERIA FOR SELECTION OF CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN

Selection of CPECs can vary from the selection of COPCs for human health risk assessments. Exposure pathways, chemical detection limits, and mode of toxic action for ecological receptors may differ significantly from human receptors. Therefore, additional criteria for selection of CPECs have been added to the COPC screening methods described above to further identify data that are adequate for conducting an ecological risk assessment. The decision process for the selection of CPECs is summarized on Figure 3-2 and is discussed in more detail below.

Analytical detection limits for soil, sediment, and water samples may not be sufficiently sensitive to detect concentrations reported to cause adverse effects in ecological receptors, particularly in aquatic systems. RDLs for USEPA CLP methods are presented in Table 3-1. To assure that chemicals are not eliminated as CPECs if their analytical detection limits are not sufficiently low to detect chemical concentrations that could cause adverse effects, a toxicity screening step has been included in the CPEC selection process. As described in Section 3.2.1, ecological screening levels (ESLs) were developed for the purpose of evaluating analytical detection limits in the CPEC selection process. The application of ESLs in the CPEC selection process is described in Section 3.2.2.

3.2.1 Ecological Screening Levels

As discussed in Section 3.2, an additional step is included in the CPEC selection process to assure that chemicals with analytical detection limits (*e.g.*, SQLs) exceeding a level of ecological concern are not eliminated as CPECs. In general, if SQLs exceed ESLs, then those chemicals with SQLs exceeding ESLs will be carried forward as CPECs in the ecological risk assessment.

Since ESLs were developed for screening purposes only, they are not intended and may not be used as toxicological benchmarks for establishing cleanup levels.

ESLs were developed for both aquatic and terrestrial habitats. For aquatic habitats, ESLs were developed for surface waters, and are based on available water quality criteria such as the USEPA's Ambient Water Quality Criteria (AWQC) for the protection of aquatic organisms. For terrestrial habitats, ESLs were derived for small mammals and avian species using exposure values and models described in Section 10.7 and chronic toxicity data. Because avian and mammalian ESLs developed for SSFL are derived using site-specific data, these ESLs are only applicable for environmental conditions and ecological receptors found at the Facility. For terrestrial invertebrates, ESLs are based on toxicity-concentration data reported in the scientific literature. The methods used to derive ESLs are summarized in Appendix C, Attachment 1, and the ESL calculation spreadsheets are presented in Appendix C, Attachment 2. No ESLs for terrestrial plants were derived and applied because of the limited appropriate and applicable phytotoxicity data. Screening of potential effects on plants was based on findings of observational studies (see Sections 11.3 and 12.1.4 for future details).

Aquatic habitat ESLs are summarized in Table 3-2. Terrestrial habitat ESLs for small mammals, avian species, and invertebrates are summarized in Tables 3-3, 3-4, and 3-5, respectively.

3.2.2 Application of ESLs in the CPEC Selection Process

This section describes the application of aquatic habitat (water) and terrestrial habitat (soil) ESLs in the CPEC selection process for ecological risk assessments to be conducted at the SSFL. ESLs will be used in the CPEC selection process to ensure that SQLs for chemicals in soil and water samples are sufficiently low to detect a chemical concentration that could pose a risk to ecological receptors.

For aquatic habitats, the ESLs presented in Table 3-2 will be compared to investigational unit SQLs for chemicals measured in water. For terrestrial habitats, the lowest chemical-specific ESL presented in Tables 3-3, 3-4, and 3-5 will be used for comparison to investigational unit SQLs for chemicals measured in soil. Because SQLs are sample-specific detection limits, each chemical data set will comprise a range of SQLs. Therefore, only a portion of the SQLs in a data set may actually exceed the ESL, while the remaining SQLs will be lower than the ESL. Depending on the sample size, there may be a sufficient number of samples in a data set with SQLs less than ESLs to ensure that chemicals are not present at levels that could pose an ecological risk. 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 (*i.e.*, sample size, frequency of detection, number of SQLs below the ESL) will be presented in the risk assessment in cases where a chemical with one or more SQLs exceeding the ESL is excluded as a CPEC.

3.3 COMPARISON OF SITE DATA TO SOIL BACKGROUND AND GROUNDWATER COMPARISON CONCENTRATION DATA

DTSC risk assessment policy indicates metals should be included as COPCs or CPECs, if the site-specific analytical data indicate conditions are in excess of "background" (DTSC 1997). As discussed in Section 3.3.1.3, this policy is also applicable to dioxins.

The following subsections outline a method to determine whether onsite investigational unit soil and groundwater data are consistent with soil background conditions and groundwater comparison concentrations at the SSFL for purposes of selecting COPCs and CPECs. Section 3.3.1 provides the mathematical approaches for comparing investigational unit data to soil background or groundwater comparison concentration data. Appendix D provides details of the soil background data set, including the analytical data and process used to establishing site-specific soil metal and dioxin background concentrations, and tabular and graphic presentations. As discussed in Appendix D, soil metal and dioxin background concentrations are based on data collected from DTSC approved locations at and in the vicinity of SSFL.

Appendix E describes the derivation of the groundwater comparison data set and comparison concentrations. As discussed in Appendix E, a groundwater comparison data set was established to conservatively represent unimpacted, naturally occurring conditions at or below background in the vicinity of SSFL. Because of data variability related to improving analytical methods through time, sample variability, hydrogeologic complexity, and the focus of the SSFL monitoring well network on VOC impacts, there was uncertainty that the full range of background concentrations could be identified. The groundwater comparison data set provides a conservative threshold that serves as one tool to evaluate COPCs and completeness of characterization. Constituents will be selected as COPCs using these comparison concentrations, other site data, and best professional judgment. The COPC selection will be described in each investigational unit risk assessment. A more specific background determination may be made for selected constituents if necessary based on risk assessment findings during the CMS.

DTSC policy discusses the use of a simple comparison of investigational unit and metals comparison data distributions, and, if necessary, the use of a statistic called the Wilcoxon Rank Sum (WRS) Test for comparison with investigational unit data (DTSC 1997). Both approaches make use of complete available data sets for both comparison concentrations and the investigational unit. The use of all data is a more robust test, which minimizes both Type I and Type II errors (see Section 2). While the DTSC (1997) procedures for comparison of site data are focused on metals, the methods of comparison are also applicable to dioxins as discussed in Appendix D. Furthermore, it should be noted that the comparison procedures are applicable to both soil and groundwater data. As described in Appendix E, the applicability of the WRS Test for groundwater will be discussed in each investigational unit risk assessment.

Following DTSC guidance, a two-tiered approach will be used to evaluate investigational unit and comparison data sets. The first tier is a simple comparison of the investigational unit data against the comparison data. This method is referred to as the Comparison Method. For groundwater, the maximum concentration in the groundwater comparison data set will be the groundwater comparison concentration. If the maximum unit concentration does not exceed the groundwater comparison concentration, then the chemical is excluded as a COPC. If the maximum unit concentration exceeds the groundwater comparison concentration, then the data sets are further evaluated by application of the WRS Test. The groundwater comparison concentrations developed for use in risk assessments at the SSFL are presented in Table 3-6. The data and methods used to calculate groundwater comparison concentrations are presented in Appendix E.

According to DTSC, the maximum unit concentration is compared against a value representing the upper range of soil background conditions or the groundwater comparison concentrations. However, as discussed in Appendix D, the Comparison Method will not be used for selecting COPCs and CPECs in soil.

The WRS Test tests the null hypothesis (h_o) that soil background or groundwater comparison concentration data sets and investigational unit data are within the same distribution (*i.e.*, the presence of a chemical at the investigational unit or area is due to background and is not site related). The hypothesis is tested by analyzing the “location” of investigational unit data within the overall distribution. The data are placed in rank order and, if the investigational unit data tends to be located toward the upper extreme of the overall distribution, there is a decreasing probability that the observations are from the same population as background data. At some specified probability level, the investigational unit observations are declared inconsistent with

background and an alternative hypothesis (h_a) is accepted that the observations suggest site-related contamination. In instances where more than 40 percent of the site or background data sets are non detect values, then the Gehan Test will be used instead of the WRS Test (Department of the Navy 2002).

3.3.1 Mathematical Procedures

The simplest WRS Test uses the equation:

$$W_{rs} = \sum R_{ns} \tag{3-1}$$

where,

W_{rs} = Wilcoxon Rank Sum statistic

R_{ns} = rank value of each member of the n_s (unit-specific) population in a rank-ordered population comprised of n_s and n_b values (where n_b is the population of background or comparison samples)

W_{rs} may be used to estimate the probability, p, that n_s and n_b are from the same population by consulting statistical tables[iii]. An example of this procedure is shown in the example box.

For larger samples (n_b and n_s both greater than 10 samples), a further evaluation is possible using the equation:

$$Z_{rs} = \frac{W_{rs} - n_1(m+1)/2}{\sqrt{n_1 n_2 (m+1)/12}} \tag{3-2}$$

where,

n_1 = number of items in the smaller data set (this may be either the number of samples in n_s or n_b)

n_2 = number of items in the larger population data set (this may be either the number of samples in n_s or n_b)

m = $n_1 + n_2$

[iii] An abbreviated W_{rs} table is available in DTSC (1997) and more comprehensive tables are available in statistical texts.

This statistic is designated Z_{rs} because it is an approximation to the normal distribution, such that Z_{rs} may be compared to values of Z (or values of the t-distribution) to determine the probability of test populations coming from the same distribution.

Example Application of the WRS Test:

- Let unit-specific data be population n_s.
- Where ns = {1, 2.5, 5, and 6 mg/kg}.
- Let background information be population n_b, where n_b = {0.5, 1.5, 3 mg/kg}.
- Test the null hypothesis (h_o) that the data in n_s and n_b are all from the same population by placing all values (n_s and n_b combined) in a single group, sorted in ascending rank order.
- The test population in rank order is as follows (where values from n_s are shown in bold italic):

1	2	3	4	5	6	7
0.5	***1***	1.5	***2.5***	3	***5***	***6***

- The rank values of the smaller of the data sets, n_b population are 1, 3, and 5 and W_{rs} therefore equals 9.
- Select a probability (p) criterion for declaring the populations distinct. In this example, let the criterion be $p < 0.05$ (*i.e.*, less than five chances in 100 that the two sets of values would be selected at random from a single population).
- Where W_{rs} = 9 for sample sizes n_b = 3 and n_s = 4, the *p* value is greater than 0.05. Therefore, do not reject h_o, and declare the n_s population is not different from n_b.

It should be noted that, in the case of ties (two or more samples having an equal value) the rank assigned to each is the average of the rank values occupied by the group. Therefore, three equal values taking up the second, third, and fourth positions in the rank order would each be assigned a rank value of (2+3+4)/3 = 3. Where ties exist, equation 3-2 must be adjusted by subtracting a quantity from the (m+1) term, as follows:

$$Z_{rs} = \frac{W_{rs} - n_1(m+1)/2}{\sqrt{\frac{n_1 n_2}{12}\left[(m+1) - \frac{\sum_j^g t_j(t_j^{\,2}-1)}{m(m-1)}\right]}} \qquad (3\text{-}3)$$

where,

t_j = number of items in tied group j
g = total number of groups with ties

For any permutations of the test, a critical probability, usually termed α, must be specified, below which one rejects h_o (the assumption that soil background or groundwater comparison concentration data sets and investigational unit data are the same), and accepts h_a, that the investigational unit observations are site related. An α of 0.05 will be used for evaluations of individual inorganic compounds at the SSFL. This level is suggested in the DTSC (1997) guidance and is a frequently used decision level. Selecting α=0.05 is equivalent to stating that the investigational unit data should be assumed to be site related until there is less than one chance in 20 that the observed ranks of investigational unit and soil background or groundwater comparison concentration data were selected from the same population.

3.3.2 Application of the Wilcoxon Rank Sum Test

The WRS Test and Gehan Test are nonparametric, *i.e.*, they can be applied independently of the distribution of the data sets. Therefore, they can be applied to data whether or not it fits "typical" (*e.g.*, normal, log-normal) distributions and in cases where the underlying distribution is unresolvable due to small sample size or nonrandom sampling. This makes the WRS Test and Gehan Test applicable to any of the possible data sets that may be gathered at investigation units at the SSFL.

The WRS Test (or as applicable, the Gehan Test) may be employed with small data sets (indeed, DTSC guidance notes a method for sample sets of n = five to 10). As described below, Boeing anticipates that the SSFL metals soil background or groundwater comparison data sets will rarely have less than 20 samples[iv]. At this sample size, the test would be able to delineate differences between soil background or groundwater comparison concentration data sets and data from an investigational unit at the $p < 0.05$ level for as few as two unit-specific samples. Given this ability to delineate from the soil background or groundwater comparison concentration data sets, it is expected that the WRS Test (or as applicable, the Gehan Test) could be used for evaluation of almost all investigation units at the SSFL, because two or more samples would be collected. For this reason, no alternatives to the WRS Test (or as applicable, the Gehan Test) are proposed at this time.

[iv] Many background metal data sets are in excess of 30 samples.

Finally, it has previously been noted that the WRS Test (or as applicable, the Gehan Test) utilizes a data distribution rather than a sample parameter. Therefore, it is necessary to specify the total soil background or groundwater comparison concentration data set, rather than a single specific value (*e.g.*, central tendency, confidence bound) for comparison to investigational unit values.

3.3.3 Comparison Methods for Dioxins

The family of dioxin compounds consists of 75 chlorinated dibenzo-p-dioxin (CDD) and 135 chlorinated dibenzofuran (CDF) congeners. Of these compounds, it has been determined that only the 2,3,7,8-substituted congeners are toxicologically active in biological systems (USEPA 1989c). Accordingly, only the seventeen 2,3,7,8-dioxin congeners are evaluated in risk assessments (USEPA 1989c).

Dioxins are found in all media and in all parts of the world and are therefore considered to be ubiquitous in the environment (USEPA 1994c). Sources of dioxins include forest and brush fires and various combustion and chemical processes, including automobile exhaust and charcoal-fired barbecues. An extensive database of background concentrations in various environmental media has been compiled by USEPA for use in risk assessment and other scientific applications (USEPA 1994c, Appendix B). Therefore, the SRAM will apply a soil background delineation similar to the procedures described for metals to dioxin data, except that a modification is required to account for the fact that dioxins often occur as mixtures.

Consistent with a HERD memorandum (DTSC 1998a) on establishing dioxin background, a graphical representation of relative CDD and CDF concentrations in samples (a “radar” plot) will be compared to similar presentations for background to determine qualitatively if the site samples are similar to background. This would be done for five congener groups: tetra-CDD/CDFs, penta-CDD/CDFs, hexa-CDD/CDFs, hepta-CDD/CDFs, and octa-CDD/CDFs. As only the 2,3,7,8-substituted CDDs and CDFs are of toxicological interest, the five group concentrations are 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 is detected a least once in a given media at an investigational unit, it will be assumed to be present in other samples of the same media at that unit. When a congener is thus assumed to be present at an investigational unit, but is not detected in a sample, then the concentration in that sample will be estimated as one-half the SQL. In cases where a specific congener is never detected in a given media at an investigational unit, then that congener is assumed to not be present in that media at

that unit and will not be 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 is used to evaluate investigational unit and soil background CDD/CDF data sets. The data sets are 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 will be performed on the five congener groups as described above. If the WRS Test (or as applicable, the Gehan Test) is implemented, a Bonferroni correction to the statistical significance threshold, α, will be applied. As the critical significance level applied to single inorganic compounds is 0.05, the corrected term for comparison of the five CDD/CDF groups will be 0.01 (*i.e.*, 0.05/5).

Because CDD and CDF compounds frequently appear as mixtures, an additional requirement for evaluation of investigational unit data is that all "groups" of CDD and CDF classes must be shown to be consistent with soil background concentrations. If such a demonstration cannot be made, all CDD and CDF compounds must be 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 will also be applied for groundwater.

SECTION 4

4 CONCEPTUAL SITE MODEL FOR HUMAN RECEPTORS

A generalized conceptual site model (CSM) for the SSFL has been developed based on field observations, current and future site use scenarios, and data collected to date during environmental programs at the SSFL. Potential exposure pathways were considered to determine if 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 the SSFL.

Figure 4-1 depicts a diagrammatic representation of an illustrated CSM for the SSFL, including the contaminant sources, direct and indirect exposure pathways, and receptors. A generalized CSM for human receptors is shown on Figure 4-2. 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 residents and visitors who might occupy the site in the future in the event of a change in property use are future potential human receptors. 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. Justification for these selections is provided below.

4.1 SELECTION OF RECEPTORS AND PATHWAYS

The following sections present the candidate receptors and exposure pathways for the SSFL.

4.1.1 Receptors

Receptors were identified considering both current and future site use scenarios. In each case, there may be more than one receptor whose exposures are qualitatively similar in terms of the mechanisms by which they might be exposed. However, the magnitude of exposure may differ between these receptors, based on specific receptor characteristics and behaviors. Exposure parameters that may differ among receptors include body weight, skin surface area, intake rates, frequency of exposure, and duration of exposure. Specific exposure parameter values for the receptors identified here are provided in Section 5.

Where more than one receptor is plausible in terms of selecting a receptor for a human health risk assessment of a selected investigational unit, the most exposed relevant receptor will be evaluated. Other less exposed receptors might or might not be included in the risk assessment of that unit, depending on the need to provide perspective on the variability of risk with different site use. When the most exposed receptor is found not to have significant risk, the less exposed receptors also have no significant risk and the less exposed receptor need not be evaluated. Similarly, if the most exposed receptor is found to have significant risk and a risk management decision is made to protect that receptor, less exposed receptors will also be protected and may not require evaluation. However, if the most exposed receptor is found to have significant risk and a risk management decision not fully protective of this receptor is made, less exposed receptors might be evaluated to determine their risk within the context of the risk management decision.

While several receptors are described below and pertain to either current or future site use, it is anticipated that, in general, one of two receptors will be evaluated and used to support risk-based decisions. For investigational units that are physically appropriate for future residential development, the receptor to be evaluated will be a resident. This future site-use receptor is usually the most exposed and therefore will reveal high-end risk. Other plausible receptors (*e.g.*, recreational user, worker) will be presented and discussed in the specific risk assessments, but may or may not be the subject of quantitative risk assessment, depending on the needs of the risk manager.

Groundwater is being addressed in the risk assessments since direct use of groundwater is being evaluated as an exposure pathway. In addition, future impacts to groundwater due to contaminant transport from surficial media (soil, weathered bedrock, surface water, near-surface groundwater) to Chatsworth formation groundwater, or transport of contaminants within the CFOU, will be evaluated during the risk assessment and RFI. Based on characterization and modeling results, the risk assessment will use current concentrations and predicted future concentrations of contaminants in groundwater to calculate the risks associated with those concentrations. The groundwater characterization report and risk assessments will identify locations where groundwater risks may change in the future due to contaminant migration. This includes addressing predicted downgradient groundwater conditions for both potential on- and offsite receptors. Current and future potential degradation of groundwater quality in beneficial use aquifers (as designated by the RWQCB Los Angeles Basin Plan), is evaluated during the RFI when establishing well placement and sampling requirements, and addressed in the risk assessment and the CMS phase when establishing media cleanup standards and points of

compliance. Therefore, groundwater as a receptor is being directly addressed in these other project phases.

Current Site Use

Currently, the site is an operating industrial facility of approximately 2,850 acres, including the undeveloped land along its northern and southern boundaries that effectively separates adjacent property from active or formerly active portions of the SSFL. The site is completely fenced and subject to 24-hour manned security at the gates. The nearest residences to active or formerly active areas of the site are more than 3,000 feet to the south in Bell Canyon and more than 2,000 feet to the east in Woolsey Canyon.

Receptors consistent with current site conditions are limited to workers at the facility and trespassers. Given existing site security measures and steep terrain in many adjacent areas, it is not likely that trespassers could gain access to active or formerly active portions of the SSFL for frequent or prolonged periods of time. A trespasser's potential exposure is likely to be less frequent, shorter in duration, and possibly less intense than potential exposure of a site worker. Accordingly, the worker is the current site use receptor with the greatest potential exposure.

Future Site Use

Boeing currently has no plans to cease operations at the SSFL. Therefore, the most likely future site use scenario is identical to the current site use scenario. However, there is only a small portion of the property with deed restrictions (the nine former surface impoundments under Post-Closure Permit care as described in Section 1), so the possibility of future development of certain portions of the site for other purposes cannot be dismissed. It is possible that portions of the site may be developed for residential use. Other portions of the site may be used for recreational purposes, such as hiking and camping. These uses are consistent with current uses of property contiguous to the SSFL.

Potential receptors consistent with this future scenario include residents, visitors (recreational users), and workers. In areas subject to possible residential development, residential receptors would be anticipated to be the most exposed, because residential receptors are generally assumed to (1) include children, who would have higher intensity exposures for certain exposure pathways (*e.g.*, soil ingestion), particularly when considered on a body-weight basis, (2) have longer durations of exposure, and (3) have unique exposures (*e.g.*, exposure while showering) in addition to other pathways. Although certain portions of the site are not suitable for residential

development because of unfavorable physical characteristics (*i.e.*, steep terrain), the future resident was conservatively selected as the most highly exposed receptor for all units. Other plausible receptors (*e.g.*, recreational user) will be presented and discussed in the specific risk assessments, but may or may not be the subject of quantitative risk assessment, depending on the needs of the risk manager.

4.1.2 Potential Exposure Pathways

Selection of complete or potentially complete exposure pathways includes consideration of (1) the physical/chemical nature of COPCs selected for the investigational unit, (2) receptors assumed to be present at the site or investigational unit, and (3) the physical features of the site or investigational unit promoting or preventing particular pathways. Criteria for selecting complete pathways are generically discussed in the following sections. Individual risk assessments conducted at the SSFL will include site-specific exposure pathways analyses.

Current Site Use

As described above, current site use receptors with the greatest potential exposure are site workers. Trespassers are also potential receptors; however, their exposure potential is substantially less than site workers. During outdoor work activities, workers may contact compounds in soil, accessible weathered bedrock, near-shore sediment in ponds and channels, groundwater associated with seeps and springs, and surface water at the facility. Direct contact exposure to soil may occur via ingestion and dermal absorption. Current receptors may also be exposed via inhalation of nonvolatile compounds in fugitive dust. These potential exposure pathways are currently considered to be complete for the site worker in areas where work is authorized. These exposure pathways are also considered complete for trespassers.

Certain compounds detected in soil, soil vapor, weathered bedrock, and groundwater at the SSFL are volatile and may migrate to the atmosphere or into an overlying structure where workers may be exposed via inhalation of vapors in indoor air. Analysis of this potential exposure pathway includes assessment of the physical and chemical properties of detected COPCs to determine whether a compound is considered to be volatile. According to DTSC Office of Scientific Affairs, a compound with a Henry's Law Constant of 1×10^{-5} (unitless) or higher and a vapor pressure of 0.001 millimeters of mercury (mm Hg) or higher is considered volatile (DTSC 1994). Therefore, inhalation of volatile compounds in ambient and/or indoor air is considered to be a complete exposure pathway for COPCs that meet DTSC's definition of a volatile compound. Although exposure associated with this pathway is likely negligible for the trespasser due to the

low frequency of exposure, it is considered complete for the purposes of conducting risk assessments at the SSFL.

It is also possible that workers may be exposed to fugitive dust. Generally, fugitive dust generation is thought to occur as the result of vehicular traffic over unpaved, unvegetated areas, but may also occur in other areas during construction activities. A small amount of soil particulates also may be entrained by wind. Almost all road surfaces at the SSFL are paved. However, this exposure pathway will be considered complete for both the site worker and trespasser. Consistent with DTSC (1994) policy, the inhalation of fugitive dust pathway will only be evaluated for nonvolatile compounds, which are those chemicals not evaluated for the inhalation of volatile compounds pathways.

Surface soils also might be subject to runoff, which would transfer compounds in soil to sediments and/or surface water. Sediment near the edge of a water body could be contacted by a receptor in a manner similar to that by which surface soil is contacted. Therefore, the direct exposure pathways previously described for soil were also considered to be complete for sediment near the edge of a surface water body in the current exposure scenarios. During dry periods, compounds in sediment could volatize to ambient air or be present in fugitive dust. Additionally, volatile compounds in surface water might be transferred from this media to air. For both workers and trespassers, the inhalation of volatiles pathway was also considered complete for COPCs in surface water and near-shore sediment that meet DTSC's definition of a volatile compound. The inhalation of fugitive dust pathway was also considered complete for COPCs in near-shore sediment that do not meet DTSC's definition of a volatile compound.

In the current exposure scenarios, sediments in deeper water do not represent significant complete pathways for human exposure because no regular worker activity causing contact exists. Exposure to surface water is a complete pathway at the SSFL because of maintenance activities at the surface water holding ponds. Similarly, exposure to surface water and sediments in deeper water is considered insignificant for trespassers, since trespassers are unlikely to have direct contact with surface water in the holding ponds, and their frequency of visits to the site is expected to be low. However, for conducting risk assessments at the SSFL, it is conservatively assumed that these pathways are complete for the trespasser.

During outdoor activities, workers and trespassers may be exposed to groundwater flowing from seeps or springs within some units at the SSFL. Possible pathways of exposure include incidental ingestion, dermal contact, and inhalation of volatile compounds. For the trespasser, these

pathways are potentially complete. For the worker, only the inhalation pathway is potentially complete since workers would not directly contact seeps and springs. The completeness of these pathways will be further evaluated on a unit-by-unit basis, since each is dependent upon the physical characteristics of the respective seeps or springs (*e.g.*, flow rate, spatial extent, frequency of occurrence, depth of water). As described in a recent report on spring and seep sampling during June/October 2002, saturated seeps and springs almost entirely occur in undeveloped portions of the SSFL, with one noted near the boundaries of an investigational unit (MWH 2003b).

While indoors, it is possible that workers could be exposed to volatile compounds that migrate from soil, soil vapor, or groundwater through building foundations to indoor air. Therefore, for the site worker, these pathways were considered complete for the COPCs that meet DTSC's definition of a volatile compound. For the trespasser, indoor air exposures are incomplete since trespassers are not likely to have access to building facilities at the SSFL. For exposure and risk associated with volatile compounds in indoor and outdoor air, soil vapor concentrations are the preferred input into the vapor migration models and will be used at investigational units near VOC source areas where collection of soil vapor samples is technically feasible, *e.g.*, where access and soil thickness are adequate. When soil vapor samples cannot be collected at an investigational unit near VOC source areas, bulk soil media concentrations will be used as inputs to the vapor migration models. Any indoor or outdoor air concentrations and risks estimated based on bulk soil media concentrations will be noted in the risk assessment text. When soil vapor samples cannot be collected and multiple sources of volatile compounds are present (*e.g.*, both soil and groundwater contain volatile compounds), then risks from all sources will be calculated.

The completeness of the indoor air pathway is dependent upon the models used to estimate COPC concentrations in indoor air. Methods for calculating EPCs in various media, including indoor air, are presented in Section 6. The models for EPC calculations in indoor air are associated with significant uncertainty. As such, DTSC has recommended that this pathway be calculated separately from other exposures in an appendix to a risk assessment and presented as a supplement to the total risk calculation. In this way, the uncertainty associated with this pathway may be addressed easily when making risk management decisions.

Future Site Use

As described in Section 4.2.1, potential future receptors include future residents, recreational property users, and workers. All potential future receptors may be exposed to compounds in soil and weathered bedrock via direct contact pathways (ingestion and dermal exposures). These pathways are therefore considered complete for all future receptors. Potential exposure to compounds migrating from soil, soil vapor, weathered bedrock, groundwater, or surface water to ambient and/or indoor air is also considered a complete pathway for all future receptors, but only for compounds that meet DTSC's definition of a volatile compound. Future receptors may also be exposed via inhalation of nonvolatile compounds in fugitive dust. This is a complete exposure pathway for all future receptors. Residential receptors and workers may also be exposed via volatilization of compounds in soil, soil vapor, weathered bedrock, or groundwater to indoor air for compounds that meet DTSC's definition of a volatile compound. This exposure pathway is complete for future residents, incomplete for recreators since they would not have access to residences, and insignificant for workers since the amount of time spent inside a completed home would be negligible. For any unit risk assessment, exposure and risk associated with transfer of volatile compounds in soil or soil vapor will be assessed using either soil concentration data or soil vapor data as discussed above.

Future residents, workers, and recreators may be exposed to groundwater flowing from seeps or springs within some units at the SSFL. Possible pathways of exposure include incidental ingestion, dermal contact, and inhalation of volatile compounds. These pathways are potentially complete for future residents and recreators. For the worker, only the inhalation pathway is potentially complete since workers would not directly contact seeps and springs. The completeness of these pathways will be further evaluated on a unit-by-unit basis, since each is dependent upon the physical characteristics of the respective seeps or springs (*e.g.*, flow rate, spatial extent, frequency of occurrence, depth of water).

Compounds in soil may be transferred to sediments and/or surface water via runoff. Future residents and recreational receptors could contact compounds in surface water via dermal absorption while swimming or wading, depending upon the size of the water body (swimming would apply to water bodies greater than one meter in depth; wading would apply to shallower systems). Future residents and recreational receptors may also be exposed to compounds in surface water via incidental ingestion while swimming in surface waters of sufficient depth. Future residents and recreational receptors may contact compounds in exposed near-shore sediments via ingestion, dermal absorption, or inhalation of volatile compounds meeting DTSC's

definition of a volatile compound. These pathways, therefore, are considered potentially complete for these receptors. Future workers are likely to be present at the site only during construction of a residence or other building and are not assumed to be exposed to surface water or sediment by direct contact. However, exposure to volatile COPCs by future workers is a potentially complete pathway.

If residences are constructed at the SSFL in the future, it is possible that produce may be grown in impacted soil in backyard gardens. Compounds in soil may then be incorporated into edible plant tissues via root uptake. Residents could be exposed to compounds in soil via consumption of produce grown in backyard gardens. This pathway is complete for future residents, but incomplete for future workers and recreators. Although it is unlikely that weathered bedrock could support the types of vegetation grown in home gardens and consumed by residents, the physical characteristics of weathered bedrock and the ability to support vegetation will be evaluated on a unit-by-unit basis and will be subject to DTSC review.

The completeness of the food chain and indoor air pathways is dependent upon the models used to estimate COPC concentrations in these media. The compounds of significance may be limited by physicochemical properties of the COPCs. Methods for calculating EPCs in various media, including produce and indoor air, are presented in Section 6. The models for making EPC calculations in plants and indoor air are associated with significant uncertainty. As such, DTSC has recommended that these pathways be calculated separately from other exposures in an appendix to a risk assessment and presented as a supplement to the total risk calculation. In this way, the uncertainty of these pathways may be addressed easily when making risk management decisions.

Future residents could also be exposed to compounds in groundwater if homes are constructed at the SSFL in the future and water supply wells are installed to supply household water to these homes. Ingestion, dermal absorption, and inhalation (during showering) of COPCs in groundwater are considered potentially complete exposure pathways for the future resident. The completeness of pathways of exposure via domestic use of groundwater must be conducted on a unit-by-unit basis, depending on the yield and quality of groundwater.

The domestic water use pathways for the future resident will be considered complete only if groundwater quality parameters are within published drinking water standards and meet municipal or domestic supply standards as defined by the State Water Resources Control Board (SWRCB) Resolution 88-63 (*i.e.*, total dissolved solids <3,000 mg/L, deliverability >200 gal/day

[0.14 gal/min], or existing contamination that cannot be reasonably treated). TDS and yield are appropriate criteria for determining future groundwater uses. However, there may be other uses of this water, including irrigation of backyard gardens. These other potential uses of groundwater will be addressed in the uncertainty section of the risk assessment and their potential contribution to overall residential exposure and risk will be considered when making recommendations. Direct exposure to groundwater is an incomplete pathway for future workers and recreators, since neither would have access to water supply wells.

4.1.3 Physical Features Affecting the CSM

On a unit-specific basis, consideration of relevant potential exposures for each receptor requires evaluation of physical site features. The most obvious examples of these situations are for those units with surface water, seeps and springs, and weathered bedrock. At these units, the frequency and magnitude of exposure is largely a function of the characteristics of the feature.

At units that do have surface water features, evaluation of exposures in drainage areas of these water bodies may be necessary, even if the drainage goes beyond the administrative border of an investigational unit. Similarly, some units may have near-surface groundwater and others not. These near-surface groundwater units at the SSFL may or may not be connected, and they should be evaluated on a unit-by-unit basis.

The nature of exposure in a surface water body would depend on physical characteristics of the water body (*e.g.*, swimming versus wading). The risk assessments will assume that all permanent water bodies greater than one meter deep are considered "swimmable," while other water is considered "wadable." Exposure parameter values distinguishing these two activities are discussed in Section 5. However, it is worth noting that the distinction between swimmable and wadable relates to the skin surface area available for dermal uptake of compounds. A swimmable water body would be associated with dermal absorption over the entire surface area of the body, whereas wadable connotes the surface area of the body that would be covered in a person standing upright in the water body. Finally, it will be necessary to consider whether the surface water in question would continue to exist in the absence of present industrial activities before determining the relevance of the exposure pathway.

Similarly, the potential for exposure to COPCs in groundwater flowing from seeps or springs depends on the presence of seeps or springs within an investigational unit. The presence of seeps or springs at the SSFL is dependent upon a number factors, including variation in the height of the water table, slope of the land, and season. For each unit risk assessment, the potential for

active seeps and springs to occur in an investigational unit will be evaluated using land surveys and historical information. Whether to include exposure to seeps and springs in an investigational unit risk assessment will be determined on a unit-by-unit basis and will be subject to DTSC review.

Investigational units may consist of weathered bedrock or some fraction of weathered bedrock and soil. In these units, the characteristics of the weathered bedrock will be evaluated as they pertain to the completeness of possible exposure pathways. Weathered bedrock characteristics will also be considered with respect to the applicability of exposure parameters developed for use with the soil matrix. In units where both soils and weathered bedrock exist, the relative fraction of area consisting of weathered bedrock and soil will be considered in the risk assessments. Any actions taken to address issues related to the presence of both weathered bedrock and soil will be subject to DTSC review.

SECTION 5

5 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. Dose is defined as the amount of chemical absorbed into the body over a given period of time (USEPA 1989a). Dosage is defined as the amount of chemical per unit of body weight. For non-carcinogenic 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 USEPA guidance (1989a), the following general equation will be applied to assess chemical dosage for each complete or potentially complete exposure pathway considered in the risk assessment:

$$Dosage = \frac{C \times IR \times EF \times ED \times B}{BW \times AT} \quad (5\text{-}1)$$

where:

Dosage	=	ADD (mg/kg-day) for non-carcinogens; LADD (mg/kg-day) for carcinogens
C	=	chemical concentration in environmental medium (mg/kg soil; mg/L water; or, mg/m^3 air)
IR	=	intake rate (mg soil/day; L water/day; or, m^3 air/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
B	=	bioavailability (fraction)
BW	=	body weight (kg)
AT	=	averaging time (days)

With the exception of EPCs (discussed in Section 6), explanation of the specific parameters applied to this general equation and recommended parameter values are presented in this section. For bioavailability, a default value of 1 will be used for oral and inhalation exposures, unless a different value is approved by DTSC.

Estimation of exposure may proceed in a deterministic or probabilistic fashion. A deterministic analysis will be presented along with any probabilistic analyses. The former provides a "point estimate" of exposure by specifying constant values for each equation parameter. Probabilistic estimation considers a range of values that might be applied to each exposure factor. Variables for each parameter are selected at random from a probability distribution (*i.e.*, each factor is a random variable) and the risk estimate is calculated many times, resulting in a probability distribution of risk (a cumulative frequency distribution) that is a continuum of possible risk estimates accounting for the variability of each exposure parameter.

The cumulative frequency is a measure of the confidence of the estimate. That is, it shows the probability of any given risk estimate. To the extent that the random exposure values represent variation in a population, the cumulative frequency plot indicates the proportion of a specified population that might be associated with the estimated exposure (and corresponding health risk)[v].

The probabilistic approach is a comprehensive treatment of the risk estimate, which may be helpful to risk managers who are charged with balancing risk reduction against cost and/or technical feasibility of a response, and the potential to create a competing risk. However, the probabilistic method is complicated to implement. A certain amount of information about the variability in an exposure estimate may be obtained simply by using the deterministic system to calculate exposure for different point estimates (*e.g.*, reasonable maximum exposure [RME]). The point estimates may represent the typical or central tendency exposure [CTE] among the plausible range of exposures or an estimate of the RME.

Either deterministic alone or deterministic and probabilistic approaches may be used for SSFL units, depending on a unit-by-unit assessment of the practicality and need for probabilistic risk assessment. At a minimum, all units will be evaluated to provide CTE and RME dosage estimates. Based on the results of the deterministic dosage estimates, probabilistic-based dosage estimates may be calculated for specific pathways.

5.1 RECEPTORS

The concept of a receptor was introduced in Section 4 (Conceptual Site Model). As was discussed, four general receptor groups (workers, residents, trespassers, and recreational users),

[v] It is important to note that for most distributions used to specify the random variables, it is not possible to separate that variation produced by measurement error from actual variability in human behavior or physiological traits producing the exposure. As such, the cumulative frequency distribution is only a crude indication of the potential distribution of risk within a population.

with associated exposure pathways, will be used to evaluate current and estimate future human health risks and hazards at SSFL units. A general description of each group of receptors follows.

It is the general intent to initially use the particular receptor for each unit that is likely to have the greatest exposure in the risk assessment because, if an acceptable level of risk for this receptor is revealed, further evaluation is unnecessary (*i.e.*, less exposed receptors would have less exposure and consequently less risk). Thus, the risk assessment process is more efficient. Based on comparison of the exposure parameter values for each receptor (shown in Tables 5-1 through 5-5 of this section), it is concluded that the "residential" receptor is the most exposed and should be the primary receptor for evaluation. Specifically, residential receptors (both adult and child) have substantially greater RME exposure frequency and duration (24 hours/day, 350 days/year, for 30 years) than other receptors. The receptor with the next greatest RME exposure is the worker with exposure frequency and duration of eight hrs/day, 250 days/year, for 25 years. Potential exposure to trespassers or recreators would be substantially less than for either the worker or residents. Evaluation of other receptors would be useful for making risk management decisions concerning the necessity or extent of remediation required for various intended unit or partial-unit uses.

Under current land-use conditions, a current worker at the SSFL has the greatest potential for exposure to COPCs and generally represents the highest potential exposures relative to other possible current land-use scenarios, such as trespassers. Pathways for which a dosage estimate may be quantitatively assessed as a component of the current worker scenario include:

- inhalation of volatile COPCs in indoor air and ambient air
- direct contact exposure to COPCs in soil or sediment (ingestion, dermal contact, and inhalation of soil particulates)

Potential exposure to trespassers may also be evaluated in addition to the worker scenario, for appropriate areas, as a component of the current land use scenario. The approach for evaluating exposure to trespassers will be similar to the recreational land use scenario, which evaluates individuals who spend a limited time engaging in outdoor activities at the site (USEPA 1991). Pathways for which dosage will be quantitatively assessed as a component of the trespasser scenario include:

- exposure to COPCs in soil or sediment (ingestion, dermal contact, and inhalation of dust and vapors)
- exposure to COPCs in surface water (dermal contact)

Under future land use conditions, hypothetical residents and recreators are possible receptors. As a most conservative measure, residential land use, as described in the conceptual site model (Section 4) will be evaluated as the future land use scenario. The exposure assumptions for this land use scenario account for long-term daily exposure and generally represent the highest potential exposures relative to those associated with other land use scenarios (USEPA 1991). Pathways for which a dosage estimate will be quantitatively assessed as a component of the residential scenario include:

- exposure to COPCs in soil or sediment (ingestion, dermal contact, and inhalation of particulates)
- exposure to COPCs in groundwater (ingestion, dermal contact, and inhalation)
- indirect exposure to volatile COPCs migrating from soil or groundwater to indoor air
- exposure to COPCs in food (ingestion)

Recreational land use may also be evaluated in addition to the residential scenario, for appropriate areas, as a component of the future land use scenario. The recreational land use scenario evaluates individuals who spend a limited time engaging in outdoor activities at the site (USEPA 1991). Pathways for which dosage will be quantitatively assessed as a component of the recreational scenario include:

- exposure to COPCs in soil or sediment (ingestion, dermal contact, and inhalation of dust and vapors)
- exposure to COPCs in surface water (dermal contact)

The pathway-specific dosage equations for each land use scenario are presented below, along with recommended deterministic parameter values and parameter value distributions for probabilistic assessment for several parameters (see Tables 5-1 through 5-5). In some cases, it was determined that a distribution would not be applied to a parameter either because varying the parameter would not produce significantly different estimates of exposure, or because no information of the distribution was available. Sources for exposure parameter values are specified, but came primarily from default exposure parameters noted in Cal-EPA's risk assessment modeling tool, CalTOX (DTSC 1993), the DTSC *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Facilities and Permitted Facilities* (DTSC 1992), or the USEPA *Exposure Factors Handbook* (USEPA 1997a). Exposure factors will be approved by the DTSC's HERD if unavailable from the sources listed above.

CalTOX is compatible with probabilistic exposure estimations and provides default distributions for many exposure parameters (DTSC 1993). This was used as the priority source for the distributions recommended here. Alternative distributions from other sources were used only where newer or more specific distributions were available, or where no distribution was offered in DTSC (1993).

5.2 EXPOSURE TO COPCS IN SOIL OR SEDIMENT

Residential, recreational, or worker receptors may be exposed to COPCs in soil or sediment through direct contact of the medium (*e.g.*, incidental ingestion, dermal contact, inhalation of particulates) or as a result of vapor migration from subsurface depths. Dosage equations for these pathways are presented below.

5.2.1 Incidental Ingestion of Soil

Chemical uptake via ingestion of soil will be calculated for residential, recreational, or worker receptors according to the following equation (USEPA 1989a):

$$Dosage = \frac{C_{soil} \times IR \times CF \times EF \times ED \times B}{BW \times AT} \quad (5\text{-}2)$$

where:

$Dosage$	=	dosage for each chemical of concern (mg/kg-day)
C_{soil}	=	soil concentration (mg/kg)
IR	=	soil ingestion rate (mg/day)
CF	=	conversion factor (10^{-6} kg/mg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
B	=	bioavailability (fraction)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged - days) (= ED for non-carcinogens; 70 years for carcinogens)

Chemical-specific oral bioavailability factors will be applied when the oral toxicity criteria are based on administered dosage, or when oral studies are available in the peer-reviewed literature that reported gastrointestinal absorption fractions for chemicals administered in a soil matrix. The use of bioavailability factors derived from the literature will be subject to DTSC approval.

Exposure parameter values for soil ingestion are provided in Tables 5-1 through 5-5 for workers, adults, and children, respectively. It will be noted from these tables that the only exposure parameters not taken from the priority sources specified in the introduction are body weight distribution for children and exposure frequency (deterministic values and distribution) for adults and children in the recreational exposure scenario.

Body weights for children were adjusted because CalTOX evaluates a "child" between the ages of zero to 15 years, whereas this document specifies the more typical child age step of one to six years. As such, the CalTOX-specified body weight would be too high for the younger receptor, causing an underestimate of exposure. No published distributions of body weight were available for this age range, but Anderson *et al*. (1985, same data cited in USEPA 1997a) provide percentiles of body weights on a year-by-year basis for children. A three- to four-year-old child was used, as this is the mid-point age for the receptor in question and notes that the reported percentiles fit a normal distribution where the mean (50th percentile) equals 15.6 kilograms (kg), and the standard deviation equals approximately two kg.

The duration of exposure in a recreational setting has not been specified by DTSC or USEPA and was therefore based on professional judgment, using the conservative assumption that in the future the SSFL might be open to visitors. As noted in Tables 5-4 and 5-5, it is assumed that, in the future, one day every other week might be spent by adults in territory at the SSFL that is too steep or wet to be considered residential. Double this rate, one day per week, was used for children. It was assumed any value between four and eight hours per week is equally likely. It was further assumed that the period of the visit would be from four to eight hours. Thus, for probabilistic assessment, uniform distribution between these rates will be used.

5.2.2 Dermal Contact with Soil

Chemical dosage via dermal contact with surficial soil will be calculated for residential and recreational receptors according to the following equation (USEPA 2004):

$$Dosage = \frac{C_{soil} \times AF \times B \times CF \times EF \times ED}{BW \times AT} \quad (5\text{-}3)$$

where:

$Dosage$	=	dosage for each chemical of concern, mg/kg-day
C_{soil}	=	soil concentration, mg chemical/kg soil
AF	=	soil loading to skin, mg soil/day

B	=	bioavailability, fraction
CF	=	conversion factor, 10^{-6} kg/mg
EF	=	exposure frequency, days/year
ED	=	exposure duration, years
BW	=	body weight, kg
AT	=	averaging time (period over which exposure is averaged - days) (= ED for non-carcinogens; 70 years for carcinogens)

Chemical-specific dermal bioavailability factors will be taken from Cal-EPA guidance (DTSC 1994).

Exposure parameter values for dermal contact are provided in Tables 5-1 through 5-5 for workers, adults, and children, respectively. Distributions of these parameters for use in probabilistic risk assessment were obtained from DTSC (1999b) and the anticipated USEPA dermal guidance or developed from pooled data (geometric means and standard deviations) for relevant experimental groups provided in the pending dermal guidance or USEPA (1997a) using the software Crystal Ball (Decisioneering, Inc., Denver, Colorado).

5.2.3 Inhalation of Vapors

Chemical uptake via inhalation of vapors released to air at the soil surface will be calculated for residential, recreational, and worker receptors according to the following equation (USEPA 1989a):

$$Dosage = \frac{C_{air} \times IR \times EF \times ED}{BW \times AT} \quad (5\text{-}4)$$

where:

$Dosage$	=	dosage for each chemical of concern (mg/kg-day)
C_{air}	=	vapor concentration in air (mg/m^3)
IR	=	inhalation rate (m^3/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)

AT = averaging time (period over which exposure is averaged - days)
(= ED for non-carcinogens; 70 years for carcinogens)

The air concentration for this algorithm may be computed from a vapor transport model described in Section 6, or from direct measurements of vapors in air. Exposure parameter values for vapor inhalation are provided in Tables 5-1 through 5-5 for workers, adults, and children. Deterministic adult inhalation rates were obtained from USEPA (1997a) and were set at recommended resting rates for the residential exposure and a rate midway between the values listed in USEPA (1997a) for light and moderate activity for the recreational scenario. Distributions were obtained from CalTOX and relate to the recommended distribution for a "resting" inhalation rate in the case of residential exposure and an "active" inhalation rate for the recreational exposure. Children's rates for deterministic evaluation were obtained from USEPA (1997a) and relate to the mean inhalation rate recommended for a child from age three to five years. The distribution provided by CalTOX for children relates to ages zero to 15 years and would not be appropriate for the one- to six-year-old receptor considered here. Therefore, the distribution assigned is the adult distribution multiplied by 0.75, which is the approximate ratio of child to adult breathing rates selected for the deterministic evaluation.

This equation may also be used to quantify exposure to vapors migrating from groundwater into a structure (see Section 5.3). Because the migration pathway from groundwater would be through soil overburden, it is possible that use of modeling of vapor transport from groundwater and soil could amount to "double counting" the resulting ambient indoor air concentration. As such, indoor air concentrations should be computed separately for soil and groundwater sources, and only the higher estimated concentration used for quantifying exposure.

5.2.4 Inhalation of Particulates

Chemical uptake via inhalation of particulates (for nonvolatile compounds) will be calculated for residential, recreational, or worker receptors according to the following equation (USEPA 1989a):

$$Dosage = \frac{C_{soil} \times CF \times IR \times EF \times ED}{PEF \times BW \times AT} \quad (5\text{-}5)$$

where:

$Dosage$ = dosage for each chemical of concern (mg/kg-day)
C_{soil} = concentration in soil (mg/kg)

PEF	=	particulate emission factor ($m^3/\mu g$)
CF	=	conversion factor (10^{-9} kg/µg)
IR	=	inhalation rate (m^3/workday)
EF	=	exposure frequency (workdays/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged - days) (= *ED* for non-carcinogens; 70 years for carcinogens)

Exposure parameter values for particulate inhalation are provided in Tables 5-1 through 5-5 for workers, adults, and children, respectively.

5.3 EXPOSURE TO COPCS IN GROUNDWATER

Residential receptors may be exposed to COPCs in groundwater through ingestion of groundwater or as a result of showering (*e.g.*, dermal contact, inhalation). Residential, trespasser, and recreational receptors may also be exposed (*e.g.*, ingestion, dermal contact, inhalation of VOCs released to ambient air) to groundwater in seeps or springs at units where seeps and springs exist. The potential for exposure to groundwater in seeps and springs will be evaluated on a unit-by-unit basis at those units where seeps and springs exist, since possible exposure by these pathways is a function of the physical characteristics of unit-specific seeps and springs. Depending on the spatial area and yield of seeps and springs, exposure parameter values may vary substantially across units. Unit-specific parameter values (*e.g.*, intake rates, exposure frequencies) related to seeps and springs will be presented to DTSC during the conduct of unit risk assessments and will be subject to DTSC approval.

Calculation methods for estimating domestic groundwater exposures to residential receptors are discussed below.

5.3.1 Ingestion of Groundwater

Chemical uptake via ingestion of groundwater will be calculated according to the following equation (USEPA 1989a):

$$Dosage = \frac{C_{gw} \times IR \times EF \times ED}{BW \times AT} \quad (5\text{-}6)$$

where:

Dosage	=	dosage for each chemical of concern (mg/kg-day)
C_{gw}	=	concentration in groundwater (mg/L)
IR	=	groundwater ingestion rate (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged - days) (= *ED* for non-carcinogens; 70 years for carcinogens)

Exposure parameter values for groundwater ingestion are provided in Tables 5-2 and 5-3 for residential adult and child receptors, respectively. While the deterministic parameter values are from USEPA (1997a) or DTSC guidance, these reports actually parameterize total fluid intake rather than only groundwater intake. Accordingly, a distribution for tapwater consumption more realistically reflects the contemplated groundwater exposure. These distributions were published by Roseberry and Burmaster (1992) and refer to adults and one- to 11-year-old children for the adult and child exposures, respectively.

5.3.2 Dermal Contact with Groundwater and Inhalation of Groundwater Vapor COPCs

Chemical uptake via dermal contact with groundwater and inhalation of vapors during showering (note that this inhalation pathway is different from exposure due to vapors migrating from the subsurface, which was covered in Section 5.2.3) will be estimated for residential receptors by assuming that the dosage associated with these pathways is equal to the dosage received via groundwater ingestion (USEPA 1997a). This methodology results in very conservative estimates of total groundwater dosage and will therefore be used as a screening methodology. If necessary, USEPA dosage equations for dermal and inhalation exposures associated with showering will be applied to refine the dosage estimates for these pathways (USEPA 1997a).

5.4 DERMAL CONTACT WITH SURFACE WATER

Dermal contact with surface water is a potentially complete exposure pathway for workers and recreators. For SSFL workers, the potential for direct contact with surface water is site specific and negligible due to the small amount of time that workers work in pond areas. Worker exposure is further limited by standard safety precautions taken when working in all areas of the SSFL. Therefore, worker contact with surface water is a potentially complete pathway. Chemical uptake via dermal contact with surface water will be calculated for recreational receptors according to the following equation (USEPA 2004):

$$Dosage = \frac{DA_{event} \times EV \times EF \times ED \times SA}{BW \times AT} \quad (5\text{-}7)$$

where:

$Dosage$	=	dosage for each chemical of concern (mg/kg-day)
DA_{event}	=	absorbed dosage per surface area-event (mg/cm^2-event)
EV	=	event frequency (events/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
SA	=	skin surface area available for contact (cm^2)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged - days) (= ED for non-carcinogens; 70 years for carcinogens)

where

$$DA_{event} = K_p{}^{w} \times C_w \times t_{event} \quad (5\text{-}8)$$

and,

$K_p{}^{w}$	=	chemical permeability coefficient in water (cm/hr)
C_w	=	chemical concentration in water (mg/cm^3)
t_{event}	=	duration of event (hr)

Site-specific information for each exposure unit will be used to identify whether a swimming or wading scenario is most suitable and appropriate skin surface areas will be used accordingly. Skin surface area values for swimming are provided in Tables 5-4 and 5-5 for adults and children, respectively. However, as mentioned in the discussion of conceptual site models of exposure (Section 4), surface area exposed during wading is a function of water depth and will have to be determined on a unit-by-unit basis. As described in Section 5.2.1, it is estimated that one day every other week might be spent by adults in territory at the SSFL that is too steep or wet to be considered residential. Double this rate, one day per week, was used for children. During this time, recreators may be engaged in various activities such as hiking, wading, and swimming.

5.5 EXPOSURE TO COPCS IN FOOD

Future residential receptors may be exposed to COPCs by ingestion of produce in which the chemicals have accumulated; however, as acknowledged by USEPA (1991, 1996b), this pathway is only relevant for a limited number of compounds. USEPA identifies three separate food groups for characterizing food intake dosages:

- fruits and vegetables
- fish and shellfish
- meat, eggs, and dairy products

For the SSFL, it cannot be ruled out that fruits and vegetables may be grown onsite in the future. Accordingly, these food sources will be quantitatively assessed for future residential receptors.

USEPA's food intake equation, given below, will be applied to assess potential site-related chemical intake from food ingestion.

$$Dosage = \frac{C_p \times IR \times F \times EF \times ED}{BW \times AT} \quad (5\text{-}9)$$

where:

$Dosage$	=	dosage for each chemical of concern (mg/kg-day)
C_p	=	concentration in food item (mg/g)
F	=	fraction of produce locally grown (unitless)
IR	=	intake rate (g/kg-day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
AT	=	averaging time (period over which exposure is averaged - days) (= ED for non-carcinogens; 70 years for carcinogens)

Exposure parameter values for residential ingestion of homegrown fruits and vegetables are provided in Tables 5-2 and 5-3 for adults and children, respectively. Deterministic values for adult and three- to five-year-old child consumption rates were obtained from USEPA (1997a) and relate specifically to homegrown produce in the western United States. Accordingly, the F term in the above equation was set at 1.0.

Biotransfer of chemicals from soil to plants (produce) will be calculated using the soil to plant biotransfer model described in the DTSC CalTOX model (DTSC 1993). The DTSC model provides equations for estimating both above-ground (leaf and fruit) produce concentrations as well as below-ground (root) produce concentrations. Consumption rate data as described in the preceding paragraph are not specific to above- and below-ground produce. Therefore, it will be conservatively assumed that one-half an individual's total produce consumption is associated with above-ground produce, and one-half is associated with below-ground plants. This assumption is conservative because it his highly unlikely that most individual's consume a higher amount of below-ground produce than above-ground produce, yet the biotransfer factors for below-ground produce are 35 times greater than those for above-ground produce.

Distributions of produce consumption were obtained from DTSC (1993). This value representing total combined consumption of fruit and vegetables must be adjusted to account for locally grown produce. The distribution of the F term was also taken from CalTOX.

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SECTION 6

6 EXPOSURE POINT CONCENTRATIONS FOR HUMAN HEALTH RISK ASSESSMENT

This section presents the methodology for estimating EPCs for complete and potentially complete exposure pathways at the site for the human health risk assessment. Exposure pathways were identified in Section 4, which presented criteria for selecting potential exposure pathways and receptors at individual investigational units at the site. Complete or potentially complete exposure pathways include direct contact with soil, sediment, surface water, and regional near-surface and/or Chatsworth formation groundwater associated with seeps and springs; inhalation of chemicals transported from soil, groundwater, or surface water to air; and indirect exposure to compounds in soil via uptake into produce.

To estimate potential exposures via complete or potentially complete exposure pathways, compound concentrations in media in areas where receptors may be exposed (*e.g.*, exposure points) are necessary. EPCs can be estimated through direct measurement (*e.g.*, sampling and analysis of a medium) or through prediction (*e.g.*, modeling). Direct measurement involves the sampling and analysis of soil, water, air, and produce, including QA/QC validation of the sample results, for the target chemical(s). In risk assessments of investigational units at the site, measured concentrations will be used whenever available and appropriate. As recommended by USEPA (1989a), "J" qualified data (*i.e.*, the value is estimated) will be used in the calculation of EPCs.

In some cases, direct measurement may not be possible or practical because it is difficult to obtain a sample (*e.g.*, beneath a building). In these cases, predictive models may be used. Predictive models require knowledge of environmental fate and transport modeling to estimate chemical concentrations in a given medium. All predictive models will be submitted to DTSC for review and approval. In some cases, the report containing the risk assessment may also be the same report describing the model. In this case, it is recognized that acceptance of the risk assessment conclusions is contingent on approval of the model.

The source of data used to define exposures for complete or potentially complete pathways identified at each OU at the SSFL is presented in Table 6-1 and discussed in this section. EPCs will be estimated for the following media: soil, air, sediment, surface water, groundwater, and produce. EPCs for several chemical classes (*e.g.*, inorganics, volatiles, and high and low

molecular weight semi-volatile organic compounds (SVOCs), as defined in DTSC 1994) will be estimated in these media.

For direct contact pathways, EPCs in soil will be based on measured concentrations. EPCs in other media will be based on measured concentrations when data are available. When measured concentrations are not available or are uncertain, EPCs will be modeled. Various models to estimate EPCs are presented in regulatory guidance documents (*e.g.*, USEPA 1993a, 1996b, 2002a), ranging in complexity from simple analytical expressions through fully integrated numerical models. It is recognized that acceptance of the risk assessment conclusions is contingent on approval of each model. Site specific physical parameters for the SSFL are presented in Appendix F.

This section describes methodologies for calculating EPCs, consisting of groundwater, surface soil and accessible weathered bedrock, surface sediment, surface water, and seeps and springs. Secondary pathways, such as potential food sources, may also be addressed.

6.1 EXPOSURE POINT CONCENTRATIONS IN GROUNDWATER

In all cases, groundwater contaminated with volatile chemicals will be assumed to provide a source for volatilization of these compounds into ambient and indoor air. As described in Section 2, in cases where groundwater meets the SWRCB definition of a drinking water source standard for domestic water (Resolution 88-63), the resource will be assumed to have the potential for exposure through ingestion and dermal absorption, as well as inhalation of compounds volatilized during showering or washing.

EPCs for the Surficial OU will be developed on an investigational unit basis. EPCs will be the maximum concentrations measured from near-surface groundwater wells from within a particular investigational unit and from areas which are up gradient from the investigational unit. For the CFOU, EPCs will be the maximum concentrations measured from Chatsworth formation groundwater at an investigational unit, in a Reporting Area, or upgradient from these areas. The most recent three year troundwater monitoring data will be evaluated to determine whether this adequately reflects water concentrations to which potential receptors will be exposed. All historical groundwater monitoring data will be evaluated to assure representativeness for the three-year period used. Data, including soil vapor measurements, collected during field investigations of areas overlying groundwater will be the basis for modeling the volatilization of COPCs from groundwater to indoor and ambient air. At investigational units where soil vapor data is not available, groundwater and bulk soil concentrations will be used.

Since the groundwater metals data set consists of both total and dissolved analytical results, both filtered and unfiltered samples will be considered for use in risk assessment at an investigational unit. When adequate monitoring data for groundwater units are not available, an initial approach to estimating potential groundwater concentration will be a leachate model approved by DTSC and USEPA. All models used to estimate EPCs for water will be submitted to DTSC. It is recognized that acceptance of the risk assessment conclusions is contingent on approval of the model.

6.2 EXPOSURE POINT CONCENTRATIONS IN SURFACE SOIL AND SEDIMENT

Ingestion of and dermal absorption from soil and surface sediment are potentially complete exposure pathways at the site. Data collected during field investigations at the site will form the basis for soil/surface sediment (hereafter collectively referred to as soil) EPCs used to estimate chemical-specific dosages for these pathways.

As described in Section 6.2.1, deterministic estimates of EPCs will be calculated for all investigational units. In cases where the sampling density is not consistent across units, area-weighting may also be used at those units to estimate EPCs as described in Section 6.2.2.

6.2.1 Deterministic Estimation of Exposure Point Concentrations

For all adequately characterized investigational units, and consistent with DTSC guidance (1992), the chemical-specific soil EPC for the RME will be characterized as the lower of (1) the maximum detected concentration or (2) the 95 percent UCL of the arithmetic mean concentration.

The UCL is calculated differently depending on the nature of the distribution of the data and on spatial considerations in the case of soil ingestion exposure scenarios and where measured concentrations are used as source terms for indirect exposures (*e.g.*, volatilization from the subsurface). Spatial distributions are discussed in Section 6.2.2. In the case of normally distributed data with no spatial component, the UCL is:

$$UCL = \bar{x} + (t_{\alpha} * s/\sqrt{n-1}) \qquad (6\text{-}1)$$

where,

UCL	=	a specified limit (*i.e.*, 95 percent) on the estimate of the arithmetic mean
$\bar{x}$	=	mean concentration
t_{α}	=	the value of t for a specified confidence level, α
s	=	the standard deviation of the distribution

n = number of independent analytical samples

If the data are log-normally distributed and no spatial considerations are required, the UCL is:

$$UCL = e^{\bar{x}+0.5s^2+\sigma H\sqrt{n-1}} \quad (6\text{-}2)$$

where,

UCL = a specified limit (*i.e.*, 95 percent) on the estimate of the arithmetic mean
$\bar{x}$ = mean of the sample distribution
s = the standard deviation of the sample distribution
H = a statistic accounting for interaction of the distribution developed by Land (1975)
n = number of independent analytical samples

Where neither normal nor log-normal distributions are encountered, the 95 percent UCL will be estimated using nonparametric statistical methods (*e.g.*, bootstrapping) as described in recent USEPA risk assessment guidance (USEPA 1997b, 2002a). Nonparametric statistical calculations will be performed using the most current version of USEPA's ProUCL software.

The chemical-specific exposure concentration for the most likely (average) exposure, also referred to as the CTE concentration, will be characterized as the arithmetic mean soil concentration. As recommended in DTSC guidance (1992), one-half of the analytical reporting limit concentration will be used as a representative concentration for non detect results for COPCs.

The methods described above are applicable only to adequately characterized investigational units with data sets comprising at least three samples. In cases where only one sample is available, the single measured sample result will be used for both the CTE and RME concentrations. In cases where only two samples are available, the CTE concentration will be estimated as the arithmetic mean of the two measured values, and the RME exposure concentration will be estimated as the maximum measured value.

6.2.2 Spatial Distribution Considerations

For area-specific soil EPCs, DTSC (1992) and USEPA (1989a) guidance will be followed. For areas where spatial sampling has adequately characterized contamination, the spatial distribution

of COPCs will be evaluated to determine the appropriate method for estimating soil EPCs. In cases where sampling density is not consistent across an exposure area, area-weighted averaging will be applied, as recommended by DTSC (1992).

Area-weighted averaging may be conducted in a number of ways, ranging in complexity from constructing polygons from lines drawn equidistant between sampling locations (Thiessen polygons) (Clifford *et al*. 1995) to establishing unbiased estimates of concentration and variance change with distance and using the results to construct a spatial grid of estimated concentrations (ordinary kriging) (Isaaks and Srivastava 1989). The latter is data intensive and unlikely to be feasible for many of the investigation units at the SSFL. Thus, it is proposed that area-weighting be conducted using Thiessen polygons.

To construct Thiessen polygons, a perpendicular line is drawn equidistant between sampling points. For samples surrounded by other sampling points, where the set of lines meet, it creates a polygon. The outermost samples are truncated at a defined boundary, such as the border of the investigational unit or a defined exposure area. It is assumed that the concentration observed at the sampling point within each polygon is the best representation of concentrations within the entire area of that polygon.

Figures 6-1 and 6-2 illustrate this procedure. On Figure 6-1, polygons have been created by using a geographic information system (GIS), which also calculates the area included in each space. Hypothetical data are shown on Figure 6-2. The hypothetical COPC concentration and area associated with each polygon is shown in Table 6-2.

The area-weighted concentration is calculated using the following formula (Isaaks and Srivastava 1989):

$$\overline{x}_{sc} = \sum_{i=1}^{n} p_i c_i \qquad (6\text{-}3)$$

where,

$\overline{x}_{sc}$ = area-weighted mean concentration (mg/kg)

c_i = the concentration representing the condition within polygon, *i*, where there are $i = 1$ through n polygons

p_i = the proportion of the total area that is incorporated in polygon *i* (unitless)

It is also possible to calculate the variance of area-weighted samples using the formula (Isaaks and Srivastava 1989):

$$s_{sc}^{\ 2} = \sum_{i=1}^{n} p_i c_i^{\ 2} - \left(\sum_{i=1}^{n} p_i c_i\right)^2 \qquad (6\text{-}4)$$

where,

$s_{sc}^{\ 2}$ = variance of the distribution (mg^2/kg^2) of area-weighted sample

and all other parameters are as described above

Under the assumption that the concentration data may be modeled as a t-distribution, a confidence limit on the estimated area-weighted mean may be calculated as:

$$UCL = \overline{x}_{sc} + (t_\alpha * s_{sc} / \sqrt{n-1}) \qquad (6\text{-}5)$$

where,

UCL = a specified confidence limit on the estimate of the mean
t_α = the value of t for a specified confidence level, α
$\overline{x}_{sc}$ = area-weighted estimator of the mean (μ)
s_{sc} = the sample standard deviation, which is the square root of the sample variance (s^2)
n = the number of polygons used to estimate the distribution

It is typical to calculate the 95 percent UCL, for which the appropriate value of t would be calculated at $\alpha = 0.1$ for a two-tailed distribution.

Table 6-2 illustrates this procedure and also presents the estimated mean and 95 percent UCL of the unweighted data for comparison. It can be seen that the size of the polygons strongly influences the outcome. In the example case, the weighted mean and 95 percent UCL are greater than the unweighted statistics, because the higher observed concentrations are associated with polygons of large area. If the reverse were true (*i.e.*, high concentrations associated with small polygons — a condition that frequently exists when "hot spots" (areas of known contamination) are intensively sampled relative to other areas of an investigation unit), area-weighted means and UCLs would be lower than statistics calculated ignoring spatial dependence. This is illustrated

with a hypothetical data set shown in Table 6-3. The only difference in these data is that the hypothetical concentrations for SS-2 and SS-17 have been transposed, such that the highest concentration is now associated with a small polygon, and a low concentration is applied to a larger polygon.

Where area-weighted data appear to be log-normally distributed, means and standard deviations of log-transformed data and the statistical parameters will be applied to the so-called Land evaluation or "H" for calculating the UCL on the mean of log-normally distributed data (Land 1975; USEPA 1992c) discussed previously or may be bootstrapped as described in USEPA (1997b).

6.2.3 Land Use-Specific Exposure Areas

For recreational land use scenarios and for trespassers, soil EPCs will be determined using summary statistics on the data set for a reasonable exposure area. For direct contact soil pathways, all sample data within the zero to two feet below ground surface (bgs) profile will be employed.

For a residential land use scenario, exposure activities and data distributions (*e.g.*, potential hot spot areas) will be considered in the selection of an appropriate data set for soil EPCs. Surface samples, as well as a depth-weighted average of data for zero to 10 feet bgs (or to the maximum depth above bedrock of shallower than 10 feet) will be evaluated for direct contact soil EPCs.

For a worker land use scenario, exposure activities and data distributions (*e.g.*, potential hot spot areas) will be considered in the selection of an appropriate data set for soil EPCs. Surface samples (zero to two feet bgs), as well as a depth-weighted average of data for zero to 10 feet bgs (or to the maximum depth above bedrock of shallower than 10 feet) will be evaluated for direct contact soil EPCs. The depth interval representing the higher concentrations will be used to assess exposure to workers.

Physical or topographic conditions at an investigational unit may indicate that one or more potential human receptors would not have access to a specific area within an investigational unit, while other receptors may have access. Similarly, for the same reasons, it may not be feasible to construct future residential or commercial buildings within a specific area of an investigational unit. Examples of such areas include rock outcrops, steep terrain, and drainages. Therefore, it may be appropriate, in certain cases, to exclude chemical data collected within inaccessible areas, for specific receptors, in the calculation of EPCs. In such cases, this decision will be

clearly stated in the risk assessment, approved by DTSC, and discussed in the uncertainty section of the risk assessment.

6.3 EXPOSURE POINT CONCENTRATIONS IN SURFACE WATER

Ingestion of chemical contaminants and dermal absorption of chemicals from surface water are potentially complete exposure pathways at the site. Accordingly, EPCs will be evaluated for surface water COPCs. Surface water sampling and analysis will be used for EPCs for surface water pathways. EPCs for surface water will be calculated as described for soils in Section 6.2.1.

6.4 EXPOSURE POINT CONCENTRATIONS IN AIR

Inhalation of compounds in air represents a potentially complete exposure pathway at the site. Measured concentrations of compounds in air at the site are not available. Furthermore, when direct air sampling is used in a risk assessment, significant background air sampling data are necessary to characterize site-related chemical concentrations in air. As such, EPCs in air will be modeled, assuming that volatile compounds in the subsurface may volatilize to ambient air, and particulate-bound compounds in soil may be present in air as a result of fugitive dust emissions. Based on the results of the modeling, either DTSC or Boeing may recommend additional field work (*e.g.*, direct measurement of surface soil flux from soil and groundwater sources) to further refine modeling predictions. Methods for estimating EPCs in air as a result of volatilization are described in detail in Appendix G. Methods for estimating EPCs in air as a result of volatilization and fugitive dust emissions are summarized in the following sections.

6.4.1 Fugitive Dust Emissions

Fugitive dust may be resuspended to air from surface soils in unpaved areas of the site. As an initial conservative evaluation of EPCs for particulates in air, the particulate emission factor (PEF), recommended by USEPA (1996b) as the basis of a default value for particulate EPCs will initially be applied. The PEF relates the concentration of a chemical in soil with the concentration as suspended particulates in air. USEPA has updated the PEF equation since 1993, which was the basis of the DTSC *Preliminary Endangerment Assessment (PEA) Manual*'s default equation (DTSC 1994). A detailed discussion of USEPA's rationale for correcting the PEF equation is provided in USEPA (1996b, Section 2.4.5, p. 31-32).

The current USEPA default PEF equation is as follows:

$$PEF = \frac{LS \times V \times DH \times 3{,}600\,\text{sec/}hour}{A} \times \frac{1{,}000\,\text{g/kg}}{0.036 \times (1\text{-}G) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x)} \quad (6\text{-}6)$$

where,

PEF	=	particulate emission factor (m^3/kg)
LS	=	width of contaminated area (m, unit-specific)
V	=	wind speed in the mixing zone (1.78 m/s, site-specific)[1]
G	=	fraction of vegetative cover (0.5, unitless)
0.036	=	respirable fraction (g/m^2-hr, USEPA default)
U_m	=	annual windspeed (1.78 m/s, site-specific)[vi]
U_t	=	equivalent threshold of windspeed at 7 m (11.32 m/s, USEPA default)[vii]
$F(x)$	=	function dependent on U_m/U_t (0.194 unitless, USEPA default)

Using soil concentrations and the estimated PEF, air COPC concentrations are calculated as follows:

$$Ca = \frac{Cs}{PEF} \quad (6\text{-}7)$$

where,

Ca	=	concentration of COPC in air (mg/m^3)
Cs	=	concentration of COPC in soil (mg/kg)
PEF	=	particulate emission factor (m^3/kg)

6.4.2 Volatilization from Soil and Groundwater to Ambient Air

Ambient air concentrations of volatile compounds from the subsurface will be estimated using a steady-state vapor flux model combined with an ambient air dispersion model. The results of the flux model serves as an input to the dispersion model to estimate ambient air concentrations.

[vi] Based on mean annual wind speed measurement data for SSFL for the year 1997.

[vii] The equivalent threshold value of wind speed (U_t) at 7 m of 11.32 m/s is the USEPA (1996b) default value based on a soil aggregate size distribution of approximately 0.9 mm. A site-specific U_t may be calculated for individual units in cases where surficial soil characteristics indicate that use of the USEPA default value would overestimate exposure. Unit-specific soil grain size data collected with all soil samples at SSFL would be used to calculate U_t and F(x) following USEPA (1996b) guidance.

Appendix G provides more detail on the equations, input parameters and use of the models. These two models are discussed separately below.

Vapor Flux Model

The vapor flux model is a steady-state model that simulates vapor flux through the gaseous and aqueous phases of the subsurface to the ground surface. The model accounts for upward diffusive flux as well as downward advective flux due to recharge. The model is a steady-state model and does not account for changes in concentration over time. The model equations are presented in Appendix G and represent a refined approach to estimate flux which accounts for the potential transport of vapors through fractures and matrix in the bedrock in addition to the vadose zone soils. The potential for migration through bedrock fractures is not specifically addressed in the Jury model (Jury *et al*. 1983, 1990), or similarly based models used by USEPA (1996 and 2002b) and American Society for Testing and Materials (ASTM 2000).

Air Dispersion Model

Two air dispersion models are presented for use in Appendix G. The first model is the USEPA Q/C simplified air dispersion model. USEPA Soil Screening Guidance (1996 and 2002b) presents the Q/C dispersion factor that relates an estimated flux-rate to an ambient air concentrations. The second model is the Industrial Source Complex 3 (ISC3) model (USEPA 1995) which allows for more site-specific considerations in the modeling but also requires an additional level of resources to run. The ISC3 model will be used when results of the Q/C dispersion model estimates risks to either onsite or offsite receptors that exceed acceptable criteria. The Q/C dispersion model terms assume that the receptor is located directly over the source area. The use of this model may not be adequate to evaluate potential downwind receptors. To evaluate potential downwind receptors further air dispersion modeling maybe necessary. The ISC3 is a steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex. This model can account for the following: settling and dry deposition of particles; downwash; area sources; plume rise as a function of downwind distance; separation of point sources; and limited investigational unit-specific terrain adjustment.

6.4.3 Indoor Air Concentrations from Volatile Emissions from Soil and Groundwater

The potential human exposures via indoor vapor inhalation of VOCs originating in subsurface soil or groundwater are calculated using the model of Johnson and Ettinger (1991). Appendix G

provides more detail on the equations, input parameters and use of this model that accounts for vapor migration through fractured bedrock. The Johnson and Ettinger model calculates an attenuation factor that relates a soil vapor concentrations from a subsurface source to indoor air. Three transport mechanisms are considered:

- Diffusion through vadose zone soils, porous bedrock, and fractured bedrock;
- Convection into the building due to the negative pressure differential between the subsurface and building; and
- Mixing of vapors within a building resulting from building ventilation.

The CTE and RME EPCs for soil vapor used as inputs to the Johnson and Ettinger (1991) model will be calculated as described for soil in Section 6.2. If it is necessary to use groundwater or soil data to model indoor air concentrations, then the CTE and RME concentrations calculated for these media, as described in Sections 6.1 and 6.2, respectively, will be used as concentration inputs to the model.

6.5 EXPOSURE POINT CONCENTRATIONS IN PRODUCE

Consumption of produce-containing compounds from soil via root uptake was identified as a potentially complete exposure pathway under a future hypothetical scenario. Because there is substantial uncertainty associated with the modeling of plant uptake, the resulting exposure and risk estimates will be summarized separately. As discussed by USEPA (1996b), a comparison of risk-based plant concentrations with risk-based soil ingestion and leachate-based soil concentrations, indicates that the soil-plant-human exposure pathway may be of concern for two of the six metals evaluated by USEPA: arsenic and cadmium. USEPA (1996b) states that direct pathway risk assessment (*i.e.*, soil ingestion) is likely to be protective of the soil-plant-human pathway for the other four metals (mercury, nickel, selenium, and zinc). In addition, USEPA reports that data presented regarding phytotoxicity of these metals suggest that toxic effects to plants will generally occur below levels that would be harmful to humans (USEPA 1996b). Since organic contaminants may also be present in soil, this potential exposure pathway will be examined. As an initial evaluation, EPCs in plants will be evaluated using a recommended screening approach from USEPA (1996b, Section 2.7 and Appendix G). The equation for calculating plant uptake using this approach is:

$$C_p = S_c \times BTF_p \tag{6-8}$$

where:

C_p = compound concentration in plant (mg/kg)
S_c = concentration in soil (mg/kg)
BTF_p = biotransfer factor [(mg/kg plant)/(mg/kg soil)]

Biotransfer factors will be obtained from chemical-specific literature where possible. Alternative sources are compendia of uptake factors for inorganic compounds (*e.g.*, Baes and Sharp 1983; DTSC 1994), or model uptake factors based on regression of empirical information on physical properties, primarily the octanol-water partition coefficient (K_{ow}) (*e.g.*, Travis and Arms 1988; Briggs *et al*. 1982, as modified by Ryan *et al*. 1988; and USEPA 1993a).

Soil concentrations used in this model will be the arithmetic mean concentration for the typical exposure and the 95 percent UCL for the RME of concentrations measured within an area encompassing the typical backyard garden. Only shallow soil (zero to two feet bgs) concentrations will be used, as the biotransfer factors refer to the root zone.

If the results of the conservative screening evaluation for the soil-plant-human pathway indicate the need for direct sampling, it will be implemented to support a more refined evaluation of EPCs for this pathway. Additionally, ongoing collaborative research efforts currently are underway with USEPA and the State of California (USEPA 1996b). Applicable results of this research will be considered in the evaluation of EPCs in produce.

6.6 EXPOSURE POINT CONCENTRATIONS AT SEEPS AND SPRINGS

Seeps and springs identified at an investigational unit will be evaluated in the risk assessment. In cases where it is determined that existing groundwater data, either near-surface or Chatsworth formation groundwater (depending on the groundwater source), are representative of specific seeps or springs, then existing groundwater data will be used as EPCs. If the groundwater source is not representative of specific seeps, then those seeps and springs will be sampled and that data used as EPCs. The CTE and RME concentrations will be calculated using the methods described for soil in Section 6.2.

SECTION 7

7 HUMAN HEALTH 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 human health risk assessment. This section will present the dosage-response assessment for the COPCs identified for each investigational unit. Chemicals will be identified as having carcinogenic and/or non-carcinogenic toxicity criteria and will be evaluated in accordance with OEHHA and DTSC guidelines (DTSC 1992, 1994; OEHHA 2003). The chemical-specific toxicological criteria for each COPC will be presented in tabular format. Specific reference sources for the toxicity criteria will be cited.

Toxicity criteria for chemicals that have been detected onsite and may be selected as COPCs during the human health risk assessment are presented in Tables 7-1 and 7-2. It should be noted that hazard identification for each of the investigational units has not been completed. This list is provided based on the data collected to date and may not be complete or may include compounds that will not be selected as COPCs.

7.1 NON-CARCINOGENIC HEALTH EFFECTS

It is widely accepted that non-carcinogenic health effects from chemical substances occur only after a threshold dosage is reached. For the purposes of establishing health criteria, this threshold dosage is usually estimated from the no observed adverse effect level (NOAEL) or the lowest observed adverse effect level (LOAEL) determined from chronic animal studies. The NOAEL is defined as the highest dosage at which no adverse effects are observed, while the LOAEL is defined as the lowest dosage at which adverse effects are observed.

Safety factors are applied to the NOAEL or LOAEL observed in animal studies or human epidemiological studies to establish “reference doses” (RfDs). An RfD is an estimate of a dosage level that is not expected to result in adverse health effects in persons exposed for a lifetime, even among the most sensitive members of the population. The RfD is utilized in the risk characterization to estimate the potential for non-carcinogenic health hazards.

7.2 CARCINOGENIC HEALTH EFFECTS

Regulatory agencies have generally assumed that carcinogenic agents should be treated as if they do not have toxicological thresholds. In short, the dosage-response curve utilized for regulation

of carcinogens only predicts zero risk when there is zero dosage (*i.e.*, for all dosages greater than zero, some risk is assumed to be present). Cancer risks from potential human exposures to carcinogenic chemicals are modeled mathematically using either animal or human data. USEPA generally uses the linearized multistage model for low-dosage extrapolation. The model is considered to be one of the most conservative of any models that may be applied and has been recognized by USEPA to overpredict incremental cancer risks.

Cancer risks for exposure to carcinogens are defined in terms of upper bounds on probabilities. The probabilities identify the likelihood of a carcinogenic response in an individual that receives a given dosage of a particular chemical (based on mathematical modeling of the animal or human data). These probabilities are expressed in terms of the cancer slope factor (CSF). The CSF represents the upper bound on the probability of a carcinogenic response (per unit dosage) and is usually expressed as milligrams per kilogram per day $(mg/kg\text{-}day)^{-1}$. The CSF multiplied by the predicted chemical dosage provides an estimate of the incremental upper-bound cancer risk.

7.3 CHEMICAL-SPECIFIC TOXICITY CRITERIA

The appropriate chemical-specific toxicity criteria will be identified for each COPC. 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; USEPA 2005a)
3. Health Effects Assessment Summary Table (HEAST; USEPA 1997c)
4. USEPA criteria documents
5. Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles
6. Environmental Criteria and Assessment Office (ECAO)
7. Other sources

Although the use of OEHHA CSFs is recommended by DTSC, USEPA CSFs will also be presented and discussed in this section. USEPA CSFs have been subjected to peer-review by USEPA expert panels and are recognized by USEPA, all states other than California, and members of the scientific community as valid dose-response criteria. Table 7-1 provides non-cancer toxicological data for certain compounds, as an example of the data available from the preferred sources (Cal-EPA and USEPA sources including IRIS and HEAST). Toxicological data for carcinogens are provided in Table 7-2. Toxicity data for many chemicals are

unavailable; therefore, it may be necessary to supplement data from the preferred sources with alternative sources and professional judgments.

Professional judgments on toxicity factors may include (1) deriving new RfDs from literature information and standard uncertainty factors when acceptable standards are not available, (2) applying route-to-route extrapolations where data indicate similar toxic endpoints would exist for different exposure routes, and (3) application of structure-activity assumptions to justify use of a HERD-approved surrogate toxicity factor for a compound of similar structure. An example of this last approach is presented in Table 7-1, where the RfD of xylene (an alkyl-substituted benzene) is provided for other substituted benzene compounds (1,2,4- and 1,3,5-trimethylbenzene), and the RfD for pyrene (a low-molecular weight PAH) is provided for acenaphthylene and phenanthrene, which are also low molecular weight PAHs. A conference with DTSC (HERD) will be employed to attain approval whenever professional judgment is required to supplement the toxicity database.

7.4 TOXICITY EQUIVALENT FACTORS FOR DIOXIN AND PCB CONGENERS

The toxicity criteria used to assess dioxin and coplanar PCB congeners will be the TEFs developed by the World Health Organization and published by Van den Berg *et al*. (1998). TEFs are measures of the relative toxicity of a dioxin or coplanar PCB congener to the toxicity of 2,3,7,8-TCDD. TEFs may be applied to exposure concentrations, dosages, or toxicity values. For risk assessment conducted at the SSFL, dioxin and PCB congener-specific TEFs will be applied to toxicity criteria (*i.e.*, the CSF for 2,3,7,8-TCDD) to generate congener-specific toxicity values that will then applied to congener-specific exposure levels to estimate risk. This is the preferred method as it allows for further evaluation of potential risk posed by individual congeners.

The specific coplanar PCB and dioxin congeners that will be evaluated in risk assessments at the SSFL are the 12 non-ortho- and mono-ortho-substituted coplanar PCB congeners and 17 2,3,7,8-substituted dioxin congeners for which TEFs have been presented by Van den Berg *et al*. (1998). The specific coplanar PCB and dioxin congeners and their respective human health TEFs are presented in Table 7-3.

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SECTION 8

8 HUMAN RISK CHARACTERIZATION

Risk characterization "…serves as the bridge between risk assessment and risk management and is therefore a key step in the ultimate site decision-making process" (USEPA 1989a). Because the risk assessment plays such a critical role in ultimate site decisions, it is imperative that the results (*i.e.*, the risk characterization) are clearly and accurately portrayed, and that a framework is provided for the interpretation of the results by reviewers and managers. Accordingly, the risk assessment will follow USEPA's recommended outline for presentation of the risk characterization (USEPA 1989a, Chapters 8 and 9). The primary components of the risk characterization are discussed in detail in the remainder of this section of the work plan. In an effort to standardize the presentation of human health risk assessment data inputs and results, USEPA (2001) has developed standardized reporting tables. Examples of these tables are presented in Appendix H, and may be used to summarize human health risk assessments at the SSFL.

8.1 CHARACTERIZATION OF POTENTIAL CARCINOGENIC HEALTH RISKS

Potential carcinogenic health risks will be 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 (*i.e.*, the theoretical excess [above background] carcinogenic risk) is the risk attributed to exposure to the COPCs at the site (USEPA 1989a) and is independent of chemical exposures in our daily lives that are not related to the SSFL. For example, National Cancer Statistics indicate that each person has a three in 10 chance, or 300,000 chances in one million, of developing cancer during his or her lifetime. Consequently, a cancer risk of 10^{-4} corresponds to a theoretical[viii] probability of one-in-ten thousand, which is in addition to (*e.g.*, in excess of) the three in 10 background cancer risk. Expressed mathematically, the receptor allowed an incremental upper-bound cancer risk of 10^{-4} has a risk of 300,010 chances in one million. The actual risk is less than the upper bound and may be as low as zero (USEPA 1986, 1989a). This fact is based on the regulatory goal to not underestimate risk and on the uncertainty associated with characterization of chemical-specific dosage-response relationships at low dosages.

[viii] The risk is a theoretical value (based on the assumptions used in the toxicity and exposure assessments), and not an actual (*e.g.*, based on statistical trends reported for the population) risk.

For each COPC identified as a potential human carcinogen, the theoretical upper-bound excess cancer risk is based on the LADD and a factor relating dosage to cancer risk (the CSF). CSFs presented in Section 7 will be used to characterize carcinogenic risk. These values are, in general, upper-bound estimates on the slope of the cancer-response/exposure relationship. The following equation (USEPA 1989a; DTSC 1992) will be applied to estimate cancer risk for each relevant exposure pathway:

$$Excess\ Cancer\ Risk = LADD \times CSF \quad (8\text{-}1)$$

The calculations will be performed separately for children and adults. A total lifetime excess cancer risk will be calculated by first (1) summing chemical-specific risks calculated for all complete pathways, for both age groups, and then (2) summing risks for all COPCs evaluated as potential carcinogens. This approach is conservative as different chemical classes (and often individual chemicals within a chemical class) often act by different mechanisms of action and at different target organs. In addition, the current regulatory approach assumes that exposure to a carcinogen at any dosage will present some risk (USEPA 1986, 2005b). Cancer risk estimates will be expressed using one significant figure (USEPA 1989a). If the deterministic exposure approach is used, risk estimates for both the CTE and RME will be presented as recommended by USEPA (1989a,b, 1992b). A frequency distribution of risk estimates will be presented, if a probabilistic approach is used.

8.2 CHARACTERIZATION OF POTENTIAL NON-CARCINOGENIC HEALTH EFFECTS

Potential non-carcinogenic adverse health effects will be characterized by comparing predicted dosages for the site to RfDs (see hierarchy of information presented in Section 7). To calculate a hazard quotient (HQ), the ADD for each relevant COPC, received as a result of the exposure assumed (*e.g.*, upper-bound dosage averaged over the exposure period), will be divided by the chemical-specific RfD as shown in the following equation:

$$Hazard\ Quotient = ADD/RfD \quad (8\text{-}2)$$

When available, pathway-specific RfDs will be applied. For each chemical, the HQs will be summed for all complete pathways to estimate the chemical-specific HQ. As a first tier analysis, all HQs (*e.g.*, for all chemicals, regardless of target organ) will be summed as the basis for conservatively estimating a screening hazard index (HI) for each exposure scenario. If the result exceeds a value of 1.0, then target organ-specific HIs will be calculated based on target organs as recommended by USEPA (1989a).

Hazard quotients and indices will be calculated separately for chronic (greater than seven years), subchronic (two weeks to seven years) and "shorter term" (if relevant) exposure periods as specified by USEPA (1989a). HIs will expressed using appropriate significant figures for both CTE and RME scenarios (USEPA 1989a,b; 1992b) in the case of deterministic assessment, or as a frequency distribution, if probabilistic assessment is used.

8.3 SENSITIVITY ANALYSIS

A sensitivity analysis may be performed to evaluate the magnitude of impact of exposure parameter values, exposure modeling assumptions, and toxicity values on the final exposure and risk estimates. This analysis differs from the uncertainty analysis described in Section 8.4 to the extent that the sensitivity analysis focuses on the mathematical relationships between variables used in the exposure and risk calculations and does not address the issues of uncertainty and variability of individual parameter values. A sensitivity analysis is warranted in cases where there is some evidence that risks are driven by one or more parameter values which may overestimate or underestimate risk; determination of its need will be done on a unit-by-unit basis. If performed, the results of the sensitivity analysis will be used to focus the uncertainty analysis described in Section 8.4 on those variables that have the greatest impact on the final risk estimates.

8.4 ASSESSMENT AND PRESENTATION OF UNCERTAINTY

As recommended by USEPA (1989a, 1992b), an assessment of uncertainties in the risk characterization estimates will be presented. The risk estimates are based on conservative risk assessment methodologies and assumptions (applied to both the toxicity assessment and exposure assessment). Accordingly, it is critical that uncertainties associated with the conservative practices employed, as well as those associated with known or potential data gaps, be thoroughly addressed such that the numerical estimates are placed in the proper perspective by risk managers.

The risk assessment will identify and evaluate those COPCs with the greatest contribution to the cumulative risk (*e.g.*, "risk drivers"). USEPA has defined risk drivers "as those chemicals which contribute at least 90 percent of the total estimated risk." Specifically, a percent contribution to risk (or hazard), by chemical and by pathway, will be assessed and may be presented in graphic and/or tabular format. The subsequent uncertainty analysis will focus on the identified "risk drivers."

In the case of deterministic risk assessment, discussion of uncertainties will be largely qualitative. The probabilistic approach to exposure assessment provides a quantitative depiction of uncertainty assessment, as an enhancement to qualitative discussion of uncertainty.

8.5 SPECIAL CASES

8.5.1 Risk Characterization for Lead

If lead is selected as a COPC, the current Lead Spread model will be used to predict blood lead levels for both children and adults. Site-specific chemical concentration data will be used as the basis for soil ingestion, inhalation, and dermal contact pathways. Initially, default values (as provided in the model) will be used for dietary intake and drinking water intake pathways; however, site-specific data may be used.

The blood lead concentration identified as acceptable, for both children and adults, is 10 micrograms per deciliter (µg/dL) (DTSC 1992). The Center for Disease Control (CDC 1991) has identified the LOAEL for lead to be 10 µg/dL for children and 30 µg/dL for adults. As recommended by DTSC (1992), the 90th, 95th, 98th, and 99th percentile blood lead concentrations predicted by the model will be evaluated for both children and adults. While DTSC identifies the 99th percentile blood lead level as a "point of departure" (*e.g.*, remedial actions would not be implemented when predicted blood lead levels are less than 10 µg/dL), risk management considerations may also require assessment of the 90th, 95th, and 98th percentile blood lead levels predicted by the model.

8.5.2 Risk Characterization for Dioxin and PCB Congeners

The specific dioxin and coplanar PCB congeners that will be considered in risk assessments at the SSFL are the 17 2,3,7,8-substituted dioxin congeners and 12 non-ortho- and mono-ortho-substituted coplanar congeners for which TEFs were developed by WHO and published by Van den Berg *et al*. (1998). The congeners and TEFs were discussed in Section 7.4 and are summarized in Table 7-3.

Risk estimates for dioxins and coplanar PCBs conducted under this SRAM will be 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 will be estimated at one-half the SQL. In cases where a congener is

never detected in a given media at an investigational unit, that congener will be assumed not present.

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

It not appropriate to include both estimated Aroclor risks and PCB congener risks in the cumulative risk estimate, as this would essentially be "double-counting". Therefore, DTSC has requested that only Aroclor risks included in the cumulative risk estimates, and that PCB congeners risks presented with the risk estimates for other chemicals, but not included in the cumulative risk estimate.

8.5.3 Risk Characterization for Total Petroleum Hydrocarbons

For the purpose of evaluation in the SSFL RFI risk assessment program, 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 (see Section 2.8). When TPH is detected in the gasoline range, then BTEX compounds are added as COPCs. When TPH is detected in the diesel range, then PAHs are added as COPCs. Concentrations of BTEX or PAHs are determined by using the site-specific extrapolation factors.

8.5.4 Risk Characterization for Special Exposure Pathways

Indoor Air Exposure Associated with Soil Vapor

The presence of volatile compounds in soil vapor is the result of partitioning of COPCs from either groundwater or soils into the soil pore air space. Volatile COPCs in soil pore air space may migrate upward through the soil column, through building foundation cracks, and into building air space. Given the complexity of the migration pathways for soil vapor to indoor air, the models available for predicting indoor air concentrations inherently contain substantial uncertainty. Therefore, DTSC has requested that risk estimates related to the soil vapor pathway be presented separately in the risk assessment and discussed in the uncertainty analysis.

Exposure through Plant Uptake

Evaluation of direct exposure through plant uptake and subsequent ingestion utilizes models that may or may not accurately predict actual conditions. This pathway was included specifically as a requirement of DTSC, who, in recognition of the state of the science of this particular exposure assessment, recommended that the evaluation be carried out separately from other exposures. As such, the estimates for this pathway will be uncoupled from other estimated risks and presented separately to facilitate evaluation by risk managers. Uptake data from the ecological validation study may be useful in determination of parameters utilized in the plant ingestion portion of the human health risk assessment.

8.5.5 Evaluation of Potential Inter-Site Sediment Migration

An evaluation of inter-site sediment migration (to a downgradient investigational unit, or from an upgradient investigational unit) will be performed on all investigational unit reports and risk assessments. However, a preliminary evaluation of the potential for significant migration of COPCs from the investigational unit under evaluation to a downgradient investigational unit through transport of sediment will be evaluated in each risk assessment if a mechanism for sediment transport is suggested by the direction and slope of the land, or by the presence of creeks or ditches connecting the two units. This determination will be described in each risk assessment. Further evaluation of the potential impacts of sediment migration to a downgradient unit will be determined by comparison of the human health receptors and exposure pathways that are relevant to the investigational unit under evaluation and the downgradient unit as follows:

1. Investigation unit and the downgradient unit, then it will be assumed that human health risks at the adjacent unit could be as high as those at the site under evaluation. In these cases, it is conservatively assumed that no attenuation or dilution occurs during sediment transport, and that the concentrations of COPCs at an adjacent downgradient site could be as high as those at the site under evaluation. Therefore, if the risk assessment for the investigational unit under evaluation shows a potential for further action, then it will be assumed that risks at the adjacent site may also be unacceptable. Likewise, if the risk assessment for the investigational unit under evaluation concludes that no further action is necessary, then it will be assumed that risks at the downgradient site are also acceptable.

2. If the human health receptors and exposure pathways are more sensitive at the downgradient unit as compared to the investigational unit under evaluation, then additional quantitative assessment will be performed using the soil concentration data from the investigational unit

under evaluation and applying that data to the more sensitive human health conditions at the downgradient unit. For human risk assessment, child receptors will be considered more sensitive than adult receptors, and residential scenarios more sensitive than worker scenarios, and worker scenarios more sensitive than recreational scenarios.

The initial comparison of receptors, exposure pathways, and habitats will be described in the investigational unit risk assessments. Should quantitative evaluation of potential impacts to a downgradient unit be necessary, such evaluations will follow the methods as described in this SRAM, and will be presented in the investigation unit risk assessment as an attachment.

8.6 PRESENTATION OF RISK CHARACTERIZATION RESULTS FOR RISK MANAGERS

Because many factors must be weighed by the DTSC risk manager, it is imperative that the results of the risk assessment be presented in a format that allows the DTSC risk manager to integrate and weigh decision factors appropriately and optimally.

USEPA emphasizes the importance of providing information to risk managers regarding key assumptions, rationale, and the extent of scientific consensus; the uncertainties associated with risk characterization estimates; and the effect of reasonable alternative assumptions on conclusions and estimates (USEPA 1992b). In particular, the risk manager should be able to understand which components of the risk assessment (*e.g.*, chemicals, pathways, and assumptions) contribute most significantly to the results of the assessment. Pie charts or tables that show percent contribution to total risk (for chemicals as well as for pathways) are particularly useful to a risk manager who must integrate uncertainty into risk management decisions; accordingly, tables and charts may be used to present risk characterization results.

Since deterministic risk estimates do not provide any information regarding the distribution of risk, results of probabilistic risk assessments will be used in the interpretation of deterministic risk estimates. Probabilistic risk estimates will be presented with respect to appropriate percentile benchmarks (*i.e.*, 50th and 90th percentile of the distribution), and benchmark risk levels (*i.e.*, 10^{-4}, 10^{-5}, 10^{-6}) will be presented with respect to the correlating percentile on the distribution. Similarly, probabilistic HI estimates will be presented with respect to appropriate percentile benchmarks (*i.e.*, 50th and 90th percentile of the distribution), and benchmark HIs (*i.e.*, 0.1, 1.0, 10) will be presented with respect to the correlating percentile on the distribution.

A final risk management consideration is that of new data that may become available subsequent to completion of the baseline risk assessment. When remedial action activities occur over a

significant period of time (*e.g.*, months to years), it is important for the risk manager to consider newly published information (site-specific and chemical-specific) as it becomes available to ensure that final site decisions are protective of human and environmental health and are based on all available information. Following completion of the baseline risk assessment, Boeing will submit relevant site-specific or chemical-specific information, as it becomes available, to DTSC for consideration in risk management decisions on specific units.

SECTION 9

9 ECOLOGICAL RISK ASSESSMENT PROBLEM FORMULATION

The steps of an ecological risk assessment are outlined in DTSC guidance (1996) and are shown in the risk assessment flowchart on Figure 1-1. Problem formulation is the first step in the ecological risk assessment process and is intended to establish the scope of the ecological risk assessment and identify major factors to be considered. Key components of the problem formulation are the identification of representative ecological receptors, selection of CPECs[ix], analysis of complete or potentially complete exposure pathways, and exposure routes, identification of assessment endpoints, and the development of a conceptual site model. Accordingly, the problem formulation contains the information needed to complete a Scoping Assessment as described in DTSC (1996) guidance.

To facilitate the identification of ecological receptors and potentially complete exposure pathways for the purpose of evaluating potential biological effects, a biological characterization of the SSFL was conducted. The results of the biological surveys are reported in the *Biological Conditions Report, Santa Susana Field Laboratory, Ventura County, California* (provided in Appendix I with addendum). The Biological Conditions Report (BCR) describes vegetation communities and plant and wildlife species that were observed or could potentially occur at the SSFL. The BCR provides information on an SSFL-wide basis; however, detailed vegetation mapping, wildlife, and sensitive species occurrences have been prepared for certain units currently being investigated as part of the corrective action provisions of the RFI. While the BCR provides an overview of existing biological conditions for the SSFL, the identification of representative species and exposure pathways must be conducted on an investigational unit basis and reported in unit-specific ecological risk assessments.

The BCR will be used as a basis to prepare the biological characterization of a given investigational unit evaluated in an ecological risk assessment. Additional site visits, vegetation mapping, and biological surveys may also be performed. The types of information obtained for the investigational unit from the BCR or site visits will include:

[ix] Selection of CPECs was discussed in Section 3.

- identification of vegetation communities and other habitat types found at the specific unit and associated exposure area that may be potentially affected by unit-related chemicals or remediation,
- identification of species and biological communities present or potentially present at the investigational unit or associated exposure area,
- identification of species that are considered to be essential to, or indicative of, normal ecosystem or biological community functions, and
- identification of special status species and their habitats at the investigational unit or associated exposure area.

The BCR contains extensive information concerning habitats and species observed throughout the SSFL. Evaluations of each unit and adjacent areas will be performed to gain additional understanding of the area and species interactions at that particular unit.

9.1 IDENTIFICATION OF ECOLOGICAL RECEPTORS

An ecological receptor is an organism, population, or community that is potentially exposed to chemicals, either onsite or as a result of chemical migration to offsite areas. The purpose of identifying unit-specific ecological receptors is to focus the analysis on the potential for chemicals to adversely affect the specific biological resources present at the investigational unit. Sensitive species onsite or potentially occurring onsite can also be identified. All wildlife and plant species occurring in the vicinity of the investigational unit are potential ecological receptors. The general trophic relationships between ecological receptors at the SSFL are shown on Figure 9-1. Because it is neither practical nor necessary to evaluate the potential risk to every organism occurring at an investigational unit, representative species are chosen to represent groups of ecological receptors with similar life histories or sensitivities. Representative species are ecological receptors that are (1) potentially exposed to chemicals that originated at the investigational unit and (2) related to the unit-specific assessment endpoints as described in Section 9.6. In some instances, however, representative species are surrogate species that are similar to unit-specific ecological receptors with respect to their life history requirements, but are better supported (*e.g.*, have regulatory approved exposure factors) and/or are better studied (*e.g.*, more complete toxicity information).

9.1.1 Method for Selecting Representative Species

DTSC recommends that representative species selected for a given investigational unit include a primary producer, a primary consumer, and higher level consumers (DTSC 1996). Furthermore,

DTSC guidance suggests that California species of special concern, federally and state-listed threatened or endangered species, and species that are proposed for federal or state listing be included as representative species (DTSC 1996). Representative species will be identified using the following criteria:

- Species considered essential to, or indicative of, healthy functioning ecosystems
- Species vital to the structure and function of the food web (*e.g.*, principal prey species or top predators, based on trophic relationships)
- Species that represent ecological niches or guilds
- Species for which toxicological data are readily available in the literature
- Species that link viable exposure pathways and CPECs
- Species that provide protective estimates of exposure and risk to other members of the guild
- Species considered sensitive by federal or state regulatory agencies

The biological, toxicological, and societal criteria listed above are summarized for potential representative species found at the SSFL in Table 9-1. The assessment endpoints in this table will be discussed further in Section 10.

9.1.2 Representative Species

Based on the information provided in Table 9-1, representative species that meet most of the requirements were identified. Due to the variety of plant species observed throughout the SSFL and the lack of information concerning invertebrate receptors (*e.g.*, species occurring at the SSFL), generic lower trophic level aquatic and terrestrial species were identified as representative species. Lower trophic level receptors generally uptake chemicals through direct contact with abiotic media, therefore the more complex exposure models, that incorporate life history information, used for higher trophic level species are not appropriate. Proposed general representative species for the SSFL ecological risk assessments include:

- Generic aquatic plant (aquatic primary producer)
- Generic aquatic invertebrate (aquatic primary consumer)
- Generic aquatic species (aquatic primary/secondary consumer)
- Great blue heron (aquatic tertiary consumer)
- Generic terrestrial plant (terrestrial primary producer)
- Generic soil invertebrate (terrestrial detritivore/primary consumer)
- Deer mouse (terrestrial primary/secondary consumer)
- Thrush (terrestrial primary/secondary consumer)

- Mule deer (terrestrial primary consumer)
- Red-tailed hawk (terrestrial secondary/tertiary consumer)
- Bobcat (terrestrial secondary/tertiary consumer)

Ecological receptors from each of the trophic levels in aquatic and terrestrial habitats were chosen as representative species. The food web interactions for these species are shown on Figure 9-1. Not all of the representative species listed above will be evaluated for each investigational unit; only those associated with the habitats occurring at that unit will be evaluated. For example, aquatic receptors would not be evaluated at units with only terrestrial habitat types. Therefore, it is likely that a subset of the representative species listed above will be evaluated in each of the unit-specific ecological risk assessments.

Aquatic plants, invertebrates, and fish represent receptors with potential exposures to chemicals in sediment and surface water, and are prey species for fish-eating birds, such as the great blue heron. In addition to being a food source, aquatic plants provide refuge and nesting habitats for various species. Invertebrates and fish were selected because they may bioconcentrate or bioaccumulate chemicals through the food chain. The great blue heron was included as a receptor species because it is at the top of the aquatic food chain. The aquatic representative species were chosen to increase the specificity of the risk assessments, and expand the representation of feeding guilds and prey species.

Terrestrial plants were chosen because they provide forage for herbivores, (*i.e.*, may bioaccumulate and expose higher trophic levels to unit-related chemicals) are directly exposed to chemicals in the soil, and are indicative of the status of wildlife habitat. The California state-protected Santa Susana tarplant (*Hemizonia minthornii*) was not specifically chosen as a representative species because it may have low potential for exposure to CPECs at most investigational units since it grows out of small pockets of soil covering bedrock. In general, only limited toxicological information exists for plant species. For each unit, a qualitative assessment of effects of site-related chemicals on vegetation will be made by comparing factors such as abundance and diversity between areas with detected chemical concentrations and site-specific reference locations (see Section 11.3, Section 12.1.4, and Appendix I).

Soil invertebrates were selected because they provide forage for insectivores (*i.e.*, may bioaccumulate and expose higher trophic levels to investigational unit-related chemicals) and are directly exposed to chemicals in the soil.

The deer mouse was chosen because it is prevalent throughout the SSFL, it is a prey species for carnivores (*e.g.*, raptors and bobcats), it is a burrowing mammal, and it represents several exposure pathways. The deer mouse is directly exposed to soil and has complete ingestion exposure pathways for both insects and plants. The mule deer was selected as a representative species because its diet consists almost entirely of vegetation, it has a relatively large home range, and its rate of food consumption is relatively high as compared to other species.

The thrush was selected because it is representative of a primary and secondary consumer, is observed frequently at the SSFL, and has a high ingestion rate relative to body weight.

The red-tailed hawk and bobcat were chosen as representative species because of their prevalence on the SSFL, and because as high trophic level carnivores, they are exposed to chemicals though ingestion of a number of different prey items.

Due to the lack of relevant toxicity data in the peer-reviewed literature, adult amphibians and reptiles were not quantitatively evaluated in the ecological risk assessments for SSFL (Sparling *et al*. 2000). As no special-status amphibian species are found in the ponds at SSFL, ambient water quality criteria (AWQC) are anticipated to be protective of early-life stage exposures of amphibian embryos and tadpoles (DTSC 2005a).

9.2 IDENTIFICATION OF COMPLETE OR POTENTIALLY COMPLETE EXPOSURE PATHWAYS

An exposure pathway is the means by which a representative species is exposed to a CPEC. A complete exposure pathway must include four components: (1) a source and mechanism of chemical release, (2) a retention or transport mechanism through an environmental medium, (3) a point of potential contact with the impacted medium (*i.e.*, an exposure point), and (4) an exposure route (a mechanism of uptake) at the exposure point USEPA (1989c). The exposure pathway is considered incomplete if any of the four components are determined to be absent, with the exception that the transport mechanism is not required if the ecological receptor is in direct contact with the release point of the CPEC. Exposure to ecological receptors may occur directly through primary exposure pathways or indirectly through secondary exposure pathways (*e.g.*, exposures through food webs). Potential exposure pathways evaluated for the ecological risk assessments are discussed below.

9.2.1 Surface Water

Potential surface water pathways include direct contact, root contact, and ingestion. Terrestrial organisms may be dermally exposed to waterborne CPECs as a result of wading or swimming in contaminated waters and aquatic receptors may be exposed through osmotic exchange or respiration of surface waters. However, dermal exposures have been identified as not typically contributing to risks (USEPA 2000a, 2000b) and will not be evaluated. Terrestrial and aquatic receptors may ingest waterborne CPECs if surface waters are used as a drinking source. CPECs may be taken up by terrestrial or aquatic plants whose roots are in contact with surface water and/or pore water; aquatic plants (*e.g.*, algae and emergent plants) may also uptake CPECs through direct contact. Inhalation of vapors from contaminated surface water may also occur, but this is a less than significant pathway when compared to direct contact and ingestion; therefore, this pathway will not be evaluated.

9.2.2 Sediment

Potential exposure pathways to sediments are evaluated for those units containing surface water bodies (*e.g.*, ponds, streams). Receptors such as the great blue heron that forage in surface water bodies may incidentally ingest sediments associated with prey species such as benthic invertebrates. Terrestrial receptors may have direct contact with sediments while wading or drinking from a water source but this pathway is considered less than significant due to the expected minimal duration of this exposure; therefore, this pathway will not be evaluated. Aquatic receptors may be directly exposed to sediment-associated contaminants by physical contact and by osmotic exchange, respiration, or ventilation of sediments in the water column or in pore water. Bottom feeding aquatic organisms may also ingest sediments associated with feeding on benthic organisms. Emergent aquatic plants may be exposed to CPECs through root contact with contaminated sediments or pore water exchange.

9.2.3 Soil

For purposes of ecological risk assessments at the SSFL, only soil to a depth of six feet bgs will be evaluated (DTSC 1998b). Burrowing animals may be exposed to CPECs at substantially deeper soil depths than other species. It was with this consideration that the soil depth interval of up to six feet bgs forms the basis for ecological risk assessments. While the zero to six foot depth interval is appropriate for the burrowing animals (*e.g.*, deer mouse), this depth interval is not appropriate for most other terrestrial receptors that would only be exposed to CPECs in “surface” soils (*i.e.*, no more than two feet deep) (See Section 10.2).

Dermal contact, foliar deposition (deposition of soil or dust on plant leaves), and ingestion are the potential exposure routes for CPECs in soil. The dermal contact pathway is considered less than significant than other exposure pathways such as soil and food ingestion (USEPA 2000a, 2000b). Therefore, this pathway will not be evaluated. Terrestrial plants may be exposed to CPECs in the soil by foliar deposition or pore water uptake through the roots. Incidental ingestion by terrestrial target receptors may occur while foraging, grazing on vegetation, or grooming.

9.2.4 Air

Exposure routes of airborne CPECs include inhalation of vapors and/or dust. Airborne CPECs are usually limited to burrowing animals that may be exposed to CPECs while in their burrow or while digging or foraging. While air pathways may be potentially complete for surface-dwelling terrestrial wildlife species, they are considered less significant relative to other routes of exposure (USEPA 2005c); therefore, this pathway will not be evaluated for these receptors.

9.2.5 Groundwater

At many sites, groundwater is considered to be inaccessible to representative species (*i.e.*, groundwater occurs at depths greater than six feet bgs) (see Section 10.2, *Soil Depth Intervals For Terrestrial Representative Species*). However, representative species may be exposed to CPECs in groundwater, for example where groundwater comes to the surface in seeps or springs and plant roots can come into contact with groundwater that is near the ground surface (See Section 10.2).

The significance of groundwater pathways for other receptors will be addressed on an investigational unit-basis; dependent on the depth to groundwater, presence of seeps, and presence of representative species. If there are no obvious exposure pathways between groundwater and receptors, groundwater will not be evaluated in the ecological risk assessment. Rationale will be provided for each investigational unit that does not address groundwater as a significant pathway.

9.2.6 Food Webs

CPECs may also pass up the food web through ingestion of prey species by higher trophic level predators. Aquatic and terrestrial receptors, with the exception of primary producers, may be exposed to CPECs through the consumption of contaminated food items. A food web showing

the relationship between receptors at the SSFL is provided on Figure 9-1. Higher trophic level fauna (*e.g.*, hawk and bobcat) may be exposed to chemicals accumulated by prey species (*e.g.*, mouse). Representative species exposure through ingestion of prey will be evaluated using food web models as described in Section 10. Potentially complete exposure pathways that will be evaluated on an investigational unit specific basis are presented on Figure 9-2.

9.3 INTEGRATION OF REPRESENTATIVE SPECIES AND EXPOSURE PATHWAYS

Not all representative species occur at each investigational unit, just as not all potential exposure pathways are applicable to each investigational unit and/or representative species. To determine which pathways and representative species are appropriate for ecological risk assessment at each of the investigational units on the SSFL, the following questions will be addressed:

- What habitats and representative species are present?

  The presence or absence of certain habitats at an investigational unit will determine the representative species evaluated for that investigational unit. For example, if no water is present, there is no need to evaluate aquatic receptors.

- Which CPECs are present?

  Selection of CPECs for ecological risk assessment purposes will follow the procedure described in Sections 3.1 and 3.2. If no CPECs are present at the site or investigational unit, then there is no exposure.

- Of the relevant pathways, which ones apply to the representative species present?

  Once the representative species, CPECs, and potential exposure pathways have been derived for the investigational unit, pathways that link the representative species and CPECs will be evaluated.

Once a chemical is selected as a CPEC, its physicochemical properties will be used to determine if it may be transported to representative species via identified exposure pathways. Potential pathways for each representative species are identified in Table 9-2. CPECs specific to a particular pathway and representative species will be selected by physicochemical properties (*e.g.*, molecular weight, Henry's law constant). The effects of physicochemical properties on routes of exposure and representative species uptake are discussed further in Section 10.

9.4 ECOLOGICAL CONCEPTUAL SITE MODEL

The ecological CSM is a diagrammatic representation of potential sources of CPECs, primary and secondary exposure pathways, and ecological receptors that may be exposed to CPECs via a particular pathway. The generalized CSM on Figure 9-2 evaluates potentially complete and significant exposure pathways for the SSFL and integrates biotic and abiotic exposure routes; it is an example of the individual CSMs that will be created for each investigational unit.

9.5 SELECTION OF EXPOSURE AREAS

As defined in Section 1.7, an "exposure area" is the minimum area that will sustain an assumed exposure for ecological receptors. Accordingly, an exposure area for a particular representative species is the area where the species occurs and may come into contact with unit-specific chemicals. For the purposes of an ecological risk assessment, with few exceptions, an exposure area is defined as an individual area, called an investigational unit, of the SSFL that has been delineated based on the presence of chemicals and past operations. Either individually or combined into groups, the SWMUs and AOCs, defined under the Corrective Action requirements of RCRA, are considered units. For the SSFL ecological risk assessments, an exposure area will be the investigational unit.

In addition, an exposure area may be the home range of the representative species and may potentially encompass several units and areas outside the investigational units. Aquatic plants, aquatic invertebrates, and fish are limited to areas of open water; therefore, their exposure area is defined by the limits of the water body. As terrestrial plants are sessile, the exposure area for plants will be the area of the individual unit. Similarly, as soil invertebrates are considered not to move great distances, the exposure area for soil invertebrates will be the area of the investigational unit. Determining the exposure area for the other representative species depends on life history requirements and home range of the receptor as well as and the type and amount of habitat present at an investigational unit, the area of the investigational unit and the distribution of suitable habitat throughout the SSFL.

There are four representative species at the SSFL with home ranges that are larger than the size of any of the investigational units: bobcat, red-tailed hawk, mule deer, and great blue heron. The typical home range sizes and diet for these receptors are listed below.

Representative Species	Home Range Size	Diet
Bobcat	1.8 to 20.7 sq. mi. (Zezulak and Schwab 1980)	Mostly rabbits and rodents (75%) with some deer, birds, reptiles, amphibians, invertebrates, and vegetation (Zeiner *et al*. 1990a)
Red-tailed Hawk	0.3 to 3.8 sq. mi. (Zeiner *et al*. 1990b)	Small mammals (68%), small birds (17.5%), reptiles and amphibians (7%), and invertebrates (3.2%) (Sherrod 1978)
Mule Deer	0.20 to 1.19 sq. mi. for does (Taber and Dasmann 1958) 0.15 to 3.2 sq. mi. for bucks (Chapman and Feldhammer 1992)	Vegetation (100%)
Great Blue Heron	1.8 to 10 miles from nest (Zeiner *et al*. 1990b; USEPA 1993b)	Fish (75%); aquatic invertebrates (USEPA 1993b; Zeiner *et al*. 1990b)

There are a variety of developed land and wildlife habitats across the SSFL. The amount of foraging habitat available at each investigational unit will determine the relative proportion of exposure that particular unit contributes to the total exposure of the large home-range representative species. Based on the types of prey species or food items of the bobcat, great blue heron, mule deer, and red-tailed hawk and the types of habitats that occur at the SSFL, the habitats that these three species would be expected to most frequently use on the facility are listed below.

Representative Species	Foraging Habitats	Reference
Bobcat	Native and nonnative grasslands, Venturan coastal sage scrub, chaparral, coast live oak woodlands, rock outcrops, coast live oak riparian forest, and southern cottonwood willow riparian forest	Zeiner *et al*. 1990a

Representative Species	Foraging Habitats	Reference
Red-tailed Hawk	Native and nonnative grasslands, Venturan coastal sage scrub, rock outcrops, ruderal habitat	Zeiner *et al*. 1990b
Great Blue Heron	Open water, freshwater marsh, undifferentiated wetlands, surface waters, native and nonnative grasslands	Zeiner *et al*. 1990b
Mule Deer	Native and nonnative grasslands, coast live oak woodlands, coast live oak riparian forest, and southern cottonwood willow riparian forest, Venturan coastal sage scrub, chaparral,	Wallmo 1978, 1981

Native and nonnative grasslands are the primary habitats of rodents and all four of the large home range species include rodents in their diets; therefore, they would be expected to forage in these habitats. Bobcats generally use the cover of scrub, rock outcrops, and trees to stalk and capture prey in the open (Zeiner *et al*. 1990a). Bobcats are not considered to use dense habitat types like Baccharis scrub or some of the wetland habitats that do not afford adequate cover. Red-tailed hawks forage over open grasslands and fields, over rock outcrops, and in the more open Venturan coastal sage scrub as opposed to dense chaparral (Zeiner *et al*. 1990b). Although hawks use woodlands and riparian habitats for perching or nesting, they generally do not forage in these habitats. Great blue heron are expected to spend the majority of its foraging time in and around the edges of the ponds and marsh, but not in the woodlands (Zeiner *et al*. 1990b). Mule deer are expected to forage primarily on small branches and leaves of trees, and occasionally on new scrub growth and grasses (Wallmo 1978, 1981).

The calculation of a representative species' exposure and risk at each investigational unit and for the SSFL facility as a whole will be a step-wise process, progressing from smaller spatial scales to large spatial scales (see Section 12.1.3). The first step assumes the large home range representative species forages in appropriate habitats within a single investigational unit, *i.e.*, the exposure area is the area of appropriate habitats within an investigational unit. The second step assumes the large home range representative species forages in appropriate habitats among investigational units within a single Reporting Area, *i.e.*, the exposure area is the area of appropriate habitats within a Reporting Area. The last step assumes the large home range

representative species forages in appropriate habitats among Reporting Areas across the entire SSFL facility, *i.e.*, the exposure area is the area of appropriate habitats within the SSFL property line.

Specific steps to calculate risks to large home range representative species are described in more detail in Section 12 and Appendix J.

9.6 ENDPOINTS

An assessment endpoint is an explicit expression of the environmental value that is to be protected (USEPA 1992d). Selection of assessment endpoints is designed to focus the ecological risk assessment on those ecological features or resources that have substantial aesthetic, social, or economic value or are important in the biological functions or biodiversity of the system. Definition of appropriate assessment endpoints avoids making decisions on the basis of trivial or insignificant effects.

A measurement endpoint is a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint. Measurement endpoints often are expressed as the statistical or arithmetic summaries of the observations that make up the measurement. (USEPA 1992d)

Successful ecological assessments are based on adequate definition of assessment endpoints and their associated measurement endpoints (Beanlands and Duinker 1983; Suter 1993). Establishing appropriate assessment and measurement endpoints requires that ecological species and functions purportedly at risk be identified and that some measurable aspect of these values be defined (Barnthouse *et al*. 1986; USEPA 1989c,d, 1992d; Norton *et al*. 1992; Suter 1993). This element is crucial because both assessment and measurement endpoints must be specific and relevant and should be limited to organisms that spend a significant portion of their lives or derive a significant portion of their diet or physiological needs from the investigational unit. The relationship between the assessment goals, assessment endpoints, and measurement endpoints is shown in Table 9-3.

9.6.1 Assessment Endpoints

Assessment endpoints are formal expressions of the actual environmental values to be protected from risk (Suter 1993). They need to be specific and should be tied directly to specific ecological values requiring protection. Well-crafted assessment endpoints provide a clear, logical

connection between regulatory policy goals and anticipated ecotoxicological investigations. The assessment goal for the SSFL is to protect wildlife and plant species from certain chronic or acute effects resulting from site-related chemicals. This goal is used as a basis for defining assessment endpoints applicable to all sites, as follows:

1. Protect raptor species from acute (mortality) and chronic (*e.g.*, reproductive, growth, disease, and behavioral impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.
2. Protect the abundance of raptor and bobcat prey items (*e.g.*, rodents) by limiting acute and chronic adverse effects from direct and/or secondary exposure to site-related CPECs.
3. Protect bobcat from acute (mortality) and chronic (*e.g.*, reproductive impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.
4. Protect mule deer from acute (mortality) and chronic (*e.g.*, reproductive impairment) adverse effects from secondary exposure to site-related CPECs.
5. Protect the abundance of native terrestrial vegetation by limiting acute and chronic adverse effects from exposure to site-related CPECs.
6. Protect the abundance of great blue heron prey items (*e.g.*, fish, and aquatic invertebrates) by limiting acute and chronic adverse effects from direct and/or secondary exposure to site-related CPECs.
7. Protect great blue heron from acute (mortality) and chronic (*e.g.*, reproductive, growth, and behavioral impairment, disease) adverse effects from direct and/or secondary exposure to site-related CPECs.
8. Protect the abundance of benthic invertebrate community by limiting acute and chronic adverse effects from exposure to site-related CPECs.
9. Protect the abundance of terrestrial invertebrate community by limiting acute and chronic adverse effects from exposure to site-related CPECs.
10. Protect the abundance of wetland and aquatic vegetation by limiting acute and chronic adverse effects from exposure to site-related CPECs.

Assessment endpoints for each investigational unit will vary depending on the types of contamination, habitat, and receptors that occur on each site.

9.6.2 Measurement Endpoints

For the purposes of SSFL ecological risk assessments, measurement endpoints include mortality, reproductive impairment, reduction of growth, and other less serious effects to individuals that

are most relevant to assessment endpoints (*e.g.*, protection of populations and communities of concern and their food sources). Not all of these measurement endpoints will be assessed by direct measure of the ecological population, rather they are evaluated during exposure and effect analysis and risk characterization through modeling (Section 10.4, Section 11) and estimation of HQs (Section 12).

Indicators of aquatic and terrestrial habitat quality as well as field observations will provide a "weight of evidence approach" to qualitatively assess measurement endpoints during this risk assessment. Information collected during development of the BCR or site investigation (*e.g.*, soil or rock staining) will then be used to further support or refute the results of the conservative assumptions made during the risk assessment.

SECTION 10

10 ECOLOGICAL EXPOSURE ASSESSMENT

Assessing the potential for adverse effects to ecological receptors due to contact with environmental chemicals requires the estimation of exposure to these chemicals. Such exposure estimation is a critical step in the ecological risk assessment process. Exposure estimates are also needed to quantitatively evaluate the relative importance of various chemical sources or pathways when considering remediation strategies. Exposure analysis attempts to quantify the magnitude or type of actual and/or potential exposures of ecological receptors to site-specific chemicals, termed chemical stressors. This section identifies methods for characterizing representative species exposure to chemicals identified at the investigational units.

Various terms are used to describe chemical intake rates and concentrations in environmental media. Specific estimates of average or upper-bound chemical concentrations in abiotic media, such as soil, sediment, air, and water at locations where an ecological receptor may contact them, are referred to as EPCs (see Section 10.1). In contrast to the EPC, an exposure point value (EPV) is an estimate of the concentration of a chemical in the tissues of a representative prey species in a particular exposure area (see Section 10.5). Specifically, the EPV is a whole body tissue concentration in prey species consumed by the receptor, also sometimes referred to as the body burden tissue concentration.

10.1 CALCULATION OF EXPOSURE POINT CONCENTRATIONS

As described in Section 6 for human health risk assessment, EPCs will be computed both as the arithmetic mean and the 95 percent UCL of the arithmetic mean, to represent CTE and RME concentrations, respectively. The method selected for calculating of the 95 percent UCL will be based on the results of statistical tests to determine the type of data distribution. The statistical tests and equations that will be used are identical to those described for the human health risk assessment (shown in Section 6.1).

For any chemical selected as a CPEC, as described in Section 3.1 and 3.2, if the investigational unit-specific data set contains any value classified as a positive detect, then all non detect samples are included in the EPC calculation as values equal to one-half the SQL. If the data set contains only non detect values then the chemical will not be carried forward in the risk assessment, unless a substantial number of the SQLs for a given chemical are greater than the site-specific ESL. Justification (*e.g.*, total number of samples, number of samples with SQLs

below ESLs) for exclusion of a chemical on this basis will be provided in the risk assessment. In cases where there are an insufficient number of SQLs below the ESL to conclude that a chemical is not present at concentrations that may pose and ecological risk, then the chemical will be carried forward in the risk assessment, with individual samples concentrations estimated at one-half the SQL. Site-specific ESLs for the SSFL are presented in Section 3.2.

Terrestrial species at the SSFL have been identified and described in the BCR (Appendix I). Based on the listing of known terrestrial mammalian, avian, and plant species at the SSFL, representative species' were selected as ecological receptors to be evaluated in site-specific ecological risk assessments at the SSFL (Section 9). These include representative prey species (*e.g.*, plants, soil invertebrates), primary/secondary consumers (*e.g.*, thrush, deer mouse), avian carnivore (*e.g.*, red-tailed hawk), mammalian carnivores (*e.g.*, bobcat), and large mammalian herbivores (*e.g.*, mule deer). Potential risks to these representative species will be used to infer potential risks to other taxonomically and trophically related ecological receptors that may occur at an investigational unit. As previously described, potential hazards to plants will be qualitatively assessed as described in Section 12.1.4. Of the representative classes of species selected as potential receptors for ecological risk assessment at the SSFL, prey species and the primary/secondary consumers would have the greatest and most significant direct contact with soils. Higher trophic species such as the avian and mammalian carnivores are primarily exposed to CPECs through the consumption of prey species. Therefore, direct contact with soil will be evaluated for primary and secondary consumers only. Burrowing animals may be exposed to CPECs at substantially deeper soil depths than other species (see Section 9.2.3 and 10.2 for further details regarding soil depth intervals).

For aquatic receptors, current EPCs will be calculated from the available surface water (unfiltered samples) and sediment concentration data using the same approach as was described above for soil. Data from unfiltered surface water samples provide a protective measure of exposure to aquatic biota and are appropriate for estimating current surface water (drinking water) exposures to terrestrial biota. At some sites, future discharge of the groundwater to the surface may result in hypothetical future exposures to contaminants in groundwater. Future exposures predicted using fate and transport models are derived using groundwater data (mostly filtered samples). Consequences to risk estimates associated with future surface water exposures due to the use of filtered versus unfiltered samples will be discussed in the uncertainty analysis of the risk assessments.

These water and sediment EPCs will be used as the measures of exposure for aquatic receptors for ecological risk characterization.

The upper stratum or biotic zone for sediment is considered the top two centimeters. This upper stratum is thought to be most important from an ecological perspective because most of the biota associated with sediments are found in this stratum. However, to account for the possible resuspension of sediments, all sediment concentration data up to a depth of two feet bgs will be used for developing sediment EPCs.

10.2 SOIL DEPTH INTERVALS FOR TERRESTRIAL REPRESENTATIVE SPECIES

The purpose of this section is to clarify the approach, and to identify and establish species-specific soil depth intervals for evaluation in ecological risk assessments at the SSFL. An important factor to consider when evaluating a species' exposure to soil is the species' habitat use.

Plants. It should be noted that in ecological risk assessments for SSFL, calculation of exposures to plants are considered only in regard to calculating exposures to higher trophic level biota that consume plants—potential risks to plants themselves are evaluated using field observations (see Section 11.3 and 12.1.4). Accordingly, only the root zones of plants that are likely to be food sources for representative plant consumers are considered in ecological risk assessments for SSFL. In general, herbaceous grasses and forbs are considered the preferred food for small mammals (as represented by the deer mouse). Mule deer browse and graze, preferring forbs, grasses, and tender new growth of various shrubs (*e.g.*, ceanothus, bitterbrush) (Zeiner *et al*. 1990a).

Clearly, the root zone depth will vary depending on environmental variables such as soil type and moisture content, and on the plant species. Most herbaceous grasses and forbs occurring on the SSFL are considered to have relatively shallow root systems (*i.e.*, less than two feet bgs). Raven *et al*. (1986) reports that much of the root hairs, and thus much of the root absorption, is found in surface soils. Moreover, in an article published in SETAC News 1998 that discusses the soil depths accessed by plants, the author recommends a soil depth of 39 inches bgs for plants (B. Davis 2000). Accordingly, for the most part, the soil depth interval used to calculate the uptake of CPECs into plants consumed by representative herbivores will be zero to two feet bgs.

It should be noted that the root zone of some plants observed at SSFL are known to extend to depths well below two feet bgs. Chamise, which has been observed at the SSFL, was reported to

have a maximum root penetration depth of 25 feet bgs (Hellmers *et al*. 1955). Coast live oaks have tap roots that penetrate to depths of 36 feet bgs (USDA 2003). Accordingly, where appropriate, deeper soil depth intervals that are relevant for vegetation observed at a site and likely to be consumed by representative herbivorous consumers will be considered on a unit-by-unit basis.

Soil Invertebrates. Although some soil invertebrates (*e.g.*, earthworms) may burrow up to three feet in depth, they generally consume vegetation and detritus in surface soils (Nuutinen and Butt 2002). As with plants, the calculation of exposures to soil invertebrates is important in estimating exposures to insectivorous consumers (*e.g.*, thrush, deer mouse). As both the thrush and deer mouse primarily glean insects from the ground or in vegetation—*i.e.*, glean soil invertebrates that are primarily exposed to surface soils. Accordingly, the soil depth interval used to evaluate risks and the uptake of CPECs into soil invertebrates consumed by insectivores will be zero to two feet bgs.

Deer Mouse. A number of small mammal species live on the surface or in shallow burrows. However, some small mammal species will construct burrows in deeper soils. Accordingly, to address potential exposures to CPECs in deeper soils, a soil depth interval of up to six feet bgs was considered for the deer mouse.

Consistent with DTSC's (1998b) EcoNOTE No. 1, the soil depth interval with greatest potential exposure and risk will be selected as the soil depth interval for assessing exposure and risk to burrowing animals in the risk assessment. Accordingly, the zero to two feet bgs, zero to four feet bgs, and zero to six feet bgs depth intervals will be evaluated to determine which soil depth interval is likely to pose the greatest exposure and risk. The soil depth interval representing the greatest potential exposure and risk will be selected using a concentration-toxicity screen. For each chemical detected within a depth interval the toxicity-adjusted concentration will be calculated as the measured concentration divided by the appropriate ESL. Next, the sum of chemical-specific toxicity-screen results within each depth interval will be calculated. The soil depth interval with highest summed concentration-toxicity value will be selected to evaluate potential risks to the deer mouse.

Mule Deer. The primary exposure route for larger herbivorous mammals is through the consumption of aboveground vegetation. In particular, the mule deer grazes or browses, preferring tender new growth of various forbs, grasses, and shrubs (Zeiner *et al*. 1990a).

Accordingly, direct contact with surface soil (zero to two feet bgs) will be evaluated for the mule deer.

Red-Tailed Hawk and Bobcat. The primary exposure route to higher trophic species such as the red-tailed hawk and the bobcat is through the consumption of prey species. Therefore, direct contact with soil will not be evaluated for the red-tailed hawk and bobcat.

10.3 ESTIMATION OF VOC CONCENTRATIONS IN BURROW AIR

Burrow air concentrations may either be measured directly or estimated, for example using a steady-state soil to burrow air partitioning model (Hope 1995). To evaluate these options, burrow air VOC concentrations estimated using the Hope (1995) model were compared against soil vapor measurements taken within the same area of the SSFL as the soil samples. Measured soil vapor concentrations were found to be greater than the modeled burrow air concentrations. Because soil vapor measurements account for VOC vapor migration from all potential sources and represent measured rather than modeled data, soil vapor data will be used to estimate EPCs for airborne VOCs in burrows—modeled concentrations will only be used when VOCs are detected in the soil horizon of interest and measured soil vapor data are not available. The estimated burrow air EPCs will be used to calculate the applied daily dose for the deer mouse. In the event that this approach suggests risks to burrowing animals, additional evaluations may be performed in order to estimate an EPC for VOCs in burrow air.

10.4 BIOTA SEDIMENT/SOIL ACCUMULATION FACTORS

Biota sediment/soil accumulation factors (BAFs) will be used to estimate aquatic and terrestrial receptor tissue concentrations from sediment and soil concentration data, respectively. The estimated concentrations will subsequently be used for calculation of exposures in food chain models described in Section 10.5 through 10.7.

The relationship between chemical concentration in soil or sediment and tissue is described by Equation 10-1:

$$BAF = C_{tissue} / C_{soil/sed} \quad (10\text{-}1)$$

where:

BAF = bioaccumulation factor (unitless)
C_{tissue} = concentration in tissue (mg/kg dry weight)

$C_{soil/sed}$ = concentration in soil or sediment (mg/kg dry weight)

Chemical-specific BAFs will be obtained from one of three sources: (1) site-specific BAFs, (2) applicable BAF value obtained from the scientific literature, or (3) a surrogate BAF based on a chemical with similar structure and activity relationship. Site-specific BAFs will preferentially be used when available. The methods used to obtain data for deriving site-specific BAFs are described below.

To validate exposure models for higher trophic levels species presented later in this section, paired biotic and abiotic chemistry samples have been collected for use in calculating site-specific BAFs. The data used to derive BAFs for the SSFL include (1) colocated soil and terrestrial organism samples, and (2) colocated sediment and aquatic organism samples. Throughout this section, colocated tissue and soil or sediment samples are referred to as "paired data" or "paired samples." Four sites were selected and approved by the DTSC for the BAF study (Ogden 2000d). Two sites, the Bravo Area (SWMUs 5.13, 5.14, and 5.15) and the Component Test Laboratory III (CTL-III) (SWMU 4.7), were sampled for soil and colocated terrestrial organisms consisting of various plants, invertebrates, and vertebrates. The other two locations, the R2A/R2B Ponds (SWMU 5.26) and the Silvernale Reservoir (SWMU 6.8), were sampled for sediments and colocated aquatic organisms consisting of plants, invertebrates, and fish.

Soil and tissue samples collected at the Bravo Area were analyzed for metals and PCB congeners. Soil and tissue samples collected at CTL-III were analyzed for PAHs and dioxins. Sediment and tissue samples collected at the R2A/R2B Ponds were analyzed for metals, PAHs, and dioxins. Sediment and tissue samples collected at Silvernale Reservoir were analyzed for PCB congeners. Metals, PAHs, PCBs, and dioxins were analyzed by USEPA Methods 6010B/7000, 8270, 1668, and 1613B, respectively. All analytical data were validated. The sample locations, sample media, numbers of samples collected from each media, and the analytes of interest are summarized in Table 10-1. Sampling and analysis for this study were performed as outlined in the DTSC-approved work plan (Ogden 2000d). Description of the field and analytical procedures used for this sampling event and individual sample results will be presented in the RFI report.

Only paired (soil-tissue or sediment-tissue) data in which a given analyte was detected in *both* soil and sediment and tissue were used to derive BAFs. Normalization by the fraction of organic carbon measured in soil and sediment was not done in the present calculations because total

organic carbon (TOC) data were not available for all soil and sediment samples. Furthermore, normalization of tissue data by lipid content is not necessary for this particular set of BAFs because the BAFs are intended for use in calculating food chain exposures. The same measures of tissue-specific lipid concentrations would then be used in the exposure models, thus canceling out the initial lipid normalization.

The following method was used to calculate BAFs at the SSFL. First, the ratio of tissue chemical concentration to soil or sediment chemical concentration was calculated for each set of paired (colocated) data. Next, the 75th percentile of the distribution of individual BAFs was estimated for each tissue type, as follows, for data sets with one to four paired samples:

- 1 paired sample – the single ratio was selected as the BAF.
- 2 paired samples – the average of the two ratios was selected as the BAF.
- 3 paired samples – If the approximate 75th percentile ratio (calculated as the average plus one standard deviation) was less than the maximum value, then it was selected as the BAF. If the average plus one standard deviation was greater than the maximum sample, then the approximate 75th percentile was estimated as the midpoint between the arithmetic mean ratio and the maximum ratio.
- 4 paired samples – If the approximate 75th percentile ratio (calculated as the average plus one standard deviation) was less than the maximum value, then it was selected as the BAF. If the average plus one standard deviation was greater than the maximum sample, then the second highest value was selected as the BAF.

Tables 10-2 and 10-3 present the site-specific BAFs for aquatic and terrestrial receptors, respectively.

All analytical data for tissues except for the terrestrial vertebrate (*i.e.*, deer mouse) data were reported on a dry weight basis, consistent with analytical data for soil and sediment. The mouse tissue data were converted to a dry weight basis using percent moisture content for mouse tissue as reported in the Wildlife Exposure Factors Handbook (USEPA 1993b). Therefore, all reported BAFs were derived on dry weight basis. In cases where a default BAF value of 1 is used in ecological risk assessments, it is assumed that it is based on a dry weight relationship. BAF values obtained from the scientific literature will be converted to a dry weight basis, if necessary. The spreadsheets used to calculate the BAFs are presented in Appendix K.

Perchlorate has been detected in soils at a sites. To support effective decision-making for these few sites, both human health and ecological risk assessments will evaluate potential risks due to

exposures to perchlorate in soil. Information obtained from the scientific literature and from discussions with Dr. Andrew Jackson of Texas Tech University, a recognized expert who has conducted numerous studies on the uptake of perchlorate into plants, were used to develop a (soil-to-plant) BAF for perchlorate (see Appendix K-9). Based on the available scientific information and recommendations from Dr. Jackson, a (soil-to-plant) BAF of 282 was derived for perchlorate. This BAF has been approved by DTSC for the use in screening for risk assessments (DTSC 2005b). It should be noted that groundwater at SSFL wherein perchlorate has been detected is typically located well below root zones. However, unit-specific conditions will be considered when estimating potential perchlorate exposures to biota at SSFL. If new information suggests the need, a (water-to-plant) BAF for perchlorate will be developed.

10.5 Estimation of Exposure Point Values for Representative Aquatic Prey Species

EPV calculations are based on the predicted exposure pathways previously discussed in Section 9.2. Information on the habitats and prey of the representative species used in determining appropriate exposure scenarios is provided in Section 9.

10.5.1 Generic Aquatic Invertebrate

Aquatic invertebrates are potentially exposed to chemicals in sediment, food, and the water column. To estimate exposure to higher tropic level organisms that consume aquatic invertebrates, chemical concentrations in aquatic invertebrate tissues (EPVs) will either be measured directly or estimated by multiplying the sediment concentration by the site-specific BAF for aquatic invertebrates.

$$EPV_{ai} = EPC_{sed} \times BAF_{ai} \text{ or } = \text{direct measurement} \qquad (10\text{-}2)$$

where:

EPV_{ai} = chemical body burden in aquatic invertebrates, mg/kg (dry weight)
EPC_{sed} = sediment exposure point concentration, mg/kg (dry weight)
BAF_{ai} = chemical-specific bioaccumulation factor for aquatic invertebrates, unitless

Equation 10-2 is from Hope (1995).

To calculate a range of potential EPVs, the EPC in the above equation will be calculated as a 95 percent UCL and a mean sediment concentration. For species with large home ranges, aquatic invertebrate EPVs will be estimated using the protocol presented in Section 12.1.3.

10.5.2 Generic Fish

Fish are potentially exposed to chemicals in sediment, food, and the water column. To estimate exposure to higher trophic level organisms that consume fish, the chemical body burden in fish is either measured directly or estimated by multiplying the sediment concentration by the site-specific BAF for fish.

$$EPV_f = EPC_{sed} \times BAF_f \text{ or } = \text{direct measurement} \quad (10\text{-}3)$$

where:

EPV_f	=	chemical body burden in fish, mg/kg (dry weight)
EPC_{sed}	=	sediment exposure point concentration, mg/kg (dry weight)
BAF_f	=	site-specific biota to sediment bioaccumulation factor for fish, unitless

Equation 10-3 is adapted from Hope (1995).

To calculate a range of potential EPVs, the EPC in the above equation will be calculated as a 95 percent UCL and a mean sediment concentration. For species with large home ranges, generic fish EPVs will be estimated using the protocol presented in Section 12.1.3.

10.6 Estimation of Exposure Point Values for Representative Terrestrial Prey Species

As discussed above, an EPV is an estimate of the concentration of a chemical in the tissues of a representative prey species in a particular exposure area. Specifically, the EPV is a whole body tissue concentration in prey species consumed by the receptor, also sometimes referred to as the body burden tissue concentration.

EPV calculations are based on the predicted exposure pathways previously discussed in Section 9.2. Information on the habitats and prey of the representative species used in determining appropriate exposure scenarios is provided in Section 9.

10.6.1 Terrestrial Plant

Terrestrial plants may be exposed to chemicals by foliar deposition (*e.g.*, rainsplash), root contact, or foliar uptake (vapor or dust). Chemical uptake by plants may be affected by chemical concentrations, physiochemical properties of the chemical, and the physical processes of the plant itself. For example, some plants are able to regulate the uptake of chemicals that are also important nutrients, or may sequester potentially toxic compounds so they do not adversely affect the plant. To estimate exposure to higher trophic level organisms that consume plants, concentrations in plant tissues will be either measured directly or will be estimated by multiplying soil concentrations by the site-specific bioaccumulation factor for plants. The following model will be used to estimate the concentrations of chemicals in plants via uptake by plant roots.

$$EPV_p = BAF_{tp} \times EPC_s \text{ or } = \text{direct measurement} \quad (10\text{-}4)$$

where:

EPV_{tp} = chemical concentration in terrestrial plant, mg/kg (dry weight)
EPC_s = soil exposure point concentration, mg/kg (dry weight)
BAF_{tp} = chemical-specific bioaccumulation factor for the terrestrial plants, unitless

Equation 10-4 is from Hope (1995).

To calculate a range of potential EPVs, the EPC in the above equation will be calculated as a 95 percent UCL and a mean soil concentration. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

10.6.2 Soil Invertebrate

Terrestrial invertebrates are exposed to chemicals in the soil through direct contact and ingestion. Chemical concentrations terrestrial soil invertebrate tissues will either be measured directly or estimated by multiplying the soil concentration by the site-specific BAF for terrestrial invertebrates.

$$EPV_{ti} = EPC_s \times BAF_{ti} \text{ or } = \text{direct measurement} \quad (10\text{-}5)$$

where:

EPV_{ti} = chemical body burden in terrestrial invertebrate, mg/kg (dry weight)

EPC_s = soil exposure point concentration, mg/kg (dry weight)
BAF_{ti} = chemical-specific bioaccumulation factor for terrestrial invertebrates, unitless

Equation 10-5 is adapted from Hope (1995).

To calculate a range of potential EPVs, the EPC in the above equation will be calculated as a 95 percent UCL and a mean soil concentration. For species with large home ranges, soil invertebrate EPVs will be estimated using the protocol presented in Section 12.1.3.

10.6.3 Deer Mouse

To estimate exposures of higher trophic level organisms that consume deer mice, concentrations of chemicals in the deer mouse (body burden or EPV) will be either measured directly or calculated using the site-specific soil to deer mouse bioaccumulation factor.

$$EPV_d = EPC_s \times BAF_d \text{ or } = \text{direct measurement} \quad (10\text{-}6)$$

where:

EPV_d = chemical body burden in deer mouse tissue, mg/kg (dry weight)
EPC_s = soil exposure point concentration, mg/kg (dry weight)
BAF_d = chemical-specific bioaccumulation factor for deer mice, unitless

Equation 10-6 is adapted from Hope (1995).

To calculate a range of potential EPVs, the EPC in the above equation will be calculated as a 95 percent UCL and a mean soil concentration. For species with large home ranges, deer mouse EPVs will be estimated using the protocol presented in Section 12.1.3.

10.7 Estimation of Applied Daily Doses for Receptors of Interest

The previous sections have presented the estimation of EPCs for the abiotic media and EPVs for the representative prey species. This section presents the approach for estimating the ADDs for the receptors of interest foraging in the aquatic and terrestrial habitats at SSFL. The ADD is defined as the average daily dose received by a receptor over the duration of exposure. The ADD is the measure of exposure that is required for calculating receptor- and chemical-specific HQs using toxicity values that are reported for derived as daily doses in investigational units of mg/kg-day. Applicable toxicity values are described in Section 11.

Terrestrial receptors may be exposed to chemicals present in soil, sediments, air, and surface water through ingestion, inhalation, or direct contact with abiotic media. They may also be exposed through ingestion of prey items that have been exposed to chemicals present at the exposure unit. Terrestrial receptors are also mobile and may be exposed to chemicals and concentrations in varying media as they move between habitat types and sites. Dermal contact, inhalation, and ingestion are the three possible exposure routes through which a terrestrial receptor may come in contact with a chemical.

Dermal and inhalation routes were not included in the development of potential exposures because the contribution from these routes of exposure to overall risks has been shown to be generally less than one percent (USEPA 2000a,b). Inhalation pathways will be considered for the deer mouse since this is a representative burrowing organism. However, inhalation of chemicals will be considered negligible for surface dwelling large mammals and birds (USEPA 2000a). Exposures to volatile compounds are minimal for surface-dwelling terrestrial receptors because of the nature of the chemical (volatile compounds volatilize from soil and surface water to the air where they are rapidly diluted and dispersed). Conversely, burrowing animals may be exposed to volatile compounds during use of burrows, where dispersion and dilution of vapors is likely to be reduced compared to the surface. Therefore, inhalation exposure of volatile compounds in burrow air will be estimated for the deer mouse as described in Section 10.7.2.

The ingestion exposure route is the primary exposure route that will be evaluated for terrestrial receptors at the SSFL. Higher trophic level animals tend to consume a variety of prey species; estimates of ingestion exposure must also account for diversity, seasonality, and proportionality of the prey items in the diet. Additionally, animals may favor one habitat over another or vary their use of habitats depending on seasonality and reproductive needs. Oral ingestion exposure calculations should also account for spatial factors. Food, habitat, and life history parameters used in the exposure models for representative species are listed in Table 10-4. Calculations of exposure will be based on the mean and 95 percent UCL EPC chemical concentrations and the mean and 95 percent UCL EPV concentrations in prey species.

If the representative species' home range is smaller than the exposure area (*i.e.*, for plants, invertebrates, thrush, and deer mouse), area-use factors will be set to one—the representative species is considered to spend 100 percent of its time within the exposure area.. However, if the representative species' home range is greater than the exposure area (*i.e.*, red-tailed hawk, great blue heron, and bobcat) the representative species is considered to spend a portion of its time within the exposure area. In this case, the exposure calculations will be modified by the ratio of

the exposure area to the representative species home range area (area use factor = exposure area / home range area). For representative species with large home ranges, an evaluation of potential cumulative exposures across investigational units, and, if needed, across Reporting Areas will be conducted to address potential risks at spatial scales that may occur at scales greater than an investigational unit (see Sections 10.8 and 12.1.3).

10.7.1 Great Blue Heron

Great blue heron and other aquatic foraging birds are potentially exposed to chemicals by direct contact with soil, sediment, and surface water; inhalation of air; and ingestion of soil, sediment, water, and prey items. To estimate exposure of great blue heron to CPECs, ingestion will be considered as the primary and most significant exposure route. The following model considers ingestion of aquatic invertebrates, fish, and surface water; incidental ingestion of sediment, based on prey information in Section 9.5. This exposure medium was selected based on relevance to existing toxicological criteria (see Section 11) for piscivorous birds.

$$ADD_h = \{[(EPV_{ai} \times R_h \times F_{ai}) + (EPV_f \times R_h \times F_{hf}) + (EPC_{sed} \times R_h \times F_{sed}) + (EPC_{sw} \times Q_h)]/W_h\} \times \Psi_h \times \Theta_h \quad (10\text{-}7)$$

$$Q_h = 0.0059 \times W_h^{0.67} \quad (10\text{-}8)$$

where:

ADD_h	=	applied daily dosage to great blue heron from consumption, mg/kg-d
EPV_{ai}	=	chemical concentration in aquatic invertebrate, mg/kg (dry weight) (Equation 10-2)
R_h	=	food intake rate for great blue heron, kg/d (dry weight) (Table 10-4)
F_{ai}	=	fraction of aquatic invertebrate in great blue heron diet, unitless (Table 10-4)
EPV_f	=	chemical concentration in fish, mg/kg (Equation 10-3) (dry weight)
F_f	=	fraction of fish in great blue heron diet, unitless (Table 10-4)
EPC_{sed}	=	chemical concentration in sediment, mg/kg (dry weight)
F_{sed}	=	fraction of incidentally ingested sediment, unitless (Table 10-4)
EPC_{sw}	=	chemical concentration in surface water, mg/L
Q_h	=	calculated water intake of great blue heron, L/d
W_h	=	mean weight of adult great blue heron, kg (Table 10-4)
Ψ_h	=	fraction of year spent at SSFL, unitless (Table 10-4)

Θ_h = fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

The food intake rate (R_h) for the great blue heron is calculated from predictive equations presented in Nagy (2001) for carnivorous birds. Equation 10-7 is from Hope (1995) and Equation 10-8 is from USEPA (1993b). These equations are based on metabolic energy requirements. Therefore, as presented in Table 10-4, the sum of the dietary fractions is 1.0. Beyer *et al*. (1994) as well as others (*e.g.*, USEPA 1993b) have presented estimates of soil ingestion as percentages of the diet. Because soil ingestion does not contribute to metabolic energy requirements, these fractional amounts have been added to the total ingestion rate.

To calculate a range of potential ADDs, both the EPCs and the EPVs in the above equation will be calculated as 95 percent UCL and mean soil concentrations. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

10.7.2 Deer Mouse

Deer mice are potentially exposed to chemicals through direct contact with soil, inhalation of air, ingestion of water and prey, and incidental ingestion of soil. Deer mice are known to inhabit a variety of habitats, including all terrestrial habitats on the SSFL. They are primarily granivores, but are also known to regularly eat small invertebrates. Therefore, exposure models for consumption of both plants and invertebrates were selected. Chemical concentrations in the terrestrial invertebrates will be measured directly or estimated by multiplying the soil concentration by the site-specific bioaccumulation factor for terrestrial invertebrates (Equation 10-5). The following equations will be used to estimate deer mice exposure via ingestion of chemicals present at a site.

$$ADD_d = \{[(EPV_{ti} \times R_d \times F_{ti}) + (EPV_{tp} \times R_d \times F_{tp}) + (EPC_{sw} \times Q_d) + (EPC_s \times R_d \times F_s)]/W_d\} \times \Psi_d \times \Theta_d \quad (10\text{-}9)$$

$$Q_d = 0.099 \times W_d^{0.9} \quad (10\text{-}10)$$

where:

ADD_d = applied daily dosage to deer mouse, mg/kg-d

EPV_{ti} = chemical concentration in terrestrial invertebrate, mg/kg (dry weight) (Equation 10-5)

F_{ti} = fraction of invertebrate in deer mouse diet, unitless (Table 10-4)

R_d = food intake rate of deer mouse, kg/d (dry weight)

EPV_{tp} = chemical concentration in terrestrial plant, mg/kg (dry weight) (Equation 10-4)
F_{tp} = fraction of terrestrial plant in deer mouse diet, unitless (Table 10-4)
EPC_{sw} = exposure point concentration of chemicals in surface water, mg/L
EPC_s = exposure point concentration of chemicals in soil, mg/kg (dry weight)
F_s = fraction of soil in deer mouse diet, unitless (Table 10-4)
Q_d = water intake rate of deer mouse diet, L/d
W_d = mean weight of adult deer mouse, kg (Table 10-4)
Ψ_d = fraction of year spent at SSFL, unitless (Table 10-4)
Θ_d = fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

The food intake rate (R_d) for the deer mouse is taken from Nagy (2001). Equation 10-9 is from Hope (1995) and Equation 10-10 is from USEPA (1993b). These equations are based on metabolic energy requirements. Therefore, as presented in Table 10-4, the sum of the dietary fractions is 1.0. Beyer *et al*. (1994) as well as others (*e.g.*, USEPA 1993b) have presented estimates of soil ingestion as percentages of the diet. Because soil ingestion does not contribute to metabolic energy requirements, these fractional amounts have been added to the total ingestion rate.

To calculate a range of potential ADDs, both the EPCs and the EPVs in the above equation will be calculated as 95 percent UCL and mean soil concentrations. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

Generally, it is not necessary to calculate an ADD for the inhalation pathway (*e.g.*, deer mouse exposed to burrow air), because burrow air VOC concentrations will usually be used directly to calculate an HQ using a toxicity reference concentration (RfC) derived or reported in the same investigational units as burrow air concentrations (mg/m^3). RfCs for inhalation exposures are described in Section 11. In the unusual case where a toxicity RfC is not available for a VOC and there exists an acceptable inhalation toxicity value reported in the units of dose (mg/kg-day), then the daily dosage resulting from the inhalation of the volatile chemical in burrow air may be estimated using the following equations.

$$ADDv_d = [(IR_d \times EPC_{ba}) / W_d] \times \Psi_d \times \Theta_d \times B_d \quad (10\text{-}11)$$

$$IR_d = 0.54576 \times W_d^{0.8} \quad (10\text{-}12)$$

where:

$ADDv_d$ = applied daily dosage to the deer mouse from vapor inhalation, mg/kg-d
IR_d = deer mouse resting inhalation rate, m^3/d
EPC_{ba} = concentration of volatile chemical in burrow air, mg/m^3
B_d = fraction of day spent in burrow, unitless (Table 10-4)
W_d = mean weight of adult deer mouse, kg (Table 10-4)
Ψ_d = fraction of year spent at SSFL, unitless (Table 10-4)
Θ_d = fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

Equation 10-11 is from Hope (1995) and Equation 10-12 is from USEPA (1993b). This dose-based calculation of an inhalation exposure to a volatile chemical in burrow air assumes that the detected chemical concentration in burrow air is equivalent to the concentration that passes across the lungs.

10.7.3 Thrush

Thrush are primarily exposed to CPECs through intake of food, water, and soil. Thrush may inhabit a variety of habitats, including many of the terrestrial habitats on the SSFL. Thrush primarily forage on insects, spiders, worms, and other invertebrates (Zeiner *et al*. 1990b), but are also known to regularly eat berries, fruits, and seeds. Therefore, exposure models for consumption of both plants and invertebrates were selected. Chemical concentrations in the terrestrial invertebrates will be measured directly or estimated by multiplying the soil concentration by the site-specific bioaccumulation factor for invertebrates (Equation 10-2). The following equations will be used to estimate thrush exposure to chemicals present at a site. Only the ingestion exposure route will be evaluated as previously discussed in Section 10.6.

$$ADD_{th} = \{[(EPV_{ti} \times R_{th} \times F_{ti}) + EPV_{tp} \times R_{th} \times F_{tp}) + (EPC_{sw} \times Q_{th}) + (EPC_s \times R_{th} \times F_s)]/W_{th}\} \times \Psi_{th} \times \Theta_{th} \quad (10\text{-}13)$$

$$Q_{th} = 0.059 \times W_{th}^{0.67} \quad (10\text{-}14)$$

where:

ADD_{th} = applied daily dosage to thrush, mg/kg-d
EPV_{ti} = chemical concentration in terrestrial invertebrate, mg/kg (dry weight) (Equation 10-5)
F_{ti} = fraction of terrestrial invertebrates in thrush diet, unitless (Table 10-4)
R_{th} = food intake rate of thrush diet, kg/d (dry weight)

EPV_{tp} = chemical concentration in terrestrial plant, mg/kg (dry weight) (Equation 10-4)
F_{tp} = fraction of terrestrial plants in thrush diet, unitless (Table 10-4)
EPC_{sw} = exposure point concentration of chemicals in surface water, mg/L
EPC_s = exposure point concentration of chemicals in soil, mg/kg (dry weight)
F_s = fraction of soil in thrush diet, unitless (Table 10-4)
Q_{th} = water intake rate of thrush diet, L/d
W_{th} = mean weight of adult thrush, kg (Table 10-4)
Ψ_{th} = fraction of year spent at SSFL, unitless (Table 10-4)
Θ_{th} = fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

The food intake rate (R_{th}) for the thrush is calculated from predictive equations presented in Nagy (2001) for passerines. Equation 10-13 is from Hope (1995) and Equation 10-14 is from USEPA (1993b). These equations are based on metabolic energy requirements. Therefore, as presented in Table 10-4, the sum of the dietary fractions is 1.0. Beyer *et al.* (1994) as well as others (*e.g.*, USEPA 1993b) have presented estimates of soil ingestion as percentages of the diet. Because soil ingestion does not contribute to metabolic energy requirements, these fractional amounts have been added to the total ingestion rate.

To calculate a range of potential ADDs, both the EPCs and the EPVs in the above equation will be calculated as 95 percent UCL and mean soil concentrations. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

10.7.4 Mule Deer

For the purpose of this evaluation, it is assumed that the primary exposure routes for mule deer are food ingestion, water ingestion, and soil ingestion. Mule deer are known to inhabit a variety of habitats, including all terrestrial habitats on the SSFL. They are primarily herbivores, and an exposure model based primarily on consumption of plants was selected. Chemical concentrations in the plants will be measured directly or estimated by multiplying the soil concentration by the site-specific bioaccumulation factor for plants (Equation 10-4). The following equations will be used to estimate mule deer exposure via ingestion of plants and incidental ingestion of chemicals present at a site.

$$ADD_d = \{[(EPV_{tp} \times R_d \times F_{tp}) + (EPC_{sw} \times Q_d) + (EPC_s \times R_d \times F_s)]/W_d\} \times \Psi_d \times \Theta_d \quad (10\text{-}15)$$

$$Q_d = 0.099 \times W_d^{0.9} \text{ (in kg)} \quad (10\text{-}16)$$

where:

ADD_d	=	applied daily dosage to mule deer, mg/kg-d (dry weight)
R_d	=	food intake rate of mule deer, kg/d (dry weight)
EPV_{tp}	=	chemical concentration in terrestrial plant, mg/kg (dry weight) (Equation 10-4)
F_{tp}	=	fraction of terrestrial plant in mule deer diet, unitless (Table 10-4)
EPC_{sw}	=	exposure point concentration of chemicals in surface water, mg/L
EPC_s	=	exposure point concentration of chemicals in soil, mg/kg (dry weight)
F_s	=	fraction of soil in mule deer diet, unitless (Table 10-4)
Q_d	=	water intake rate of mule deer diet, L/d
W_d	=	mean weight of adult mule deer, kg (Table 10-4)
Ψ_d	=	fraction of year spent at SSFL, unitless (Table 10-4)
Θ_d	=	fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

The food intake rate (R_d) for the mule deer is taken from Nagy (2001). Equation 10-15 is from Hope (1995) and Equation 10-16 is from USEPA (1993b). These equations are based on metabolic energy requirements. Therefore, as presented in Table 10-4, the sum of the dietary fractions is 1.0. Beyer *et al*. (1994) as well as others (*e.g.*, USEPA 1993b) have presented estimates of soil ingestion as percentages of the diet. Because soil ingestion does not contribute to metabolic energy requirements, these fractional amounts have been added to the total ingestion rate.

To calculate a range of potential ADDs, both the EPCs and the EPVs in the above equation will be calculated as 95 percent UCL and mean soil concentrations. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

10.7.5 Red-Tailed Hawk

The red-tailed hawk is primarily exposed to chemicals through ingestion of prey items. For purposes of this work plan, deer mice were chosen as representative prey for the hawk and will comprise 100 percent of the red-tailed hawk's diet. While red-tailed hawk are also potentially exposed to chemicals via direct contact with soils (dermal contact) and inhalation of air, these exposure routes will not be evaluated as discussed previously. Red-tailed hawk water requirements are met in most instances from food intake (Zeiner *et al*. 1990b); therefore, uptake

of surface water was not factored into the model. Incidental soil ingestion is considered a negligible pathway compared to the ingestion of prey; therefore, that pathway is not evaluated. The following model will be used to estimate the ADD:

$$ADD_{rt} = \{(EPV_d \times R_{rt} \times F_d)/W_{rt}\} \times \Psi_{rt} \times \Theta_{rt} \quad (10\text{-}17)$$

where:

ADD_{rt}	=	daily dosage to red-tailed hawk from prey, mg/kg-d
EPV_d	=	chemical concentration in deer mouse, mg/kg (dry weight) (Equation 10-6)
R_{rt}	=	food intake rate for red-tailed hawk, kg/d (dry weight)
F_d	=	fraction of deer mouse in red-tailed hawk diet, unitless (Table 10-4)
W_{rt}	=	mean weight of adult red-tailed hawk, kg (Table 10-4)
Ψ_{rt}	=	fraction of year spent at SSFL, unitless (Table 10-4)
Θ_{rt}	=	fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

The food intake rate (R_{rt}) for the red-tailed hawk is calculated from predictive equations presented in Nagy (2001) for carnivorous birds. Equation 10-17 is from Hope (1995). This equation is based on metabolic energy requirements. Therefore, as presented in Table 10-4, the sum of the dietary fractions is 1.0.

To calculate a range of potential ADDs, both the EPCs and the EPVs in the above equation will be calculated as 95 percent UCL and mean soil concentrations. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

10.7.6 Bobcat

The bobcat is potentially exposed to chemicals through direct contact with soil, inhalation of air, ingestion of water and prey, and incidental ingestion of soil. For purposes of this work plan, the bobcat is primarily exposed to chemicals through the ingestion of contaminated prey and/or ingestion of surface water. In the exposure model, deer mice were chosen as representative of bobcat prey and will comprise 100 percent of the bobcat's diet. While bobcat are also potentially exposed to chemicals via direct contact with soils (dermal contact) and inhalation of air, these exposure routes will not be evaluated as discussed previously in Section 10.6. Incidental soil ingestion is considered a negligible pathway compared to the ingestion of prey; therefore, that

pathway is not evaluated. The following equations will be used to estimate the daily dosage for the bobcat.

$$ADD_{bc} = \{[(EPV_d \times R_{bc} \times F_d) + (EPC_{sw} \times Q_{bc})]/W_{bc}\} \times \Psi_{bc} \times \Theta_{bc} \quad (10\text{-}18)$$

$$Q_{bc} = 0.099 \times W_{bc}^{0.9} \quad (10\text{-}19)$$

where:

ADD_{bc}	=	applied daily dosage for the bobcat, mg/kg-d
EPV_d	=	chemical concentration in deer mouse, mg/kg (dry weight) (Equation 10-6)
R_{bc}	=	food intake rate for bobcat, kg/d (dry weight)
F_d	=	fraction of deer mice in diet, unitless (Table 10-4)
EPC_{sw}	=	environmental concentration of chemical in surface water, mg/kg
Q_{bc}	=	water intake rate for bobcat, L/d
W_{bc}	=	mean weight of adult bobcat, kg (Table 10-4)
Ψ_{bc}	=	fraction of year spent at SSFL, unitless (Table 10-4)
Θ_{bc}	=	fraction of time on SSFL spent in exposure unit, unitless (Table 10-4)

The food intake rate (R_{rt}) for the red-tailed hawk is calculated from predictive equations presented in Nagy (2001) for carnivorous mammals. Equation 10-18 is from Hope (1995) and Equation 10-19 is from USEPA (1993b). These equations are based on metabolic energy requirements. Therefore, as presented in Table 10-4, the sum of the dietary fractions is 1.0.

To calculate a range of potential ADDs, both the EPCs and the EPVs in the above equation will be calculated as 95 percent UCL and mean soil concentrations. For species with large home ranges, terrestrial plant EPVs will be estimated using the protocol presented in Section 12.1.3.

10.8 LARGE HOME RANGE SPECIES EXPOSURE

As previously discussed in Section 9.5, the calculation of a large home range representative species exposure and risk at each investigational unit and for the SSFL as a whole will be a step-wise process, progressing from smaller spatial scales to larger spatial scales (see Section 12.1.3 and Appendix J). The first step assumes the large home range representative species forages in appropriate habitats within a single investigational unit. The second step assumes large home range representative species forages in appropriate habitats among investigational units within a single Reporting Area. The last step assumes the large home range representative species forages

in appropriate habitats among Reporting Areas across the entire SSFL facility. Specific steps to calculate risks to large home range species following this step-wise process are described in Section 12. Further details and an example of how the exposure and risk will be calculated is included in Appendix J.

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SECTION 11

11 ECOLOGICAL EFFECTS ASSESSMENT

Toxicity benchmarks are necessary for evaluating potential effects to ecological receptors in lieu of empirically measuring effects in ecological receptors. There are no standard toxicity benchmarks for every medium or every species, and occasionally the absence of toxicity benchmarks can limit the ability to quantify risks to certain species for specific pathways. Availability of toxicity benchmarks was one of the parameters used to select representative species for the SSFL (Section 9).

DTSC generally recommends that toxicity benchmarks be expressed as either RfCs, concentrations in abiotic media that are not expected to have adverse effects on lower trophic level organisms, or Toxicity Reference Values (TRVs), dosages of chemicals that are not expected to adversely effect higher trophic level receptors. For aquatic receptors, there is very little exposure parameter information available, and toxicity data are almost always reported as exposure concentrations. Therefore, the RfC is the preferred toxicity value for use in site-specific aquatic risk assessments at the SSFL. TRVs are the preferred toxicity benchmarks for use in site-specific terrestrial risk assessments at the SSFL. TRVs are the primary toxicity values available for mammalian and avian species, and the use of TRVs implies an estimate of site-specific exposure in terms of average daily dose. In contrast to RfCs, the use of TRVs also allows for the assessment of risks to higher trophic level receptors though body size extrapolation and receptor-specific exposure assumptions.

RfCs and TRVs are generally derived from the results of laboratory or field toxicity tests reported in peer-reviewed literature or other technical publications. Toxicity benchmarks, which refer to both the type and magnitude (concentration or dosage) of observed toxicity include, but are not limited to, the following:

<u>Reference Concentrations</u>

- lowest federal or state acute or chronic AWQC
- sediment quality guidelines (SQGs)
- no observed effect concentration (NOEC)
- lowest observed effect concentration (LOEC)
- lowest chronic value (LCV)
- median lethal concentration (LC_{50})

- median effective concentration (EC_{50})

Toxicity Reference Values

- no observed effect level (NOEL)
- NOAEL
- lowest observed effect level (LOEL)
- LOAEL
- median lethal dose (LD_{50})
- median effective dose (ED_{50})

Of the above toxicity benchmarks, "no effect" concentrations or exposure levels (*i.e.*, NOECs, NOAELs) will be the preferred toxicity endpoints for selection and/or derivation of TRVs and RfCs. When appropriate AWQC, NOECs, or NOAELs are not available, other toxicity benchmarks, such as LOECs and LOAELs, will be converted to aquatic and terrestrial NOECs or terrestrial NOAEL values following methodology described in Section 11.1 and 11.2, respectively.

The principal sources of toxicity benchmarks that were reviewed for the derivation of risk assessment TRVs and RfCs at the SSFL include:

Terrestrial Birds and Mammals

- EFA West (1998), as cited in DTSC (2000)
- ORNL Toxicological Benchmarks (Sample *et al*. 1996)
- ATSDR chemical-specific Toxicological Profiles
- USEPA's IRIS database (USEPA 2005a)
- Region 6 Combustor Guidance (USEPA 1999)

Soil Invertebrates

- ORNL Toxicological Benchmarks (Efroymson *et al*. 1997; Will and Suter 1995)
- Ecological Soil Screening Levels (USEPA 2003a-b, 2005d-n)
- Region 6 Combustor Guidance (USEPA 1999)
- Sverdrup *et al*. (2002)

Aquatic Biota

- National Recommended AWQC (USEPA 2002b)

- USEPA's ECOTOX database, as presented in USEPA (2002c)

Sediment Invertebrates

- MacDonald *et al*. (2000) – metals
- Johnson *et al*. (2002) – PAHs
- Meader *et al*. (2002) – PCBs

To develop TRV values needed to derive ESLs, EFA West (1998) values were used where available (ESL derivation is presented in Appendix C). For compounds without TRV values from EFA West (1998), the lowest available TRV for a particular chemical was selected from the other sources cited above.

For development of TRVs to derive ESLs, the most conservative (lowest) and appropriate toxicity value applicable to the assessment endpoints described in Section 9.6, will be used. Generally, these assessment endpoints are established to protect species populations and abundance of food and prey species. While mortality, reproductive effects, and developmental effects are considered to be toxic endpoints that directly impact populations, its is also possible that toxic effects considered less serious could impact a population at lower exposure levels than would produce mortality, reproductive effects, and developmental effects. Therefore, the selection of appropriate toxicity studies and toxic endpoints for derivation of TRVs to calculate ESLs will consider the established assessment endpoints presented in Section 9.6 as well as the nature of other "less serious" toxic effects and the relative magnitude of their no effects levels. Baseline risk assessment TRVs are not presented in this SRAM, but will be derived on a case-by-case basis as required for investigational unit risk assessments.

The following sections describe the specific selection or derivation of toxicity benchmarks for use in SSFL ecological screening evaluations.

11.1 REFERENCE CONCENTRATIONS

11.1.1 Aquatic Receptors

Benchmark RfCs for surface waters were obtained from the National Recommended Water Quality Criteria for Priority Pollutants, AWQC table (USEPA 2002b). AWQC are intended to prevent significant toxic effects associated with either acute or chronic exposures to species occurring in a water body. AWQC are designed to protect for acute exposures at the lower 5th percentile of the distribution of species with a safety factor of two and to protect for chronic

exposures at a similar level. AWQC are calculated with higher emphasis on the most sensitive species for which reliable toxicity data are available. Thus, their use as RfCs implies that they will be protective of all organisms found in aquatic habitats at the SSFL.

For compounds without freshwater AWQC values, the principal source for aquatic toxicity data for chemical-specific RfC development was the USEPA ECOTOX database (USEPA 2002c). For aquatic species, a common toxicological endpoint is the LC_{50}, the chemical concentration that was lethal to 50 percent of the test animals in a specified time period. Because the 96-hour LC_{50}s represent acute exposures and the RfCs are designed to protect against chronic exposures, the 96-hour LC_{50} data are divided by an uncertainty factor of 100 to approximate chronic NOEC values (see Section 11.1.3 for further discussion of uncertainty factors). If no 96-hour LC50 was reported, an alternate duration was selected if available. If no chemical-specific toxicity information was available in ECOTOX, a chemical with structural similarity was selected as a surrogate. RfCs for dioxin and PCB congeners were generated using the World Health Organization congener-specific TEFs for fish (Van den Berg *et al*. 1998) and the LC_{50} for 2,3,7,8-TCDD. As pointed out by DTSC (2005a), a caveat summarized by Van den Berg *et al*. (1998) noted that tissue-based TEFs applied to dioxin, furan, or PCB congener soil, sediment, food, or water exposure concentrations generates highly uncertain risk estimates.

The available AWQCs, 96-hour LC_{50} values and the chronic RfCs for the chemicals identified in surface water at the SSFL to date are presented in Table 11-1. RfCs may also be derived from primary toxicity studies in cases where there is more recent toxicity information that has become available since the publication of the above-cited sources.

Benchmark RfCs for sediments are based on recommended sediment quality criteria as published by MacDonald *et al*. (2000), Johnson *et al*. (2002), and Meader *et al*. (2002) for metals, PAHs, and PCBs, respectively. Sediment RfCs are presented in Table 11-2.

11.1.2 Terrestrial Invertebrates

Studies on soil concentrations that pose a risk to invertebrate receptors are limited. Soil benchmarks were obtained primarily from Efroymson *et al*. (1997), USEPA EcoSSLs (2003a-b, 2005d-n), USEPA Combustor Guidance (1999), and Sverdrup *et al*. (2002). Benchmarks for chemicals not listed will be derived from the literature. The RfCs for terrestrial invertebrates are presented in Table 11-3.

11.2 TOXICITY REFERENCE VALUES

In agreement with DTSC, TRVs for terrestrial mammalian and avian species for use in baseline risk assessment are not presented in this SRAM, but will be derived as needed on a site-specific basis during the preparation of investigational unit risk assessments. However, terrestrial mammal and bird TRVs were derived for the purpose of deriving ESLs, and are presented in Appendix C. The methods described below generally apply to the selection or derivation of TRVs for both ESLs and for use in baseline risk assessments.

As recommended by DTSC, the following secondary sources were evaluated for the identification and selection of applicable TRVs for terrestrial wildlife at the SSFL:

- Navy/Biological Technical Advisory Group (BTAG) TRVs summarized in EFA West (1998);
- Toxicity benchmark values developed and/or summarized for wildlife by ORNL (Sample *et al*. 1996);
- Toxicity values summarized in the ATSDR chemical-specific Toxicological Profiles; and,
- The USEPA's IRIS.

These secondary sources were reviewed to select the lowest screening values for ESLs. It should be noted that without thorough review of all the primary studies and other relevant literature, the values obtained from these sources are only as defensible as the secondary literature sources cited. To develop TRVs for site-specific ecological risk assessments, the primary literature will be reviewed.

For the purpose of selecting applicable TRVs to derive ESLs from the above-cited sources, the effects considered ecologically relevant include growth, reproduction, mortality, and other less serious effects that are relevant to assessment endpoints described in Section 9.6 (*i.e.*, protection of receptor populations and communities and their food sources). The relevancy of the route of administration was considered secondary to the effect. The highest NOAEL lower than the lowest LOAEL is used when available. If a NOAEL is derived by application of an uncertainty factor to a LOAEL (to adjust for endpoint) and the derived NOAEL TRV value is lower than an actual measured NOAEL, the measured NOAEL is used. Uncertainty factor (UF) application was performed using the same methods as were used for deriving ESL TRVs, as described in Section 3.2.1.2, and below.

For chemicals without chronic dose-response-based NOAELs, but for which other toxicity values were available, uncertainty factors were applied to extrapolate these other toxicity values to chronic NOAELs. These other toxicity values include less than chronic NOAELs (*e.g.*, subchronic NOAELs), LOAELs, and LD_{50}s. Specifically, a UF of 5 was used to adjust LOAEL TRVs to NOAEL TRVs; a UF of 2 was used to extrapolate TRVs derived from subchronic studies to chronic TRVs. An uncertainty factor of 100 was used to adjust LD_{50} values to chronic NOAEL equivalent values. Uncertainty factors were combined as necessary.

If no toxicity values were available for a particular compound, appropriate surrogate chemical chronic NOAELs were used as the mammalian TRVs. Surrogate chemicals were selected based on structural chemistry, specifically, the active moiety/functional group of the chemical, and are expected to exhibit toxicity equal to, or greater than, the particular compound without toxicity values. Therefore, uncertainty factors were not included to account for surrogate use. This process was only performed for chemicals for which a NOAEL, LOAEL, or LD_{50} toxicity value was available. In those cases where appropriate chemical surrogates were not identified, the most conservative TRV within the chemical class (*e.g.*, VOCs, metals, etc.) was used as the TRV.

To develop TRVs for dioxin PCB congeners, congener specific TEFs compiled by Van den Berg *et al*. (1998) were applied to the mammalian and avian 2,3,7,8-TCDD TRVs. The TEFs serve as weighting factors to generate 2,3,7,8-TCDD equivalent toxic potency for the other 16 2,3,7,8-substituted dioxin congeners and 12 coplanar PCB congeners. The mammalian and avian specific 2,3,7,8-TCDD TRVs were multiplied by the congener-specific TEFs to derive the congener specific TRVs.

Finally, laboratory studies may have been conducted on species other than the receptor species selected for ecological risk assessment at the SSFL. If toxicity values used were not based on data for that specific species, an allometric conversion based on body size (*i.e.*, weight and surface area) was used to extrapolate between species, but only in cases where there was a 100-fold difference between test species' and representative species' body weights as recommended by DTSC (1999c). The body size adjusted TRVs, referred to here as "adjusted NOAEL-equivalent toxicity values," were calculated using the allometric conversion described in Equation 11-1 (Sample and Arenal 1999):

$$TRV_{adj} = TRV_t \, (BW_t/BW_r)^{SF} \qquad (11\text{-}1)$$

Where:

TRV_{adj} = Adjusted NOAEL-equivalent TRV (mg/kg of body weight per day)
TRV_t = NOAEL-equivalent toxicity reference value for test organism (mg of chemical/kg of body weight per day)
BW_t = Body weight for test organism (kg)
BW_r = Body weight for receptor species (kg)
SF = Body size scaling factor (unitless)

Sample and Arenal (1999) developed chemical-specific mammalian scaling factors (SFs) for 167 chemicals and avian SFs for 194 chemicals. A body size SF of (1 – 0.94), or 0.06, was used to extrapolate TRVs between mammalian species for which chemical-specific SFs were not available (Sample and Arenal 1999). An SF of zero was used in Equation 11-1 to extrapolate TRVs between avian species. Mineau *et al*. (1996) identified a mean SF of (1 - 1.15) for birds; Sample and Arenal (1999) recently reported a mean SF of (1 - 1.2) for birds. However, in an earlier study, Sample *et al*. (1996) reported that scaling factors for a majority of the chemicals evaluated (29 of 37) were not significantly different from 1. Therefore, a SF of zero for TRV extrapolation between avian species was determined to be more appropriate for scaling between avian species.

From an ecological standpoint, basing a TRV on a NOAEL may be unduly conservative because exceedance of a NOAEL does not necessarily imply an adverse effect at the receptor population level. The U.S. Navy and the BTAG along with other consultants and federal agencies produced a consensus publication (Engineering Field Activity, West; EFA West) in 1998. EFA West proposed both conservative TRV-low values for use in screening and TRV-high values that represent a mid-range adverse effect level. The EFA West TRVs were intended to be used to quickly screen sites that were clean and those sites where impacts were likely to occur. It should be noted that as initially agreed among the EFA West participants, these draft TRVs were only to be used at Navy sites in the San Francisco Bay area. Nevertheless, the DTSC has sanctioned the use of TRV-high values to estimate the upper limit of an estimated hazard quotient with the caveat that if the value is exceeded, the adverse effect upon which the TRV was derived can be assumed to occur (DTSC 2000). A small mammal health protective goal based on effects to an individual is not consistently demonstrated through the EFA West selection of TRV high values. TRV high endpoints range from, for example, a TRV high LOAEL for effect of a 50 percent reduction in fetuses (PCBs) to a TRV high LOAEL for hair loss (thallium). Therefore, EFA West TRV high values are not always appropriate for protection against population level ecological effects. The population level ecological significance of the critical effect was taken into

consideration, and professional judgment was applied in the use of EFA West TRV-high values as TRVs.

11.3 TOXICITY CRITERIA FOR PLANTS

Plants are an assessment endpoint, specifically to protect the abundance of native terrestrial vegetation by limiting acute and chronic adverse effects from exposure to site-related chemicals. Efforts to obtain appropriate and applicable toxicity data for plants have proven that plant toxicity data are limited. The majority of phytotoxicity studies readily available in the scientific literature used exposure media such as vermiculite and hydroponics that are not representative of natural soil conditions. The effect of using such media is illustrated in the comparison of soil TRVs for metals, which are purportedly protective of plants, to the ambient background metal concentrations at the SSFL. The comparison suggests that significant adverse impacts to plants should result from ambient background metal concentrations in soils at the SSFL. However, both native and nonnative plant species appear to thrive throughout the SSFL property, despite exposure to ambient soil metal concentrations well above the literature-derived TRVs. Moreover, the toxicity data available from plant toxicity studies have only been conducted on very few organic chemicals.

For the vast majority of chemicals requiring evaluation at the SSFL, there are no phytotoxicity data. This endpoint is more readily assessed and characterized through observational studies (*i.e.*, transect studies) at each site during the ecological risk assessment. Since the abundance of native terrestrial vegetation is a function of numerous factors, including anthropogenic impediments (*i.e.*, buildings, roadways, other structures), a qualitative observational assessment of plant abundance will be performed (see Section 12.1.4). In cases where there is evidence suggesting that chemical contamination may have adversely impacted the abundance of native terrestrial vegetation, additional quantitative assessments may be conducted.

11.4 CRITICAL TISSUE CONCENTRATIONS

Critical tissue concentrations are chemical concentrations in organism tissue that correlate to the absence of adverse effects. As an additional line of evidence, terrestrial and/or aquatic receptor tissue concentrations may be estimated using site-specific BAFs or literature-based BAFs. Estimated receptor tissue concentrations will be compared to relevant critical tissue concentrations reported in the scientific literature (*e.g.*, Kabata-Pendias and Pendias 1992; Beyer *et al*. (1996), Jarvinen and Ankley (1999); Meader *et al*. 2002) to support the risk assessment. Additional lines of evidence will be discussed in the uncertainty section of the risk assessment.

SECTION 12

12 ECOLOGICAL RISK CHARACTERIZATION

Risk characterization combines information concerning exposure to chemicals with information about the potential effects of those chemicals to estimate potential ecological risks to representative species. Risk characterization addresses the following questions:

- Are ecological receptors currently exposed to site-related CPECs at levels capable of causing harm, or is future exposure of receptors likely?
- If adverse ecological effects are observed or predicted, what are the types, extent, and severity of effects?
- What are the principal uncertainties associated with the risk characterization?

Generally, a weight-of-evidence approach is used. In other words, the physicochemical properties, bioavailability, historical site use, and areal distribution of CPECs, in addition to the quantitative risk estimates, are used to determine the potential for ecological risk. Moreover, the suitability of available habitat at a given investigational unit for ecological receptor species of concern is determined. The following sections describe the proposed methodology for each individual line of evidence, as well as ways to combine and evaluate all the evidence. The uncertainty analysis will be discussed in Section 12.3.

12.1 RISK ESTIMATION METHODOLOGY

Risk estimation is the calculation of potential risk by comparing either the exposure concentration or exposure dosage (*i.e.*, the EPCs or ADDs) to the RfC or TRV, respectively. Risks will be estimated by calculating HQs and HIs as described below.

12.1.1 Hazard Quotients

DTSC (1996) defines an HQ as "the chemical-specific ratio of the dosage by an exposure route to the TRV for that route, or the chemical-specific ratio of a concentration in a medium to the RfC for that medium." As described in Section 10, ADDs and EPCs are estimates of the dosage or concentration (respectively) of a chemical experienced by a representative species in a particular exposure area.

HQs will be calculated using the following equation:

$$HQ_{ij} = ADD_{ij} / TRV_{ij} \quad (12\text{-}1)$$

$$HQ_{ij} = EPC_{ij} / RfC_{ij} \quad (12\text{-}2)$$

where:

HQ_{ij}	=	hazard quotient for the ith CPEC for the jth target receptor
ADD_{ij}	=	average daily dosage for the ith CPEC for the jth target receptor
TRV_{ij}	=	toxicity reference value for the ith CPEC for the jth target receptor
EPC_{ij}	=	exposure point concentration for the ith CPEC in abiotic media
$RfCij$	=	reference concentration value for the ith CPEC for the jth target receptor

Both the CTE and RME will be evaluated in the estimation of HQs. Each of these exposure values will be considered qualitatively in the uncertainty analysis of the risk assessment. RfCs and TRVs are discussed further in Section 11. Estimation of HQs from ADDs and TRVs will include HQ estimates using the screening TRVs used to derive ESLs. If a chemical-specific HQ exceeds a value of 1 when using the ESL TRV, then the relevance and applicability of the ESL TRV will be evaluated, and if necessary, a more relevant and applicable TRV will be derived for calculation of the HQ. Both HQs, based on the ESL TRV and on a more relevant and applicable TRV, will be presented in the risk assessment.

If the exposure concentration is less than an acceptable effect or dosage concentration (HQ less than 1), then it is inferred that there exists a negligible potential for adverse effects. If a chemical-specific HQ exceeds a value of 1 when using the ESL TRV, then the relevance and applicability of the ESL TRV to the stated assessment endpoints will be evaluated, and if necessary, a more relevant and applicable TRV will be presented in the risk assessment. The likelihood of an adverse effect to the representative species will be evaluated with respect to other lines of evidence and uncertainty discussed in Sections 12.2 and 12.3, respectively.

12.1.2 Hazard Index

HQs are chemical and exposure pathway specific. However, representative species present at an investigational unit are usually exposed to more than one chemical and pathway. HIs are calculated to determine the potential cumulative effects of chemicals and pathways on a representative species. For each representative receptor, HIs will initially be calculated by summing all HQs for a given representative species across all exposure pathways. Since HQs are considered to be additive only for those chemicals that act through similar mechanisms or on the

same target organ, then in cases where the initially estimated HI exceeds 1, HIs will be calculated separately for each class of structurally similar chemicals that have a similar mechanism of action and the same target organ. HQs for individual chemicals will be used for chemicals that do not act similarly on the same organs.

As inferred by the preceding discussion, some chemicals have been shown to act through similar mechanisms or on the same target organ, and thus can be considered to have additive effects on organisms. For instance, coplanar PCBs and dioxins are believed to exhibit similar toxic action to that of 2,3,7,8-TCDD, but with differing relative degrees of toxicity among the individual PCB and dioxin congeners. These compounds are all highly lipophilic and persistent and readily bioaccumulate in food chains. As with 2,3,7,8-TCDD, at certain doses they all may cause body weight loss, thymic atrophy, dermal lesions, impairment of immune responses, hepatotoxicity, carcinogenesis, teratogenicity, and reproductive toxicity (Safe 1990). TEFs for these chemicals relative to 2,3,7,8-TCDD will be used to evaluate the toxicity of specific dioxins and coplanar PCB congeners (Van den Berg *et al*. 1998). In addition to estimating HQs for coplanar PCB congeners, HQs will also be estimated for Aroclor mixtures using appropriate TRVs for Aroclors. HQs for Aroclors will be included, as applicable, in the calculation of cumulative HIs; however, estimated HQs for coplanar PCBs will be presented separately due the high degree of uncertainty associated with their TEFs and to avoid potential "double counting" of exposure and risk. Other individual chemicals with similar toxicological characteristics may have an additive effect and will be added together, as necessary, for separate HI calculations.

Therefore, it is likely that there will be several HIs and HQs for each representative species, depending on the classes of CPECs that are evaluated. An HI value greater than or equal to 1 suggests the potential for adverse cumulative effects. Each HQ and HI calculated for each representative species will be evaluated for its contribution to ecological risk at each investigational unit.

12.1.3 Large Home Range Species Risk Calculations

Species with large home ranges (*e.g.*, red-tailed hawk, bobcat, mule deer, and great blue heron) may be exposed to chemicals at more than one investigational unit, as described in Sections 9 and 10. Therefore, the risk calculation will take into account potential exposure at one investigational unit, all investigational units with appropriate habitats within a Reporting Area, and across the entire facility. The steps for calculating the risk for each of these three exposure

scenarios are given below. A detailed example of how the risks will be calculated is provided in Appendix J.

Step 1. Calculation of Individual Investigational Unit Risk

Step 1a – Select investigational units for evaluation. Using information provided in the BCR (Appendix I) and methodology described in this SRAM (Sections 9 through 12), select investigational units for evaluation based on (1) appropriate foraging habitat for the large home range species of concern and (2) the presence of a complete exposure pathway in air, soil, sediment, or surface water, for the habitat. Each investigational unit will be evaluated, provided each contains appropriate habitat for the large home range species of concern.

Step 1b – Calculate large home range species exposure at each investigational unit assuming that the species forages 100 percent of the time (assume area use factor = 1) in the investigational unit. This will provide a conservative method for assessing risk presented in an investigational unit.

Step 1c – Calculate the HQ based on the methodology described in Step 1b above and in Section 12.1.1. The relative exposure at each investigational unit will be divided by the TRV to calculate the HQ. For CPECs with similar toxic effects (*e.g.*, PAHs), HQs will be added to calculate an HI. If the HQ or HI for the individual investigational unit is less than 1, then a decision identifying acceptably low risk to large home range species at 100 percent usage can be made for a site; however, the site will still be evaluated as part of the incremental risk to large home range species. The resulting HQ and HI values will be used to rank each investigational unit for potential ecological risk. Proceed to Step 2.

Step 2. Calculation of Combined Investigational Unit Risk

Step 2a – Calculate exposure of large home range species at all investigational units with appropriate foraging habitat. Relative exposure at each investigational unit will be calculated with a species-specific adjusted area use factor for each investigational unit that is based on the percent of foraging habitat provided in the investigational unit divided by the total foraging habitat provided by all investigational units.

Step 2b – Calculate HQs and/or HIs based on methodology previously discussed.

Step 2c – Add chemical-specific HQs or HIs for each investigational unit to calculate a "total HQ or HI" for the large home range species. If the combined investigational unit HQ

and/or HI is less than 1, then no additional iterations would be necessary because risk would be identified as acceptably low. If the "total HQ" and/or HI is greater than 1, further investigation is necessary. Total HQ or HI values will be used to rank each investigational unit for potential ecological risk and to identify potential contamination hot spots. Proceed to Step 3.

Step 3. Calculation of Facility-wide Risk

Step 3a – Identify and quantify acreage of appropriate habitat for large home range species that is not associated with investigational units but is contained within the entire facility.

Step 3b – Calculate facility-wide exposure assuming the large home range species evaluated in Step 2 also forage in habitats that are not part of investigational units (*i.e.*, exposed across the entire facility and not just in contaminated sites). Relative exposure at an investigational unit will be calculated with an adjusted area use factor based on the summed percent of foraging habitat on each investigational unit and the foraging habitat outside the investigational units divided by the total foraging habitat on all investigational units. Because this step incorporates all appropriate habitats available at the SSFL, and not just habitats occurring at a given investigational unit, background concentrations of metals and dioxins will be included in the exposure calculations.

Step 3c – Calculate the HQ and/or HI based on previously described methodology.

The resulting HQs will be added for each investigational unit and the areas outside of the investigational units at the SSFL to calculate a facility-wide total HQ or HI for the large home range species. This HQ and/or HI can be used to support risk management decisions.

The results of this iterative, large home range species risk assessment will be used to facilitate the risk decision and management processes as described in Section 12.4.

12.1.4 Evaluation of Plants in Ecological Risk Assessments

Plants are identified as assessment endpoints, specifically to protect the abundance of native terrestrial vegetation by limiting acute and chronic adverse effects from exposure to site-related CPECs. However, appropriate and applicable toxicity data for plants are limited (see Section 11). The abundance of native terrestrial vegetation is more readily assessed and characterized through observational studies (*i.e.*, transect studies) at each site during the ecological risk assessment. In cases where there is evidence suggesting that chemical contamination may have adversely impacted the abundance of native terrestrial vegetation, additional quantitative assessments may

be conducted. Following is a summary of the general approach to be used for risk assessments of investigational units at the SSFL.

The investigation units at the SSFL have terrestrial vegetation distributions ranging from highly disturbed and patchy to relatively continuous undisturbed stands of native vegetation. Because of the wide variability of potential habitat occurrence at each of the individual investigational units to be evaluated, the following three general approaches will be used to evaluate potential effects to vegetation at the SSFL potentially attributable to chemical concentrations in surface soil.

1. For those investigational units with relatively highly disturbed and patchy distributions of vegetation types, specific vegetation communities associated with soil sampling efforts will be identified and an attempt will be made to find similar vegetation communities at locations within the investigational unit that have not been impacted by soil chemical concentrations. A semi-quantitative comparison will be made between these two areas to document changes, if any, that may be attributable to the presence of chemical concentrations in soil.

2. For those investigational units with relatively large or continuous stands of vegetation, a semi-quantitative, visual comparison will be made between vegetation communities occurring in known areas of CPEC concentrations (based on soil sampling results) and similar vegetation communities in areas where soil sampling has not occurred. This approach is based on the assumption that soil sampling efforts at an investigational unit targeted areas where chemical impacts were possible based on historical practices and operations.

3. For those investigational units with relatively highly disturbed areas (*e.g.*, pavement) and no complete exposure pathways, areas with similar chemical concentrations and relatively undisturbed vegetation will be located. As above, these areas will be compared to areas of lower chemical concentrations or areas with no history of chemical use or presence. A semi-quantitative comparison (*e.g.*, dominant species, number of species, abundance, percent cover, etc.) will be made between these two areas to document changes, if any, that may be attributable to the presence of chemical concentrations in soil.

Any areas of damaged, unhealthy, or otherwise anomalous vegetation associations within investigational units will be documented, and an attempt will be made to determine potential causes for the changes. The information will be summarized in the investigational unit risk assessments.

12.1.5 Evaluation of Potential Inter-Site Sediment Migration

The potential for significant migration of CPECs from the investigational unit under evaluation to a downgradient investigation unit through transport of sediment will be evaluated in each risk assessment for a Reporting Area. If a mechanism for sediment transport is suggested by the direction and slope of the land or by the presence of creeks or ditches connecting the two investigational units, this determination will be initially identified in each appropriate described in each site-specific risk assessment and fully discussed in the risk assessment for the appropriate Reporting Area. Evaluation of the potential impacts of sediment migration to a downgradient unit will be identified by a comparison of the ecological habitats, receptors, and exposure pathways that are relevant to the investigational unit under evaluation and the downgradient unit as follows:

1. If the ecological receptors and exposure pathways are identical at the investigational unit under evaluation and the downgradient unit, then it will be assumed that ecological risks at the adjacent unit could be has high as those at that site under evaluation. In these cases, it is conservatively assumed that no attenuation or dilution occurs during sediment transport, and that the concentrations of CPECs at an adjacent downgradient site could be as high as those at the site under evaluation. Therefore, if the risk assessment for the investigational unit under evaluation shows a potential unacceptable risk, then it will be assumed that risks at the adjacent site may also be unacceptable. Likewise, if the risk assessment for the investigational unit under evaluation concludes that risks are acceptable, then it will be assumed that risks at the downgradient site are also acceptable.

2. If the ecological receptors and exposure pathways are more sensitive at the downgradient unit as compared to the investigational unit under evaluation, then additional quantitative assessment will be performed using the soil concentration data from the investigational unit under evaluation and applying that data to the more sensitive ecological conditions at the downgradient unit. In general, for ecological risk assessment an aquatic habitat will be considered more sensitive than a terrestrial habitat.

The initial comparison of receptors, exposure pathways, and habitats will be described in the investigational unit risk assessments. Should quantitative evaluation of potential impacts to a downgradient unit be necessary, such evaluations will follow the methods as described in this SRAM, and will be presented in the investigation unit risk assessment as an attachment or the risk assessment for the Reporting Area.

12.2 WEIGHT OF EVIDENCE ANALYSIS AND RISK DESCRIPTION

A weight-of-evidence approach will be used to evaluate the risk to each representative species from different chemicals and the likelihood of adverse effects, taking into account factors such as the following: resulting HQ or HI values; past chemical use history at the site (*i.e.*, chemical of concern was used primarily in one portion of the site); habitat suitability for ecological receptors of concern (small amount of appropriate habitat onsite with extensive habitat offsite); physicochemical properties of chemicals (*i.e.*, chemical form in the environment, persistence, and mobility); bioavailability of chemicals (is a chemical bound to soil or in a form that is not readily absorbed; exposure assumptions (assuming a thrush spends 100 percent of its time in the most contaminated portion of the site); uncertainty factors used in derivation of toxicity criteria; and the uncertainty analysis discussed in Section 12.3. Using all lines of evidence, an estimate of the risk to each representative species will be determined.

Evaluating potential risk to ecological receptors will be an iterative process. The calculated HQs or HIs and the weight-of-evidence analysis will be used to support recommendations for the next phase of work, if necessary. It is possible that there will be HQs and HIs for chemicals and groups, respectively, that are greater than 1. An HQ or HI value of 1 will not be an absolute point of departure for ecological risk; rather, it will be used as a guideline. To simplify the risk description process, the value of one will be used as the point of reference for evaluating the environmental significance of HQs or HIs. HQs and HIs will be calculated based on the mean (CTE) and 95 percent UCL (RME) exposures for each representative species at each investigational unit. If the RME HQ or HI is less than 1, then risks to ecological receptors will be considered *de minimis* and no further action with respect to ecological risk assessment will be proposed (Figure 12-1). If the maximum HQ or HI is greater than 1, then the mean HQ or HI values will be examined. The likelihood of an adverse effect to representative species will depend on the magnitude of the risk quotient or index, the general toxicity of the chemical and its endpoint being evaluated, the bioavailability of the chemical, and other factors that will be taken into account in the weight-of-evidence analysis. For instance, an HQ of 10 based on the 95 percent UCL exposure concentration may be calculated for a terrestrial mammal exposed to lead using a TRV based on a soluble form of lead. However, only total lead was measured onsite and risk would be expected to be less than 10 due to expected lower bioavailability of total versus soluble lead. Existing habitats onsite will be considered; however, the entire site is considered for exposure to account for any changes onsite for land use in the future.

The need for refinement of exposure and toxicity assumptions will be made using professional judgment according to the flowchart on Figure 12-1. Uncertainty associated with each component of the ecological risk assessment will be identified as described below. Risk decision criteria will be based on the risk characterization, and recommendations to risk managers will be made as discussed in Section 12.4.

12.3 UNCERTAINTY ANALYSIS

Estimates of the potential for adverse effects from exposure to CPECs must often be made with imperfect information (data gaps) and may include several sources of uncertainty. To ensure that risk management decisions protective of ecological receptors are made despite these uncertainties, conservative assumptions are made that may overestimate rather than underestimate potential risks to these receptors. The principal common sources of uncertainty in the ecological risk assessment are described below and should be considered when evaluating risk estimates and when formulating risk management decisions for any investigational unit.

The uncertainty analysis section of the ecological risk assessment will summarize assumptions made for each element of the assessment and will evaluate the validity, strengths, and weaknesses of the analyses, as well as qualify the uncertainties associated with each risk estimate. This analysis addresses uncertainty associated with each component of the assessment: hazard identification, representative species, exposure estimation, toxicity criteria, and risk characterization. An important step in the ecological risk assessment will be to identify data gaps that may hinder or prevent the determination of potential risk and that need to be filled to facilitate such a determination.

Hazard Identification and Quantification

Uncertainty may be introduced in the selection and quantification (*i.e.*, statistical estimation of environmental concentrations) of the CPECs due to incomplete site chemical characterization. A comprehensive site characterization has been completed at each investigational unit with input from DTSC; therefore it is unlikely that chemicals are under-represented. Uncertainty is also introduced by the possibility that some detection limits were not adequate to register CPEC concentrations capable of inducing long-term chronic adverse effects in ecological receptors. There is uncertainty surrounding the substitution of the SQL for non detected chemical concentrations that are greater than toxicity criteria. Uncertainty in these components will be qualitatively evaluated for each investigational unit.

Receptor Selection

Knowledge of the potential suite of ecological receptors at the SSFL is based on previous field observations over several dates during different seasons. The range of representative species in this assessment encompasses range of potential receptors at the site. Therefore, it is unlikely that ecological receptors are under-represented in the species inventory. Uncertainties associated with representative species selection, diet, habitat use, ranges, and biology will be discussed qualitatively. Uncertainty concerning representation of feeding guilds and trophic levels at the facility is likely to be low, based on biological surveys of the facility and life history information available for most of the species.

Exposure Estimation

Uncertainty arises from the selection of exposure pathways and the quantitative estimation of contaminant uptakes. Factors that might reduce exposure rates, such as bioavailability from soil or surface water; degradation rates in soil or surface water; metabolic transformation in vegetation or invertebrates; receptor avoidance of contaminated soils, sediments, or surface water; dilution over distance; or frequency of receptor exposure to contaminated media, could add uncertainty to results. The collection of paired abiotic and biotic samples for exposure model validation will reduce some of these uncertainties. Uncertainties associated with exposure model assumptions and calculations will be discussed qualitatively.

Toxicity Criteria

Applicability of literature-derived toxicity data depends upon types of results available and methods used to arrive at these results. Test endpoints produced by laboratory and field tests may be reported as formally defined toxicological endpoints or as less stringently defined measures of mortality or sublethal effect; variations in format introduce a source of error when combined into a single TRV or RfC. Thus, seemingly equivalent toxicity values may be significantly different owing to differences in test protocols, test conditions, or responses of individual organisms (Lewis *et al*. 1990). Uncertainty surrounding toxicity criteria will be evaluated qualitatively.

Risk Characterization

The quotient method compares two point estimates, one for exposure and one for effect, to determine their position relative to each other. Each of these single point estimates actually represents a data set with a unique set of statistical characteristics, characteristics that strongly

influence the assessment of actual risk and the quantification of uncertainty. Focusing the risk characterization on a quotient of two numbers that have uncertainty associated with each creates additional uncertainty. Uncertainty associated with the risk characterization step will be qualitatively assessed.

12.4 ECOLOGICAL RISK DECISION CRITERIA

Ecological decisions made with the information provided in an ecological risk assessment will be based on a weight-of-evidence analysis. Information that will be synthesized and evaluated in the weight-of-evidence analysis includes:

- Identified CPECs and potential exposure pathways
- Estimated and field-verified EPCs
- Estimated and potentially field-verified toxicity evaluations
- Persistence and bioaccumulation potential
- Life history, home range and foraging habits of representative species of concern

In addition, the weight-of-evidence analysis will consider the toxicological endpoint of the toxicity value used to calculate the HI, the magnitude of any uncertainty factors used to develop the final toxicity value, the uncertainty contained in exposure models, the quality of the onsite habitat relative to offsite habitat, and the range of representative species evaluated. Risk, relative to selected assessment endpoints (Section 9), will be characterized after this weight-of-evidence analysis is completed.

Based on the weight-of-evidence analysis, one of three following recommendations will be made to risk managers:

1. No further action with respect ecological risk will be recommended for investigational unit(s) where *de minimus* risk (HI<1) to ecological receptors is identified for small home range species (*i.e.*, representative species that spend the majority of their life span within an investigational unit) and large home range species (*i.e.*, representative species that spend the majority of their life span outside of investigational units or forage across multiple investigational units). Single investigational units will not be recommended for no further action until cumulative risks to large home range representative species are evaluated across multiple investigational units.

2. Further evaluation by risk managers will be recommended for individual sites or site combinations where potential risk exceeds an HI of 1. 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 and the United States Fish and Wildlife Service, must be consulted in the selection of a remedial alternative.

3. A Phase III Impact Assessment may be recommended for sites where potential risk to ecological receptors is identified, and where it is determined that remediation may cause adverse effects to ecological receptors or their habitats.

SECTION 13

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TABLES

Table 1-1 (1 of 1)
Land Acquisition History at SSFL

LOCATION*	SSFL AREA	OWNERSHIP HISTORY	DATE DEED TRANSFERRED TO SSFL	GRANT DEED NUMBER	ACRES	LAND USE
A/B/C/D	I	3/1/47 portions of parcels A,B,C &D leased by North American Aviation, with option to purchase parcels A & B	NA	Recorded 4-29-47 as Document 8260, Book 786, Page 164	617.56 (leased)	Undeveloped
A	I	Ida M. Dundas ** (prior owner Lewis Mortimer & Gene Mortimer)	4/27/1954 to North American Aviation	No. 11872 Book 1198 Pg. 278 CA-0-1661-03	430.28	Undeveloped
B	I, III and IV	Henry William Silvernale, Beulah A. Silvernale, Wiliam W. Hall, Elizabeth Hall	4/2/1954 to North American Aviation	No. 9323 Book 1193 Pg 278	1095.55 (451.18) 644.37	Undeveloped
C	I and II	Portion of Silvernale Property (see above) transferred to USAF	12/31/1958 to USAF	No. 57603 Book 1688 Pgs 212-245 CA-0-164-005	451.18	Undeveloped
D	Undeveloped Property (South)	Spruce Land Corp. (Developer of Bell Canyon)	9/30/1968 to North American Rockwell Corporation	No. 50795 Book 3373 Pg. 508 CA-0-1661-010	1032.3	Undeveloped
E	Undeveloped Property (South)	Geopac Property	4/16/1976 to Rockwell International Corporation	No. 30727 Book 4574 Pg. 788 CA-0-1664-002	110.25	Undeveloped
F	Undeveloped Property (North)	Brandeis Bardin Institute Property	2/15/1998 to Boeing North American, Inc.		181.7	Undeveloped

Total Deeded Acreage 2850.08

* For property location, see Figure 1-2.
** Two additional deeds were later recorded for very small parts (< 1 acre each) of the Dundas parcel.
1) Estate of Marian F. Lewis, 6/1/59, Grant Deed No. 20988, Book 1740, pg. 238.
2) John Jacob Groebli & Norma C. Groebli, 6/1/59, Grant Deed No. 28989, Book 1740, pg. 241.

Table 1-2 (Page 1 of 1)

Chemical Use and Wastes Generated at the SSFL

Chemical or Waste Category	Use	Types of Chemicals Used / Stored / Produced
Petroleum Test Fuels	Large engine and component systems testing	RP-1 (kerosene-based), JP-4 (jet fuel),
Storable Test Fuels	Small engine and component testing	monomethyl hydrazine (MMH), unsymmetrical dimethyl hydrazine (UDMH), hydrazine derivatives, N-nitrosodimethylamine
Oxidizers	Engine and component system testing	Nitrogen tetraoxide (NTO), inhibited red fuming nitric acid (IRFNA), liquid oxygen (LOX), and fluorine compounds
Solvents	Cleaning	Trichloroethene (TCE), tetrachloroethene (PCE), 1,1,1-trichloroethane (TCA), 1,1-dichloroethane (DCA), chlorofluorocarbons (Freon compounds), 1,4-dioxane
Caustic and Acidic Solutions	Laboratory testing	Potassium hydroxide, sodium hydroxide, hydrochloric and other acids
Scrap Metals	Construction	Copper, lead, zinc, etc.
Polychlorinated Biphenyls	Pre-1980 transformers, waste oils	Primarily Aroclor 1254 / 1260 mixtures
Petroleum Fuel and Solvent Burn Products	Generated through burning practices	Polyaromatic hydrocarbons (PAHs) and dioxins/furans
Solid Propellants and Energetic Compounds	Igniters and energetic testing	Perchlorate, beryllium, gycildyl azide polymer (GAP), RDX, HMX, and C-4
Vehicle Fuels	Transportation	Petroleum hydrocarbons (gasoline-range)
Waste Oil	Maintenance operations, lubricating oils	Petroleum hydrocarbons (oil-range)
Construction Debris	Construction	Concrete, asphalt, wood, scrap metal, and asbestos
“Green Liquor” Wastewater	Coal gasification processes	Water containing organic and sulfur compounds, and ash (generated from coal gasification operations)
Incinerator Ash	Refuse burning (paper, wood, etc.)	PAHs and dioxins
Photographic Waste	Photo and X-Ray development	Silver
Nuclear Energy Research Wastes	Area IV nuclear energy, research and testing	Sodium potassium (NaK)
Pyrophoric material	Ignition source	Triethyl aluminum/triethyl boron (TEA/TEB)
Biocides	Control algal growth in ponds [(a)]	Sodium hypochlorite [(a)]

(a) Biocides are not currently used in cooling waters or water treatment systems at the SSFL; sodium hypochlorite, an oxidizer, was used at sewage treatment plants as a disinfectant.

Sources: SAIC 1994; ICF 1993; Ogden 1996.

See Acronym List for definitions of acronyms.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
AREA I						
4.1	B-1 Area	Boeing	DTSC	RCRA Corrective Action	RFI	Originally a UST site under VCEHD. DTSC assumed oversight of field sampling after 1999 site review.
4.2	Area I Landfill	Boeing	VCEHD/ RWQCB DTSC	RCRA Corrective Action	RFI	DTSC lead for characterization; site action and lead agency determination based on results.
4.3	Building 324 Instrument Lab, Hazardous Waste Tank	Boeing	DTSC	RCRA Corrective Action	RFI	
4.4	Building 301 Equipment Lab, TCA Unit and Used Product Tank	Boeing	DTSC	RCRA Corrective Action	RFI	
4.5	LOX Plant Waste Oil Sump and Clarifier	NASA	DTSC	RCRA Corrective Action	RFI	Accelerated cleanup performed during 1993 (removal of clarifier).
4.6	LOX Plant Asbestos and Drum Disposal Area	NASA	VCEHD/ VCAPCD DTSC	RCRA Corrective Action	RFI	Asbestos cleanup conducted in 1990 under oversight of VCEHD and VCAPCD; NFA required by VCEHD.
4.7	Component Test Laboratory III (CTL-III)	Boeing	DTSC	RCRA Corrective Action	RFI	
4.8	Area I Thermal Treatment Facility (TTF)	Boeing	DTSC	RCRA Part A Permit Interim Status	RFI Undergoing closure	Awaiting approval of risk assessment methodology.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
4.9	Advanced Propulsion Test Facility (APTF)	Boeing	DTSC	RCRA Corrective Action	RFI	
4.10	APTF Surface Impoundment-1 (APTF - 1)	Boeing	DTSC	PC Permit RCRA Corrective Action	Closed	Soil vapor sampling near impoundment performed during RFI (included in APTF site). Groundwater monitoring ongoing as specified in PC Permit (1995).
4.11	APTF Surface Impoundment-2 (APTF - 2)	Boeing	DTSC	PC Permit RCRA Corrective Action	Closed	Soil vapor sampling near impoundment performed during RFI (included in APTF site). Groundwater monitoring ongoing as specified in PC Permit (1995).
4.12	Laser Engineering Test Facility (LETF)/ Component Test Lab I (CTL-I)	Boeing	DTSC	RCRA Corrective Action	RFI	Site expanded to include CTL-I during RFI field program; accelerated cleanup performed in 1993 (fluoride).
4.13	LETF Pond	Boeing	DTSC	RCRA Corrective Action	Closed	Clean–closed by DHS 1984.
4.14	Canyon Test Area and Ponds	Boeing	DTSC	RCRA Corrective Action	RFI	
4.15	Bowl Test Area and Ponds	Boeing	DTSC	RCRA Corrective Action	RFI	
4.16	Area I Reservoir (R-1 Pond)	Boeing	DTSC	RCRA Corrective Action	RFI	Surface water discharge from ponds monitored under RWQCB jurisdiction at NPDES outfall locations.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
4.17	Perimeter Pond	Boeing	DTSC	RCRA Corrective Action	RFI	Surface water discharge from ponds monitored under RWQCB jurisdiction at NPDES outfall locations.
4.18	Area I Air Stripping Towers (Canyon, Area I Road)	Boeing	DTSC VCAPCD	RCRA Part B Permit	Standby	Part of groundwater treatment system under jurisdiction of DTSC; currently inactive on standby. When operational, air discharges permitted by VCAPCD.
4.20	Former Rocketdyne Employee Shooting Range (Gun Club) [(a)]		NA	NA	NA	Included in RFA but property belongs to SMMC
4.19	Area I AOCs (combined and listed as a SWMU in RFA)	Boeing				
Area I – AOC	Happy Valley	Boeing	DTSC	RCRA Corrective Action	RFI	Interim measures (IM) performed in 1999 and 2003 (UXB 2002 and MWH 2004).
Area I – AOC	Component Test Laboratory V (CTL-V)	Boeing	DTSC	RCRA Corrective Action	RFI	New AOC added to RFI after DTSC site review.
Area I – AOC	APTF Aboveground Tanks	Boeing	DTSC	RCRA Corrective Action	RFI	Includes fuel, hydrazine, and ozonator ASTs at APTF site (SWMU 4.9). Ozonator tank exempt from RCRA.
Area I Leach Fields[(b)] (16):					Inactive	There are no active leach fields onsite; formerly under WDR issued by RWQCB.
Area I – AOC	Engine Test Facility, Building 312 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At B-1 Area site (SWMU 4.1).

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area I – AOC	Instrument Lab, Building 324 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At IEL site (SWMUs 4.3, 4.4, AOC).
Area I – AOC	Chemistry Lab, Building 300 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At IEL site (SWMUs 4.3, 4.4, AOC). Leach field not found during RFI.
Area I – AOC	Solid Propellants Building 359 Leach Field and Sump	Boeing	DTSC	RCRA Corrective Action	RFI	RFA listed leach field incorrectly as Building 259; co-located sump added to RFI in 1996. Both at Building 359 Area site (Area I AOC). IM in progress.
Area I – AOC	Service Building 741 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At Building 359 Area site (Area I AOC).
Area I – AOC	Loading Building 376 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	Building 376 is at Building 359 Area site (Area I AOC), but facility records indicate leach field did not exist.
Area I – AOC	Research Storage Yard, Building 423 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	Combined with Building 317 leach field at LETF site (SWMU 4.12).
Area I – AOC	Canyon Control Center, Building 375 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	Not listed in RFA, but included in CCR. Exact location and existence uncertain. Facility records show leach field did not exist.
Area I – AOC	Canyon Pretest, Building 382 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At Canyon site (SWMU 4.14).

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area I – AOC	LETF, Building 317 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At LETF site (SWMU 4.12); combined with Building 423 leach field.
Area I – AOC	CTL-I, Building 309 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At LETF/CTL-I site (SWMU 4.12).
Area I – AOC	Bowl Control Center, Building 900 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At Bowl site (SWMU 4.15).
Area I – AOC	Bowl Pretest, Building 901 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	Incorrectly listed in RFA as Building 905 (office trailer), and in CCR as Building 906 (change room). Leach field at Bowl site (SWMU 4.15).
Area I – AOC	CTL-III Test, Buildings 411/ 413 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At CTL-III site (SWMU 4.7).
Area I – AOC	CTL-III Welding, Building 412 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At CTL-III site (SWMU 4.7).
Area I – AOC	CTL-V Workshop, Building 439/420 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI	At CTL-V site (Area I AOC).
Area I USTs[(b)] (2):						

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area I – AOC	Buildings 301/324 Gasoline USTs (UT-37/UT-38)	Boeing	DTSC	RCRA Corrective Action	RFI	Former gasoline USTs in parking lot west of B324 (at IEL, SWMUs 4.3/4.4). VCEHD jurisdiction of LUFT program; UT-37/UT-38 soil investigation oversight transferred to DTSC in 2000 (Beach 2000).
Area I – AOC	Building 301 Diesel UST (UT-44)	Boeing	VCEHD	LUFT	RFI (Closed)	Closed 1994. Former diesel UST located north of Building 301. Additional sampling requested by DTSC in area of tank for RFI at IEL site.
AREA II						
5.1	Area II Landfill	NASA	VCEHD/ RWQCB DTSC	RCRA Corrective Action	RFI	DTSC lead for characterization; site action and lead agency determination based on results.
5.2	ELV Final Assembly, Building 206	NASA	DTSC	RCRA Corrective Action	RFI	Site expanded during RFI field program to include area near Building 203.
5.3	Building 231 PCB Storage Facility	NASA	DTSC	Former RCRA Part A Permit	Closed	Closed 1998 by DTSC.
5.4	RD-9 Area Ultraviolet Light/ Hydrogen Peroxide (UV/H_2O_2) Treatment System	NASA	DTSC	RCRA Part B Permit	Standby	Part of groundwater treatment system under jurisdiction of DTSC. Currently inactive on standby.
5.5	Building 204 Former Waste Oil UST (UT-50)	NASA	DTSC	RCRA Corrective Action	RFI	Former waste oil UST closed by VCEHD in 1991. DTSC requested additional assessment for RFI.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
5.6	Former Area II Incinerator Ash Pile	NASA	DTSC	RCRA Corrective Action	RFI	Accelerated cleanup performed during 1993 (removal of ash pile).
5.7	Hazardous Waste Storage Area (HWSA) Waste Coolant Tank (WCT)	Boeing	DTSC	RCRA Corrective Action	RFI	Former tank used to store cutting oil.
5.8	HWSA Container Storage Area	Boeing NASA	DTSC	Former RCRA Part A Permit	Closed	Closed 1998 by DTSC.
5.9	Alfa Test Area	NASA	DTSC	RCRA Corrective Action	RFI	
5.10	Alfa Test Area Tanks	NASA	DTSC	RCRA Corrective Action	RFI	
5.11	Alfa Skim and Retention Ponds and Drainage	NASA	DTSC	RCRA Corrective Action	RFI	Previous sampling performed in channels for PC Permit.
5.12	Alfa/Bravo Skim Pond (ABSP)	NASA	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment performed during RFI (included in Bravo site). Groundwater monitoring ongoing as specified in PC Permit (1995).
5.13	Bravo Test Area	NASA	DTSC	RCRA Corrective Action	RFI	
5.14	Bravo Test Stand Waste Tank	NASA	DTSC	RCRA Corrective Action	RFI	

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
5.15	Bravo Skim Pond and Drainage	NASA	DTSC	RCRA Corrective Action	RFI	Previous sampling performed in channels for PC Permit.
5.16	Storable Propellant Area Surface Impoundment-1 (SPA-1) and Drainage	NASA	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment performed during RFI (included in SPA site); groundwater monitoring ongoing as specified in PC Permit (1995).
5.17	SPA Surface Impoundment-2 (SPA-2) and Drainage	NASA	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment performed during RFI (included in SPA site); groundwater monitoring ongoing as specified in PC Permit (1995).
5.18	Coca Test Area	NASA	DTSC	RCRA Corrective Action	RFI	
5.19	Coca Skim Pond and Drainage	NASA	DTSC	RCRA Corrective Action	RFI	
5.20	Propellant Load Facility (PLF) Waste Tank	NASA	DTSC	RCRA Corrective Action	RFI	Tank never used.
5.21	PLF Ozonator Tank	NASA	DTSC	RCRA Corrective Action	RFI	Ozonator tank received RCRA variance from DTSC.
5.22	PLF Surface Impoundment	NASA	DTSC	RCRA Corrective Action	Closed	Closed by DHS in 1989.
5.23	Delta Test Area	NASA	DTSC	RCRA Corrective Action	RFI	

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
5.24	Delta Skim Pond and Drainage	NASA	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment performed during RFI (included with Delta site); groundwater monitoring ongoing as specified in PC Permit (1995).
5.25	Purge Water Tank near Delta Treatment System	NASA	DTSC	RCRA Corrective Action	NFA	Polypropylene AST intermittently used since 1992 as temporary holding tank for groundwater to transfer to treatment system; DTSC did not request further investigation during 1999/2000 site review.
5.26	R-2A and R-2B Ponds and Drainage	NASA	DTSC	RCRA Corrective Action	RFI	Surface water discharge from ponds monitored under RWQCB jurisdiction at NPDES outfall locations.
5.27	Area II Air Stripping Towers (Delta and Bravo)	NASA	DTSC VCAPCD	RCRA Part B Permit	Operational	Part of groundwater treatment system under jurisdiction of DTSC; air discharges permitted by VCAPCD.
5.29	RD-51 Watershed [(c)]	(c)	(c)	(c)	(c)	
5.28	Area II AOCs (combined and listed as a SWMU in RFA)					
Area II – AOC	Building 515 Sewage Treatment Plant (STP) Area	NASA	RWQCB DTSC	NPDES Permit RCRA Corrective Action	Inactive RFI	When operational, discharges from sewage treatment plant under RWQCB jurisdiction (NPDES permit). Site includes Building 211 leach field (Area II AOC) and downslope area near RD-9 groundwater treatment system (SWMU 5.4).

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area II – AOC	Storable Propellant Area (SPA)	NASA	DTSC	RCRA Corrective Action	RFI	
Area II – AOC	Alfa/Bravo Fuel Farm (ABFF) and Stormwater Basin	NASA	RWQCB DTSC	SPCC RCRA Corrective Action	Operational RFI	Site added to RFI field program when soil impacts observed at fuel farm during underground pipeline removal.
Area II – AOC	Coca/Delta Fuel Farm (CDFF)	NASA	DTSC	RCRA Corrective Action	RFI	New AOC added to RFI after DTSC site review (Boeing 1997a).
Area II – AOC	Drainage Pipes Under ABSP	NASA	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment drainage performed during RFI (included in Bravo site); groundwater monitoring ongoing as specified in PC Permit (1995).
Area II Leach Fields[(b)] (10):					Inactive	There are no active leach fields onsite; formerly under WDR Permit issued by RWQCB.
Area II – AOC	Area II Service Area, Building 211	NASA	DTSC	RCRA Corrective Action	RFI	Included with Building 515 STP site (Area II AOC).
Area II – AOC	Alfa Control Ctr, Building 208	NASA	DTSC	RCRA Corrective Action	RFI	At Alfa site (SWMUs 5.9/10/11).
Area II – AOC	Alfa Pretest, Building 212	NASA	DTSC	RCRA Corrective Action	RFI	North of Alfa site (SWMUs 5.9/10/11).
Area II – AOC	Bravo Pretest, Building 217	NASA	DTSC	RCRA Corrective Action	RFI	At Bravo site (SWMUs 5.13/14/15).

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area II – AOC	Bravo Recording Ctr, Building 213	NASA	DTSC	RCRA Corrective Action	RFI	At Bravo site (SWMUs 5.13/14/15).
Area II – AOC	Coca Pretest, Building 222	NASA	DTSC	RCRA Corrective Action	RFI	At Coca site (SWMUs 5.18/19).
Area II – AOC	Coca Upper Pretest, Building 234	NASA	DTSC	RCRA Corrective Action	RFI	At Coca site (SWMUs 5.18/19). Not listed in RFA but included in CCR.
Area II – AOC	Coca Control Center, Building 218	NASA	DTSC	RCRA Corrective Action	RFI	At Coca site (SWMUs 5.18/19). Listed incorrectly as Building 216 in RFA.
Area II – AOC	Delta Control Ctr, Building 224	NASA	DTSC	RCRA Corrective Action	RFI	At PLF site (SWMU 5.20/21/22).
Area II – AOC	Delta Pretest, Building 223	NASA	DTSC	RCRA Corrective Action	RFI	At Delta site (SWMU 5.23).
Area II USTs[(b)] (4 Sites)						
Area II – AOC	Building 207 Diesel UST (UT-53)	NASA	VCEHD	LUFT	Closed	Closed 1996. Former diesel UST on north side of Building 207.
Area II – AOC	UST across from Alfa/Bravo Fuel Farm (ABFF) (UT-52)	NASA	VCEHD	LUFT	Closed	Closed 1994. Former gasoline UST north of ABFF site (Area II AOC) along road.
Area II – AOC	Building 206 Diesel UST (UT-51)	NASA	VCEHD	LUFT	Closed	Closed 1996. Former diesel UST east of Building 206 (ELV site, SWMU 5.2).

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area II – AOC	Two Underground Tanks at Plant Services (UT-48 and UT-49)	NASA	VCEHD	LUFT	RFI (Tanks closed)	UT-48 closed 1996; former fuel oil UST located on east side of Building 204. UT-49 closed by VCEHD 1991; former gasoline UST located on south side of Building 204. Additional soil sampling requested by DTSC in area for Building 204 site.
AREA III						
6.1	Engineering Chemistry Laboratory (ECL) Building 270, Waste Tank, and Container Storage Area	Boeing	DTSC	RCRA Corrective Action	RFI	
6.2	ECL Pond and Suspect Water Pond	Boeing	DTSC	PC Permit RCRA Corrective Action	ECL Pond – Closed Suspect Pond -RFI	Soil vapor sampling near ECL Pond during RFI (included in ECL site); groundwater monitoring and remediation ongoing as specified in PC Permit (1995).
6.3	ECL Collection Tank	Boeing	DTSC	RCRA Corrective Action	RFI	Formerly used as groundwater transfer tanks under DTSC jurisdiction; secondary containment installed; no documented releases.
6.4	Building 418 Compound A Facility	Boeing	DTSC	RCRA Corrective Action	RFI	
6.5	Systems Test Laboratory IV (STL-IV) Test Area and Ozonator Tank	Boeing	DTSC	RCRA Corrective Action	RFI	Ozonator tank exempt from RCRA.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
6.6	STL-IV-1 Impoundment and Drainage	Boeing	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment during RFI (included in STL-IV site); groundwater monitoring ongoing as specified in PC Permit (1995).
6.7	STL-IV-2 Impoundment and Drainage	Boeing	DTSC	PC Permit	Closed	Soil vapor sampling near impoundment during RFI (included in STL-IV site); groundwater monitoring ongoing as specified in PC Permit (1995).
6.8	Silvernale Reservoir and Drainage	Boeing	DTSC	RCRA Corrective Action	RFI	Surface water discharge from ponds monitored under RWQCB jurisdiction at NPDES outfall locations.
6.9	Environmental Effects Laboratory (EEL)	Boeing	DTSC	RCRA Corrective Action	RFI	Accelerated cleanup performed in 1993 (limited TPH excavation).
6.10	STL-IV Groundwater Treatment System	Boeing	DTSC VCAPCD	RCRA Part B Permit	Operational	Part of groundwater treatment system under jurisdiction of DTSC; air discharges permitted by VCAPCD.
6.11	Area III AOCs (combined and listed as a SWMU in RFA)					
Area III – AOC	Building 260 ECL Runoff Tanks	Boeing	DTSC	RCRA Corrective Action	RFI	Aboveground tanks removed, area near tanks included in ECL site (SWMU 6.1).
Area III – AOC	Area III Sewage Treatment Plant (STP) Pond	Boeing	RWQCB DTSC	NPDES Permit RCRA Corrective Action	Inactive RFI	When operational, discharges from STP under RWQCB jurisdiction (NPDES permit). Catchment pond added to RFI field program during 1999/2000 DTSC site review.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area III Leach Fields [(b)] (2):					Inactive	There are no active leach fields onsite; formerly under WDR Permit issued by RWQCB.
Area III – AOC	ECL, Building 270	Boeing	DTSC	RCRA Corrective Action	RFI	At ECL site (SWMUs 6.1/6.3).
Area III – AOC	SSET F Area, Buildings 253/254	Boeing	DTSC	RCRA Corrective Action	RFI	At STL-IV site (SWMU 6.5); listed incorrectly in RFA as located in Area IV.
AREA IV						
7.1	Building 056 Landfill	DOE	DTSC	RCRA Corrective Action	RFI	
7.2	Building 133 Hazardous Waste Management Facility	DOE	DTSC	RCRA Part B Permit	Inactive	Closure plan submitted to DTSC.
7.3	Building 886 Former Sodium Disposal Facility (FSDF)	DOE	DTSC	RCRA Corrective Action	RFI	Interim measures completed in 2000 (IT 2002).
7.4	Old Conservation Yard (OCY) Container Storage Area and Fuel Tanks	DOE	DTSC	RCRA Corrective Action	RFI	
7.5	Building 100 Trench	DOE	DTSC	RCRA Corrective Action	RFI	

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
7.6	Radioactive Materials Handling Facility (RMHF)	DOE	DOE/DHS DTSC	Part A Permit Interim Status	Operational	Site under DTSC/DOE jurisdiction; Part A permit administered by DTSC. Closure plan in preparation.
7.7	Rockwell International Hot Laboratory (RIHL), Building 020	DOE	DTSC	RCRA Corrective Action	RFI	Site investigation pending.
7.8	New Conservation Yard	Boeing	DTSC	RCRA Corrective Action	RFI	
7.9	ESADA Chemical Storage Yard	Boeing	DTSC	RCRA Corrective Action	RFI	
7.10	Building 005 Coal Gasification Process Development Unit (PDU)	Boeing	DTSC	RCRA Corrective Action	RFI	
7.11	Building 029 Reactive Metal Storage Yard	DOE	DTSC	RCRA Part B Permit	Operational	Closure plan submitted to DTSC.
7.12	Area IV AOCs (combined and listed as a SWMU in RFA)					
Area IV - AOC	Building 059 Former SNAP Reactor Facility	DOE	DOE/DHS DTSC	DOE Closure RCRA Corrective Action	RFI	Site undergoing demolition and decontamination under DHS/DOE jurisdiction; unrestricted release anticipated in 2005. Groundwater monitoring ongoing; RFI sampling scheduled after unrestricted release.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area IV-AOC	Southeast Drum Storage Yard	Boeing	DTSC	RCRA Corrective Action	RFI	
Area IV-AOC	Sodium Reactor Experiment (SRE) Complex Area	Boeing	DTSC	RCRA Corrective Action	RFI	New AOC added to RFI after DTSC site review (DTSC 1998).
Area IV-AOC	Building 065 Metals Laboratory Clarifier	DOE	DTSC	RCRA Corrective Action	RFI	New AOC added after DTSC site review in 1999/2000.
Area IV-AOC	Building 457 Hazardous Materials Storage Area (HMSA)	DOE	DTSC	RCRA Corrective Action	RFI	New AOC added after DTSC site review in 1999/2000.
Area IV-AOC	Area IV Pond Dredge Area	Boeing	DTSC	RCRA Corrective Action	RFI	New AOC added after DTSC site review in 1999/2000.
Area IV Leach Fields (15):					Inactive	There are no active leach fields onsite; formerly under WDR issued by RWQCB.
Area IV – AOC	AI-Z1, Building 003	Boeing	DTSC	RCRA Corrective Action	RFI (removed)	At SRE site (Area IV AOC).
Area IV – AOC	AI-Z2, Building 064	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Included in DOE leach fields RFI site (Area IV COC). Incorrectly listed as Building 014 in RFA.
Area IV – AOC	AI-Z3, Building 030	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Included in DOE leach fields RFI site (Area IV AOC). Not located during RFI.

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SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area IV – AOC	AI-Z4, Building 093	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Incorrectly listed as Building 003 in RFA. Part of DOE leach fields RFI site.
Area IV – AOC	AI-Z5, Building 021	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Regulatory assignment subject to review pending approval of RMHF (SWMU 7.6) closure plan (Part A Permit).
Area IV – AOC	AI-Z6, Building 028	DOE	DTSC	RCRA Corrective Action	NFA (not present)	Not located during CCR investigation- facility records confirm the building never had a leach field. DTSC did not require further investigation during 1999/2000 site review.
Area IV – AOC	AI-Z7, Building 010/ 012	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Not located during CCR or RFI. Included in DOE leach fields RFI site (Area IV AOC). Incorrectly listed as Building 012 in RFA and CCR.
Area IV – AOC	AI-Z8, Building 005/006	Boeing	DTSC	RCRA Corrective Action	RFI (removed)	At PDU RFI site (SWMU 7.10).
Area IV – AOC	AI-Z10, Building 383	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Incorrectly listed as Building 483 in RFA. Included in DOE leach fields RFI site (Area IV AOC).
Area IV – AOC	AI-Z11, Building 009	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Included in DOE leach fields RFI site (Area IV AOC).
Area IV – AOC	AI-Z12, Building 020	DOE	DTSC	RCRA Corrective Action	RFI (removed)	At RIHL RFI site (SWMU 7.7).
Area IV – AOC	AI-Z13, Building 373	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Included in DOE leach fields RFI site (Area IV AOC).

SWMUs and AOCs at SSFL

SWMU or AOC	Description	Responsible Party	Regulatory Jurisdiction	Current Regulatory Program	Current Status	Comments
Area IV – AOC	AI-Z14, Building 363	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Included in DOE leach fields RFI site (Area IV AOC).
Area IV – AOC	AI-Z15, Building 353	DOE	DTSC	RCRA Corrective Action	RFI (removed)	Included in DOE leach fields RFI site (Area IV AOC).
Area IV-AOC	Building 008 Warehouse	Boeing	DTSC	RCRA Corrective Action	RFI (not present)	Building 008 incorrectly listed in RFA as Area I leach field. Included as Boeing Area IV Leach Field RFI site.
Area IV-AOC	Building 011 Leach Field	Boeing	DTSC	RCRA Corrective Action	RFI (removed)	Leach field (AI-Z9) identified during investigation. Included as Boeing Area IV Leach Field RFI site.
7.13	SRE Watershed[(c)]	(c)	(c)	(c)	(c)	

Notes: All SWMUs and AOCs (except those added by DTSC during the field program) are described in the RFA Report (SAIC 1994) and CCR (ICF 1993). Site descriptions for all SWMUs/AOCs added during RFI are further described in the RFI WPAA (Ogden 2000b) and this document.

See Acronym List for acronym definitions

(a) The former Rocketdyne Employee Shooting Range is an offsite location and is owned by SMMC. It is included in this table because it was listed in the RFA.

(b) Individual leach fields and USTs located in Areas I, II, and III are all associated with existing SWMUs and/or AOCs, and are being evaluated as part of those sites. Individual Area IV leach fields located outside of other RFI sites have been grouped as RFI sites by owner. Nine of these are being evaluated as a single AOC (DOE Leach Fields RFI site), and two are being evaluated as a separate AOC (Boeing Leach Field RFI site). Of the remaining five leach field sites in Area IV, four are being evaluated with associated RFI sites, and one is pending approval of a RCRA closure plan. Please note that this table reflects corrections to site identification errors in the RFA (e.g., Building 008 listed as an Area I leach field in the RFA, but it is an Area IV warehouse).

(c) The RD-51 and SRE watersheds were identified as SWMUs in the RFA (SAIC 1994) based on radiologic sample data collected during initial sampling in 1993 (McLaren Hart 1993). Subsequent resampling of these areas did not detect or confirm initial data (McLaren Hart 1995).

Table 1-4 (Page 1 of 3)
RFI SITES AT SSFL

RFI Site SWMU Number or AOC and Name	**Sampling Plan Reference**
AREA I	
B-1 Area 4.1 B-1 Area AOC Building 312 Leach Field	DTSC site review 1999/2000
Area I Landfill 4.2 Area I Landfill	Area I & II Landfills Work Plan (MWH 2003e)
Instrument and Equipment Laboratories (IEL) 4.3 Building 324 Instrument Lab, Hazardous Waste Tank 4.4 Building 301 Equipment Lab, TCA Unit and Used Product Tank AOC Buildings 301/324 Gasoline USTs (UT-37/UT-38) AOC Building 301 Diesel UST (UT-44) AOC Building 300 Leach Field AOC Building 324 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Liquid Oxygen (LOX) Plant 4.5 LOX Plant Waste Oil Sump and Clarifier 4.6 LOX Plant Asbestos and Drum Disposal Area	WPA (Ogden 1996) DTSC site review 1999/2000
Component Test Laboratory III (CTL-III) 4.7 CTL-III AOC Building 413 Leach Field AOC Building 412 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Advanced Propulsion Test Facility (APTF) 4.9 Advanced Propulsion Test Facility AOC APTF Aboveground Tanks	WPA (Ogden 1996)
LETF/CTL-I 4.12 Laser Engineering Test Facility (LETF)/ Component Test Laboratory I (CTL-I) AOC Building 309 Leach Field AOC Building 317 Leach Field AOC Building 423 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Canyon Area 4.14 Canyon Area AOC Building 375 Leach Field AOC Building 382 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Bowl Area 4.15 Bowl Area AOC Building 900 Leach Field AOC Building 901 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
R-1 Pond 4.16 Area I Reservoir (R-1 Pond)	WPA (Ogden 1996)
Perimeter Pond 4.17 Perimeter Pond	Identified in WPA DTSC site review 1999/2000
Building 359 Area AOC Building 359 Leach Field/Sump AOC Building 376 Leach Field AOC Building 741 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Happy Valley AOC Happy Valley	WPA (Ogden 1996)
Component Test Laboratory V (CTL-V) AOC CTL-V AOC Building 439 Leach Field	Letter Work Plan (Boeing 1997); Building 439 Leach Field identified in RFA
AREA II	
Area II Landfill 5.1 Area II Landfill	Area I & II Landfills Work Plan (MWH 2003e)
Expendable Launch Vehicle (ELV) 5.2 ELV Final Assembly, Building 206	WPA (Ogden 1996)
Building 204 USTs 5.5 Building 204 Former Waste Oil UST (UT-50) AOC Underground Tanks at Plant Services (UT-48 and UT-49)	WPA (Ogden 1996)
Former Area II Incinerator Ash Pile 5.6 Former Area II Incinerator Ash Pile	WPA (Ogden 1996)
Hazardous Waste Storage Area (HWSA) Waste Coolant Tank (WCT) 5.7 Hazardous Waste Storage Area Waste Coolant Tank	WPAA (Ogden 2000b)

Table 1-4 (Page 2 of 3)
RFI SITES AT SSFL

RFI Site SWMU Number or AOC and Name	**Sampling Plan Reference**
AREA II (Cont'd)	
Alfa Area 5.9 Alfa Test Area 5.10 Alfa Test Area Tanks 5.11 Alfa Skim and Retention Ponds and Drainage AOC Building 208 Leach Field AOC Building 212 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Bravo Area 5.13 Bravo Test Area 5.14 Bravo Test Stand Waste Tank 5.15 Bravo Skim Pond and Drainage AOC Building 213 Leach Field AOC Building 217 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Coca Area 5.18 Coca Test Area 5.19 Coca Skim Pond and Drainage AOC Building 222 Leach Field AOC Building 234 Leach Field AOC Building 218 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Propellant Load Facility (PLF) 5.20 PLF Waste Tank 5.21 PLF Ozonator Tank 5.22 PLF Surface Impoundment (Closed) AOC Building 224 Leach Field	Identified in WPA DTSC site review 1999/2000
Delta Area 5.23 Delta Test Area AOC Building 223 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
R-2 Ponds 5.26 R-2A and R-2B Ponds and Drainage	Identified in WPA DTSC site review 1999/2000
Building 515 Sewage Treatment Plant (STP) AOC Building 515 STP Area AOC Building 211 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Alfa/Bravo Fuel Farm (ABFF) AOC ABFF and Stormwater Basin	DTSC site review 1997
Coca/Delta Fuel Farm (CDFF) AOC CDFF	Letter Work Plan (Boeing 1997)
Storable Propellant Area (SPA) AOC SPA	WPA (Ogden 1996)
AREA III	
Engineering Chemistry Laboratory (ECL) Area 6.1 ECL Building 270, Waste Tank, and Container Storage Area 6.2 ECL Suspect Water Pond 6.3 ECL Collection Tank AOC Building 260 ECL Runoff Tanks AOC Building 270 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Compound A Facility 6.4 Building 418 Compound A Facility	WPA (Ogden 1996)
Systems Test Laboratory IV (STL-IV) 6.5 STL-IV Test Area and Ozonator Tank AOC Buildings 253/254 Leach Field	WPA (Ogden 1996) DTSC site review 1999/2000
Silvernale Reservoir 6.8 Silvernale Reservoir and Drainage	WPA (Ogden 1996)
Environmental Effects Laboratory (EEL) 6.9 EEL	WPA (Ogden 1996)
Sewage Treatment Plant (STP) Pond AOC Sewage Treatment Plant (STP) Pond	DTSC site review 1999/2000
AREA IV	
Building 56 Landfill 7.1 Building 56 Landfill	WPA (Ogden 1996) B56 Landfill WP
Former Sodium Disposal Facility (FSDF) 7.3 Building 886 FSDF	Identified in WPA DTSC site review 1999/2000
Old Conservation Yard (OCY) 7.4 OCY Container Storage Area and Fuel Tanks	WPA (Ogden 1996)

Table 1-4 (Page 3 of 3)
RFI SITES AT SSFL

RFI Site SWMU Number or AOC and Name	**Sampling Plan Reference**
AREA IV (Cont'd)	
Building 100 Trench 7.5 Building 100 Trench	DTSC site review 1999/2000
Rockwell International Hot Laboratory (RIHL) 7.7 RIHL, Building 20 AOC Building 20 Leach Field	WPA (Ogden 1996) (revised in WPAA)
New Conservation Yard (NCY) 7.8 NCY	WPA (Ogden 1996)
Empire State Atomic Development Authority (ESADA) 7.9 ESADA Chemical Storage Yard	Identified in WPA DTSC site review 1999/2000
Coal Gasification Process Development Unit (PDU) 7.10 Building 005 Coal Gasification PDU AOC Buildings 005/006 Leach Field	Identified in WPA DTSC site review 1999/2000
Sodium Reactor Experiment (SRE) Area AOC SRE AOC Building 003 Leach Field	Letter Work Plan (Boeing 1997)
Southeast Drum (SE Drum) Storage Yard AOC SE Drum Storage Yard	DTSC site review 1999/2000
Pond Dredge Area AOC Pond Dredge Area	WPAA (Ogden 2000b)
Boeing Area IV Leach Fields AOC Building 011 Leach Field AOC Building 008 Warehouse	DTSC site review 1999/2000
Systems for Nuclear Auxiliary Power (SNAP) Facility AOC Building 59, SNAP Facility	WPAA (Ogden 2000b)
Building 65 Metals Laboratory Clarifier AOC Building 65, Metals Laboratory Clarifier	WPAA (Ogden 2000b)
Hazardous Materials Storage Area (HMSA) AOC Building 457, Former HMSA	WPAA (Ogden 2000b)
DOE Leach Fields AOC Building 009 Leach Field AOC Building 010 Leach Field AOC Building 030 Leach Field AOC Building 064 Leach Field AOC Building 093 Leach Field AOC Building 353 Leach Field AOC Building 363 Leach Field AOC Building 373 Leach Field AOC Building 383 Leach Field	DTSC site review 1999/2000
RMHF Leach Field AOC Building 021 Leach Field	Pending

Notes:

1. Sampling plans included in referenced document or as directed during field investigation by DTSC.

2. Because of proximity, the Building 011 and Building 008 sites will be reported together as one RFI site.

3. Only SWMUs and AOCs considered part of each RFI site are listed. No RCRA permitted units or closed USTs shown, with the exception of tanks for which DTSC has requested additional characterization. All SWMUs and AOCs included in the RFI are listed here and designated in Table 1-3 by "RFI" under "Current Status."

4. Leach Field AOCs originally introduced in the RFA (SAIC 1994).

See Acronym List for acronym definitions

Table 2-1 (1 of 2)

Sample Analytical Suites

Laboratory Analytical Method [a, b]	Types of Chemicals
Organics	
Methods 8290, 1613	Dioxin and Furan Compounds
Method 8330	Energetic Compounds
Methods 8010/8020, 8021, 8240, 8260, TO-14A	Volatile Organic Compounds[c]
Methods 418.1, 8015, 8015M	Petroleum Hydrocarbons
8321, CARB-429[d]	Polycyclic Aromatic Hydrocarbons
Methods 1668, 8080, 8082	Polychlorinated Biphenyls
Method 8270 SIM	Semivolatile Organic Compounds (selected list, low detection limits)
Method 8270	Semivolatile Organic Compounds (standard list and detection limits)
Method 1625	n-Nitrosodimethylamine
Inorganics	
Methods 6010/6020/7000[e]	Metals
None Established [f]	Tributyltin
Method SM2320	Alkalinity (total, bicarbonate, carbonate)
Method 300.0	Bromide, ortho-Phosphate
Methods 300, SM429, SM4500	Chloride, Nitrate
Method 335.0	Cyanide
Methods 300.0, 340.2, SM413	Fluoride
Methods 8315, ASTM D19, NIOSH 3500	Formaldehyde
Methods 7196, 7199	Hexavalent Chromium
None Established [g]	Hydrazine compounds

Table 2-1 (2 of 2)

Sample Analytical Suites

Laboratory Analytical Method [a, b]	Types of Chemicals
Method 300.0, 354.1	Nitrite
Method 300(M) [h], 314.0, 8321M[i], 331.0	Perchlorate
Methods 150.1, 9040, 9045	pH
Methods 300.0, 375.4	Sulfate
Method 376.1	Sulfide
Method 160.2	Total Dissolved Solids
Method 160.1	Total Suspended Solids

Notes:

(a) Analytical methods listed include historical and current laboratory procedures used for sample analysis at investigational units. This table provides a comprehensive list of analytical methods for any sample collected at an investigational unit that may be used in the risk assessment and is not meant to replace an agency-approved sampling and analysis plan for future investigations.

(b) As several revisions of the method may have been used, the letters designating the revisions have been omitted.

(c) Samples are currently collected and prepared according to Method 5035.

(d) California Air Resources Board isotope dilution method.

(e) Other methods may include 7470, 7471, 7740, 7841

(f) No formal regulatory-approved method exists; the method of Krone et al. (1989) has been approved by the Department of Toxic Substance Control (DTSC).

(g) No formal regulatory-approved method exists; the laboratory may use an ion chromatography procedure as approved by DTSC.

(h) Prior to the promulgation of USEPA 314.0, Method, the Department of Health Services (DHS) and DTSC reviewed and found acceptable an analytical procedure similar to Method 300.

(i) Prior to the promulgation of USEPA 331.0, DTSC reviewed and found acceptable a modified method 8321 (liquid chromatography/mass spectrometry/mass spectrometry) for confirmation purposes.

Table 2-2 (1 of 1)

Data Qualifier Reference Table

Qualifier	Organics	Inorganics
U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.	The associated value is an estimated quantity.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."	Not applicable.
NJ	The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.	Not applicable.
UJ	The analyte was not deemed above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.	The material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and to meet quality control criteria. The presence or absence of the analyte cannot be verified.	The data are unusable. (Note: Analyte may or may not be present.)

Table 2-3 (1 of 1)

Qualification Code Reference Table

Qualifier	Organics	Inorganics
H	Holding times were exceeded.	Holding times were exceeded.
S	Surrogate recovery was outside QC limits.	The sequence or number of standards used for the calibration was incorrect
C	Calibration %RSD or %D was noncompliant.	Correlation coefficient is <0.995.
R	Calibration RRF was <0.05.	%R for calibration is not within control limits.
B	Presumed contamination from preparation (method) blank.	Presumed contamination from preparation (method) or calibration blank.
L	Laboratory Blank Spike/Blank Spike Duplicate %R was not within control limits.	Laboratory Control Sample %R was not within control limits.
Q	MS/MSD recovery was poor.	MS recovery was poor.
E	Not applicable.	Duplicates showed poor agreement.
I	Internal standard performance was unsatisfactory.	ICP ICS results were unsatisfactory.
A	Not applicable.	ICP Serial Dilution %D was not within control limits.
M	Tuning (BFB or DFTPP) was noncompliant.	Not applicable.
T	Presumed contamination from trip blank.	Not applicable.
+	False positive – reported compound was not present.	Not applicable.
-	False negative – compound was present but not reported.	Not applicable.
F	Presumed contamination from FB or ER.	Presumed contamination from FB or ER.
$	Reported result or other information was incorrect.	Reported result or other information was incorrect.
?	TIC identity or reported retention time has been changed.	Not applicable.
D	The analysis with this flag should not be used because another more technically sound analysis is available.	The analysis with this flag should not be used because another more technically sound analysis is available.
P	Instrument performance for pesticides was poor.	Post Digestion Spike recovery was not within control limits.
*#	Unusual problems found with the data. The number following the asterisk (*) is the reference to a description of where the problem can be found.	Unusual problems found with the data. The number following the asterisk (*) is the reference to a description of where the problem can be found.

Notes:
BFB = bromofluorobenzene
D = difference
DFTPP = decafluorotriphenylphosphine
ER = equipment rinsate
FB = field blank
ICP = inductively coupled plasma
ICS = internal check standard
MS/MSD = matrix spike/matrix spike duplicate
QC = quality control
R = recovery
RPD = relative percent difference
RRF = relative response factor
RSD = relative standard deviation
TIC = tentatively identified compound

Table 2-4 (1 of 1)
PCB Sampling Locations and Analyses [a]

RFI Site	Number of Samples
Bravo Area	3
Silvernale Reservoir	2
Old Conservation Yard	1
Component Test Laboratory	1

Notes:

a. Aroclor mixtures and PCB congeners were analyzed using USEPA methods 8082 and 1668, respectively.
PCB- polychlorinated biphenyl

Table 2-5 (1 of 1)

Summary of Aroclor to PCB Congener Extrapolation Factors [a]

PCB Congener	Aroclor 1254[b] Extrapolation Factor (EF) (ng congener/kg soil)/(µg Aroclor/kg soil)	Aroclor 1260[c] Extrapolation Factor (EF) (ng congener/kg soil)/(µg Aroclor/kg soil)
77	1.5E-02	1.3E-02
81	3.0E-03	2.3E-03
105	1.2E-01	8.2E-02
114	4.5E-03	1.5E-03
118	2.7E-01	1.6E-01
123	3.0E-03	2.3E-03
126	7.5E-03	6.4E-03
156	6.3E-02	5.5E-02
157	1.2E-02	2.5E-02
167	2.1E-02	4.3E-02
169	3.7E-04	6.4E-04
189	3.0E-03	6.4E-03

Notes:

(a) Extrapolation factors are the maximum ratios of PCB congener (ng/kg) to Aroclor (µg/kg) concentration.

(b) Evaluation is based on seven paired Aroclor 1254 and congener samples.

(c) Evaluation is based on two paired Aroclor 1260 and congener samples.

EF - Aroclor to PCB congener extrapolation factor

PCB - polychlorinated biphenyl

kg - kilogram

ng - nanogram

µg - microgram

Table 2-6 (1 of 1)

Molecular Formulas for Petroleum Constituents

Chemical	Molecular Formula
2-Methylnaphthalene	$C_{11}H_{10}$
Acenaphthene	$C_{12}H_{10}$
Acenaphthylene	$C_{12}H_{8}$
Anthracene	$C_{14}H_{10}$
Benzene	$C_{6}H_{6}$
Benzo(a)anthracene	$C_{18}H_{12}$
Benzo(a)pyrene	$C_{20}H_{12}$
Benzo(b)fluoranthene	$C_{20}H_{12}$
benzo(e)pyrene	$C_{20}H_{12}$
Benzo(g,h,i)perylene	$C_{22}H_{12}$
Benzo(k)fluoranthene	$C_{20}H_{12}$
Chrysene	$C_{18}H_{12}$
Dibenz(a,h)anthracene	$C_{22}H_{14}$
Ethylbenzene	$C_{8}H_{10}$
Fluoranthene	$C_{16}H_{10}$
Fluorene	$C_{13}H_{10}$
Indeno(1,2,3-cd)pyrene	$C_{22}H_{12}$
m,p-Xylene	$C_{8}H_{10}$
Naphthalene	$C_{10}H_{8}$
o-Xylene	$C_{8}H_{10}$
Perylene	$C_{20}H_{12}$
Phenanthrene	$C_{14}H_{10}$
Pyrene	$C_{16}H_{10}$
Toluene	$C_{7}H_{8}$
Xylenes (total)	$C_{8}H_{10}$

Table 2-7 (1 of 1)

TPH and Petroleum Constituent Sampling Locations and Analyses [a]

Sample Locations	Number of Samples	Analyses Performed [b]
Bowl Area (SWMU 4.15 and AOC)	4	TPH, PAHs, 2-methylnapthalene, napthalene
Building 204 (SWMU 5.5 and AOC)	1	
Alfa Area (SWMU 5.9, 5.10,5.11)	2	
Bravo Area (SWMU 5.13, 5.14, 5.15)	2	
Alfa Bravo Fuel Farm (AOC)	2	
Coca/Delta Fuel Farm (AOC)	2	
B-1 Area (SWMU 4.1)	1	
Old Conservation Yard (SWMU 7.4)	1	
ELV (SWMU 5.2)	1	
Bowl Area (SWMU 4.15 and AOC)	3	TPH, BTEX
Bravo Area (SWMU 5.13,5.14 and 5.15)	1	
Alfa Bravo Fuel Farm (AOC)	2	
Coca/Delta Fuel Farm (AOC)	1	
B-1 Area (SWMU 4.1)	1	
Old Conservation Yard (SWMU 7.4)	1	

Notes:

a. Soil samples were analyzed using methods USEPA 8015B, CARB-429, and USEPA 8260B for TPHs. PAHs and BTEX, respectively.

b. After chemical analyses, all data were validated following Level IV protocol.

TPH-total petroleum hydrocarbons.

PAH- polycyclic aromatic hydrocarbons.

BTEX- benzene, toluene, ethylbenzene, and xylene.

Table 2-8 (1 of 1)

Summary of TPH to Petroleum Constituent Extrapolation Factors

Chemical	Extrapolation Factor (mg PC/kg soil)/(mg TPH/kg/soil)
Benzene	1.2E-04 [a]
Ethylbenzene	1.2E-04 [a]
Toluene	1.2E-04 [a]
m,p-Xylene	3.6E-04 [a]
o-Xylene	8.0E-05 [a]
Xylene (total)	4.4E-04 [a]
2-Methylnaphthalene	2.8E-02 [a]
Naphthalene	6.9E-03 [a]
Acenaphthene	5.7E-04 [b]
Acenaphthylene	7.0E-05 [b]
Anthracene	3.7E-04 [b]
Benzo(a)anthracene	2.7E-05 [b]
Benzo(a)pyrene	2.7E-05 [b]
Benzo(b)fluoranthene	4.3E-05 [b]
Benzo(e)pyrene	2.1E-04 [b]
Benzo(g,h,i)perylene	2.2E-04 [b]
Benzo(k)fluoranthene	2.1E-05 [b]
Chrysene	5.9E-05 [b]
Dibenz(a,h)anthracene	1.1E-05 [b]
Fluoranthene	7.5E-05 [b]
Fluorene	5.7E-04 [b]
Indeno(1,2,3-cd)pyrene	2.4E-05 [b]
Perylene	1.2E-04 [b]
Phenanthrene	1.5E-03 [b]
Pyrene	1.4E-04 [b]

Notes:

(a) Applicable to the TPH C08-C11 fraction.

(b) Applicable to the TPH C11-C30 fraction

TPH - total petroleum hydrocarbons

PC - petroleum constituent

Table 3-1 (1 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Inorganics	ICP-MS	ICP	ICP-MS	ICP						
Aluminum	N/A	50	N/A	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Antimony	2	10	0.001	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	1	5	0.0005	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Barium	1	10	0.0005	0.001	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium	0.5	4	0.0003	0.0005	N/A	N/A	N/A	N/A	N/A	N/A
Boron	N/A	50	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	1	5	0.0005	0.0005	N/A	N/A	N/A	N/A	N/A	N/A
Calcium	N/A	100	N/A	0.015	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	2	5	0.001	0.001	N/A	N/A	N/A	N/A	N/A	N/A
Cobalt	1	10	0.0005	0.001	N/A	N/A	N/A	N/A	N/A	N/A
Copper	2	10	0.001	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Iron	20	40	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A
Lead	1	5	0.0005	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	N/A	50	N/A	0.0063	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	20	N/A	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	2	20	0.0005	0.001	N/A	N/A	N/A	N/A	N/A	N/A
Mercury	N/A	0.2	0.00002	0.00002	N/A	N/A	N/A	N/A	N/A	N/A
Molybdenum	2	20	0.001	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	2	10	0.001	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	N/A	500	N/A	0.05	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	2	10	0.001	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Silver	1	10	0.0005	0.001	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	N/A	500	N/A	0.05	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	1	10	0.0005	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium	2	10	0.001	0.001	N/A	N/A	N/A	N/A	N/A	N/A
Zinc	20	20	0.01	0.005	N/A	N/A	N/A	N/A	N/A	N/A
Zirconium	N/A	200	N/A	25	N/A	N/A	N/A	N/A	N/A	N/A
Polychlorinated Biphenyls										
Aroclor 1016	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor 1221	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor 1232	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3-1 (2 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Polychlorinated Biphenyls										
Aroclor 1242	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor 1248	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor 1254	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor 1260	0.5	1	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-28 (2,4,4')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-44 (2,2',3,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-52 (2,2',5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-66 (2,3',4,4')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-77 (3,3',4,4')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-81 (3,4,4',5)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-101 (2,2',3,5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-105 (2,3,3',4,4')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-114 (2,3,4,4',5)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-118 (2,3',4,4',5)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-123 (2',3,4,4',5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-126 (3,3',4,4',5)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-128 (2,2',3,3',4,4')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-138 (2,2',3,4,4',5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-153 (2,2',4,4',5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-156 (2,3,3',4,4',5)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-157 (2,3,3',4,4',5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-167 (2,3',4,4',5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-169 (3,3',4,4',5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-170 (2,2',3,3',4,4',5)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-180 (2,2',3,4,4',5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-187 (2,2',3,4',5,5',6)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-189 (2,3,3',4,4',5,5')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-195 (2,2',3,3',4,4',5,6)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-206 (2,2',3,3',4,4',5,5',6)	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB-209 (2,2',3,3',4,4',5,5',6,6')	0.001	N/A	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3-1 (3 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Polychlorinated Dioxins/Furans										
2,3,7,8-TCDD	0.00001	N/A	0.001	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,7,8-PeCDD	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,4,7,8-HxCDD	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,6,7,8-HxCDD	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,7,8,9-HxCDD	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,4,6,7,8-HpCDD	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OCDD	0.0001	N/A	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,3,7,8-TCDF	0.00001	N/A	0.001	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,7,8-PeCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,3,4,7,8-PeCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,4,7,8-HxCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,6,7,8-HxCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,3,4,6,7,8-HxCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,7,8,9-HxCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,4,6,7,8-HpCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3,4,7,8,9-HpCDF	0.00005	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OCDF	0.0001	N/A	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Semivolatile Organic Compounds										
1,2,4-Trichlorobenzene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichlorobenzene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dichlorobenzene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4,5-Trichlorophenol	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4,6-Trichlorophenol	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dichlorophenol	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dinitrophenol	20	N/A	660	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dinitrotoluene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dinitrotoluene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Chloronaphthalene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Chlorophenol	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3-1 (4 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Semivolatile Organic Compounds										
2-Methylnaphthalene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Nitroaniline	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Nitrophenol	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,3'-Dichlorobenzidine	20	N/A	830	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Nitroaniline	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4,6-Dinitro-2-methylphenol	20	N/A	420	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Bromophenyl-phenylether	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Chloro-3-methylphenol	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Chloroaniline	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Chlorophenyl-phenylether	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,4-Methylphenol	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Nitroaniline	20	N/A	830	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Nitrophenol	20	N/A	830	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoic Acid	20	N/A	830	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzyl Alcohol	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
bis(2-Chloroethoxy)methane	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
bis(2-Chloroethyl)ether	10	N/A	170	N/A	N/A	N/A	N/A	N/A	N/A	N/A
bis(2-Chloroisopropyl)ether	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
bis(2-Ethylhexyl)phthalate	50	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylbenzylphthalate	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h)Anthracene	20	N/A	420	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzofuran	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octylphthalate	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-butylphthalate	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethylphthalate	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethylphthalate	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexachlorobenzene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexachlorobutadiene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexachlorocyclopentadiene	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3-1 (5 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Semivolatile Organic Compounds										
Hexachloroethane	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Nitroso-di-n-propylamine	10	N/A	250	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Nitrosodiphenylamine (1)	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrobenzene	20	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentachlorophenol	20	N/A	830	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthylene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)anthracene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g,h,i)perylene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chrysene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluorene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indeno(1,2,3-cd)pyrene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	10	N/A	330	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Volatile Organic Compounds	low[b]	medium[c]	low[b]	medium[c]	TO-15 SIM	TO-15 SIM	TO-15	TO-15	TO-15 SIM	TO-15 SIM
1,1,1-Trichloroethane	1	2	1	2	1	180	0.0011	0.198	0.00011	0.0198
1,1,1,2-Tetrachloroethane	1	5	2	5	1	143	0.014	2.00	N/A	N/A
1,1,2,2-Tetrachloroethane	1	2	2	2	1	143	0.0014	0.200	N/A	N/A
1,1,2-Trichloroethane	1	2	1	2	1	180	0.0011	0.198	0.000099	0.0178
1,1-Dichloroethane	1	2	1	2	1	243	0.00081	0.197	0.000081	0.0197
1,1-Dichloroethene	1	5	2	5	1	248	0.00079	0.196	0.0000395	0.0098
1,2,4-Trimethylbenzene	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A
1,3,5-Trimethylbenzene	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A

Table 3-1 (6 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Volatile Organic Compounds	low[b]	medium[c]	low[b]	medium[c]	TO-15 SIM	TO-15 SIM	TO-15	TO-15	TO-15 SIM	TO-15 SIM
1,2-Dibromo-3-chloropropane	5	5	10	5	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichlorobenzene	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloroethane	0.5	2	1	2	1	243	0.00081	0.197	0.000081	0.0197
1,3-Dichlorobenzene	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	1	2	1	2	N/A	N/A	0.0012	0.000196	N/A	N/A
2-Butanone	10	10	10	10	N/A	N/A	N/A	N/A	N/A	N/A
2-Chloro-1,1,1-Trifluoroethane	50	50	50	50	N/A	N/A	N/A	N/A	N/A	N/A
2-Chloroethyl Vinyl Ether	5	5	5	5	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	10	10	10	10	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	0.5	0.5	1	2	1	308	0.00064	0.197	0.0001504	0.0463
Bromodichloromethane	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A
Bromoform	1	5	2	5	N/A	N/A	N/A	N/A	N/A	N/A
Bromomethane	1	5	2	5	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Tetrachloride	0.5	5	2	5	1	156	0.0013	0.203	N/A	N/A
Chlorobenzene	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A
Chloroethane	1	5	2	5	1	367	0.0011	0.404	N/A	N/A
Chloroform	1	2	1	2	1	201	0.00097	0.195	0.0000679	0.0136
Chloromethane	1	5	2	5	N/A	N/A	0.00082	0.000391	N/A	N/A
Chlorotrifluoroethene	50	50	50	50	N/A	N/A	N/A	N/A	N/A	N/A
cis-1,2-Dichloroethene	1	2	1	2	1	248	0.00079	0.196	0.0000553	0.0137
cis-1,3-Dichloropropene	0.5	2	1	2	N/A	N/A	0.00091	0.000197	N/A	N/A
Dichlorodifluoromethane	2	5	5	5	1	199	0.00099	0.197	N/A	N/A
Ethylbenzene	0.5	2	1	2	1	227	0.00087	0.197	N/A	N/A
Methylene Chloride	5	5	10	20	1	283	0.00069	0.195	0.000414	0.1172
Tetrachloroethene	1	2	1	2	1	145	0.0014	0.203	0.00014	0.0203
Toluene	0.5	2	1	2	1	261	0.0011	0.287	N/A	N/A
trans-1,2-Dichloroethene	1	2	1	2	1	248	0.00079	0.196	0.0000553	0.0137
trans-1,3-Dichloropropene	1	2	1	2	N/A	N/A	N/A	N/A	N/A	N/A
Trichloroethene	1	2	1	2	1	183	0.0011	0.201	0.00004125	0.0075
Trichlorofluoromethane	1	5	2	5	1	175	0.0022	0.385	N/A	N/A
Trichlorotrifluoroethane	10	10	10	10	1	128	0.0031	0.397	N/A	N/A

Table 3-1 (7 of 7)

Reportable Detection Limits [a]

Analyte	Water µg/L	Water µg/L	Soil µg/kg	Soil µg/kg	Soil Vapor ug/L	Soil Vapor ppbv	Air ug/L	Air ppbv	Air ug/L	Air ppbv
Volatile Organic Compounds	low[b]	medium[c]	low[b]	medium[c]	TO-15 SIM	TO-15 SIM	TO-15	TO-15	TO-15 SIM	TO-15 SIM
Vinyl Chloride	0.5	5	2	5	1	384	0.00051	0.196	1.9125E-05	0.0073
Xylene (total)	1.5	4	3	4	N/A	N/A	N/A	N/A	N/A	N/A
Xylenes, m-, p-	N/A	N/A	N/A	N/A	2	150	0.0022	0.330	N/A	N/A
Xylene, o-	N/A	N/A	N/A	N/A	1	75	0.00087	0.065	N/A	N/A

Notes:

µg/L = micrograms compound per liter of water

µg/kg = micrograms compound per kilogram soil or sediment

[a] Reportable detection limits (RDLs) are the reporting limits currently achievable by Del Mar Analytical, or other subcontract laboratories. Typical reporting limits will generally be equal to or lower than the values listed here. The actual detection limits achieved for a chemical in a specific sample are referred to as Sample Quantiation Limits (SQLs). SQLs, not RDLs, are used to evaluate data and estimate exposure in the risk assessments. Method detection limits (MDLs) should be sufficiently low enough to allow evaluation of risk for all pathways.

[b] Detection limit for typical soil/water extraction volume

[c] Detection limit for soil/water extracted in larger volume

Table 3-2 (1 of 2)
Criteria for Evaluating Levels of Detection for Sediment and Water Samples

Analyte	Sediment (mg/kg)		Water (µg/L)	
	Sediment Criteria[1]	Reference	Water Criteria[2]	Reference
Inorganics				
Antimony				
Arsenic	5.9	TEL	150.0	NRWQC-ch
Beryllium			0.5	NAWQC-ch*
Cadmium	0.6	TEL	1.1	NAWQC-ch
Chromium III	37.3	TEL	74.0	NRWQC-ch**
Chromium VI			11.0	NRWQC-ch
Copper	34.0	ER-L	9.0	NRWQC-ch**
Iron			1,000.0	NAWQC-ch
Lead	35.0	TEL	2.5	NRWQC-ch**
Mercury	0.15	ER-L	0.012	NAWQC-ch
Nickel	18.0	TEL	52.0	NRWQC-ch**
Selenium			5.0	NRWQC-ch
Silver	1.0	ER-L	0.1	NAWQC-ch
Thallium			4.0	NAWQC-ch*
Zinc	123.1	TEL	110.0	NAWQC-ch
Pesticides				
4,4'-DDD	0.002	ER-L		
4,4'-DDE	0.002	ER-L		
4,4'-DDT	0.001	ER-L	0.001	NAWQC-ch
Dieldrin	0.00002	ER-L	0.002	NAWQC-ch
Endosulfan (alpha and beta)			0.056	NAWQC-ch
Endrin	0.002	TEL	0.002	NAWQC-ch
gamma-BHC (Lindane)	0.0009	TEL	0.060	NAWQC-ch
Heptachlor			0.004	NAWQC-ch
Polychlorinated Biphenyls				
Aroclor 1016	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Aroclor 1221	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Aroclor 1232	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Aroclor 1242	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Aroclor 1248	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Aroclor 1254	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Aroclor 1260	0.023	ER-L PCBs	0.014	NAWQC-ch PCBs
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	0.016	ER-L	52.00	NAWQC-ch*
Acenaphthylene	0.044	ER-L		
Anthracene	0.085	ER-L		
Benzo(a)anthracene	0.032	TEL		
Benzo(a)pyrene	0.032	TEL		
Chrysene	0.057	TEL		
Fluoranthene	0.111	TEL		
Fluorene	0.019	ER-L		
Naphthalene	0.160	ER-L	62.00	NAWQC-ch*
Phenanthrene	0.042	TEL		
Pyrene	0.053	TEL		

Table 3-2 (2 of 2)
Criteria for Evaluating Levels of Detection for Sediment and Water Samples

Analyte	Sediment (mg/kg)		Water (µg/L)	
	Sediment Criteria[1]	Reference	Water Criteria[2]	Reference
Semivolatile Organic Compounds				
1,2-Dichlorobenzene			76.30	NAWQC-ch*
1,3-Dichlorobenzene			76.30	NAWQC-ch*
1,4-Dichlorobenzene			76.30	NAWQC-ch*
2,4-Dichlorophenol			36.50	NAWQC-ch*
2,4-Dinitrotoluene			23.00	NAWQC-ch*
2-Chlorophenol			200.00	NAWQC-ch*
2-Methylnaphthalene	0.070	ER-L		
Aniline			15.00	NAWQC-ch*
bis(2-Ethylhexyl)phthalate			0.30	NAWQC-ch*
Butylbenzylphthalate			0.30	NAWQC-ch*
Di-n-Butylphthalate			0.30	NAWQC-ch*
Di-n-Octyl Phthalate			0.30	NAWQC-ch*
Dibutylphthalate			0.30	NAWQC-ch*
Diethylphthalate			0.30	NAWQC-ch*
Hexachlorobutadiene			0.93	NAWQC-ch*
Hexachlorocyclopentadiene			0.52	NAWQC-ch*
Hexachloroethane			54.00	NAWQC-ch*
Pentachlorophenol			13.00	NAWQC-ch***
Phenol			256.00	NAWQC-ch*
Volatile Organic Compounds				
1,1,2,2-Tetrachloroethane			240.00	NAWQC-ch*
1,1,2-Trichloroethane			940.00	NAWQC-ch*
1,2-Dibromoethane			2,000.00	NAWQC-ch*
1,3-Dichloropropene			24.40	NAWQC-ch*
2,2-Dichloropropane			570.00	NAWQC-ch*
Acrolein			2.10	NAWQC-ch*
Acrylonitrile			260.00	NAWQC-ch*
Chlorobenzene			5.00	NAWQC-ch*
Chloroform			124.00	NAWQC-ch*
Tetrachloroethylene			84.00	NAWQC-ch*
Trichloroethylene			2,190.00	NAWQC-ch*

Notes:

[1] National Oceanic and Atmospheric Administration (NOAA) Status and Trends Effects Range-Low (ER-L) and Threshold Effects Level (TEL) criteria for evaluating sediment detection limits

[2] National Ambient Water Quality Criteria (NAWQC) and National Recommended Water Quality Criteria (NRWQC) chronic (ch) freshwater criteria for evaluating surface water and shallow groundwater detection limits

*NAWQC chronic freshwater criteria that were lowest observable adverse effects level (LOAEL) values that have been divided by 10 to convert the LOAEL values to no observable adverse effects level (NOAEL) criteria

**NRWQC is hardness dependent

***NAWQC criteria is pH dependent on 7.8 pH.

Table 3-3 (1 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
1,2,3,4,6,7,8-HpCDD	9.6E-04
1,2,3,4,6,7,8-HpCDF	4.9E-04
1,2,3,4,7,8,9-HpCDF	4.3E-04
1,2,3,4,7,8-HxCDD	4.5E-05
1,2,3,4,7,8-HxCDF	4.7E-05
1,2,3,6,7,8-HxCDD	4.6E-05
1,2,3,6,7,8-HxCDF	5.4E-05
1,2,3,7,8,9-HxCDD	4.3E-05
1,2,3,7,8,9-HxCDF	4.3E-05
1,2,3,7,8-PeCDD	4.4E-06
1,2,3,7,8-PeCDF	1.0E-04
2,3,4,6,7,8-HxCDF	4.9E-05
2,3,4,7,8-PeCDF	9.8E-06
2,3,7,8-TCDD	4.3E-06
2,3,7,8-TCDF	4.3E-05
OCDD	1.2E-01
OCDF	9.7E-02
Aluminum	1.2E+01
Antimony	9.5E-02
Arsenic	1.9E+00
Barium	1.5E+01
Beryllium	5.0E+00
Boron	9.2E+00
Cadmium	2.1E-02
Chromium	9.3E+02
Cobalt	8.9E+00
Copper	2.1E+00
Hexavalent Chromium	1.4E+01
Lead	2.8E+00
Manganese	2.9E+01
Mercury	2.9E+00
Methyl mercury	1.1E+00
Molybdenum	1.1E-01
Nickel	1.0E-01
Selenium	1.7E-01
Silver	5.4E-01

Table 3-3 (2 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
Thallium	1.4E+00
Vanadium	1.5E+00
Zinc	2.1E+01
Aroclor 1016	1.6E+00
Aroclor 1221	1.6E+00
Aroclor 1232	7.7E-02
Aroclor 1242	7.9E-02
Aroclor 1248	1.6E-02
Aroclor 1254	7.7E-02
Aroclor 1260	7.7E-02
Aroclor 1262	7.7E-02
PCB-105	8.5E-03
PCB-114	8.8E-04
PCB-118	8.2E-03
PCB-123	7.5E-03
PCB-126	1.4E-05
PCB-156	2.6E-03
PCB-157	2.5E-03
PCB-167	1.2E-01
PCB-169	4.3E-04
PCB-189	2.0E-02
PCB-77	1.3E-02
PCB-81	1.2E-02
Perchlorate	4.2E-06
1,1,1,2-Tetrachloroethane	7.6E+01
1,1,1-Trichloroethane	4.3E+03
1,1,2,2-Tetrachloroethane	6.0E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	2.1E+02
1,1,2-Trichloroethane	8.3E+00
1,1-Dichloroethane	2.1E+02
1,1-Dichloroethene	2.9E-01
1,1-Dichloropropene	2.2E+01
1,2,3-Trichlorobenzene	6.3E+01
1,2,3-Trichloropropane	1.2E+01
1,2,4-Trichlorobenzene	6.3E+01
1,2,4-Trimethylbenzene	6.4E+02

Table 3-3 (3 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
1,2-Dibromo-3-chloropropane	2.2E+01
1,2-Dibromoethane	2.5E+01
1,2-Dichloro-1,1,2-Trifluoroethane	1.9E+03
1,2-Dichlorobenzene	3.7E+02
1,2-Dichloroethane	2.1E+02
1,2-Dichloropropane	2.5E+01
1,2-Diphenylhydrazine	8.5E+00
1,3,5-Trimethylbenzene	6.4E+02
1,3,5-Trinitrobenzene	1.1E+01
1,3-Dichlorobenzene	3.2E+02
1,3-Dichlorobenzene	3.2E+02
1,3-Dichloropropane	2.2E+01
1,3-Dichloropropene	4.4E+00
1,3-Dinitrobenzene	7.5E-01
1,4-Dichlorobenzene	1.6E+02
2,2-Dichloropropane	2.2E+01
2,4,5-Trichlorophenol	2.1E+02
2,4,6-Trichlorophenol	4.3E+02
2,4,6-Trinitrotoluene	3.2E-01
2,4-Dichlorophenol	1.3E+00
2,4-Dimethylphenol	1.1E+02
2,4-Dinitrophenol	1.2E+01
2,4-Dinitrotoluene	1.3E+00
2,6-Dinitrotoluene	2.5E+00
2-AMINO-4,6-DNT	1.3E+00
2-Butanone	7.6E+03
2-Chloroethylvinylether	7.3E-01
2-Chloronaphthalene	5.3E+02
2-Chlorophenol	2.1E+01
2-Chlorotoluene	3.2E+02
2-Hexanone	2.4E+03
2-Methylnaphthalene	2.1E+02
2-Methylphenol	1.1E+02
2-Nitroaniline	2.3E+01
2-Nitrophenol	2.3E+01
2-Nitrotoluene	1.3E+00

Table 3-3 (4 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
3,3'-Dichlorobenzidine	1.3E+00
3,5-Dimethylphenol	2.1E+02
3-Methylphenol	2.1E+02
3-Nitroaniline	2.3E+01
3-Nitrotoluene	1.3E+00
4,4'-DDD	3.4E+00
4,4'-DDE	3.4E+00
4,4'-DDT	3.4E+00
4,6-Dinitro-2-methylphenol	2.3E+01
4-AMINO-2,6-DNT	1.3E+00
4-bromofluorobenzene	6.3E+01
4-Bromophenyl phenyl ether	4.3E+00
4-Chloro-3-methylphenol	2.1E+01
4-Chloroaniline	1.1E+01
4-Chlorophenyl phenyl ether	1.3E+00
4-Chlorotoluene	3.2E+02
4-Methyl-2-Pentanone	2.4E+03
4-Methylphenol	2.1E+02
4-Nitroaniline	2.3E+01
4-Nitrophenol	2.3E+01
4-Nitrotoluene	1.3E+00
Acenaphthene	2.7E+02
Acenaphthylene	7.5E+02
Acetone	4.3E+01
Acrolein	2.3E+02
Acrylonitrile	4.3E-01
Aldrin	4.3E-01
alpha-BHC	2.1E-01
Aniline	5.3E+01
Anthracene	1.4E+03
Azobenzene	4.3E+00
Benzene	4.3E+00
Benzidine	2.3E+00
Benzo(a)anthracene	5.6E+00
Benzo(a)pyrene	5.6E+00
Benzo(b)fluoranthene	5.6E+00

Table 3-3 (5 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
Benzo(g,h,i)perylene	6.4E+00
Benzo(k)fluoranthene	5.8E+00
Benzoic Acid	3.1E+01
Benzyl Alcohol	3.1E+01
beta-BHC	2.1E-01
bis(2-Chloroethoxy)methane	1.5E+02
bis(2-Chloroethyl)ether	1.5E+02
bis(2-Chloroisopropyl) ether	1.5E+02
Bis(2-ethylhexyl)phthalate	7.8E+01
Bromobenzene	4.3E+00
Bromochloromethane	2.5E+01
Bromodichloromethane	1.5E+01
Bromoform	3.8E+01
Bromomethane	2.5E+01
Butyl benzyl phthalate	3.4E+02
Carbazole	4.3E+03
Carbon disulfide	4.7E+01
Carbon tetrachloride	1.5E+00
Chlordane	3.4E-01
Chlorobenzene	8.7E+01
Chlorodibromomethane	7.6E+01
Chloroethane	7.3E+01
Chloroform	2.4E-01
Chloromethane	2.5E+01
Chlorotrifluoroethene	1.6E+01
Chlorotrifluoromethane	6.4E+01
Chrysene	2.4E+00
cis-1,2-Dichloroethene	6.8E+01
cis-1,3-Dichloropropene	2.2E+01
Decahydronaphthalene	2.1E+02
delta-BHC	2.1E-01
Dibenz(a,h)anthracene	5.6E+00
Dibenzofuran	4.3E+03
Dibromochloromethane	4.6E+01
Dibromomethane	2.5E+01
Dichlorobenzenes	3.2E+02

Table 3-3 (6 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
Dichlorodifluoromethane	6.4E+01
Dieldrin	8.5E-02
Diethylphthalate	6.9E+03
Dimethyl phthalate	6.9E+03
Dimethylphenol isomer	2.1E+02
Di-n-butylphthalate	5.1E+02
Di-n-octyl phthalate	1.5E+03
Endosulfan Sulfate	6.4E-01
Endrin	1.3E-01
Ethylbenzene	2.1E+02
Fluoranthene	1.2E+02
Fluorene	1.5E+02
Formaldehyde	5.9E+01
Freon 113	1.9E+03
Heptachlor	5.6E-01
Heptachlor Epoxide	1.6E-02
Hexachlorobenzene	3.4E-01
Hexachlorobutadiene	8.5E-01
Hexachlorocyclopentadiene	1.3E+01
Hexachloroethane	2.1E+00
Hexanal	2.4E+03
HMX	6.4E+01
Hydrazine	5.0E-02
Indeno(1,2,3-cd)pyrene	5.8E+00
Isophorone	4.8E+02
Isopropylbenzene	4.1E+02
Lindane	2.1E-01
m,p-Xylene	6.4E+02
Methyl Isobutyl Ketone	7.6E+03
Methyl tert-butyl ether	6.1E+01
Methylene chloride	2.5E+01
Methylphenol	2.1E+02
Monochlorobenzene	3.2E+02
Monomethylhydrazine	5.0E-02
Naphthalene	2.1E+02
n-Butylbenzene	4.1E+02

Table 3-3 (7 of 9)

Terrestrial Mammalian Ecological Screening Levels[a]

Soil	
Chemical	Terrestrial Mammal ESL (mg/kg)
Nitrobenzene	2.0E+00
Nitrobenzene	2.0E+00
Nitrosodimethylamine	5.6E+01
N-Nitrosodimethylamine	5.6E+01
N-Nitrosodi-n-propylamine	5.6E+01
N-Nitrosodiphenylamine	5.6E+01
Nonane	2.4E+03
n-Propylbenzene	4.1E+02
o-Xylene	6.4E+02
Pentachlorophenol	1.3E+01
Pentanal	2.4E+03
Phenanthrene	6.2E+01
Phenol	2.6E+02
p-Isopropyltoluene	6.4E+02
Pyrene	7.6E+01
Pyridine	2.1E+00
RDX	4.3E+01
sec-Butylbenzene	4.1E+02
Styrene	6.4E+02
tert-Butylbenzene	4.1E+02
Tetrachloroethene	2.1E+00
Tetramethylcyclohexane Isomer	6.4E+02
Tetryl	2.8E+01
Thiobismethane	4.7E+01
Toluene	2.5E+00
Total xylenes	6.4E+01
trans-1,2-Dichloroethene	9.7E+02
trans-1,3-Dichloropropene	4.4E+00
Trichloroethene	3.0E+00
Trichlorofluoromethane	3.0E+02
Trimethyl benzene	6.4E+02
Unsymetricaldimethylhydrazin	5.0E-02
Vinyl acetate	5.0E+02
Vinyl chloride	7.3E-01

Table 3-3 (8 of 9)

Terrestrial Mammalian Ecological Screening Levels [a]

Inhalation -- for Burrowing Mammals Only	
Chemical	Terrestrial Mammal ESL (mg/m^3)
1,1,1-Trichloroethane	38
1,1,2-Trichloroethane	0.057
1,1-Dichloroethane	36
1,1-Dichloroethene	0.60
1,1-Dichloropropene	4.1
1,2,3-Trichlorobenzene	50
1,2,4-Trichlorobenzene	50
1,2,4-Trimethylbenzene	16
1,2-Dichlorobenzene	50
1,2-Dichloroethane	42
1,2-Dichloroethene	1.9
1,2-Dichloropropane	1.2
1,2-Dichlorotetrafluoroethane (Freon 114)	91
1,3,5-Trimethylbenzene	16
1,3-Dichlorobenzene	50
1,4-Dichlorobenzene	50
2-Butanone (MEK)	869
2-Hexanone	2.4
2-Methylnaphthalene	0.38
Acetone	1305
Benzene	0.57
Carbon disulfide	0.24
Carbon tetrachloride	0.63
Chlorobenzene	58
Chloroethane	992
Chloroform	0.24
Chloromethane	0.74
cis-1,2-Dichloroethene	1.9
Dichlorodifluoromethane (Freon 12)	91
Ethylbenzene	23
Ethylene dibromide	0.58
Fluorene	0.17
Freon 113	91
Isopropylbenzene (cumene)	23
m,p-Xylenes	16
Methyl tert-butyl ether (MTBE)	258

Table 3-3 (9 of 9)

Terrestrial Mammalian Ecological Screening Levels [a]

Inhalation -- for Burrowing Mammals Only	
Chemical	Terrestrial Mammal ESL (mg/m^3)
1,1,1-Trichloroethane	38
Methylene Chloride	0.87
Naphthalene	0.38
n-butylbenzene	23
n-Propylbenzene	23
o-Xylene	16
p-cymene (p-isopropyltoluene)	16
Phenanthrene	0
sec-butylbenzene	23
Styrene	38
t-butylbenzene	23
Tetrachloroethene	24
Toluene	0.084
trans-1,2-Dichloroethene	1.9
Trichloroethene	6.4
Trichlorofluoromethane (Freon 11)	90.9
Vinyl chloride	0.56
Xylenes (total)	16

Notes:

(a) Spreadsheets used to derive terrestrial mammal ESLs are presented in Appendix C, Attachment C-4.

ESL - ecological screening level

ug/m^3 air - micrograms per cubic meter

Table 3-4 (1 of 3)

Terrestrial Avian Ecological Screening Levels [a]

Chemical	Terrestrial Avian ESL (mg/kg)
1,2,3,4,6,7,8-HpCDD	1.3E-01
1,2,3,4,6,7,8-HpCDF	8.7E-03
1,2,3,4,7,8,9-HpCDF	6.3E-03
1,2,3,4,7,8-HxCDD	1.5E-03
1,2,3,4,7,8-HxCDF	8.0E-04
1,2,3,6,7,8-HxCDD	7.4E-03
1,2,3,6,7,8-HxCDF	1.1E-03
1,2,3,7,8,9-HxCDD	6.6E-04
1,2,3,7,8,9-HxCDF	6.3E-04
1,2,3,7,8-PeCDD	6.8E-05
1,2,3,7,8-PeCDF	9.6E-04
2,3,4,6,7,8-HxCDF	8.6E-04
2,3,4,7,8-PeCDF	8.9E-05
2,3,7,8-TCDD	6.3E-05
2,3,7,8-TCDF	4.4E-06
OCDD	1.6E+00
OCDF	1.4E+00
Aroclor-1254	3.7E-01
Aroclor-1260	8.1E-02
PCB-105	8.6E-02
PCB-114	3.7E-02
PCB-118	8.0E-01
PCB-123	7.3E-01
PCB-126	1.6E-04
PCB-156	1.5E-01
PCB-157	1.4E-01
PCB-167	1.4E+00
PCB-169	6.3E-02
PCB-189	2.8E+00
PCB-77	2.8E-04
PCB-81	1.4E-04
Aluminum	9.1E+02
Arsenic	3.7E+01
Barium	4.5E+01
Boron	2.3E+01
Cadmium	4.5E-03
Copper	1.1E+00

Table 3-4 (2 of 3)

Terrestrial Avian Ecological Screening Levels [a]

Chemical	Terrestrial Avian ESL (mg/kg)
Lead	1.3E-02
Manganese	3.4E+02
Mercury	8.8E-01
Methyl Mercury	1.7E-01
Molybdenum	1.8E+00
Nickel	1.5E+00
Selenium	6.8E-01
Vanadium	1.0E+02
Zinc	2.6E+01
1,2-Dichloroethane	7.6E+01
1,3-Dinitrobenzene	1.9E+00
2,4-Dinitrophenol	5.9E-01
2-Nitroaniline	3.3E+01
3-Nitroaniline	5.9E+00
4,4'-DDE	1.2E-02
4,4'-DDT	1.2E-02
4-Chloroaniline	4.4E+00
4-Methylphenol	4.3E+00
4-Nitroaniline	3.3E+00
Acenaphthene	2.5E+00
Acetone	2.4E+04
alpha-BHC	2.5E+00
Aniline Surrogate	2.5E+01
Anthracene	2.4E+00
Benzoic Acid	4.4E+00
Benzyl Alcohol	4.4E+00
beta-BHC	2.5E+00
Bis(2-ethylhexyl)phthalate	4.9E+00
Chlordane	1.4E+00
delta-BHC	2.5E+00
Dieldrin	3.4E-01
Dimethylphthalate	4.4E+00
Di-n-butylphthalate	4.9E-01
Di-n-octylphthalate	3.9E+01
Endosulfan Sulfate	4.4E+01
Endrin	4.4E-02
Fluorene	1.6E+00
Heptachlor	5.9E+00

Table 3-4 (3 of 3)

Terrestrial Avian Ecological Screening Levels [a]

Chemical	Terrestrial Avian ESL (mg/kg)
Hexachlorobenzene	1.2E+02
Hexachlorobutadiene	1.4E+01
Lindane	8.9E+00
Pentachlorophenol	3.9E+01
Phenanthrene	1.3E+00
Phenol	5.0E+00

Notes:

(a) Spreadsheets used to derive terrestrial avian ESLs are presented in Appendix C, Attachment C-2.

ESL - ecological screening level

mg/kg - milligrams per kilogram

Table 3-5 (1 of 2)

Terrestrial Invertebrate Ecological Screening Levels [a]

Chemical	Terrestrial Invertebrate ESL (mg/kg soil)
2,3,7,8-TCDD	5.0E+02
Antimony	7.8E+01
Arsenic	NA
Barium	3.3E+02
Beryllium	4.0E+01
Cadmium	1.4E+02
Chromium	NA
Copper	3.2E+01
Hexavalent Chromium	2.0E-01
Lead	1.7E+03
Mercury	1.0E-01
Methyl mercury	2.5E+00
Nickel	1.0E+02
Selenium	7.7E+00
Vanadium	NA
Zinc	2.0E+02
Aroclor 1016	5.0E+01
Aroclor 1254	5.0E+01
1,2,3-Trichlorobenzene	2.0E+01
1,2,4-Trichlorobenzene	2.0E+01
1,2-Dichloropropane	7.0E+02
1,4-Dichlorobenzene	2.0E+01
2,4,5-Trichlorophenol	9.0E+00
2,4,6-Trichlorophenol	1.0E+01
4-Nitrophenol	7.0E+00
Benzo(a)pyrene	2.5E+04
Carbazole	3.4E+01
Chlorobenzene	4.0E+01
Dibenzofuran	6.2E+01
Dieldrin	NA
Dimethyl phthalate	2.0E+02
Fluoranthene	3.8E+01
Fluorene	2.7E+01
Nitrobenzene	4.0E+01

Table 3-5 (2 of 2)

Terrestrial Invertebrate Ecological Screening Levels [a]

Chemical	Terrestrial Invertebrate ESL (mg/kg soil)
N-Nitrosodiphenylamine	2.0E+01
Pentachlorophenol	6.0E+00
Phenanthrene	3.4E+01
Phenol	3.0E+01
Pyrene	1.8E+01

Notes:

(a) Spreadsheet used to derive terrestrial invertebrate ESLs is presented in Appendix C, Attachment C-3.

ESL - ecological screening level

NA - Not available. Data were insufficient. USEPA EcoSSL (2003a-b, 2005d-n)

mg/kg - milligrams per kilogram

Table 3-6 (1 of 1)

Groundwater Comparison Concentrations for Metals and Selected Inorganic Compounds

	All Concentrations in µg/L				
Constituent	**SSFL Groundwater Comparison Concentration[a]**	**CA DHS MCLs**	**Ca DHS NLs**	**OEHHA PHGs**	**USEPA PRGs**
Antimony	2.5	6		20	15
Arsenic	7.7	50		0.004	0.05
Barium	150	1,000		2000	2,600
Beryllium	ND < 0.14	4		1	73
Boron	340		1,000		7,300
Cadmium	0.2	5		0.07	18
Chromium	14	50			55,000
Cobalt	1.9				730
Copper	4.7	1,000[b]	1,300	170	1,500
Fluoride	800	2,000		1,000	2,200
Iron	4,100	300[b]			11,000
Lead	11		15	2	
Magnesium	77,000				
Manganese	150	50[b]	500		880
Mercury	ND <0.063	2		1.2	11
Molybdenum	2.2				180
Nickel	17	100		12	730
Selenium	1.6	50			180
Silver	ND <0.17	100[b]			180
Strontium	800				22,000
Thallium	ND< 0.13	2		0.1	2.40
Tin	ND <2.4				22,000
Vanadium	2.6		50		36
Zinc	6,300	5,000[b]			11,000
Potassium	9,600				
Sodium	190,000				
Sulfate	376,000	250,000[b]			

(a) Groundwater Comparison Concentrations represent the maximum value retained in the Final Groundwater Comparison Data Set (Appendix E)

(b) Secondary MCL - Non-health based criterion (i.e. based on aesthetic, discoloration issues).

Note: A Groundwater Comparison Concentration was not established for aluminum because of insufficient data. Dissolved analysis was only conducted on one sample.

ND = Non Detect. Groundwater mercury, silver and tin results greater than values shown will undergo further evaluation.

µg/L = Micrograms per liter

Ca DHS - California Department of Health Services

MCL - Maximum Contaminant Level

NL = Notification Level

OEHHA PHG - Office of Environmental Health Hazard Assessment Public Health Goals

USEPA PRG - United States Environmental Protection Agency Preliminary Remediation Goal for tap water

Sources:
Ca DHS MCLs from http://www.dhs.ca.gov/ps/ddwem/chemicals/MCL/EPAandDHS.pdf
Ca DHS Notification Levels (NL) from DHS website - http://www.dhs.ca.gov/ps/ddwem/
OEHHA PHGs from http://www.oehha.ca.gov/water/phg/allphgs.html

Table 5-1 (1 of 3)

Exposure Assessment Parameters for Workers

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
General Parameters:			
Body Weight (BW)	Value: 70 kg Rationale: Average body weight, USEPA 1997	Lognormal mean: 71 kg standard deviation: 14.2 Source: CalTOX 1994[1]	Value: 70 kg Rationale: Average body weight, USEPA 1997
Exposure Frequency (EF)	Value: 8 hrs/d, 219 d/yr Rationale: DTSC 1999	Constant	Value: 8 hrs/d, 250 d/yr Rationale: USEPA 1997
Exposure Duration (ED)	Value: 9 years Rationale: DTSC 1999	Continuous variable across age-specific occupational tenure reported by Carey (1988) as presented by USEPA (1997)	Value: 25 years Rationale: DTSC 1999
Averaging Time (AT)	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration Rationale: USEPA 1997	Carcinogenic Effects: Constant at 75 years Noncarcinogenic Effects: Co-vary with exposure duration	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration Rationale: USEPA 1997
Inhalation of Particulates and/or Vapors:			
Breathing Rate (BR)	Value: 1.3 m^3/hr Rationale: Hourly average for outdoor workers, USEPA 1997	Lognormal mean: 1.44 m^3/hr standard deviation: 0.66 m^3/hr Rationale: General construction workers and laborers reported by Linn et al. (1993) as presented by USEPA (1997)	Value: 2.0 m^3/hour Rationale: Midpoint between moderate and heavy activity values, USEPA 1997

Table 5-1 (2 of 3)

Exposure Assessment Parameters for Workers

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Dermal Contact with Soil:			
Soil Adherence Factor (AF)	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.02 mg/cm^2 Rationale: Weighted soil adherence for face, forearms, and hands for pooled groundskeepers data (USEPA 1997, Table 6-13); typical activity combined with 50th percentile body part-specific soil adherence factors	Empirical Distribution Rationale: Distribution from anticipated USEPA Dermal Guidance or fitted distribution of pooled data from sources cited in that Guidance	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.2 mg/cm^2 Rationale: Weighted soil adherence for face, forearms, and hands for pooled utility workers data (USEPA 1997, Table 6-13); high-end activity combined with 50th percentile body part-specific soil adherence factors
Surface Area (SA)	Value: 2,500 cm^2 Rationale: DTSC 1999	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-2, 6-3), summed across relevent body parts, and fitted to Crystal Ball	Value: 2,500 cm^2 Rationale: DTSC 1999
Bioavailability (B)	Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals DTSC 1994	Constant	Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals DTSC 1994
Incidental Soil Ingestion:			
Ingestion Rate (IR_{soil})	Value: 50 mg/day Rationale: Based on range of plausible soil ingestion rates for adults, USEPA 1997	Lognormal mean: 9.94 mg/day standard deviation: 19.9 mg/day Source: CalTOX 1994[1]	Value: 200 mg/day Rationale: RME ingestion rate, DTSC, personal communication, T.R. Hathaway, 3/30/00

Table 5-1 (3 of 3)

Exposure Assessment Parameters for Workers

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval

[1] CalTOX computer model version 1994.
Crystal Ball (Decisioneering, Inc., Denver, CO)

Table 5-2 (1 of 4)

Exposure Assessment Parameters for a Residential Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
General Parameters:			
Body Weight (BW)	Value: 70 kg Rationale: Average body weight, USEPA 1997	Lognormal mean: 71 kg standard deviation: 14.2 Source: CalTOX 1994[1]	Value: 70 kg Rationale: Average body weight, USEPA 1997
Exposure Frequency (EF)	Value: Pathway-specific Rationale: USEPA 1997	Continuous variable between selected pathway specific average exposure duration and 350 days/year Rationale: professional judgment	Value: 350 days/year (unless otherwise specified in guidance) Rationale: USEPA 1997; DTSC 1992
Exposure Duration (ED)	Value: 9 years Rationale: Average residence time, USEPA 1997	Selected exposure duration from distribution given below, less 6 years for child exposure (truncated at 0 years) Lognormal mean: 9.37 years standard deviation: 2.52 years Source: CalTOX 1994[1]	Value: 24 years (30-year lifetime minus 6 years as child) Rationale: 95th percentile value for residence time, USEPA 1997
Averaging Time (AT)	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 9 years (3,285 days) Rationale: USEPA 1997	Carcinogenic Effects: Constant at 75 years Noncarcinogenic Effects: Co-vary with exposure duration	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 24 years (8,760 days) Rationale: USEPA 1997

Table 5-2 (2 of 4)

Exposure Assessment Parameters for a Residential Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Inhalation of Particulates and/or Vapors:			
Breathing Rate (BR)	Value: 0.43 m^3/hr Rationale: Mean value for resting inhalation rate; CalTOX 1994	Lognormal mean: 0.43 m^3/hr standard deviation: 0.09 m^3/hr Source: Resting inhalation rate; CalTOX 1994[1]	Value: 0.55 m^3/hour Rationale: Recommended value for RME (midpoint between male and female values), USEPA 1997
Hours of day spent in or near home	16.3 hours/day Rationale: CalTOX average	Lognormal mean: 16.3 hours/day standard deviation: 2.24 hours/day Source: CalTOX 1994[1]	24 hours./day Rationale: Maximum hours in a day
Dermal Contact with Soil:			
Soil Adherence Factor (AF)	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.01 mg/cm^2 Rationale: Weighted soil adherence for face, forearms, hands, and lower legs for "groundskeepers" (USEPA 1997, Table 6-13); typical activity combined with 50th percentile body part-specific soil adherence factors	Empirical Distribution Rationale: Distribution from anticipated USEPA Dermal Guidance or fitted distribution of pooled data from sources cited in that Guidance	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.07 mg/cm^2 Rationale: Weighted soil adherence for face, forearms, hands, and lower legs for "gardeners" (USEPA 1997, Table 6-13); typical activity combined with 50th percentile body part-specific soil adherence factors
Skin Surface Area (SA)	Value: 5,700 cm^2 Rationale: Exposed surface area for head, hands, lower legs, and forearms; USEPA 1997	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-2, 6-3), summed across relevant body parts, and fitted with Crystal Ball	Value: 5,700 cm^2 Rationale: Exposed surface area for head, hands, lower legs, and forearms; USEPA 1997

Table 5-2 (3 of 4)

Exposure Assessment Parameters for a Residential Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Bioavailability (B)	Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals DTSC 1994	Constant	Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals DTSC 1994
Incidental Soil Ingestion:			
Ingestion Rate (IR_{soil})	Value: 50 mg/day Rationale: Based on range of plausible soil ingestion rates for adults, USEPA 1997	Lognormal mean: 9.94 mg/day standard deviation: 19.9 mg/day Source: CalTOX 1994[1]	Value: 100 mg/day Rationale: Based on range of plausible soil ingestion rates for adults, USEPA 1997
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval
Ingestion of Groundwater During Domestic Use			
Ingestion Rate (IR_{gw})	Value: 1.0 L/day (non-VOCs) Value: 2.0 L/day (VOCs) Rationale: Value for non-VOCs from DTSC (1994) accounts for ingestion pathway only. Value for VOCs accounts for chemical uptake via dermal contact with groundwater and inhalation of vapors during showering by assuming that the dosage associated with these pathways is equal to the dosage received via groundwater ingestion as described in Section 5.3.2.	Empirical Distribution Source: Distribution of water consumption rates as reported by Roseberry and Burmaster (1992)	Value: 1.5 L/day (non-VOCs) Value: 3.1 L/day (VOCs) Rationale: Value for non-VOCs from DTSC (1994) accounts for ingestion pathway only. Value for VOCs accounts for chemical uptake via dermal contact with groundwater and inhalation of vapors during showering by assuming that the dosage associated with these pathways is equal to the dosage received via groundwater ingestion as described in Section 5.3.2.
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in water matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in water matrix; subject to DTSC approval

Table 5-2 (4 of 4)

Exposure Assessment Parameters for a Residential Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Ingestion of Homegrown Food/Fish:			
Ingestion Rate, Fruit	Value: 1.20 g/kg-day Rationale: 50th percentile value of homegrown fruit consumption in the western U.S., USEPA 1997	Lognormal mean: 4.2 g/kg-day standard deviation: 0.84 g/kg-day Source: Distribution for consumption of fruits and vegetables combined, CalTOX 1994[1]	Value: 5.39 g/kg-day Rationale: 90th percentile value of homegrown fruit consumption in the western U.S., USEPA 1997
Ingestion Rate, Vegetables	Value: 0.9 g/kg-day Rationale: 50th percentile value of homegrown vegetable consumption in the western U.S., USEPA 1997		Value: 4.64 g/kg/day Rationale: 90th percentile value of homegrown vegetable consumption in the western U.S., USEPA 1997
Fractions of fruit and vegetable local	Value: 1 Rationale: Deterministic value is for homegrown produce	Lognormal mean: 0.24 standard deviation: 0.17 Source: CalTOX 1994[1]	Value: 1 Rationale: Deterministic value is for homegrown produce

[1] CalTOX computer model version 1994.
Crystal Ball (Decisioneering, Inc., Denver, CO)

Table 5-3 (1 of 4)

Exposure Assessment Parameters for a Residential Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
General Parameters:			
Body Weight (BW)	Value: 15 kg Rationale: Average body weight, USEPA 1997; DTSC 1992	Normal mean: 15.6 kg standard deviation: 2 kg Rationale: Fit of reported percentiles of body weight for 3- to 4-year-olds (midpoint of 1- to 6-year-old receptor) as reported in Anderson et al. 1985	Value: 15 kg Rationale: Average body weight, USEPA 1997; DTSC 1992
Exposure Frequency (EF)	Value: Pathway-specific Rationale: USEPA 1997	Continuous variable between selected pathway specific average exposure duration and 350 days/year Rationale: Professional judgment	Value: 350 days/year Rationale: RME, USEPA 1997; DTSC 1992
Exposure Duration (ED)	Value: 6 years Rationale: RME, USEPA 1997; DTSC 1992	Constant	Value: 6 years Rationale: RME, USEPA 1997; DTSC 1992
Averaging Time (AT)	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 6 years (2,190 days) Rationale: Average lifetime, USEPA 1997 Exposure duration, DTSC 1992	Carcinogenic Effects: Constant at 75 years Noncarcinogenic Effects: Co-vary with exposure duration	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 6 years (2,190 days) Rationale: Average lifetime, USEPA 1997 Exposure duration; DTSC 1992

Table 5-3 (2 of 4)

Exposure Assessment Parameters for a Residential Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Inhalation of Particulates and/or Vapors:			
Breathing Rate (BR)	Value: 0.35 m^3/hour Rationale: Mean rate for 3- to 5-year-old, USEPA 1997	Lognormal mean: 0.35 m^3/hour standard deviation: 0.07 m^3/hour Source: Adult resting inhalation rate times 0.75 (ratio of recommended mean rates in adults vs children per USEPA 1997); CalTOX 1994[1]	Value: 0.35 m^3/hour Rationale: Mean rate for 3- to 5-year-old, USEPA 1997
Hours of day spent in or near home	Value: 24 h/d Rationale: Small preschool child not anticipated to spend large amounts of time away from home	Constant	24 h/d Rationale: Small preschool child not anticipated to spend large amounts of time away from home
Dermal Contact with Soil:			
Soil Adherence Factor (AF)	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.06 mg/cm^2 Rationale: Weighted soil adherence for hands, face, forearms, lower legs, and feet for "day care kids" (USEPA 1997, Table 6-13); typical activity combined with 50th percentile body part-specific soil adherence factors	Empirical Distribution Rationale: Distribution from anticipated USEPA Dermal Guidance or fitted distribution of pooled data from sources cited in that Guidance	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.2 mg/cm^2 Rationale: Weighted soil adherence for hands, face, forearms, lower legs, and feet for "children playing in wet soil" (USEPA 1997, Table 6-13); high-end activity combined with 50th percentile body part-specific soil adherence factors
Skin Surface Area (SA)	Value: 2,800 cm^2 Rationale: Exposed skin surface area for hands, head, forearms, lower legs, and feet; USEPA 1997	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-6, 6-7), adjusted for fraction of skin exposed, and fitted with Crystal Ball	Value: 2,800 cm^2 Rationale: Exposed skin surface area for hands, head, forearms, lower legs, and feet; USEPA 1997

Table 5-3 (3 of 4)

Exposure Assessment Parameters for a Residential Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Bioavailability (ABS)	Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals DTSC 1994	Constant	Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals DTSC 1994
Incidental Soil Ingestion:			
Ingestion Rate (IR_{soil})	Value: 100 mg/day Rationale: Average value, USEPA 1997	Lognormal arithmetic mean 86 mg/day standard deviation 191 mg/day Source: CalTOX 1994[1]	Value: 200 mg/day Rationale: RME, DTSC 1992
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval
Ingestion of Groundwater During Domestic Use			
Ingestion Rate (IR_{gw})	Value: 0.75 L/day (non-VOCs) Value: 1.5 L/day (VOCs) Rationale: Value for non-VOCs from DTSC (1994) accounts for ingestion pathway only. Value for VOCs accounts for chemical uptake via dermal contact with groundwater and inhalation of vapors during showering by assuming that the dosage associated with these pathways is equal to the dosage received via groundwater ingestion as described in Section 5.3.2.	Empirical Distribution Source: Distribution of water consumption rates as reported by Roseberry and Burmaster (1992)	Value: 1.3 L/day (non-VOCs) Value: 2.5 L/day (VOCs) Rationale: Value for non-VOCs from DTSC (1994) accounts for ingestion pathway only. Value for VOCs accounts for chemical uptake via dermal contact with groundwater and inhalation of vapors during showering by assuming that the dosage associated with these pathways is equal to the dosage received via groundwater ingestion as described in Section 5.3.2.
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in water matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in water matrix; subject to DTSC approval

Table 5-3 (4 of 4)

Exposure Assessment Parameters for a Residential Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Ingestion of Homegrown Food/Fish:			
Ingestion Rate, Fruit	Value: 2.15g/kg-day Rationale: 50th percentile value for adult times 1.79 (ratio of adult to 3- to 5-year-old consumption for all U.S. regions combined), USEPA 1997	Lognormal mean: 7.5 g/kg-day standard deviation: 1.5 g/kg-day Source: Distribution for consumption of fruits and vegetables combined, by children, CalTOX 1994[1]	Value: 5.43 g/kg-day Rationale: 90th percentile value for adult, times 1.008 (ratio of adult to 3- to 5-year-old consumption for all U.S. regions combined), USEPA 1997
Ingestion Rate, Vegetables	Value: 1.01 g/kg-day Rationale: 50th percentile value for adult times 1.13 (ratio of adult to 3- to 5-year-old consumption for all U.S. regions combined), USEPA 1997		Value: 5.66 g/kg-day Rationale: 90th percentile value for adult times 1.22 (ratio of adult to 3- to 5-year-old consumption for all U.S. regions combined), USEPA 1997
Fractions of fruit and vegetable local	Value: 1 Rationale: Deterministic value is for homegrown produce	Lognormal mean: 0.24 standard deviation: 0.17 Source: CalTOX 1994[1]	Value: 1 Rationale: Deterministic value is for homegrown produce

[1] CalTOX computer model version 1994.
Crystal Ball (Decisioneering, Inc., Denver, CO)

Table 5-4 (1 of 3)

Exposure Assessment Parameters for a Recreational Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
General Parameters:			
Body Weight (BW)	Value: 70 kg Rationale: Average body weight, USEPA 1997	Lognormal mean: 71 kg standard deviation: 14.2 Source: CalTOX 1994	Value: 70 kg Rationale: Average body weight, USEPA 1997
Exposure Frequency (EF)	Value: 4 hours/day, 1 day every other week, 50 weeks/year Rationale: Site-specific assumption	Constant weekly frequency, with uniform: minimum 4 hours/day maximum 8 hours/day Rationale: Site-specific assumption	Value: 8 hours/day, 1 days/week, 50 weeks/year Rationale: Site-specific assumption
Exposure Duration (ED)	Value: 9 years Rationale: Average residence time, USEPA 1997	Selected exposure duration from distribution given below, less 6 years for child exposure (truncated at 0 years) Lognormal mean: 9.37 years standard deviation: 2.52 years Source: CalTOX 1994[1]	Value: 24 years (30-year lifetime minus 6 years as child) Rationale: 95th percentile value for residence time, USEPA 1997
Averaging Time (AT)	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 9 years (3,285 days) Rationale: USEPA 1997	Carcinogenic Effects: Constant at 75 years Noncarcinogenic Effects: Co-vary with exposure duration	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 24 years (8,760 days) Rationale: USEPA 1997

Table 5-4 (2 of 3)

Exposure Assessment Parameters for a Recreational Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Inhalation of Particulates and/or Vapors:			
Breathing Rate (BR)	Value: 1.3 m^3/hour Rationale: Midpoint between recommended values for RME for light and moderate activity, USEPA 1997	Lognormal mean: 1.28 m^3/hour standard deviation: 0.38 m^3/hour Source: active inhalation rate; CalTOX 1994[1]	Value: 1.3 m^3/hour Rationale: Midpoint between recommended values for RME for light and moderate activity, USEPA 1997
Dermal Contact with Soil:			
Soil Adherence Factor (AF)	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.01 mg/cm^2 Rationale: Weighted soil adherence for hands, face, and forearms for "Soccer Nos. 2&3" (USEPA 1997, Table 6-13); typical activity combined with 50th percentile body part-specific soil adherence factors	Empirical Distribution Rationale: Distribution from anticipated USEPA Dermal Guidance or fitted distribution of pooled data from sources cited in that Guidance	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.9 mg/cm^2 Rationale: Weighted soil adherence for hands, face, and forearms for "archeologists" (USEPA 1997, Table 6-13); high-end activity combined with 50th percentile body part-specific soil adherence factors
Skin Surface Area (SA)	Value: 5,700 cm^2 Rationale: Exposed skin surface area for hands, head, lower legs, and forearms; USEPA 1997	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-2, 6-3), summed across relevent body parts, and fitted with Crystal Ball	Value: 5,700 cm^2 Rationale: Exposed skin surface area for hands, head, lower legs, and forearms; USEPA 1997
Bioavailability (B)	Value: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994	Constant	Value: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994
Dermal Contact with Surface Water:			
Event Frequency (EV)	Value: 0.5 Rationale: Site-specific assumption	Constant Rationale: Site-specific assumption	Value: 0.5 Rationale: Site-specific assumption

Table 5-4 (3 of 3)

Exposure Assessment Parameters for a Recreational Adult

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Time of Event (t_{event})	Value: 1 hr Rationale: Site-specific assumption	Uniform Distribution: Minimum 1 hr Maximum 2 hrs Rationale: Site-specific assumption	Value: 2 hrs Rationale: Site-specific assumption
Skin Surface Area (SA)	Value: 18,150 cm^2 Rationale: Total skin surface area for adult (male and female averaged), based on the 50th percentile of the distribution from USEPA 1997, Tables 6-2 and 6-3	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-2 and 6-3), and fitted with Crystal Ball	Value: 18,150 cm^2 Rationale: Total skin surface area for adult (male and female averaged), based on the 50th percentile of the distribution from USEPA 1997, Tables 6-2 and 6-3
Bioavailability (ABS)	Value: Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994[1]	Constant	Value: Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994[1]
Incidental Soil Ingestion:			
Ingestion Rate (IR_{soil})	Value: 50 mg/day Rationale: Based on range of plausible soil ingestion rates for adults, USEPA 1997	Lognormal mean: 9.94 mg/day standard deviation: 19.9 mg/day Source: CalTOX 1994[1]	Value: 100 mg/day Rationale: Based on range of plausible soil ingestion rates for adults, USEPA 1997
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval

[1] CalTOX computer model version 1994.
Crystal Ball (Decisioneering, Inc., Denver, CO)

Table 5-5 (1 of 4)

Exposure Assessment Parameters for a Recreational Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
General Parameters:			
Body Weight (BW)	Value: 15 kg Rationale: Average body weight (at midpoint of 1- to 6-year-olds), USEPA 1997; DTSC 1992	Normal mean: 15.6 kg standard deviation: 2 kg Rationale: Fit of reported percentiles of body weight for 3- to 4-year-olds (mid-point of 1- to 6-year-old receptor) as reported in Anderson et al. 1985	Value: 15 kg Rationale: Average body weight (at midpoint of 1- to 6-year-olds); USEPA 1997; DTSC 1992
Exposure Frequency (EF)	Value: 4 hours/day, 1 day/week, 50 weeks/year Rationale: Site-specific assumption	Uniform: minimum 4 hours/week maximum 8 hours/week Rationale: Site-specific assumption	Value: 8 hours/day, 2 days/week, 50 weeks/year Rationale: Site-specific assumption
Exposure Duration (ED)	Value: 6 years Rationale: RME, USEPA 1997; DTSC 1992	Constant	Value: 6 years Rationale: RME, USEPA 1997; DTSC 1992
Averaging Time (AT)	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 6 years (2,190 days) Rationale: Average lifetime, USEPA 1997; Exposure duration, DTSC 1992	Carcinogenic Effects: Constant at 75 years Noncarcinogenic Effects: Co-vary with exposure duration	Value: Carcinogenic Effects: 75 years (27,375 days) Noncarcinogenic Effects: AT = Exposure duration or 6 years (2,190 days) Rationale: Average lifetime, USEPA 1997; Exposure duration, DTSC 1992

Table 5-5 (2 of 4)

Exposure Assessment Parameters for a Recreational Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Inhalation of Particulates and/or Vapors:			
Breathing Rate (BR)	Value: 1.1 m^3/hour Rationale: Midpoint between recommended values for RME for light and moderate activity in children; USEPA 1997	Lognormal mean: 1.08 m^3/hour standard deviation: 0.32 m^3/hour Source: Active inhalation rate in adults times 0.86 (ratio of child to adult recommended rates in USEPA 1997); CalTOX 1994[1]	Value: 1.1 m^3/hour Rationale: Midpoint between recommended values for RME for light and moderate activity in children, USEPA 1997
Dermal Contact with Soil:			
Soil Adherence Factor (AF)	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.06 mg/cm^2 Rationale: Weighted soil adherence for hands, face, forearms, lower legs, and feet for "day care kids" (USEPA 1997, Table 6-13); typical activity combined with 50th percentile body part-specific soil adherence factors	Empirical Distribution Rationale: Distribution from anticipated USEPA Dermal Guidance or fitted distribution of pooled data from sources cited in that Guidance	Value: Value from anticipated USEPA Guidance on Dermal Assessment or 0.2 mg/cm^2 Rationale: Weighted soil adherence for hands, face, forearms, lower legs, and feet for "children playing in wet soil" (USEPA 1997, Table 6-13); high-end activity combined with 50th percentile body part-specific soil adherence factors
Skin Surface Area (SA)	Value: 2,800 cm^2 Rationale: Exposed skin surface area for hands, head, forearms, lower legs, and feet; USEPA 1997	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-6, 6-7), adjusted for fraction of skin exposed, and fitted with Crystal Ball	Value: 2,800 cm^2 Rationale: Exposed skin surface area for hands, head, forearms, lower legs, and feet; USEPA 1997

Table 5-5 (3 of 4)

Exposure Assessment Parameters for a Recreational Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Bioavailability (ABS)	Value: Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994[1]	Constant	Value: Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994[1]
Dermal Contact with Surface Water:			
Event Frequency (EV)	Value: 0.5 Rationale: Site-specific assumption	Constant Rationale: Site-specific assumption	Value: 0.5 Rationale: Site-specific assumption
Time of Event (t_{event})	Value: 1 hr Rationale: Site-specific assumption	Uniform Distribution: Minimum 1 hr Maximum 2 hrs Rationale: Site-specific assumption	Value: 2 hrs Rationale: Site-specific assumption
Skin Surface Area (SA)	Value: 6,560 cm^2 Rationale: Total skin surface area based on the 50th percentile of the distribution for 1- to 6-year-olds from USEPA 1997, Tables 6-6 and 6-7	Empirical Distribution Co-vary with body weight Rationale: Distribution developed from percentile values (USEPA 1997, Tables 6-6, 6-7), and fitted with Crystal Ball	Value: 6,560 cm^2 Rationale: Total skin surface area based on the 50th percentile of the distribution for 1- to 6-year-olds from USEPA 1997, Tables 6-6 and 6-7
Bioavailability (ABS)	Value: Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994[1]	Constant	Value: Chemical-specific: 0.1 for VOCs; 0.001 for Cd; 0.03 for As; 0.01 for other metals Rationale: DTSC 1994[1]

Table 5-5 (4 of 4)

Exposure Assessment Parameters for a Recreational Child

Parameter	Central Tendency Exposure (CTE)	Exposure Distribution	Reasonable Maximum Exposure (RME)
Incidental Soil Ingestion:			
Ingestion Rate (IR_{soil})	Value: 100 mg/day Rationale: Average value, USEPA 1997	Lognormal arithmetic mean: 86 mg/day standard deviation: 191 mg/day Source: CalTOX 1993	Value: 200 mg/day Rationale: RME, DTSC 1992
Bioavailability (B)	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval	Constant	Value: Chemical-specific Rationale: Current peer-reviewed literature values for chemical in soil matrix; subject to DTSC approval

[1] CalTOX computer model version 1994.
Crystal Ball (Decisioneering, Inc., Denver, CO)

Table 6-1 (1 of 1)

Data Sources for Estimating Exposure Point Concentrations

Media	Source of Exposure Point Concentration	Exposure Type
Seeps and Springs	Direct sampling and analysis of either shallow or deep groundwater, depending upon the relevant source of water	Current and future human contact, biota use
Shallow Groundwater	Direct sampling and analysis	Current and future contact, biota use
Chatsworth Formation Groundwater	Direct sampling and analysis	Current and future human contact
Soil	Direct sampling and analysis Possible predictive measure of transport to contiguous area	Current and future human contact, biota use
Sediment	Direct sampling and analysis	Current and future human contact, biota use
Surface Water	Direct sampling and analysis Possible predictive measure of transport to contiguous area	Current and future human contact, biota use
Air (indoor/outdoor)	Predictive measures	Current and future human inhalation, biota use
Biota Used as Food	Predictive measures	Future human consumption, biota use

Table 6-2 (1 of 1)

Example of Area-Weighted Statistics

Site ID (sample identification relevant to those shown in Figure 6-1)	COPC Concentration (c_i; mg/kg)	Area (square feet)	Proportion of Total Area (p_i)	p_i * c_i^2	Weighted Concentration (mg/kg)
SS-1	11.00	4,829	0.03	3.12	0.28
SS-2	3.00	969	0.01	0.05	0.02
SS-3	20.00	7,968	0.04	17.04	0.85
SS-4	2.00	5,643	0.03	0.12	0.06
SS-5	5.00	9,116	0.05	1.22	0.24
SS-6	8.00	7,985	0.04	2.73	0.34
SS-7	15.00	5,120	0.03	6.16	0.41
SS-8	5.00	18,870	0.10	2.52	0.50
SS-9	2.00	6,357	0.03	0.14	0.07
SS-10	2.00	12,544	0.07	0.27	0.13
SS-11	58.00	8,543	0.05	153.70	2.65
SS-12	330.00	15,709	0.08	9,148.62	27.72
SS-13	120.00	16,645	0.09	1,281.82	10.68
SS-14	11.00	19,918	0.11	12.89	1.17
SS-15	130.00	15,124	0.08	1,366.91	10.51
SS-16	2.00	16,984	0.09	0.36	0.18
SS-17	1,600.00	14,668	0.08	200,812.50	125.51
sum		186,993		212,810	181
sample number	17				17
mean	137				
area-weighted mean					181
standard deviation (SD)	375				
area-weighted SD					424
standard error of the mean (SEM)	94				
area-weighted SEM					103
t 0.95 (two tailed, 16 degrees of freedom)	1.76				1.76
95% upper concentration limit	302				362

Table 6-3 (1 of 1)

Example of Area-Weighted Statistics

Site ID	COPC Concentation (c_i; mg/kg)	Area (square feet)	Proportion of Total Area (p_i)	p_i * c_i^2	Weighted Concentration (mg/kg)
BSPC-6	11.00	4,829	0.03	3.12	0.28
BSPC-7	1,600.00	969	0.01	13,263.08	8.29
BRAVO3	20.00	7,968	0.04	17.04	0.85
BRAVO2	2.00	5,643	0.03	0.12	0.06
SV-5.15-2	5.00	9,116	0.05	1.22	0.24
BTSC-1-5	8.00	7,985	0.04	2.73	0.34
B-2	15.00	5,120	0.03	6.16	0.41
BTSC-1-2	5.00	18,870	0.10	2.52	0.50
BRAVO1	2.00	6,357	0.03	0.14	0.07
B-1	2.00	12,544	0.07	0.27	0.13
SV-LF-217-1	58.00	8,543	0.05	153.70	2.65
SV-5.13-2	330.00	15,709	0.08	9,148.62	27.72
BTSC-2/3-15	120.00	16,645	0.09	1,281.82	10.68
BTSC-2/3-5	11.00	19,918	0.11	12.89	1.17
SV5.13-1	130.00	15,124	0.08	1,366.91	10.51
SV5.13-4	2.00	16,984	0.09	0.36	0.18
SV5.13-3	3.00	14,668	0.08	0.71	0.24
sum		186,993		25,261	64
sample number	17				17
mean	137				
area-weighted mean					64
standard deviation (SD)	375				
area-weighted SD					145
standard error of the mean (SEM)	94				
area-weighted SEM					35
t 0.95 (two tailed, 16 degrees of freedom)	1.76				1.76
95% upper concentration limit	302				126

Summary of Non-Cancer Toxicity Values for Human Health Risk Assessment COPCs

Compound	Oral Reference Dose (mg/kg-day)						Inhalation Reference Dose (mg/kg-day)					
	Value	UF	Source	Species	Exp. Route	Effect	Value	UF	Source	Species	Exp. Route	Effect
1,1,1-Trichloroethane	0.28		USEPA 2004				0.63		USEPA 2004			
1,1-Dichloroethene	0.05	100	USEPA 2005	Rat	Water	Liver	0.057	30	USEPA 2005	Rat	Inhalation	Liver
1,1,2-Trichloroethane	0.004	1000	USEPA 2005	Mouse	Water	Blood chemistry	0.004[a]	1000	USEPA 2005	Mouse	Water	Blood chemistry
1,2,4-Trimethylbenzene	0.05		USEPA 2004				0.0017		USEPA 2004			
1,2-Dichloroethane	0.02		USEPA 2004				1.40E-03		USEPA 2004			
1,3,5-Trimethylbenzene	0.05		USEPA 2004				0.0017		USEPA 2004			
1,4-Dioxane												
2-Butanone	0.6	1000	USEPA 2005	Rat	Water	Reduced fetal BW	1.4	300	USEPA 2005	Mouse	Inhalation	Skeletal Variations
2,4,6-Trinitrotoluene	0.0005	1000	USEPA 2005	Dog	Gavage	Liver	0.0005[a]	1000	USEPA 2005	Dog	Gavage	Liver
2,4-Dimethylphenol	0.02	3000	USEPA 2005	Mouse	Gavage	Clinical signs	0.02[a]	3000	USEPA 2005	Mouse	Gavage	Clinical signs
2,4-Dinitrophenol	0.002	1000	USEPA 2005	Human	Oral	Cataract formation	0.002[a]	1000	USEPA 2005	Human	Oral	Cataract formation
2,6-Dinitrotoluene	0.001		USEPA 1997				0.001[a]		USEPA 1997			
3,3'-Dichlorobenzidine												
Aluminum	1		USEPA 2004				0.0014		USEPA 2004			
4-Amino-2,6-dinitrotoluene												
Acenaphthene	0.06	3000	USEPA 2005	Mouse	Oral	Liver	0.06[a]	3000	USEPA 2005	Mouse	Oral	Liver
Acenaphthylene	0.03		Value for pyrene				0.03[a]		Value for pyrene			
Acetone	0.9	1000	USEPA 2005	Rat	Water	Nephropathy	0.9[a]	1000	USEPA 2005	Rat	Water	Nephropathy
Anthracene	0.3	3000	USEPA 2005	Mouse	Gavage	None observed	0.3[a]	3000	USEPA 2005	Mouse	Gavage	None observed
Antimony	0.0004	1000	USEPA 2005	Rat	Oral	Blood parameters						
Aroclor 1254	2.00E-05	300	USEPA 2005	Monkey	Oral	Immunotoxicity	0.00002[a]	300	USEPA 2005	Monkey	Oral	Immunotoxicity
Arsenic	0.0003	3	USEPA 2005	Human	Oral	Skin effects	0.000143		CAPCOA 1992			
Barium	0.07	3	USEPA 2005	Human	Water	Blood pressure	0.00014	1000	USEPA 1997 Table II	Rat	Inhalation	Fetotoxicity
Benzene	0.004	300	USEPA 2005	Human	Inhalation	Dec. Lymphocyte Ct.	0.0086	300	USEPA 2005	Human	Inhalation	Dec. Lymphocyte Ct.
Benzo(a)anthracene												
Benzo(a)pyrene												
Benzo(b)fluoranthene												
Benzo(ghi)perylene												
Benzo(k)fluoranthene												
Beryllium	0.002	300	USEPA 2005	Dog	Diet	Intestinal Lesions	5.7E-06	10	USEPA 2005	Human	Occupational	Chronic Beryllium Diseas
Bis(2-ethylhexyl)phthalate	0.02	1000	USEPA 2005	Guinea Pig	Diet	Inc. rel. liver wt.	0.02[a]	1000	USEPA 2005	Guinea Pig	Diet	Inc. rel. liver wt.
Boron	0.2	66	USEPA 2005	Rat	Diet	Dec. Fetal weight	5.70E-03		USEPA 1997			
Cadmium	0.0005	10	USEPA 2005	Human	Water	Proteinurea	0.001		CAPCOA 1992			
Carbazole												
Chloride												
Chloroform	0.01	1000	USEPA 2005	Dog	Oral	Liver effects	0.014		USEPA 2004			

Summary of Non-Cancer Toxicity Values for Human Health Risk Assessment COPCs

	Oral Reference Dose (mg/kg-day)						Inhalation Reference Dose (mg/kg-day)					
Compound	Value	UF	Source	Species	Exp. Route	Effect	Value	UF	Source	Species	Exp. Route	Effect
Chromium	1.5	1000	USEPA 2005	Rat	Oral	None	5.71E-07		CAPCOA 1992			
Chromium VI	0.003	900	USEPA 2005	Rat	Water	None	2.20E-06		USEPA 2005	Human	Occupational	nasal septum atrophy
Chrysene												
cis-1,2-Dichloroethene	0.01		USEPA 2004				0.01[a]		USEPA 2004			
Cobalt	0.02		USEPA 2004				5.70E-06		USEPA 2004			
Copper	0.04		USEPA 1997	Calculated from a Treatment Technology Action l			0.000686		CAPCOA 1992			
Dibenz(ah)anthracene												
Dibutylphthalate	0.1	1000	USEPA 2005	Rat	Diet	Inc. mortality	0.1[a]	1000	USEPA 2005	Rat	Diet	Inc. mortality
Dichlorodifluoromethane	0.2	100	USEPA 2005	Rat	Diet	Reduced BW	0.057		USEPA 1997			
Dichlorofluoromethane	0.2		Surrogate - Dichlorodifluoromethane				0.057		Surrogate - Dichlorodifluoromethane			
Diesel												
Diethylphthalate	0.8	1000	USEPA 2005	Rat	Diet	Dec. weight	0.8[a]	1000	USEPA 2005	Rat	Diet	Dec. weight
2,3,7,8-TCDD												
Ethylbenzene	0.1	1000	USEPA 2005	Rat	Gavage	Liver & kidney effects	0.29	300	USEPA 2005	Rat/rabbit	Inhalation	Devel. toxicity
Fluoranthene	0.04	3000	USEPA 2005	Mouse	Gavage	Liver & kidney effects	0.04[a]	3000	USEPA 2005	Mouse	Gavage	Liver & kidney effects
Fluorene	0.04	3000	USEPA 2005	Mouse	Gavage	Blood effects	0.04[a]	3000	USEPA 2005	Mouse	Gavage	Blood effects
Fluoride	0.06	1	USEPA 2005	Human	Water	Fluorosis						
Formaldehyde	0.2	100	USEPA 2005	Rat	Water	c. wt. Gain & Liver effects						
Gasoline												
HMX	0.05	1000	USEPA 2005	Rat	Diet	Liver	0.05[a]	1000	USEPA 2005	Rat	Diet	Liver
Hydrazine							6.86E-05		CAPCOA 1992			
Indeno(123cd)pyrene												
Kerosene												
Lead												
Lube Oil												
Manganese	0.14	1	USEPA 2005	Human	Diet	CNS	1.4E-05	1000	USEPA 2005	Human	Occupational	CNS
Mercury	0.0003		CAPCOA 1992				8.57E-05	30	USEPA 2005	Human	Occupational	CNS
Methylene chloride	0.06	100	USEPA 2005	Rat	Water	Liver	0.86		USEPA 1997			
Molybdenum	0.005	30	USEPA 2005	Human	Diet	Inc. uric acid levels						
Monomethylhydrazine												
Naphthalene	0.02	3000	USEPA 2005	Rat	Gavage	Decreased BW	0.00086	3000	USEPA 2005	Mouse	Inhalation	Nasal effects
N-Nitrosodimethylamine												
N-Nitrosodiphenylamine												
Nickel	0.02	300	USEPA 2005	Rat	Diet	Dec. body wt.	6.86E-05		CAPCOA 1992			
Nitrate	1.6	1	USEPA 2005	Human	Water	Methemoglobinemia						
Nitrite	0.1	10	USEPA 2005	Human	Water	Methemoglobinemia						
Nitrobenzene	0.0005	10000	USEPA 2005	Rat/Mouse	Inhalation	Blood/Kidney/Liver	0.00057		USEPA 1997			
Perchlorate	0.00012	30	OEHHA 2005	Human		Thyroid	0.00012	30	OEHHA 2005	Human		Thyroid

Summary of Non-Cancer Toxicity Values for Human Health Risk Assessment COPCs

Compound	Oral Reference Dose (mg/kg-day)						Inhalation Reference Dose (mg/kg-day)					
	Value	UF	Source	Species	Exp. Route	Effect	Value	UF	Source	Species	Exp. Route	Effect
Phenanthrene	0.03		Value for pyrene				0.03		Value for pyrene			
Phenol	0.3	300	USEPA 2005	Rat	Gavage	Dec. body weight	0.3[a]	300	USEPA 2005	Rat	Gavage	Dec. body weight
Pyrene	0.03	3000	USEPA 2005	Mouse	Gavage	Kidney	0.03[a]	3000	USEPA 2005	Mouse	Gavage	Kidney
RDX	0.003	100	USEPA 2005	Rat	Diet	Prostate	0.003[a]	100	USEPA 2005	Rat	Diet	Prostate
Selenium	0.005	3	USEPA 2005	Human	Diet	Selenosis						
Silver	0.005	3	USEPA 2005	Human	Intravenous	Argyria						
Styrene	0.2	1000	USEPA 2005	Dog	Gavage	Blood & liver effects	0.29	30	USEPA 2005	Human	Occupational	CNS
Tetrachloroethene	0.01	1000	USEPA 2005	Mouse	Gavage	Liver	0.01		OEHHA 2005			
Thallium	0.00008	3000	USEPA 2005	Rat	Gavage	Blood parameters						
Toluene	0.2	1000	USEPA 2005	Rat	Gavage	Liver/Kidney	0.11	300	USEPA 2005	Human	Inhalation	CNS
trans-1,2-Dichloroethene	0.02	1000	USEPA 2005	Mouse	Water	Blood chemistry	0.02[a]	1000	USEPA 2005	Mouse	Water	Blood chemistry
Trichloroethene	3.00E-04		USEPA 2004				0.17		OEHHA 2005			
Trichlorofluoromethane (CFC 11)	0.3	1000	USEPA 2005	Rat	Gavage	Mortality	0.2	10000	USEPA 1997 Table II	Dog	Inhalation	Kidney & lung
Trichloropropene	0.01		USEPA 2004				3.00E-04		USEPA 2004			
Unsymmetrical dimethylhydrazine												
Vanadium	0.001		USEPA 2004									
Vinyl chloride	0.003	30	USEPA 2005	Rat	Diet	Liver	0.0290	30	USEPA 2005	Rat	Diet	Liver
Xylenes	0.2	1000	USEPA 2005	Rat	Gavage	Dec. BW; hyperactivity	0.029	300	USEPA 2005	Rat	Inhalation	Motor Activity
Zinc	0.3	3	USEPA 2005	Human	Diet	Blood parameters	0.01		CAPCOA 1992			

Note: Compounds on this table have been previously detected in environmental media at the SSFL. Because unit investigations are ongoing, this is not necessarily complete and may be revised.

[a] Value shown is based on oral route of exposure. Use of this value for inhalation exposure will require route-to-route extrapolation.

Summary of Cancer Toxicity Values for Human Health Risk Assessment COPCs

Compound	USEPA Carc. Class	Oral CSF [1/(mg/kg-day)]					Inhalation CSF [1/(mg/kg-day)]				
		Value	Source	Species	Exp. Route	Tumor Site	Value	Source	Species	Exp. Route	Tumor Site
1,1,1-Trichloroethane	D										
1,1-Dichloroethene	C										
1,1,2-Trichloroethane	C	0.072	OEHHA 2005				0.057	OEHHA 2005	Mouse	Gavage	Liver
1,2,4-Trimethylbenzene	NA										
1,2-Dichloroethane	B2	0.047	OEHHA 2005	Rat	Gavage	Circ. system	0.072	OEHHA 2005	Rat	Gavage	Circ. system
1,3,5-Trimethylbenzene	NA										
1,4-Dioxane	B2	0.027	OEHHA 2005	Mouse	Water	Liver	0.027	OEHHA 2005	Mouse	Water	Liver
2-Butanone	NA										
2,4,6-Trinitrotoluene	C	0.03	USEPA 2005	Rat	Diet	Urinary bladder	0.03[a]	USEPA 2005	Rat	Diet	Urinary bladder
2,4-Dimethylphenol	NA										
2,4-Dinitrophenol	NA										
2,6-Dinitrotoluene	B2	0.68	USEPA 2005	Rat	Diet	Liver/Mammary	0.68[a]	USEPA 2005	Rat	Diet	Liver/Mammary
3,3'-Dichlorobenzidine	B2	1.2	OEHHA 2005				1.2	OEHHA 2005	Rat	Diet	Mammary
4-Amino-2,6-dinitrotoluene	NA										
Acenaphthene	NA										
Acenaphthylene	D										
Acetone	D										
Aluminum	NA										
Anthracene	D										
Antimony	NA										
Aroclor 1254	B2	2	USEPA 1998	Rat	Diet	Liver	2	USEPA 1998	Rat	Diet	Liver
Arsenic	A	9.45	OEHHA 2005				12	OEHHA 2005	Human	Occup. Inh.	Lung
Benzene	A	0.1	OEHHA 2005	Human	Inhalation	Leukemia	0.1	OEHHA 2005	Human	Inhalation	Leukemia
Barium	D										
Benzo(a)anthracene	B2	1.2	OEHHA 2005 TEF				0.39	OEHHA 2005 TEF			
Benzo(a)pyrene	B2	12	OEHHA 2005	Hamster	Inhalation	Resp. tract	3.9	OEHHA 2005	Hamster	Inhalation	Resp. tract
Benzo(b)fluoranthene	B2	1.2	OEHHA 2005 TEF				0.39	OEHHA 2005 TEF			
Benzo(ghi)perylene	D										
Benzo(k)fluoranthene	B2	1.2	OEHHA 2005 TEF				0.39	OEHHA 2005 TEF			
Beryllium	B2						8.4	OEHHA 2005	Human	Occup. Inh.	Lung
Bis(2-ethylhexyl)phthalate	B2	0.003	OEHHA 2005				0.0084	OEHHA 2005	Rat	Diet	Liver
Boron	NA										
Cadmium	B1	0.38	OEHHA 2005				15	OEHHA 2005	Human	Occup. Inh.	Lung
Carbazole	NA	0.02	USEPA 1997	Mouse	Diet	Liver	0.02[a]	USEPA 1997	Mouse	Diet	Liver
Chloride	NA										
Chloroform	B2	0.031	OEHHA 2005	Mouse	Water	Liver	0.019	OEHHA 2005	Rat/Mice	Gavage	Kidney
Chromium	NA										

Table 7-2 (2 of 3)

Summary of Cancer Toxicity Values for Human Health Risk Assessment COPCs

Compound	USEPA Carc. Class	Oral CSF [1/(mg/kg-day)]					Inhalation CSF [1/(mg/kg-day)]				
		Value	Source	Species	Exp. Route	Tumor Site	Value	Source	Species	Exp. Route	Tumor Site
Chromium VI	A						510	OEHHA 2005	Human	Occup. Inh.	Lung
Chrysene	B2	0.12	OEHHA 2005 TEF				0.039	OEHHA 2005 TEF			
cis-1,2-Dichloroethene	D										
Cobalt	NA						9.8	USEPA 2004			
Copper	D										
Dibenz(ah)anthracene	B2	4.1	OEHHA 2005	Mouse	Water	Lung	4.1	OEHHA 2005	Mouse	Water	Lung
Dibutylphthalate	D										
Diesel	NA										
Diethylphthalate	D										
2,3,7,8-TCDD	B2	130000	OEHHA 2005	Mouse	Gavage	Liver	130000	OEHHA 2005	Mouse	Gavage	Liver
Ethylbenzene	D										
Fluoranthene	D										
Fluorene	D										
Fluoride	NA										
Formaldehyde	B1						0.021	OEHHA 2005	Rat	Inhalation	Nasal cavity
Gasoline											
HMX	D										
Hydrazine	B2	3	OEHHA 2005	Mouse	Gavage	Liver	17	OEHHA 2005	Rat	Inhalation	Nasal cavity
Indeno(123cd)pyrene	B2	1.2	OEHHA 2005 TEF				0.39	OEHHA 2005 TEF			
Kerosene											
Lead	B2										
Lube Oil											
Mercury	D										
Methylene chloride	B2	0.014	OEHHA 2005				0.0035	OEHHA 2005	Mouse	Inhalation	Lung
Molybdenum	NA										
Monomethylhydrazine	NA										
Naphthalene							0.12	OEHHA 2005	Rat	Inhalation	Nasal cavity
N-Nitrosodimethylamine	B2	16	OEHHA 2005	Rat	Water	Liver	16	OEHHA 2005	Rat	Water	Liver
N-Nitrosodiphenylamine	B2	0.009	OEHHA 2005	Rat/Mice	Oral/Gavage	Bladder/Liver	0.009	OEHHA 2005	Rat/Mice	Oral/Gavage	Bladder/Liver
Nickel	A/NA						0.91	OEHHA 2005	Human	Occup. Inhal	Lung
Nitrate	NA										
Nitrite	NA										
Perchlorate	NA										
Phenanthrene	D										
Phenol	D										
Pyrene	D										
RDX	C	0.11	USEPA 2005	Mouse	Diet	Liver	0.11[a]	USEPA 2005	Mouse	Diet	Liver
Selenium	D										
Silver	D										

Summary of Cancer Toxicity Values for Human Health Risk Assessment COPCs

Compound	USEPA Carc. Class	Oral CSF [1/(mg/kg-day)]					Inhalation CSF [1/(mg/kg-day)]				
		Value	Source	Species	Exp. Route	Tumor Site	Value	Source	Species	Exp. Route	Tumor Site
Styrene	NA										
Tetrachloroethene	NA	0.54	OEHHA 2005				0.021	OEHHA 2005	Mouse	Gavage	Liver
Thallium	D										
Trichloroethene	NA	0.013	OEHHA 2005				0.007	OEHHA 2005	Mouse	Inhalation	Lung, liver
Trichlorofluoromethane (CFC 11)	NA										
Unsymmetrical dimethylhydrazine											
Vanadium	NA										
Vinyl chloride	A	0.27	OEHHA 2005	Mouse	Inhalation	Lung	0.27	OEHHA 2005	Mouse	Inhalation	Lung
Xylenes	D										
Zinc	D										

Note: Compounds on this table have been previously detected in environmental media at the SSFL. Because unit investigations are ongoing, this is not necessarily complete and may be revised.

[a] Value shown is based on oral route of exposure. Use of this value for inhalation exposure will require route-to-route extrapolation.

Table 7-3 (1 of 1)

Coplanar PCB and Dioxin Toxicity Equivalent Factors (TEFs) for Humans *

PCB Congener	WHO TEF (unitless)
PCB-77 (3,3',4,4')	0.0001
PCB-81 (3,4,4',5)	0.0001
PCB-105 (2,3,3',4,4')	0.0001
PCB-114 (2,3,4,4',5)	0.0005
PCB-118 (2,3',4,4',5)	0.0001
PCB-123 (2',3,4,4',5')	0.0001
PCB-126 (3,3',4,4',5)	0.1
PCB-156 (2,3,3',4,4',5)	0.0005
PCB-157 (2,3,3',4,4',5')	0.0005
PCB-167 (2,3',4,4',5,5')	0.00001
PCB-169 (3,3',4,4',5,5')	0.01
PCB-189 (2,3,3',4,4',5,5')	0.0001
Dioxin Congener	**WHO TEF (unitless)**
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0001
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001

* Van den Berg *et al*. (1998)
WHO = World Health Organization

Table 9-1 (1 of 1)

Biological, Toxicological, and Societal Criteria for Selection of Reference Species [1]

	Ecological Factors					Toxicological Factors			Societal Factors		
Assessment Endpoints	Observed at Site	High Trophic Level Predator	Important Prey Species	Important to Structure or Function of	High Potential for Exposure Based on Amount and Type of Site Use	Susceptible to Bioaccumulation or Biomagnification	Toxicological Information	Directly Measurable Toxic	Species of Special Concern	Economically Important	High Social or Recreational Value
Protect raptor species from acute (mortality) and chronic (reproductive, growth, and behavioral impairment, disease) adverse effects from direct and/or secondary exposure to site-related CPECs.											
American kestrel	x	x		x	x	x	x		x		x
Cooper's hawk	x	x		x	x	x			x		x
Red-shouldered hawk	x	x		x	x	x			x		x
Red-tailed hawk	x	x		x	x	x	x		x		x
Sharp-shinned hawk	x	x		x	x	x			x		x
Protect the abundance and quality of raptor and bobcat prey items (frogs, snakes, rodents, and rabbits) by limiting acute and chronic adverse effects from direct and/or secondary exposure to site-related CPECs.											
California toad	x		x	x	x	x		x			
Pacific tree frog	x		x	x	x	x		x			
California kingsnake	x		x	x	x	x			x		
Gopher snake	x		x	x	x	x		x			
Two-striped garter snake	x		x	x	x	x			x		
Botta's pocket gopher	x		x	x	x	x		x			
Deer mouse	x		x	x	x	x	x	x			
Little pocket mouse	x		x	x	x	x	x	x			
Brush rabbit	x		x	x	x	x		x			
Desert cottontail	x		x	x	x	x		x			
San Diego black-tailed jackrabbit	x		x	x	x	x			x		
Protect bobcat from acute (mortality) and chronic (reproductive impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.	x	x		x	x	x			x		x
Protect the abundance of native terrestrial vegetation by limiting acute and chronic adverse effects from direct and/or secondary exposure to site-related CPECs.	x		x	x				x			x
Protect the abundance of great blue heron prey items (fish, frogs, snakes, rodents) by limiting acute and chronic adverse effects from direct and/or secondary exposure to site-related CPECs.	x		x	x	x	x	x	x			
Protect great blue heron from acute (mortality) and chronic (reproductive, growth, and behavioral impairment, disease) adverse effects from direct and/or secondary exposure to site-related CPECs.	x	x		x	x	x	x		x		x
Protect the abundance of benthic invertebrate community by limiting acute and chronic adverse effects from exposure to	x		x	x	x	x	x	x			
Protect the abundance of terrestrial invertebrate community by limiting acute and chronic adverse effects from exposure						x		x			
Protect the abundance of wetland and aquatic vegetation by limiting acute and chronic adverse effects from exposure to site-related CPECs.	x			x				x			x

Notes:

[1] Developed from information contained within the Biological Conditions Report (Appendix C).

[2] Indicates tissue analysis is possible (e.g., species can be readily trapped at the SSFL).

Table 9-2 (1 of 1)

Summary of Generalized Ecological Conceptual Site Model

Media	Potential Exposure Route	Terrestrial Reference Species	Aquatic Reference Species	Terrestrial Habitats	Aquatic Habitats	CPEC
Surface Water & Groundwater Seeps	Direct Contact	Yes	Yes	No	Yes	All
	Root Contact	Yes	Yes	No	Yes	All
	Ingestion	Yes	Yes	No	Yes	All
Sediment	Direct Contact	Yes	Yes	No	Yes	All
	Root Contact	Yes	Yes	No	Yes	All
	Ingestion	Yes	Yes	No	Yes	All
Groundwater	Root Contact	Yes	No	Yes	No	All
Soil	Dermal Contact	Yes	No	Yes	No	All
	Foliar Deposition	Yes	No	Yes	No	All
	Ingestion	Yes	No	Yes	No	All
Air	Inhalation (vapors)	Yes	No	Yes	No	All
	Inhalation (dust)	Yes	No	Yes	No	All
Food Web	Ingestion	Yes	Yes	Yes	Yes	All

CPEC = contaminant of potential ecological concern

Table 9-3 (1 of 4)

Summary of Assessment Goals and Endpoints

Assessment Goal	Assessment Endpoint	Measures of Exposure	Measures of Effect
Protect wildlife, fish, invertebrate, and plant species from acute or chronic effects resulting from site-related chemicals	Protect raptor species from acute (mortality) and chronic (e.g., reproductive impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.	Calculate daily dosage to red-tailed hawk using exposure models, measured chemical concentrations in abiotic and biotic media, and food web interactions.	• Compare to NOAEL dosages for the red-tailed hawk or similar raptor species.
	Protect bobcat from acute (mortality) and chronic (e.g., reproductive impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.	Calculate daily dosage to bobcat using exposure models, measured chemical concentrations in abiotic and biotic media, and food web interactions.	• Compare to NOAEL dosages for the bobcat or similar mammal species.
	Protect the abundance of raptor and bobcat prey items (e.g., rodents) by limiting acute and adverse effects from direct and/or secondary exposure to site-related CPECs.	Measure contaminant concentrations in surface soil, plants, rodents, and invertebrates at selected investigational units. Extrapolate results to other investigational units as appropriate.	• Compare to NOAEL concentrations or NOAEL dosages for prey species.
	Protect mule deer from acute (mortality) and chronic (e.g., reproductive impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.	Calculate daily dosage to mule deer using exposure models, measured chemical concentrations in abiotic and biotic media, and food web interactions.	• Compare to NOAEL dosages for the mule deer or similar mammal species.

Table 9-3 (2 of 4)

Summary of Assessment Goals and Endpoints

Assessment Goal	Assessment Endpoint	Measures of Exposure	Measures of Effect
	Protect the abundance of native terrestrial vegetation by limiting acute and chronic adverse effects from exposure to site-related CPECs.	Note any stressed vegetation or reduced density of vegetation. SSFL-specific BCFs have been calculated for use at other investigational units using concentrations measured in co-located soil and terrestrial plant samples..	• Indicators of habitat quality (e.g., vegetation survey results).
	Protect the abundance of great blue heron prey items (e.g., fish,) by limiting acute and chronic adverse effects from direct and/or secondary exposure to site-related CPECs.	Measure contaminant concentrations in surface water and sediment.	• Compare to NOAEL concentrations or NOAEL dosages for prey species.
Protect wildlife, fish, invertebrate, and plant species from acute or chronic effects resulting from site-related chemicals	Protect great blue heron from acute (mortality) and chronic (e.g., reproductive impairment) adverse effects from direct and/or secondary exposure to site-related CPECs.	Calculate daily dosage to great blue heron using exposure models, measured chemical concentrations in abiotic and bitoic media, and food web interactions.	• Compare to NOAEL dosages for the great blue heron or similar bird species.

Table 9-3 (3 of 4)

Summary of Assessment Goals and Endpoints

Assessment Goal	Assessment Endpoint	Measures of Exposure	Measures of Effect
	Protect the abundance of benthic invertebrate community by limiting acute and chronic adverse effects from exposure to site-related CPECs.	Measure contaminant concentrations in sediments. SSFL-specific BCFs have been calculated for use at other investigational units using concentrations measured in co-located surface water, sediment, and aquatic invertebrate samples.	• Compare to LOAEL concentrations for benthic invertebrate communities.
	Protect the abundance of terrestrial invertebrate community by limiting acute and chronic adverse effects from exposure to site-related CPECs.	Measure contaminant concentrations in soils. SSFL-specific BCFs have been calculated for use at other investigational units using concentrations measured in co-located soil and terrestrial soil invertebrate samples.	• Compare to LOAEL concentrations for terrestrial invertebrate communities.

Table 9-3 (4 of 4)

Summary of Assessment Goals and Endpoints

Assessment Goal	Assessment Endpoint	Measures of Exposure	Measures of Effect
	Protect the abundance of wetland and aquatic vegetation by limiting acute and chronic adverse effects from exposure to site-related CPECs.	Note any stressed vegetation or reduced density of vegetation. SSFL-specific BCFs have been calculated for use at other investigational units using concentrations measured in co-located surface water, sediment, and aquatic plant samples.	• Indicators of wetland habitat quality (e.g., vegetation survey results).

Notes:
BCF = bioconcentration factor
CPEC = contaminant of potential ecological concern
NOAEL = no observable adverse effects level

Table 10-1 (1 of 1)

BAF Study Sampling Locations and Analyses [a]

Ecological receptor	Locations	Media Sampled	Number of samples	Analyses
Fish	R2A/R2B Ponds (SWMU 5.26) Silvernale Reservoir (SWMU 6.8)	Tissue, sediment	4 4	Metals, PAHs, dioxins PCB congeners
Aquatic Invertebrate	R2A/R2B Ponds (SWMU 5.26) Silvernale Reservoir (SWMU 6.8)	Tissue, sediment	4 4	Metals, PAHs, dioxins PCB congeners
Terrestrial Vertebrate	Bravo Area (SWMU 5.13, 5.14, 5.15) Component Test Laboratory III (SWMU 4.7)	Tissue, soil	4 4	Metals, PCB congeners PAHs, dioxins
Terrestrial Invertebrate	Bravo Area (SWMU 5.13, 5.14, 5.15) Component Test Laboratory III (SWMU 4.7)	Tissue, soil	4 4	Metals, PCB congeners PAHs, dioxins
Aquatic Plant	R2A/R2B Ponds (SWMU 5.26) Silvernale Reservoir (SWMU 6.8)	Tissue, sediment	4 4	Metals, PAHs, dioxins PCB congeners
Terrestrial Plant	Bravo Area (SWMU 5.13, 5.14, 5.15) Component Test Laboratory III (SWMU 4.7)	Tissue, soil	4 4	Metals, PCB congeners PAHs, dioxins

Notes:

a. The data used to derive BAFs for the SSFL include (1) colocated soil and terrestrial organism samples, and (2) colocated sediment and aquatic organism samples.

b. Sites chosen for BAF study as approved by the DTSC.

c. Metals, PAHs, PCBs, and dioxins analyzed by USEPA Methods 6010B/7000, 8270, 1668, and 1613B, respectively

BAF - biota soil/sediment accumulation factor

PAH - polycyclic aromatic hydrocartbons

PCB - polychlorinated biphenyl

SWMU - Solid waste mangement unit

Table 10-2 (1 of 2)

Site-Specific Aquatic Bioaccumulation Factors - Santa Susana Field Laboratory

Chemical	Fish		Aquatic Invertebrates		Aquatic Plants	
	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]
1,2,3,4,6,7,8-HpCDD	3.9E-02	4	1.4E-01	4	2.8E-02	4
1,2,3,4,6,7,8-HpCDF	4.3E-02	1	1.2E-01	4	3.7E-02	4
1,2,3,4,7,8,9-HpCDF	-	-	7.3E-02	1	-	-
1,2,3,4,7,8-HxCDD	3.2E-01	4	3.6E-01	3	-	-
1,2,3,4,7,8-HxCDF	1.3E-01	2	4.2E-01	4	-	-
1,2,3,6,7,8-HxCDD	5.1E-01	4	3.6E-01	4	-	-
1,2,3,6,7,8-HxCDF	4.8E-01	3	3.6E-01	4	-	-
1,2,3,7,8,9-HxCDD	1.8E-01	4	2.8E-01	3	-	-
1,2,3,7,8-PeCDD	1.4E+00	4	5.7E-01	4	-	-
1,2,3,7,8-PeCDF	9.2E-01	4	1.0E+00	4	-	-
2,3,4,6,7,8-HxCDF	1.1E-01	2	2.2E-01	4	-	-
2,3,4,7,8-PeCDF	1.6E+00	4	6.9E-01	4	-	-
2,3,7,8-TCDD	2.5E+00	4	8.2E-01	4	-	-
2,3,7,8-TCDF	1.1E+00	4	2.5E+00	4	7.1E-02	1
Aluminum	1.8E-02	4	2.5E-02	4	1.6E-01	4
Antimony	1.8E+00	2	2.6E-01	1	5.4E-01	1
Anthracene	-	-	-	-	-	-
Arsenic	-	-	3.1E-01	4	3.5E-01	2
Barium	1.0E-01	4	1.4E+00	4	3.6E-01	4
Benzo(a)anthracene	-	-	1.1E+00	1	-	-
Benzo(a)pyrene	-	-	5.6E-01	1	-	-
Benzo(b)fluoranthene	-	-	1.4E+00	1	-	-
Benzo(g,h,i)perylene	-	-	6.4E-01	1	-	-
Benzo(k)fluoranthene	-	-	7.9E-01	2	-	-
Beryllium	-	-	1.9E-01	3	3.3E-01	1
Boron	-	-	4.3E-01	2	1.8E+00	2
Cadmium	-	-	-	-	-	-
Chromium	2.7E-01	4	4.0E-01	4	7.7E-01	4
Chrysene	-	-	1.1E+00	2	-	-
Cobalt	3.0E-02	1	9.0E-02	4	2.3E-01	4
Copper	1.2E-01	4	3.1E+00	4	3.0E-01	3
Dibenz(a,h)anthracene	-	-	3.2E+00	1	-	-
Fluoranthene	8.9E-02	1	8.3E-01	2	-	-
Fluorene	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	-	-	6.3E-01	1	-	-
Iron	2.0E-02	4	2.6E-02	4	2.1E-01	4
Lead	-	-	-	-	-	-
Magnesium	2.5E-01	4	5.3E-01	4	5.3E-01	4
Manganese	8.4E-02	4	8.6E-01	4	9.7E-01	4
Mercury	1.2E+00	4	3.0E-01	4	3.7E-01	1
Molybdenum	7.6E-01	2	-	-	-	-
Naphthalene	5.8E+00	1	-	-	-	-
Nickel	1.6E-01	4	3.4E-01	4	5.8E-01	4
OCDD	1.7E-02	4	1.7E-01	4	2.7E-02	4
OCDF	1.8E-02	4	4.0E-02	4	3.2E-02	4
PCB-105	2.7E+02	4	2.3E+01	4	1.4E+00	3
PCB-114	2.8E+02	4	3.3E+01	4	-	-
PCB-118	3.2E+02	4	2.7E+01	4	1.5E+00	4
PCB-123	3.6E+02	4	4.0E+01	4	-	-
PCB-126	1.2E+02	4	1.5E+01	4	-	-
PCB-128	2.6E+02	4	3.0E+00	4	1.4E+00	2
PCB-138	3.5E+02	4	2.1E+01	4	1.4E+00	4
PCB-153	4.3E+02	4	2.8E+01	4	1.2E+00	4
PCB-156	3.7E+02	4	2.9E+01	4	1.6E+00	1
PCB-157	2.8E+02	4	2.5E+01	4	-	-
PCB-167	3.8E+02	4	3.4E+01	4	-	-
PCB-170	5.1E+02	4	1.7E+01	4	-	-
PCB-18	5.8E+00	2	7.7E-01	2	6.5E-01	2
PCB-180	4.4E+02	4	2.3E+01	4	1.3E+00	2
PCB-187	5.3E+02	4	3.0E+01	4	-	-

Table 10-2 (2 of 2)

Site-Specific Aquatic Bioaccumulation Factors - Santa Susana Field Laboratory

Chemical	Fish		Aquatic Invertebrates		Aquatic Plants	
	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]
PCB-189	1.5E+01	2	3.2E+00	2	-	-
PCB-195	4.1E+02	4	1.2E+01	4	-	-
PCB-206	2.4E+02	4	3.8E+00	4	-	-
PCB-209	1.0E+02	4	-	-	-	-
PCB-28	8.1E+00	2	1.9E+00	2	8.8E-02	1
PCB-44	1.2E+02	4	6.9E+00	4	2.2E+00	4
PCB-52	1.7E+02	4	1.8E+01	4	1.9E+00	4
PCB-66	1.8E+02	3	1.8E+01	4	1.8E+00	4
PCB-77	1.9E+01	4	1.1E+01	4	-	-
PCB-8	5.9E+00	2	-	-	-	-
PCB-81	1.3E+02	4	1.8E+00	2	-	-
PCB-90/101	2.1E+02	4	1.7E+01	4	1.1E+00	4
Total PCB/Aroclor[c]	2.4E+02	-	1.8E+01	-	1.4E+00	-
Phenanthrene	2.6E-01	2	1.5E+00	3	-	-
Pyrene	-	-	5.9E-01	2	-	-
Selenium	4.6E+00	4	3.6E+00	4	2.2E+00	2
Silver	-	-	1.0E+00	4	-	-
Thallium	-	-	2.9E-01	3	3.5E-01	2
Vanadium	2.1E-02	4	3.5E-02	4	2.8E-01	4
Zinc	4.1E-01	4	6.6E-01	4	2.8E-01	4

Notes:

a. The bioaccumulation factor (BAF) is calculated as the ratio of tissue chemical concentration to soil chemical concentration, when the sample size = 1 the value is the ratio, when the sample size = 2 the BAF value is the mean of the two measured ratios, when the sample size = 3 or 4, the BAF is an approximation of the 75th percentile distribution of the concentration ratio values.

b Number of tissue chemical concentration to soil chemical concentration ratios used to calculate the BAF.

c. BAF for total PCB or Aroclors is based on the arithmetric mean of the PCB congener-specific BAFs.

"-" chemical either not analysed for or analytical data not sufficient for calculating a BAF

BAF - bioaccumulation factor

Table 10-3 (1 of 2)

Site-Specific Terrestrial Bioaccumulation Factors - Santa Susana Field Laboratory

Chemical	Soil to Terrestrial Vertebrates		Soil to Terrestrial Invertebrates		Soil to Terrestrial Plants	
	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]
1,2,3,4,6,7,8-HpCDD	2.9E-01	4	5.4E-01	4	3.2E-01	4
1,2,3,4,6,7,8-HpCDF	4.3E-01	3	5.4E-01	3	2.3E-01	3
1,2,3,4,7,8-HxCDD	2.4E-01	1	7.8E-01	2	-	-
1,2,3,4,7,8-HxCDF	8.1E-02	1	6.5E-01	1	-	-
1,2,3,6,7,8-HxCDD	2.2E-01	1	7.7E-01	3	1.6E-01	1
1,2,3,6,7,8-HxCDF	6.5E-01	1	2.6E-01	1	-	-
1,2,3,7,8,9-HxCDD	1.8E-01	1	9.3E-01	3	-	-
1,2,3,7,8-PeCDD	-	-	8.8E-01	2	-	-
1,2,3,7,8-PeCDF	-	-	4.3E-01	2	-	-
2,3,4,6,7,8-HxCDF	5.4E-01	1	5.6E-01	1	-	-
2,3,4,7,8-PeCDF	4.4E-01	1	5.1E-01	2	-	-
2,3,7,8-TCDF	1.9E-01	1	1.0E+00	4	-	-
Acenaphthene	-	-	2.4E+00	1	-	-
Aluminum	1.2E-01	4	3.7E-01	4	7.4E-01	4
Anthracene	-	-	2.8E+00	1	-	-
Antimony	5.8E-01	2	7.8E+00	4	5.4E+00	4
Arsenic	-	-	4.7E-01	3	7.7E-01	3
Barium	3.6E-01	4	2.8E+00	4	1.0E+00	4
Benzo(a)anthracene	1.6E+01	1	1.9E+00	1	5.2E+00	1
Benzo(a)pyrene	5.9E+00	1	1.0E+00	1	-	-
Benzo(b)fluoranthene	5.3E+00	1	2.0E+00	1	-	-
Benzo(e)pyrene	-	-	1.1E+00	1	-	-
Benzo(g,h,i)perylene	4.5E+00	1	5.3E-01	1	-	-
Benzo(k)fluoranthene	7.8E+00	1	8.9E-01	1	-	-
Beryllium	-	-	2.8E-01	3	6.1E-01	4
Boron	1.2E+01	1	4.6E+00	1	7.4E+00	1
Cadmium	-	-	2.0E+01	3	1.1E+01	3
Chromium	1.5E-01	4	2.4E+00	4	9.4E+00	4
Chrysene	6.4E+00	1	1.9E+00	1	2.8E+00	3
Cobalt	2.5E-01	4	2.1E-01	3	6.6E-01	4
Copper	7.6E-01	4	1.5E+01	4	1.9E+00	4
Dibenz(a,h)anthracene	1.6E+01	1	-	-	-	-
Fluoranthene	2.3E+00	1	9.1E-01	2	2.8E+00	3
Fluorene	-	-	3.9E+00	1	-	-
Indeno(1,2,3-cd)pyrene	7.2E+00	1	8.6E-01	1	-	-
Iron	1.0E-01	4	4.5E-01	4	6.3E-01	4
Lead	-	-	2.4E-01	2	2.1E+00	4
Magnesium	7.5E-01	4	1.2E+00	4	1.2E+00	4
Manganese	1.5E-01	4	6.6E-01	4	8.5E-01	4
Mercury	-	-	3.3E+00	3	8.2E-01	2
Molybdenum	2.9E+00	4	5.9E+00	4	1.4E+01	4
Naphthalene	-	-	-	-	-	-
Nickel	1.2E-01	4	2.1E+00	4	7.7E+00	4
OCDD	2.1E-01	4	4.7E-01	4	2.3E-01	4
OCDF	9.4E-01	3	5.0E-01	3	3.3E-01	4
PCB-105	2.7E+00	4	1.0E+01	4	3.3E+00	4
PCB-114	6.6E+00	3	2.7E+01	4	3.7E+00	2
PCB-118	2.8E+00	4	1.1E+01	4	3.2E+00	4
PCB-123	3.4E+00	2	1.3E+01	4	3.4E+00	2
PCB-126	1.8E+00	2	5.3E+00	4	2.2E+00	2
PCB-128	3.0E+00	4	5.2E+00	4	2.6E+00	4
PCB-138	2.5E+00	4	6.1E+00	4	2.9E+00	4
PCB-153	4.2E+00	4	7.1E+00	4	3.1E+00	4
PCB-156	3.9E+00	4	5.8E+00	4	2.5E+00	4
PCB-157	2.7E+01	4	5.9E+00	4	2.6E+00	4
PCB-167	4.9E+00	4	5.9E+00	4	2.8E+00	4
PCB-170	4.2E+00	4	4.2E+00	4	1.9E+00	4
PCB-18	6.5E-02	1	1.4E-01	1	-	-
PCB-180	4.2E+00	4	3.6E+00	4	2.1E+00	4
PCB-187	1.2E+00	4	7.9E+00	4	2.8E+00	4

Table 10-3 (2 of 2)

Site-Specific Terrestrial Bioaccumulation Factors - Santa Susana Field Laboratory

Chemical	Soil to Terrestrial Vertebrates		Soil to Terrestrial Invertebrates		Soil to Terrestrial Plants	
	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]	BAF [a] (unitless)	Sample Size[b]
PCB-189	7.0E+00	3	2.4E+00	4	2.2E+00	2
PCB-195	3.4E+00	3	1.9E+00	4	1.0E+00	1
PCB-206	1.8E+00	3	9.8E-01	3	7.9E-01	1
PCB-209	2.4E+00	3	1.4E+00	3	2.4E+00	1
PCB-28	-	-	1.7E+00	1	8.0E+00	1
PCB-44	-	-	7.3E+00	4	4.0E+00	4
PCB-52	-	-	1.1E+01	4	4.4E+00	4
PCB-66	1.3E+00	4	1.1E+01	4	3.5E+00	4
PCB-77	7.7E-01	1	6.2E+00	4	2.4E+00	3
PCB-8	3.7E-01	1	2.2E-01	1	-	-
PCB-81	-	-	6.0E+00	4	3.0E+00	2
PCB-90/101	2.2E-01	4	6.2E+00	4	3.6E+00	4
Total PCB/Aroclor	3.9E+00	-	6.5E+00	-	3.0E+00	-
Phenanthrene	3.4E+00	1	1.8E+00	2	7.2E+00	4
Pyrene	3.6E+00	1	2.9E+00	2	1.9E+00	3
Selenium	5.8E+00	2	1.8E+00	1	-	-
Silver	-	-	6.6E+00	3	1.7E+00	2
Thallium	-	-	1.1E+00	3	5.1E-01	4
Vanadium	1.7E-01	4	3.2E-01	4	6.9E-01	4
Zinc	3.5E+00	4	3.1E+00	4	1.6E+00	4

Notes:

a. The bioaccumulation factor (BAF) is calculated as the ratio of tissue chemical concentration to soil chemical concentration, when the sample size = 1 the value is the ratio, when the sample size = 2 the BAF value is the mean of the two measured ratios, when the sample size = 3 or 4, the BAF is an approximation of the 75th percentile distribution of the concentration ratio values.

b. Number of tissue chemical concentration to soil chemical concentration ratios used to calculate the BAF.

c. BAF for total PCB or Aroclors is based on the arithmetic mean of the PCB congener-specific BAFs.

"-" chemical either not analysed for or analytical data not sufficient for calculating a BAF

BAF - bioaccumulation factor

Table 10-4 (1 of 2)

Life History Parameters Used in Calculating Applied Daily Doses

Reference Species	Great Blue Heron	Deer Mouse	Hermit Thrush
Body Weight (kg)	2.204 (USEPA 1993)	0.0179 (Nagy 2001)	0.029 (Dunning 1993)
Food Intake Rate[a] (kg/d)	0.141	0.0038	0.0063
Prey Items (F) (fraction of diet)[b]	Fish (0.70) Deer mouse (0.15) Invertebrates (0.10) Sediment (0.05) (Zeiner et al 1990)	Invertebrates (0.30) Vegetation (0.70) Soil (0.02) (Beyer et al 1994)	Invertebrates (0.61) Vegetation (0.39) Soil (0.04)
Area Use[c] (0)	Dependent on habitat and size of the site	1	1
Seasonability[d] (Ψ)	1	1	1
Lifespan		1.6 years (Brown and Zeng 1989) Assume 0.75 amount of time per day in burrow	
Soil Depth Interval	NA (sediment)	0-2, 0-4, or 0-6 feet bgs (determined on a site-by-site basis)	0-2 feet bgs

Table 10-4 (2 of 2)

Life History Parameters Used in Calculating Applied Daily Doses

Reference Species	Red-Tailed Hawk	Bobcat	Mule Deer
Body Weight (kg)	1.224 (USEPA 1993)	10.0 (Jameson and Peeters 1988)	39.1 (Nagy 2001)
Food Intake Rate[a] (kg/d)	0.094	0.332	1.565
Prey Items (F) (fraction of diet)[b]	Deer mice (1.0) (surrogate for rodents)	Deer mice (1.0) (surrogate for rodents)	Vegetation (1.0)
Area Use[c] (0)	Dependent on habitat and size of the site	Dependent on habitat and size of the site	At least 40 ha. Dependent on habitat and size of the site
Seasonability[d] (Ψ)	1	1	1
Lifespan	18 years (USEPA 1993)	10-14 years (Zeiner et al 1990)	Approximately 8 years (Chapman & Feldhamer 1992)
Soil Depth Interval	NA	NA	0-2 feet bgs

Notes:
(a) Based on Nagy (2001).
(b) The percentage of prey items in the diet is based on the appropriate references, where indicated and assumptions used for exposure models.
(c) Area use is the fraction of time the species at the SSFL spends at an investigational unit (see Appendix D).
(d) Seasonability is the fraction of the year the species spends at the SSFL.

kg = kilograms' bgs = below ground surface
NA = Not applicable – either (i) not exposed to soil (great blue heron is exposed to sediments) or (ii) dermal contact and incidental ingestion of soil are considered to be negligible exposure pathways compared to the ingestion of prey (see Section 10.2 for further discussion of soil depth intervals).
USEPA = United States Environmental Protection Agency

Reference Concentrations for Aquatic Biota Exposed to Surface Water

Chemical Name	Scientific Name	Common Name	Endpoint	Media Type	Test Duration	Duration Units	Exposure Type[1]	ECOTOX Ref #[2]	Concentration ug/L	TEF, Surrogate, or source of alternative value[3]	Chronic RfC[4] ug/L	FW AWQC CMC ug/L[5]	FW AWQC CCC ug/L[5]
1,1,1,2-Tetrachloroethane	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	2.0E+04		2.00E+02		
1,1,1-Trichloroethane	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12858	4.2E+04		4.23E+02		
1,1,2,2-Tetrachloroethane	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12447	2.0E+04		2.03E+02		
1,1,2-Trichloro-1,2,2-trifluoroethane										Hexachloroethane	8.40E+00		
1,1,2-Trichloroethane	Jordanella floridae	Flagfish	LC50	FW	96	H	F	140	4.5E+04		4.51E+02		
1,1-Dichloroethane										1,2-Dichloroethane	1.00E+03		
1,1-Dichloroethene	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	7.4E+04		7.40E+02		
1,1'-Oxybis[2-chloroethane][8]	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	6.0E+05		6.00E+03		
1,2,3,4,6,7,8-HpCDD									1.1E-02	0.001	1.10E+01		
1,2,3,4,6,7,8-HpCDF									1.1E-02	0.01	1.10E+00		
1,2,3,4,7,8,9-HpCDF									1.1E-02	0.01	1.10E+00		
1,2,3,4,7,8-HxCDD									1.1E-02	0.5	2.20E-02		
1,2,3,4,7,8-HxCDF									1.1E-02	0.1	1.10E-01		
1,2,3,6,7,8-HxCDD									1.1E-02	0.01	1.10E+00		
1,2,3,4,7,8-HxCDF									1.1E-02	0.1	1.10E-01		
1,2,3,6,7,8-HxCDD									1.1E-02	0.01	1.10E+00		
1,2,3,6,7,8-HxCDF									1.1E-02	0.1	1.10E-01		
1,2,3,7,8,9-HxCDD									1.1E-02	0.01	1.10E+00		
1,2,3,7,8,9-HxCDF									1.1E-02	0.1	1.10E-01		
1,2,3,7,8-PeCDD									1.1E-02	1	1.10E-02		
1,2,3,7,8-PeCDF									1.1E-02	0.05	2.20E-01		
1,2,4-Trichlorobenzene	Jordanella floridae	Flagfish	LC50	FW	96	H	F	140	1.2E+03		1.22E+01		
1,2,4-Trimethylbenzene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12858	7.7E+03		7.72E+01		
1,2-Dibromo-3-chloropropane	Micropterus salmoides	Largemouth bass	LC50	FW	48	H	S	2786	2.0E+04		2.00E+02		
1,2-Dichlorobenzene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	10579	1.6E+03		1.58E+01		
1,2-Dichloroethane	Pteronarcys californicus	Stonefly	LC50	FW	96	H	S	666	1.0E+05		1.00E+03		
1,2-Dichloroethene (total)	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	1.4E+05		1.40E+03		
1,2-Dichloropropane	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12447	1.3E+05		1.27E+03		
1,3,5-Trimethylbenzene	Carassius auratus	Goldfish	LC50	FW	96	H	F	416	1.3E+04		1.25E+02		
1,3,5-Trinitrobenzene	Ictalurus punctatus	Channel catfish	LC50	FW	96	H	S	11830	3.8E+02		3.80E+00		
1,3-Dichlorobenzene	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	5.0E+03		5.00E+01		
1,3-Dinitrobenzene	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	11830	1.4E+03		1.44E+01		
1,4-Dichlorobenzene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	S	6797	8.8E+02		8.80E+00		
1-Methylnapthalene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	719	9.0E+03		9.00E+01		
2,3,4,6,7,8-HxCDF									1.1E-02	0.1	1.10E-01		
2,3,4,7,8-PeCDF									1.1E-02	0.5	2.20E-02		
2,3,7,8-TCDD	Salvelinus namaycush	Lake trout, siscowet	NOAEL	FW	48	H	R	3597	1.1E-02		1.10E-02		

Reference Concentrations for Aquatic Biota Exposed to Surface Water

Chemical Name	Scientific Name	Common Name	Endpoint	Media Type	Test Duration	Duration Units	Exposure Type[1]	ECOTOX Ref #[2]	Concentration ug/L	TEF, Surrogate, or source of alternative value[3]	Chronic RfC[4] ug/L	FW AWQC CMC ug/L[5]	FW AWQC CCC ug/L[5]
2,3,7,8-Tetrachlorodibenzofuran							S	3117	1.1E-02	0.05	2.20E-01		
2,4,5-Trichlorophenol	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	56474	2.5E+02		2.49E+00		
2,4,6-Trichlorophenol	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	3.2E+02		3.20E+00		
2,4,6-Trinitrotoluene	Daphnia magna	Water flea	LC50	FW	96	H	R	4006	9.8E+02		9.80E+00		
2,4-Dichlorophenol	Carassius auratus	Goldfish	LC50	FW	96	H	F	563	1.2E+03		1.24E+01		
2,4-Dimethylphenol	Lepomis macrochirus	Bluegill	LC50	FW	96	H	F	56473	6.3E+03		6.30E+01		
2,4-Dinitrophenol	Notopterus notopterus	Asiatic knifefish	LC50	FW	96	H	R	6432	6.0E+01		6.00E-01		
2,4-Dinitrotoluene	Gasterosteus aculeatus	Threespine stickleback	LC50	FW	96	H	R	823	6.3E+03		6.30E+01		
2,6-Dinitrotoluene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	10141	1.9E+04		1.85E+02		
2-Amino-4,6-Dinitrotoluene	Daphnia magna	Water flea	LC50	FW	96	H	R	4006	2.0E+02		2.00E+00		
2-Butanone	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12448	3.2E+06		3.22E+04		
2-Chloroethylvinylether	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	3.5E+05		3.50E+03		
2-Chloronaphthalene										Naphthalene	1.00E+01		
2-Chlorophenol	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	6.6E+03		6.60E+01		
2-Hexanone	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12858	4.3E+05		4.28E+03		
2-Methylnaphthalene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	3386	1.5E+03		1.46E+01		
2-Methylphenol	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	569	8.4E+03		8.40E+01		
2-Nitroaniline	Danio rerio	Zebra danio	LC50	FW	96	H	R	5436	1.9E+04		1.95E+02		
2-Nitrophenol	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12859	1.6E+05		1.60E+03		
2-Nitrotoluene	Poecilia reticulata	Guppy	LC50	FW	96	H	R	19263	3.0E+04		3.01E+02		
3,3'-Dichlorobenzidine	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	17138	1.1E+03		1.05E+01		
3-Nitroaniline	Poecilia reticulata	Guppy	LC50	FW	96	H	R	19263	8.1E+04		8.12E+02		
3-Nitrotoluene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	719	3.0E+04		3.00E+02		
4,6-Dinitro-2-methylphenol	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	S	666	6.6E+01		6.60E-01		
4-Amino-2,6-Dinitrotoluene	Dugesia dorotocephala	Turbellarian, flatworm	LC50	FW	96	H	R	4006	3.0E+02		3.00E+00		
4-Bromophenyl-phenylether	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	5.9E+03		5.90E+01		
4-Chloro-3-methylphenol	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	344	9.2E+02		9.17E+00		
4-Chloroaniline	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	939	2.4E+03		2.40E+01		
4-Chlorophenyl-phenylether	Salvelinus fontinalis	Brook trout	LC50	FW	96	H	R	6896	7.3E+02		7.30E+00		
4-Methyl-2-pentanone	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	12448	5.1E+05		5.05E+03		
4-Methylphenol	Lepidocephalichthyes gunte	Fish	LC50	FW	96	H	R	19254	7.0E+03		7.00E+01		
4-Nitroaniline	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	2966	1.0E+05		1.02E+03		
4-Nitrophenol	Gammarus pseudolimnaeus	Scud	LC50	FW	96	H	S	13274	2.8E+03		2.80E+01		
4-Nitrotoluene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	10141	5.0E+04		4.97E+02		
Acenaphthene	Tallaperla maria	Stonefly	LC50	FW	96	H	S	14563	2.4E+02		2.40E+00		

Reference Concentrations for Aquatic Biota Exposed to Surface Water

Chemical Name	Scientific Name	Common Name	Endpoint	Media Type	Test Duration	Duration Units	Exposure Type[1]	ECOTOX Ref #[2]	Concentration ug/L	TEF, Surrogate, or source of alternative value[3]	Chronic RfC[4] ug/L	FW AWQC CMC ug/L[5]	FW AWQC CCC ug/L[5]
Acenaphthylene										Acenaphthene	2.40E+00		
Acetone										2-Butanone	3.22E+04		
Aluminum												750	87
Aniline	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	58703	3.0E+01		3.00E-01		
Anthracene	Lepomis macrochirus	Bluegill	LC50	FW	96	H	F	3862	1.3E+00		1.27E-02		
Antimony [7a]	Daphnia magna	Water flea	LC50	FW	96	H	S	3783	5.4E+00		5.39E-02		
Aroclor-1248	Gammarus pseudolimnaeus	Scud	LC50	FW	96	H	F	530	2.9E+01		2.90E-01		
Aroclor-1254	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	6772	3.2E-01		3.20E-03		
Aroclor-1260	Perca flavescens	Yellow perch	LC50	FW	96	H	F	6797	2.0E+02		2.00E+00		
Arsenic												340	150
Azobenzene	Oryzias latipes	Medaka, high-eyes	LC50	FW	48	H	S	10132	5.0E+02		5.00E+00		
Barium [7b]	Austropotamobius pallipes p	Crayfish	LC50	FW	96	H	S	5421	3.0E+04		3.03E+02		
Benzene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	17889	5.3E+03		5.30E+01		
Benzidine	Oryzias latipes	Medaka, high-eyes	LC50	FW	48	H	S	10132	1.1E+04		1.05E+02		
Benzo(a)anthracene	Daphnia pulex	Water flea	LC50	FW	96	H	S	15337	1.0E+01		1.00E-01		
Benzo(a)pyrene	Daphnia pulex	Water flea	LC50	FW	96	H	S	15337	5.0E+00		5.00E-02		
Benzo(b)fluoranthene										Benzo(a)pyrene	5.00E-02		
Benzo(e)pyrene										Benzo(a)pyrene	5.00E-02		
Benzo(g,h,i)perylene										Benzo(a)pyrene	5.00E-02		
Benzo(k)fluoranthene										Benzo(a)pyrene	5.00E-02		
Benzoic acid	Gambusia affinis	Western mosquitofish	LC50*	FW	96	H	S	508	1.8E+05		1.80E+03		
Benzyl alcohol	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	863	1.0E+04		1.00E+02		
Beryllium [7c]	Daphnia magna	Water flea	LC50	FW	96	H	S	11951	5.6E+00		5.64E-02		
Boron		minnow	LOEC		6	H			1.8E+07	1986 AWQC	1.80E+06		
Bromodichloromethane										Trichloromethane [8]	1.33E+02		
Bromoform	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	2.9E+04		2.90E+02		
Bromomethane	Poecilia reticulata	Guppy	LC50	FW	96	H	R	5331	8.0E-01		8.00E-03		
Butyl benzyl phthalate	Cyprinodon variegatus	Sheepshead minnow	LC50	FW	96	H	S	15040	6.8E+02		6.80E+00		
Cadmium												4	2
Carbazole	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	17138	9.3E+02		9.30E+00		
Carbon Disulfide	Poecilia reticulata	Guppy	LC50	FW	96	H	R	11455	4.0E+03		4.00E+01		
Carbon tetrachloride	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	2.7E+04		2.70E+02		

Reference Concentrations for Aquatic Biota Exposed to Surface Water

Chemical Name	Scientific Name	Common Name	Endpoint	Media Type	Test Duration	Duration Units	Exposure Type[1]	ECOTOX Ref #[2]	Concentration ug/L	TEF, Surrogate, or source of alternative value[3]	Chronic RfC[4] ug/L	FW AWQC CMC ug/L[5]	FW AWQC CCC ug/L[5]
Chlorobenzene	Carassius auratus	Goldfish	LC50	FW	96	H	F	563	2.4E+03		2.37E+01		
Chloroethane										Chloromethane	5.50E+03		
Chloroform	Lepomis macrochirus	Bluegill	LC50	FW	96	H	F	5267	1.3E+04		1.33E+02		
Chloromethane	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	863	5.5E+05		5.50E+03		
Chlorotrifluoroethane										1,1,1,2-Tetrachloroethane	2.00E+02		
Chlorotrifluoroethene										Tetrachloroethene	3.60E+01		
Chromium (III)												570	74
Chrysene										Benzo(a)anthracene	1.00E-01		
Cobalt [7d]	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	20081	6.4E+02		6.38E+00		
Copper												13.0	9.0
Di-n-butylphthalate	Perca flavescens	Yellow perch	LC50	FW	96	H	F	6797	3.5E+02		3.50E+00		
Di-n-octylphthalate										Dibutyl phthalate [8]	3.50E+00		
Dibenz(a,h)anthracene										Benzo(a)pyrene	5.00E-02		
Dibenzofuran	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	17138	1.1E+03		1.05E+01		
Dibutyl phthalate [8]	Perca flavescens	Yellow perch	LC50	FW	96	H	F	6797	3.5E+02		3.50E+00		
Dibromochloromethane[6]	Cyprinus carpio	Common, mirror, colored, c	LC50	FW	4	D	R	6360	3.4E+04		3.40E+02		
Dichlorodifluoromethane										Tetrachloromethane [8]	2.43E+02		
Diethylphthalate									3.0E+00	Chronic toxicity value, 1986 AWQC	3		
Dimethylphthalate									3.0E+00	Chronic toxicity value, 1986 AWQC	3		
Ethylbenzene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	13142	4.2E+03		4.20E+01		
Fluoranthene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	19043	6.8E+00		6.83E-02		
Fluorene	Gammarus pseudolimnaeus	Scud	LC50	FW	96	H	S	9512	6.0E+02		6.00E+00		
Fluoride	Salmo trutta	Brown trout	LC50	FW	48	H	NR	448	1.3E+05		1.25E+03		
HMX	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	5966	1.5E+04		1.50E+02		
Hexachlorobenzene	Salmo trutta	Brown trout	LC50	FW	96	H	S	6797	3.0E+02		3.00E+00		
Hexachlorobutadiene	Carassius auratus	Goldfish	LC50	FW	96	H	R	540	9.0E+01		9.00E-01		
Hexachlorocyclopentadiene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	2097	7.0E+00		7.00E-02		
Hexachloroethane	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	F	4433	8.4E+02		8.40E+00		
Hexavalent Chromium												16	11
Indeno(1,2,3-cd)pyrene										Benzo(a)anthracene	1.00E-01		
Isophorone	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	15152	1.5E+05		1.45E+03		
Manganese [7e]	Daphnia magna	Water flea	LC50	FW	96	H	S	3783	4.6E+03		4.58E+01		

Reference Concentrations for Aquatic Biota Exposed to Surface Water

Chemical Name	Scientific Name	Common Name	Endpoint	Media Type	Test Duration	Duration Units	Exposure Type[1]	ECOTOX Ref #[2]	Concentration ug/L	TEF, Surrogate, or source of alternative value[3]	Chronic RfC[4] ug/L	FW AWQC CMC ug/L[5]	FW AWQC CCC ug/L[5]
Mercury												1	1
Methylene chloride	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	973	1.9E+05		1.93E+03		
Molybdenum [7f]	Daphnia magna	Water flea	LC50	FW	96	H	S	3783	2.1E+04		2.13E+02		
N-ethyl-n-nitrosoethanamine	Gammarus limnaeus	Scud	LC50	FW	96	H			5.0E+05		5.00E+03		
N-Nitrosodi-n-propylamine										N-ethyl-n-nitrosoethanamine	5.00E+03		
N-Nitrosodimethylamine	Gammarus limnaeus	Scud	LC50	FW	96	H	F	5744	2.8E+05		2.80E+03		
N-Nitrosodiphenylamine	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	5.8E+03		5.80E+01		
Naphthalene	Daphnia pulex	Water flea	LC50	FW	96	H	S	15337	1.0E+03		1.00E+01		
Nickel												470	52
Nitrobenzene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	S	16888	2.4E+04		2.43E+02		
PCB-105									1.1E-02	5.0E-06	2.20E+03		
PCB-114									1.1E-02	5.0E-06	2.20E+03		
PCB-118									1.1E-02	5.0E-06	2.20E+03		
PCB-123									1.1E-02	5.0E-06	2.20E+03		
PCB-126									1.1E-02	5.0E-03	2.20E+00		
PCB-156									1.1E-02	5.0E-06	2.20E+03		
PCB-157									1.1E-02	5.0E-06	2.20E+03		
PCB-167									1.1E-02	5.0E-06	2.20E+03		
PCB-169									1.1E-02	5.0E-05	2.20E+02		
PCB-189									1.1E-02	5.0E-06	2.20E+03		
PCB-77									1.1E-02	1.0E-04	1.10E+02		
PCB-81									1.1E-02	5.0E-04	2.20E+01		
Pentachlorophenol												19	15
Perchlorate										Toxicity Value Not Available			
Phenanthrene	Daphnia pulex	Water flea	LC50	FW	96	H	S	15337	1.0E+02		1.00E+00		
Phenol	Cyprinus carpio	Common, mirror, colored, c	LC50	FW	96	H	R	10385	1.8E+00		1.75E-02		
Pyrene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	3386	2.0E+03		2.00E+01		
Pyridine	Oncorhynchus gorbuscha	Pink salmon	LC50	FW	96	H	S	12605	1.1E+03		1.10E+01		
RDX	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5962	3.6E+03		3.60E+01		
Selenium													5
Silver												3	2
Styrene	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	3217	4.0E+03		4.02E+01		
Tetrachloroethene	Tallaperla maria	Stonefly	LC50	FW	96	H	S	14563	3.6E+03		3.60E+01		
Tetrachloromethane [8]	Danio rerio	Zebra danio	LC50	FW	96	H	F	56372	2.4E+04		2.43E+02		

Reference Concentrations for Aquatic Biota Exposed to Surface Water

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Tetryl										trinitrotoluene [8]	9.80E+00		
Thallium [7g]	Gammarus minus	Scud	LC50	FW	96	H	S	14563	8.1E+01		8.10E-01		
Toluene	Oncorhynchus kisutch	Coho salmon,silver salmon	LC50	FW	96	H	F	15191	5.5E+03		5.50E+01		
Trichloroethene	Jordanella floridae	Flagfish	LC50	FW	96	H	R	140	3.1E+03		3.10E+01		
Trichloromethane [8]	Lepomis macrochirus	Bluegill	LC50	FW	96	H	F	5267	1.3E+04		1.33E+02		
Trichlorofluoromethane										Tetrachloromethane [8]	2.43E+02		
Trinitrotoluene [8]	Daphnia magna	Water flea	LC50	FW	96	H	R	4006	9.8E+02		9.80E+00		
Vanadium [7h]	Pimephales promelas	Fathead minnow	LC50	FW	96	H	F	3783	1.0E+00		1.01E-02		
Vinyl Acetate	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	728	1.4E+04		1.40E+02		
Vinyl chloride										1,1-Dichloroethene	7.40E+02		
Xylene (total)	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	S	6797	3.3E+03		3.30E+01		
Zinc												120	120
bis(2-Chloroethoxy)methane	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	11961	1.8E+05		1.84E+03		
bis(2-Chloroethyl)ether	Lepomis macrochirus	Bluegill	LC50	FW	96	H	S	5590	6.0E+05		6.00E+03		
bis(2-Ethylhexyl)phthalate	Pimephales promelas	Fathead minnow	LC50	FW	96	H	S	15040	1.6E+02		1.60E+00		
bis-chloroisopropyl ether										1,1'-Oxybis[2-chloroethane] [8]	6.00E+03		
cis-1,2-Dichloroethene										trans-1,2-Dichloroethene	2.20E+03		
cis-1,3-Dichloropropene										1,2-Dichloropropane	1.27E+03		
Total OCDD									1.1E-02	1.00E-04	1.10E+02		
meta-xylene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	13142	8.4E+03	Xylene (total)	8.40E+01		
o-Xylene	Oncorhynchus mykiss	Rainbow trout,donaldson tro	LC50	FW	96	H	R	13142	7.6E+03		7.60E+01		
trans-1,2-Dichloroethene	Daphnia magna	Water flea	LC50	FW	48	H	S	5184	2.2E+05		2.20E+03		
trans-1,3-Dichloropropene										1,2-Dichloropropane	1.27E+03		
Calcium									3.6E+06	1986 AWQC, see text for	3.60E+06		
Chloride												860000	230000
Iron	Morone saxatilis	Striped bass	LC50	FW	96	H	S	2012	1.8E+03		1.76E+01		
Lead												65	3
Magnesium [7i]	Daphnia magna	Water flea	LC50	FW	96	H	S	915	3.2E+04				1000
Nitrate		Chinook salmon	LC50	FW	96	H			9.0E+02	1986 AWQC	9.00E+02		
Potassium	Gammarus lacustris	Scud	LC50	FW	96	H	F	13058	5.3E+04		5.32E+02		
Sodium									3.9E+06	1986 AWQC, see text for derivation	3.93E+06		

Reference Concentrations for Aquatic Biota Exposed to Surface Water

Chemical Name	Scientific Name	Common Name	Endpoint	Media Type	Test Duration	Duration Units	Exposure Type[1]	ECOTOX Ref #[2]	Concentration ug/L	TEF, Surrogate, or source of alternative value[3]	Chronic RfC[4] ug/L	FW AWQC CMC ug/L[5]	FW AWQC CCC ug/L[5]

Notes:

* The asterisk (*) on the concentration value means it was recalculated by ECOTOX staff to meet database conformity in terms of units or chemical form.

1. Abbreviations for exposure type; F=flow-through, NR=not reported, S=static, R=renewal
2. See ECOTOX Reference Table (Table 1-a) for full citation.
3. If toxicity values were not available in ECOTOX a chemical with structural similarity was selected as a surrogate. For halogenated hydrocarbons, surrogates were chosen by the number of halogen substitutions and alkyl chain characteristics, for polycyclic aromatic hydrocarbons number and size of aromatic rings were considered for surrogate selection, for all other compounds the closest structurally similar surrogate was selected. If no structurally similar surrogate was available in ECOTOX, USEPA 1986 AWQC guidance was consulted. Listed toxicity equivalency factors (TEFs) were developed for fishes (Van den Berg et al. 1998). Because there is limited evidence for ligand activation of Ah receptor or for TCDD-like toxicity in invertebrates (Wiesner et al. 2004; Van den Berg et al. 1998), it is assumed that surface water RfCs for TCDD and other dioxin/furan congeners that are applicable for fishes will also be protective of aquatic invertebrates exposed to surface water. For compounds with TEFs for fishes, the TCDD toxicity value (based on effects observed in the lake trout) was divided by the TEF.
4. Acute toxicity values were divided by 100 for adjustment to a chronic RfC. Values for beryllium, phthalates and vanadium were chronic and therefore not adjusted.
5. Freshwater Ambient Water Quality Criteria (AWQC) values take from USEPA, 1999.
6. For Dibromochloromethane, the 3-5 day test duration retrieved from ECOTOX was averaged to a 4-day (96-hr) duration for the acute to chronic exposure calculation.
7. Concentrations reported in ECOTOX were adjusted to free metal ion concentration, specific salt forms listed below.
   a. antimony trichloride, MW=228.12, CAS No. 10025919
   b. barium dichloride, MW=208.23, CAS No. 10361372
   c. beryllium dichloride, MW=79.92, CAS No. 7787475
   d. cobalt chloride, MW=129.84, CAS No. 7646799
   e. manganese sulfate, MW=151, CAS No. 7785877
   f. molybdenum trioxide, MW=143.94, CAS No. 1313275
   g. sulfuric acid, thallium salt, MW= 504.83, CAS No. 10031591
   h. vanadium pentoxide, MW=181.88, CAS No. 1314621
   i. magnesium sulfate, MW=120.37, CAS No. 7487889
   j. Iron (II) chloride, MW 126.75, CAS No. 7758943
8. Not a COPC at SSFL, data added to support use of chemical surrogate.

FW - Fresh Water
H - time in hours
D - time in days
LC_{50} - lethal concentration for 50% of study population

Table 11-1a (1 of 4)

References for Aquatic Toxicity Data Retrieved From ECOTOX.

ECOTOX Reference #	Full Citation
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Table 11-1a (2 of 4)

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Table 11-1a (3 of 4)

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Table 11-1b (1 of 1)

Summary of Freshwater Aquatic Toxicity Data Retrieval

		Source of TRV value	Number of chemicals	Chemicals in category
Chemicals in Rocketdyne analyte list[(1)]	194			
LC50 retrieved from ECOTOX	120			
		96-hr LC50	112	
		48-hr LC50	7	1,2-dibromo-3-chloropropane, 2,3,7,8-tetrachlorodibenzodioxin, azobenzene, barium, benzidine, fluoride ion, trans-1,2-dichloroethylene
		3-5 d (96-hr) LC50	1	dibromochloromethane
LC50 not retrived from ECOTOX	74			
		AWQC criteria	13	aluminum, arsenic, cadmium, chromium (III), copper, hexavalent chromium, mercury, nickel, pentachlorophenol, silver, zinc, chloride, lead
		used surrogate chemical	28	
		calculated with TEF	26	dioxins, dibenzofurans, polychlorinated biphenyls
		AWQC 1986 LC50	6	boron, diethylphthalate, dimethylphthalate, calcium, nitrate. sodium
		No relevant toxicity information obtained	1	perchlorate

Notes:

(1) Not Including compounds used as chemcial surrogates which are not SSFL COPCs .

Table 11-2 (1 of 6)

Reference Concentrations for Aquatic Biota Exposed to Sediment

	Freshwater Threshold Effects Concentration (mg/kg sediment)	Freshwater Upper Effects Threshold Concentration (mg/kg sediment)	Marine Apparent Effects Threshold (mg/kg sediment)	Selected Reference Concentration (mg/kg sediment)
Inorganic Compounds				
Aluminum	-	-	18,000	18,000
Antimony	2	3.0		2.0
Arsenic	9.79	-	-	9.79
Barium	-	-	48	48
Beryllium	-	-	-	-
Boron	-	-	-	-
Cadmium	0.99	-	-	0.99
Chromium	43.4	-	-	43.4
Hexavalent chromium	-	-	-	-
Cobalt	-	-	10	10
Copper	31.6	-	-	31.6
Lead	35.8	-	-	35.8
Manganese	-	1,100	-	1,100
Mercury	0.18	-	-	0.2
Molybdenum	-	-	-	-
Nickel	22.7	-	-	22.7
Perchlorate	-	-	-	-
Selenium	-	-	1.0	1.0
Silver	-	4.5	-	4.5
Strontium	-	-	-	-
Thallium	-	-	-	-
Tin	-	-	-	-
Vanadium	-	-	57	57
Zinc	121	-	-	121
VOCs				
1,1,1,2-Tetrachloroethane	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-
1,1,2-Trichloro-1,2,2-trifluoroet	-	-	-	-
1,1,2-Trichloroethane	-	-	-	-
1,1-Dichloroethane	-	-	-	-
1,1-Dichloroethene	-	-	-	-
1,1-Dichloropropene	-	-	-	-
1,2,3-Trichlorobenzene	-	-	-	-
1,2,3-Trichloropropane	-	-	-	-
1,2,4-Trichlorobenzene	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-

Table 11-2 (2 of 6)

Reference Concentrations for Aquatic Biota Exposed to Sediment

	Freshwater Threshold Effects Concentration (mg/kg sediment)	Freshwater Upper Effects Threshold Concentration (mg/kg sediment)	Marine Apparent Effects Threshold (mg/kg sediment)	Selected Reference Concentration (mg/kg sediment)
1,2-Dibromo-3-chloropropane	-	-	-	-
1,2-Dibromoethane	-	-	-	-
1,2-Dichlorobenzene	-	-	-	-
1,2-Dichloroethane	-	-	-	-
1,2-Dichloropropane	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-
1,3-Dichlorobenzene	-	-	-	-
1,4-Dichlorobenzene	-	-	-	-
2-Butanone	-	-	-	-
2-Chloroethylvinylether	-	-	-	-
2-Chlorotoluene	-	-	-	-
2-Chloro-1,1,1-trifluoroethane	-	-	-	-
2-Hexanone	-	-	-	-
4-Bromofluorobenzene	-	-	-	-
4-Chlorotoluene	-	-	-	-
4-Methyl-2-pentanone	-	-	-	-
Acetone	-	-	-	-
Acrolein	-	-	-	-
Acrylonitrile	-	-	-	-
Benzene	-	-	-	-
Benzidine	-	-	-	-
Bromobenzene	-	-	-	-
Bromodichloromethane	-	-	-	-
Bromoform	-	-	-	-
Bromomethane	-	-	-	-
Carbon disulfide	-	-	-	-
Carbon tetrachloride	-	-	-	-
Chlorobenzene	-	-	-	-
Chloroethane	-	-	-	-
Chloroform	-	-	-	-
Chloromethane	-	-	-	-
Chlorotrifluoroethene	-	-	-	-
cis-1,2-Dichloroethene	-	-	-	-
cis-1,3-Dichloropropene	-	-	-	-
Dibromochloromethane	-	-	-	-
Dibromomethane	-	-	-	-
Dichlorodifluoromethane	-	-	-	-
Ethylbenzene	-	-	-	-
Formaldehyde	-	-	-	-

Table 11-2 (3 of 6)

Reference Concentrations for Aquatic Biota Exposed to Sediment

	Freshwater Threshold Effects Concentration (mg/kg sediment)	Freshwater Upper Effects Threshold Concentration (mg/kg sediment)	Marine Apparent Effects Threshold (mg/kg sediment)	Selected Reference Concentration (mg/kg sediment)
Isopropylbenzene	-	-	-	-
m,p-Xylene	-	-	-	-
Methyl tert-butyl ether	-	-	-	-
Methylene chloride	-	-	-	-
n-Butylbenzene	-	-	-	-
n-Propylbenzene	-	-	-	-
o-Xylene	-	-	-	-
p-Isopropyltoluene	-	-	-	-
sec-Butylbenzene	-	-	-	-
Styrene	-	-	-	-
tert-Butylbenzene	-	-	-	-
Tetrachloroethene	-	-	-	-
Toluene	-	-	-	-
trans-1,2-Dichloroethene	-	-	-	-
trans-1,3-Dichloropropene	-	-	-	-
Trichloroethene	-	-	-	-
Trichlorofluoromethane	-	-	-	-
Vinyl acetate	-	-	-	-
Vinyl chloride	-	-	-	-
SVOCs				
1,2-Diphenylhydrazine	-	-	-	-
1,4-Dioxane	-	-	-	-
2,4,5-Trichlorophenol	-	-	-	-
2,4,6-Trichlorophenol	-	-	-	-
2,4-Dichlorophenol	-	-	-	-
2,4-Dimethylphenol	-	-	-	-
2,4-Dinitrophenol	-	-	-	-
2,4-Dinitrotoluene	-	-	-	-
2,6-Dinitrotoluene	-	-	-	-
2-Chloronaphthalene	-	-	-	-
2-Chlorophenol	-	-	-	-
2-Methylnaphthalene	-	-	-	-
2-Methylphenol	-	-	-	-
2-Nitroaniline	-	-	-	-
2-Nitrophenol	-	-	-	-
3- and 4-Methylphenol Coelutio	-	-	-	-
3-Methylphenol	-	-	-	-
4-Methylphenol	-	-	-	-

Table 11-2 (4 of 6)

Reference Concentrations for Aquatic Biota Exposed to Sediment

	Freshwater Threshold Effects Concentration (mg/kg sediment)	Freshwater Upper Effects Threshold Concentration (mg/kg sediment)	Marine Apparent Effects Threshold (mg/kg sediment)	Selected Reference Concentration (mg/kg sediment)
3,3'-Dichlorobenzidine	-	-	-	-
3-Nitroaniline	-	-	-	-
4,6-Dinitro-2-methylphenol	-	-	-	-
4-Bromophenyl phenyl ether	-	-	-	-
4-Chloro-3-methylphenol	-	-	-	-
4-Chloroaniline	-	-	-	-
4-Chlorophenyl phenyl ether	-	-	-	-
4-Nitroaniline	-	-	-	-
4-Nitrophenol	-	-	-	-
Acenaphthene		0.29		0.29
Acenaphthylene		0.16		0.16
Aniline	-	-	-	-
Anthracene	0.0572			0.0572
Benzo(a)anthracene	0.108			0.108
Benzo(a)pyrene	0.15			0.15
Benzo(b)fluoranthene			1.8	1.8
Benzo(g,h,i)perylene		0.30		0.30
Benzo(k)fluoranthene		13.4		13.4
Benzoic acid	-	-	-	-
Benzyl alcohol	-	-	-	-
bis(2-Chloroethoxy)methane	-	-	-	-
bis(2-Chloroethyl)ether	-	-	-	-
bis(2-Chloroisopropyl) ether	-	-	-	-
bis(2-Ethylhexyl)phthalate	-	-	-	-
Butyl benzyl phthalate	-	-	-	-
Carbazole	-	-	-	-
Chrysene	0.166			0.166
Dibenz(a,h)anthracene	0.423			0.423
Dibenzofuran	-	-	-	-
Diethylphthalate	-	-	-	-
Dimethyl phthalate	-	-	-	-
Di-n-butylphthalate	-	-	-	-
Di-n-octyl phthalate	-	-	-	-
Fluoranthene	0.195			0.195
Fluorene	0.0774			0.0774
Hexachlorobenzene	-	-	-	-
Hexachlorobutadiene	-	-	-	-
Hexachlorocyclopentadiene	-	-	-	-
Hexachloroethane	-	-	-	-

Table 11-2 (5 of 6)

Reference Concentrations for Aquatic Biota Exposed to Sediment

	Freshwater Threshold Effects Concentration (mg/kg sediment)	Freshwater Upper Effects Threshold Concentration (mg/kg sediment)	Marine Apparent Effects Threshold (mg/kg sediment)	Selected Reference Concentration (mg/kg sediment)
Indeno(1,2,3-cd)pyrene		0.33		0.33
Isophorone	-	-	-	-
Naphthalene	0.176			0.176
Nitrobenzene	-	-	-	-
N-Nitrosodimethylamine	-	-	-	-
N-Nitrosodi-n-propylamine	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-
Pentachlorophenol	-	-	-	-
Phenanthrene	0.204			0.204
Phenol	-	-	-	-
Pyrene	0.195			0.195
Pyridine	-	-	-	-
Total Petroleum Hydrocarbons				
C08-C11(Gasoline Range)	-	-	-	-
C11-C14(Kerosene Range)	-	-	-	-
C14-C20(Diesel Range)	-	-	-	-
C20-C30(Lubricant Oil Range)	-	-	-	-
PCDD/PCDFs				
2,3,7,8-TCDD	-	0.0088	-	0.0088
1,2,3,7,8-PeCDD	-	0.0088	-	0.0088
1,2,3,4,7,8-HxCDD	-	0.018	-	0.018
1,2,3,6,7,8-HxCDD	-	0.88	-	0.88
1,2,3,7,8,9-HxCDD	-	0.88	-	0.88
1,2,3,4,6,7,8-HpCDD	-	8.8	-	8.8
OCDD	-	88	-	88
2,3,7,8-TCDF	-	0.18	-	0.18
1,2,3,7,8-PeCDF	-	0.18	-	0.18
2,3,4,7,8-PeCDF	-	0.018	-	0.018
1,2,3,4,7,8-HxCDF	-	0.088	-	0.088
1,2,3,6,7,8-HxCDF	-	0.088	-	0.088
2,3,4,6,7,8-HxCDF	-	0.088	-	0.088
1,2,3,7,8,9-HxCDF	-	0.088	-	0.088
1,2,3,4,6,7,8-HpCDF	-	0.88	-	0.88
1,2,3,4,7,8,9-HpCDF	-	0.88	-	0.88
OCDF	-	88	-	88
Total Tetra	-	-	-	-
Total Penta	-	-	-	-

Table 11-2 (6 of 6)

Reference Concentrations for Aquatic Biota Exposed to Sediment

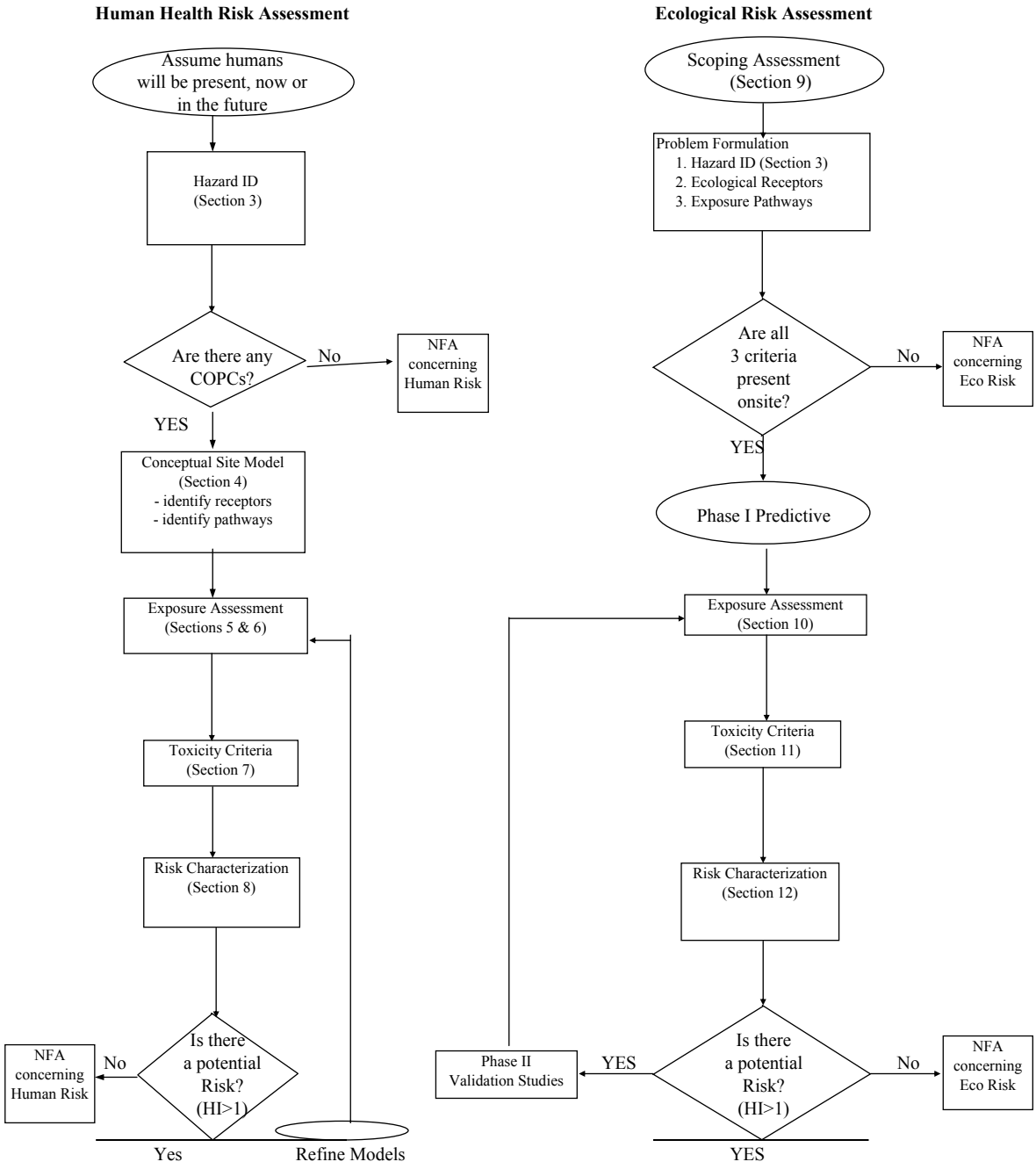
	Freshwater Threshold Effects Concentration (mg/kg sediment)	Freshwater Upper Effects Threshold Concentration (mg/kg sediment)	Marine Apparent Effects Threshold (mg/kg sediment)	Selected Reference Concentration (mg/kg sediment)
Total Hexa	-	-	-	-
Total Hepta	-	-	-	-
Total Octa	-	-	-	-
PCDD/PCDF	-	-	-	-
PCBs				
Aroclor-1016	0.0598			0.0598
Aroclor-1221	0.0598			0.0598
Aroclor-1232	0.0598			0.0598
Aroclor-1242	0.0598			0.0598
Aroclor-1248	0.0598			0.0598
Aroclor-1254	0.0598			0.0598
Aroclor-1260	0.0598			0.0598
PCB-105	-	-	-	-
PCB-114	-	-	-	-
PCB-118	-	-	-	-
PCB-123	-	-	-	-
PCB-126	-	-	-	-
PCB-156	-	-	-	-
PCB-157	-	-	-	-
PCB-167	-	-	-	-
PCB-169	-	-	-	-
PCB-189	-	-	-	-
PCB-77	-	-	-	-
PCB-81	-	-	-	-

Table 11-3 (1 of 1)

Reference Concentrations for Terrestrial Invertebrates

Analyte	Earthworms (mg/kg)
Inorganics	
Antimony	78
Arsenic	NA
Barium	330
Beryllium	40
Cadmium	140
Chromium	NA
Copper	32
Hexavalent Chromium	0.2
Lead	1700
Mercury	0.1
Methyl mercury	2.5
Nickel	100
Selenium	7.7
Vanadium	NA
Zinc	199
Organics	
2,3,7,8-TCDD	500
Aroclor 1016	50
Aroclor 1254	50
1,4-Dichlorobenzene	20
2,4,5-Trichlorophenol	9
2,4,6-Trichlorophenol	10
4-Nitrophenol	7
Benzo(a)pyrene	25000
Dimethyl phthalate	200
Fluorene	27
Nitrobenzene	40
N-Nitrosodiphenylamine	20
Pentachlorophenol	6
Phenol	30
1,2,3-Trichlorobenzene	20
1,2,4-Trichlorobenzene	20
1,2-Dichloropropane	700
Pyrene	18
Fluoranthene	38
Phenanthrene	34
Carbazole	34
Dibenzofuran	62
Chlorobenzene	40
Dieldrin	NA

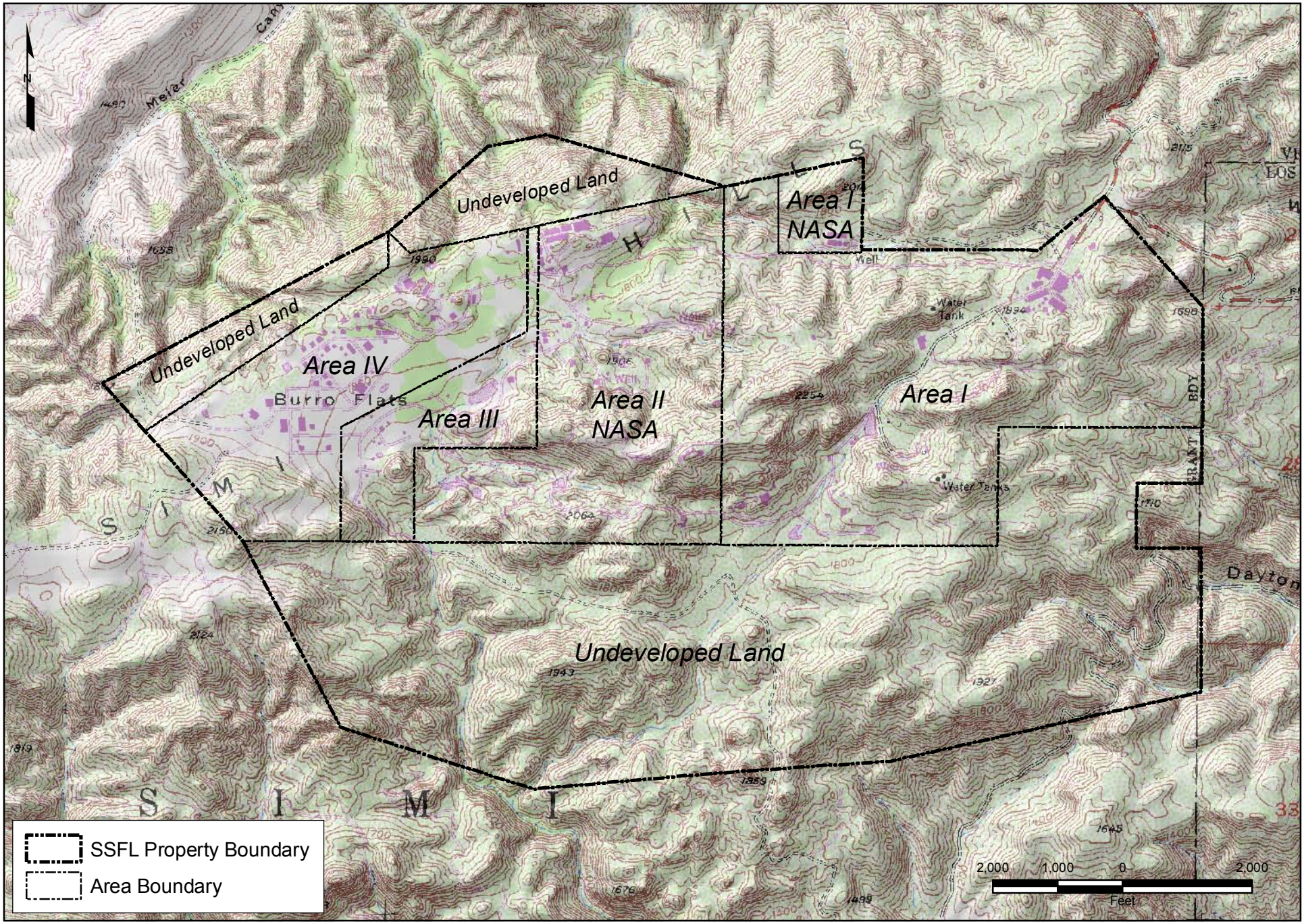
Source: USEPA (2005a-m), Efroymson et al.(1997), USEPA (1999), Sverdrup et al. (2002), Will and Suter (1995), Parmelee et al. (1997).



MWH

Santa Susana Field Laboratory (SSFL)
Risk Assessment Flow Chart

FIGURE 1-1



MWH

Santa Susana Field Laboratory (SSFL)
Site Plan

FIGURE
1-2

Project/Boeing SSFL RA/MWH_SRAM2005-Rev2/Figure 1-2.mxd

06/07/05

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of the figure should not be used because it may not accurately represent the information presented.

1783400 1788400 1793400 1798400

267400

262400

UNDEVELOPED LAND

NASA PROPERTY AREA I

UNDEVELOPED LAND

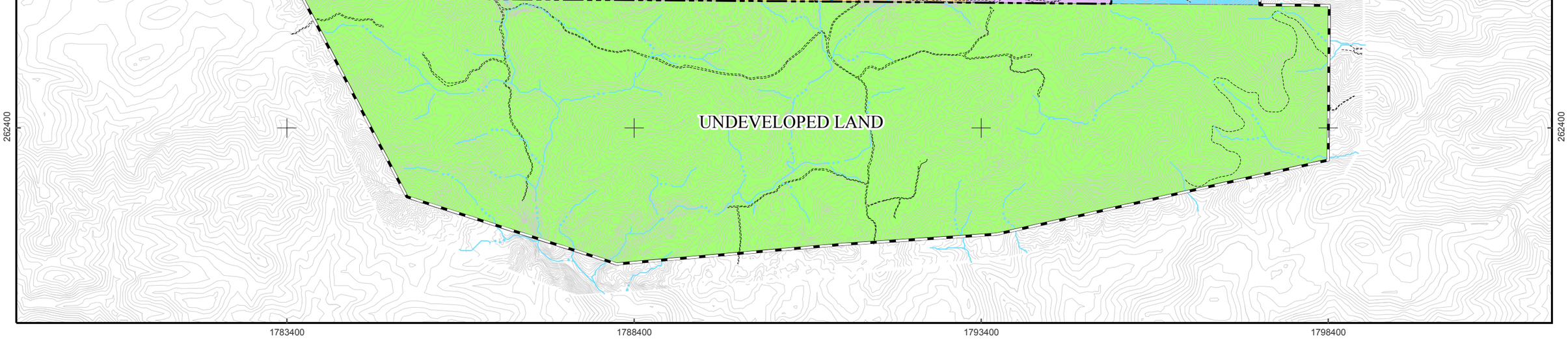
AREA IV

AREA III

AREA II (NASA)

AREA I

UNDEVELOPED LAND



N

0 700 1,400

FEET

MAP COORDINATES IN STATEPLANE, NAD 27, ZONE V

Legend

- A Dundas Parcel A
- B Silvernale Property to North American Aviation
- C Silvernale Propery to USAF
- D Spruce Property
- E Geopac Property
- F Brandeis Bardin Institute Property

Note: See Table 1-1 for Details

Base Map Legend

- Buildings
- SSFL Property Boundary
- Administrative Area Boundary
- Drainages
- Ponds
- Contours
- Dirt Roads
- Roads

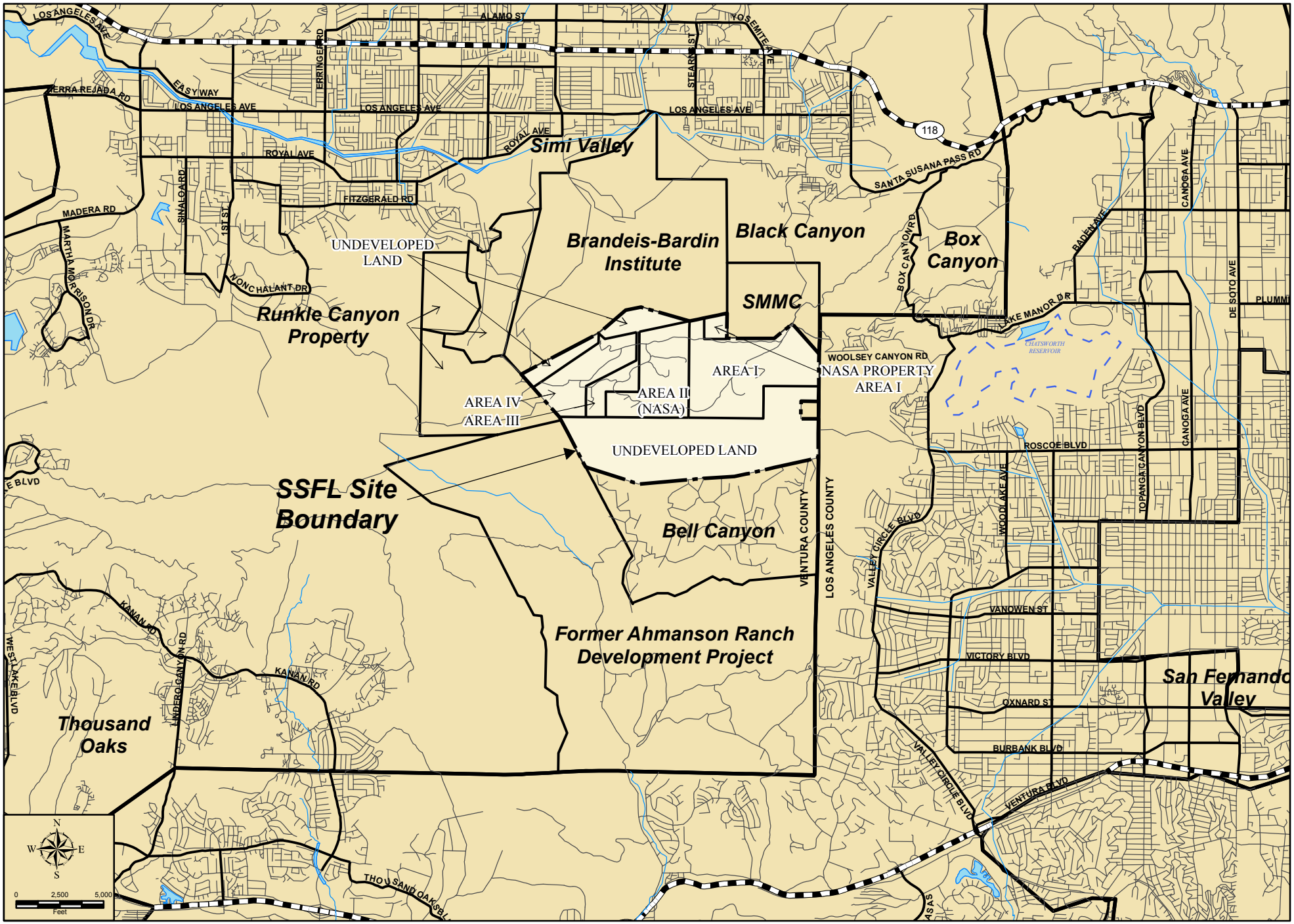
MWH

Santa Susana Field Laboratory (SSFL)
Land Acquisition History Map

FIGURE 1-3

Project/Boeing SSFL RA/MWH_SRAM2005-Rev2/Figure 1-3.mxd

06/07/05



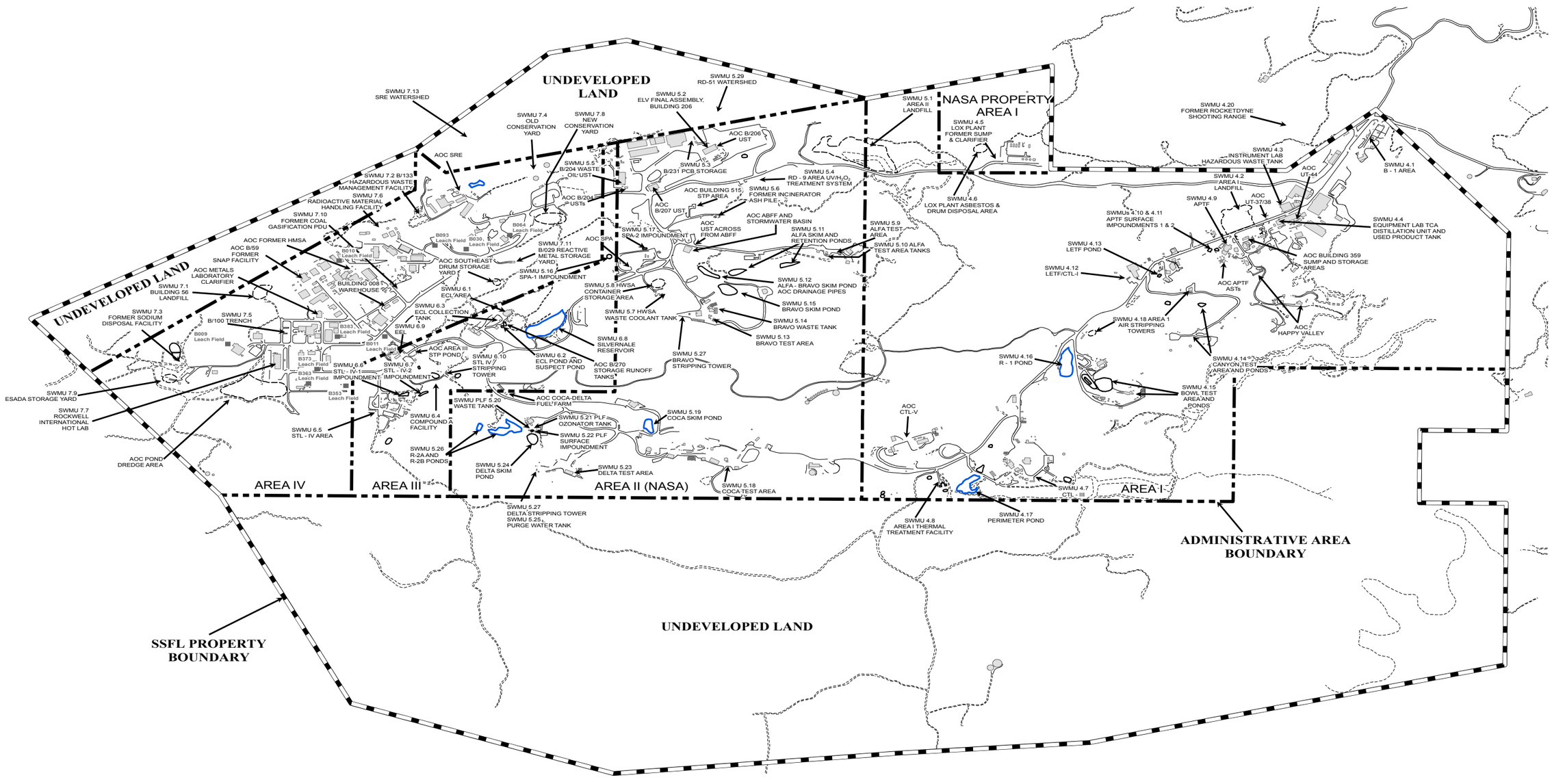
MWH

Santa Susana Field Laboratory (SSFL)
Regional Map

FIGURE
1-4

r:/rock/plots/arcmap/regional_map.mxd

06/24/04



Notes:

1. Pond and landfill boundaries are approximate.
2. Leach Field AOCs associated with other SWMUs are not shown individually on this figure.
3. See Acronym List for definitions of acronyms.

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Santa Susana Field Laboratory (SSFL)
SWMUs and AOCs

FIGURE 1-5

Project/Boeing SSFL RA/MWH_SRAM2005-Rev2/Figure 1-5.mxd

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