University of California, Davis

Site-Wide Risk Assessment Work Plan

LEHR/SCDS Environmental Restoration

MWH
MONTGOMERY WATSON HARZA

March 2002

UNIVERSITY OF CALIFORNIA. DAVIS

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March 6, 2002

Ms. Kathy Setian
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Re: Draft Site-Wide Risk Assessment Work Plan

Dear Ms. Setian:

Attached to this letter are four copies of the UC Davis Draft Site-Wide Risk Assessment Work Plan. As you requested in our December 10, 2001 meeting, we have attached copies for you, Techlaw, Dan Stralka and Sonce de Vries.

If you have any questions about the enclosed document, please call me at (530) 752-6041, or write me at the following address:

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Enclosure: Response to Comments - Waste Burial Holes Characterization Report

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SITE-WIDE RISK ASSESSMENT WORK PLAN

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SITE-WIDE RISK ASSESSMENT WORK PLAN
LEHR FACILITY
UC DAVIS, CALIFORNIA

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SITE-WIDE RISK ASSESSMENT WORK PLAN
LEHR FACILITY
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1.0 INTRODUCTION

Montgomery Watson Harza (MWH) has prepared this draft Site-Wide Risk Assessment (SWRA) Work Plan (work plan) on behalf of the University of California, Davis (UC Davis). The purpose of this work plan is to provide the approach and methods for the SWRA to be performed for the former Laboratory for Energy-Related Health Research/South Campus Disposal Site (LEHR/SCDS or Site), located at UC Davis, Davis, California (Figure 1).

The LEHR/SCDS was placed on the U.S. Environmental Protection Agency (US EPA) National Priority List on May 31, 1994. The US EPA and UC Davis signed an *Administrative Order on Consent for Removal Action and Remedial Investigation/Feasibility Study* (AOC) in September 1999 (US EPA, 1999a). The AOC states that UC Davis will perform a SWRA, which will integrate information and input from the U.S. Department of Energy (DOE) operable units (OUs) and from UC Davis OUs at LEHR/SCDS, including any required risk assessment input provided by DOE.

This document was prepared in accordance with the statutory requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA); the regulatory requirements of the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) (40 Code of Federal Regulations [CFR] 300.430 [US EPA, 1990a]); and the US EPA guidance document *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (US EPA, 1988).

1.1 PROJECT GOALS

The purpose of the SWRA is to fulfill the AOC requirements, and to perform a baseline human health and ecological risk assessment for the LEHR/SCDS Site. The results of the SWRA will provide risk managers an understanding of the potential human health and ecological risks associated with background and additional risks associated with past Site activities. The overall goal of the LEHR/SCDS Environmental Restoration is to identify and mitigate impacted media (*e.g.*, soil, sediment, and groundwater) such that post-remediation (residual) chemical concentrations in Site media are: (1) either representative of background conditions; or (2) do not pose an unacceptable risk to human health and the environment under current and anticipated future land use conditions. The SWRA will evaluate risks to human health and the environment for each of the DOE and UC Davis OUs identified at the Site, as well as for the Site as a whole. The OU boundaries defined in the AOC are shown in Figure 2.

1.1.1 Protection of Human Health

The evaluation of risk to human health will be based on estimated theoretical upper-bound cancer risks and non-cancer hazard indices (HIs) using standard US EPA methods. If the carcinogenic risks or non-

cancer HIs exceed US EPA's acceptable levels, then remedial action alternatives must be considered. The acceptable risk levels for the protection of human health are:

1. For non-carcinogenic compounds, concentrations to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating factors related to uncertainty; and
2. For known or suspected carcinogens, concentrations that represent an excess theoretical upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response. The 10^{-6} risk level is typically applied by regulatory agencies as the point of departure for determining remediation goals.

Where the sample size is large enough, the exposure point concentration used to evaluate the risk to human health will be the 95 percent upper confidence limit (UCL) on the arithmetic mean, as appropriate, for all media.

1.1.2 Protection of Ecological Receptors

The evaluation of risks to ecological receptors will be based on a comparison of Site data to ecological hazard quotients (HQs) and ecological relevance. If ecological risks exceed acceptable levels, remedial action alternatives should be considered to reduce potential risks associated with contaminants that exceed the applicable target levels. The acceptable risk levels for the protection of ecological receptors are:

1. For special status species, chemical concentrations to which individuals may be exposed to without adverse effects on growth, survival and/or reproductive success during a lifetime of exposure; and
2. For common species, concentrations to which common species populations may be exposed to without adverse effects on reproductive success during a lifetime of exposure

As above for the protection of human health, where the sample size is large enough, the exposure point concentration used to estimate the risk to human health will be the 95 percent UCL, as appropriate, for all media.

1.2 SITE-WIDE RISK ASSESSMENT PROCESS/METHODOLOGY

The SWRA will follow the basic procedures outlined in US EPA's *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (US EPA, 1989) and *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (US EPA, 1997a). Other guidance documents that will be consulted as needed include:

- US EPA. 1991a. *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual. Supplemental Guidance*;
- US EPA. 1992a. *Guidelines for Exposure Assessment*;

- US EPA. 1992b. *Supplemental Guidance to RAGS: Calculating the Concentration Term*;
- US EPA, 1998a. *Guidelines for Ecological Risk Assessment*; and
- California Environmental Protection Agency (Cal/EPA), 1992. *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities.*

Consistent with US EPA (1999b) and the National Research Council (1994) guidance, the SWRA will follow a "tiered" (or iterative) approach. The tiered approach is practical and logical, and enables the process to focus on specific objectives, such as identifying potential areas of concern that need further investigation and/or remediation and to eliminate from further consideration areas that do not pose a potential risk to human health or the environment. Figure 3 provides a diagram of the risk assessment process for the proposed LEHR/SCDS SWRA.

1.3 PURPOSE OF WORK PLAN

The objective of this work plan is to streamline the risk assessment process by obtaining regulatory approval on the risk assessment approach and methods. This work plan describes and documents the methods and procedures to be employed in the following components of the SWRA:

1. The Data Quality Objectives (DQOs): The DQO evaluation/identification process ensures the generation of adequate representative data and valid interpretations for risk assessment purposes.
2. The data evaluation methods: These are the methods used to determine exposure point concentrations.
3. Tiered risk assessment methods: The methodologies to be followed in performing the tiered risk assessment, including assessment of potential risks to human health and ecological receptors from all relevant pathways.

These components are applicable to each area of concern at the Site (see Figure 2). Area-specific conditions (*e.g.*, chemical data, site-specific parameters, etc.), which vary across the Site, will be factored into these general methods when applied to a given area.

1.4 WORK PLAN ORGANIZATION

Following this introductory section, this SWRA work plan provides the following:

Section 2.0 A discussion of the conceptual site model (CSM) and relevant historical land use conditions, site characterization data, future anticipated land uses, and potential exposure pathways.

Section 3.0 A summary of the project objectives, DQO development process, and presentation of the DQOs and agency decision rules to be relied upon.

Section 4.0 A description of all of the data evaluation methods that will be used to assure that adequate and representative data are used in the SWRA.

Section 5.0 A summary of the tiered risk assessment process that will be followed to assess potential impacts on human health and ecological receptors.

Section 6.0 A description of the report outline, project milestones and a schedule for the completion of the draft SWRA.

Section 7.0 References.

2.0 CONCEPTUAL SITE MODEL

The CSM is a tool used in risk assessment to describe relationships between chemicals and potentially exposed human and/or ecological receptor populations, thereby delineating the relationships between the suspected sources of chemicals identified at the Site, the mechanisms by which the chemicals might be released and transported in the environment, and the means by which the receptors could come in contact with the chemicals. The CSM provides a basis for defining DQOs and developing exposure scenarios.

While the current land use is a research facility, the CSM takes into account future hypothetical land-uses. For example, the CSM conservatively includes future residential development of the site, even though such use is considered unlikely and may be prohibited by deed restrictions. The CSMs presented herein were developed to assist identification of outstanding chemical data requirements for the Remedial Investigation (RI) and the SWRA. Thus, the CSMs are general but conservative in scope. All potential transfer pathways are included in the current CSM even if those pathways are unlikely to exist. For example, based on historical data, the surface soil covering the waste disposal areas is not impacted by hazardous constituents. However, for the purpose of the CSM, primary and secondary transfer pathways related to surface soil are included. For individual areas within the Site, individual CSMs will be developed and provided within the SWRA. The human health and ecological CSMs for the Site are presented in Figures 4 and 5.

2.1 PHYSICAL SETTING

Presented below is a summary of the Site, including a description of the physical setting.

2.1.1 Site Features

The Site is located in a rural area in the Sacramento Valley (Figure 1) and is currently used for research activities associated with UC Davis' Institute for Toxicology and Environmental Health (ITEH). ITEH consists of office buildings, a laboratory, and animal-handling facilities within a 15-acre fenced area. Putah Creek lies directly adjacent to the southern border of the Site formed by the Putah Creek levee.

2.1.2 Climate

The climate of the Sacramento Valley is temperate with mild winters and warm summers. The mean winter and summer temperatures are 46.9°F and 73°F, respectively. The average daily minimum in winter is 37.6°F and the average daily maximum in summer is 92.3°F. The mean annual precipitation is approximately 17 inches per year.

2.1.3 Hydrogeologic Setting

The LEHR/SCDS and surrounding area are located on the geomorphic unit termed "low-alluvial plains and fans" (California Department of Water Resources [DWR], 1978). This surface represents distal portions of alluvial fan deposits known as the Putah Creek Fan (Mann, 1992). Sediments that form these

alluvial fan deposits consist primarily of silts and clays with coarse-grained sediments occurring locally. The age of these deposits ranges from late Pleistocene to Recent. The thickness of the alluvial fan deposits is reported to be between 140 feet (Mann, 1992) and 180 feet (DWR, 1978).

The Putah Creek Fan is in erosional contact with the underlying Plio-Pleistocene Tehama Formation (Mann, 1992). The Tehama Formation consists of fine-grained sands and silts with discontinuous lenses of coarse sand and gravels.

2.1.4 Subsurface Stratigraphy

Five hydrostratigraphic units (HSUs) have been defined based on drilling and geophysical surveys completed since 1987. In descending order, the units are HSU-1, HSU-2, HSU-3, HSU-4 and an unnamed aquitard.

HSU-1 and HSU-2 form the upper and lower units, respectively, of the Putah Creek Fan and HSU-3, HSU-4, and the unnamed aquitard form the upper, intermediate, and lower units, respectively of the Tehama Formation. HSU-1 is composed predominantly of fine-grained silts and clays. HSU-2 is composed of the coarse sand and gravel deposits and is a potential source of water. HSU-3 is a thick sequence of silts and clays belonging to the Tehama Formation. There is low permeability in HSU-3. The clays and silt of the unnamed aquitard below HSU-4 are similar to those in HSU-3. HSU-4 is composed predominately of coarse-grained sandy gravel. HSU-4 is used as a source of water regionally.

2.1.5 Surface Water/Wetlands

Surface water features associated with the site include ponded water (on-site) and Putah Creek (off-site). Based on site observations, on-site standing water is storm-related and water percolates or evaporates before spring (personal communicationBold, 2002). Due to its short-lived nature, on-site surface water is not expected to be a relevant exposure pathway, but will be discussed further in the SWRA,

The "South Fork" of the Putah Creek (the present-day channel forming the southern border of the LEHR site) was created in 1872 via dredging in order to divert the original creek away from the City of Davis. (Moyle, 2002) This engineered channel is straighter than the original creek and over the years has cut a pathway 10-20 feet deeper than the original creek bed. Flow in Putah Creek is regulated by releases from Monticello Dam at Lake Berryessa and from the Putah Diversion Dam, located about 18 and 14 miles west of the Site, respectively.

In May 2000 a settlement was reached that requires permanent flows designated for environmental purposes to continue in 23 miles of lower Putah Creek as a result of a lawsuit brought by Putah Creek Council, UC Davis, the City of Davis vs. Solano Irrigation District. In the reach bordering the Site, these newly required flows are supplemented by the perennial discharge from the UC Davis Wastewater Treatment Plant. In the vicinity of the LEHR site, Putah Creek is a losing stream (Dames & Moore,

1993). Therefore, Putah Creek water may impact shallow groundwater beneath the Site, but groundwater does not impact Putah Creek. This feature will be discussed further in the SWRA.

2.1.6 Biological Resources

Biological resources will be described in the SWRA in a manner consistent with US EPA guidance (*Briefing the BTAG: Initial Description of Setting, History and Ecology of a Site,* US EPA, 1992c). Pertinent biological information will include a list of ecological resources (habitats, wildlife) located in the vicinity of the LEHR/SCDS. Primary sources of biological resource information will be:

- UC Davis' Resource Management and Planning Department;
- Peer-reviewed studies of Putah Creek wildlife and fisheries available in the literature;
- Interviews with researchers who have performed or are performing studies on Putah Creek and the adjacent UC Davis property; and
- *Draft Final Ecological Scoping Assessment for DOE Areas* (Weiss, 1997).

The biological description provided in the Tier 1 Screening Level Ecological Risk Assessment (SLERA) and Tier 2 Baseline ERA will emphasize habitats, plants and animals whose presence has been verified by field observation. Lists from the California Department of Fish and Game's Natural Diversity Database and others have been presented elsewhere (Weiss, 1997) and will be incorporated by reference only.

2.2 HISTORICAL SITE OPERATIONS/POTENTIAL SOURCES OF CONSTITUENTS OF POTENTIAL CONCERN

This section presents a brief historical description of the Site, including activities associated with environmental issues associated with the identified areas of concern.

2.2.1 Historical Operations

The Atomic Energy Commission (AEC) first sponsored radiological studies on laboratory animals at UC Davis in the early 1950s. Through the mid-1980's, research at the Site focused on the health effects from chronic exposure to radionuclides, primarily strontium-90 and radium-226, using beagles to simulate radiation effects on humans. Other related research was conducted at the Site concurrent with these long-term studies. In the early 1970s, a Cobalt-60 irradiator facility was constructed on the Site to study the effects of chronic exposure to gamma radiation in beagles.

A campus landfill, used from the 1940s until the late-1960s, consists of three separate landfill units that operated at different times. Burial holes and disposal trenches were used by DOE and UC Davis to dispose of laboratory equipment, chemicals, and low-level radioactive material until 1974.

2.2.2 OUs/Areas of Concern

The OUs/areas of concern include landfills, disposal trenches, former experimental research facilities, surface water, storm water, and groundwater throughout the Site.

A brief description of each of the OUs/areas of concern is given below.

2.2.2.1 Landfill Unit No. 1

Landfill Unit No. 1 is the oldest of the three landfills and is reported to have operated in the 1940s and 1950s. General campus wastes, possibly including chemical wastes, appear to have been disposed at Landfill Unit No. 1. Sludge from the adjacent sewage treatment plant was reportedly disposed in this landfill unit (DOE, 1988).

2.2.2.2 Landfill Unit No. 2

Landfill Unit No. 2 was operated from 1956 to 1967 and consisted of 12 east-west disposal pits that are partially covered by the Eastern Dog Pens and two geriatrics buildings. Waste disposed of in Landfill Unit No. 2 consisted of general refuse, animal parts, and laboratory chemicals. Landfill Unit No. 2 and the adjacent area is the source of chloroform and volatile organic compounds (VOCs) to groundwater.

2.2.2.3 Landfill Unit No. 3

Landfill Unit No. 3 was operated from 1963 to 1967. Waste was placed in two large, pit-like excavations and covered with a soil cap. Waste included general municipal and campus waste, construction debris, and minor quantities of laboratory waste.

2.2.2.4 Waste Burial Holes

The Waste Burial Holes were used to dispose of waste from 1956 to 1974. Low-level radiological samples and animal remains along with laboratory chemicals were disposed of in these holes. According to the records, the base of each burial pit was approximately 10 feet below ground surface (bgs). In general, the waste consisted of vials, syringes, laboratory glassware, and animal carcasses. After disposal, holes were covered with a layer of native silty fill material.

2.2.2.5 Eastern Trenches

The Eastern Trenches consist of five to seven north-south trending trenches and four to six east-west trending trenches. The trenches were used for waste disposal of general laboratory chemicals, pesticides and dog pen waste. The trenches were operational from 1957 to 1965.

2.2.2.6 Southern Trenches

The Southern Trenches consist of two east-west trending, 250-foot-long trenches. The waste disposed of consisted of animal remains, manure and gravel. The trenches were operated from 1957 to 1965.

2.2.2.7 HSU-1/HSU-2

HSU-1 and HSU-2 are the upper and lower units, respectively, of the Putah Creek Fan. HSU-1 is not a productive water bearing zone and HSU-1 is not currently utilized for domestic or irrigation purposes, while HSU-2 is a potential water source for the region.

Groundwater impacts occur primarily from unlined disposal facilities on-Site to HSU-1. Dissolved constituents in HSU-1 are constrained laterally by the fine-grained HSU-1 aquifer material. Constituents in HSU-1 can be transported in the vertical direction to HSU-2, where lateral conductivity is much higher than in HSU-1.

2.2.2.8 HSU-4

HSU-4 is a lower unit belonging to the Tehama Formation and is also a potential regional source of water. Impacted groundwater occurs primarily in the immediate vicinity of an abandoned irrigation well 22-N that served as a conduit between HSU-2 and HSU-4 prior to 1999. In 1999, this irrigation well was abandoned, and constituent concentrations in HSU-4 have declined dramatically since this well was abandoned.

2.2.2.9 Putah Creek

The South Fork of Putah Creek may have potentially received some limited storm water discharges from the Site. The potential releases of site constituents in storm water and the proximity to the Site make Putah Creek an area of concern. The potential impacts to Putah Creek from storm water runoff are limited because wastes at the LEHR/SCDS were buried, and covered with clean soil.

2.2.2.10 Southwest Trenches

Between the late 1950s and early to mid-1970s, LEHR-generated low-level radioactive waste, fecal material, and laboratory wastes were reportedly disposed in shallow pits and trenches at the Southwest Trenches area (Dames & Moore, 1993). Disposal practices consisted of excavating a trench and placing laboratory waste along with gravel and soil in the trenches. The trenches were then backfilled with native soil. In addition, chlordane was apparently either used or stored in the southwest corner of the area.

2.2.2.11 Radium/Strontium Treatment Area

Animal wastes containing primarily strontium-90 (Sr-90) and radium-226 (Ra-226) were treated using two primary systems. The Ra-226 Treatment System consisted of a single subsurface concrete tank with a distribution tank feeding three 40-feet deep dry wells and two leach fields.

The Sr-90 Treatment System consisted of a series of nine interconnected "Imhoff" tanks (Tanks A through I), and a leach field (Weiss, 2000). A major component of the Imhoff treatment system was the extraction of Sr-90 through a series of ion exchange columns before effluent wastewater was discharged to the leach field. The tanks were concrete and coated with a plastic material. In 1962, Building H-322

was built over the original leach field; therefore, a second leach field was constructed to replace the original field.

2.2.2.12 Western and Eastern Dog Pens

The Western and Eastern Dog Pens were used from 1958 through the mid-1980s to house beagles that were subjects of research on the health effects of chronic radiation (primarily strontium-90 and radium-226) exposure. Pesticides used for flea control and excreta containing residual radionuclides have potentially impacted the dog pen areas.

2.2.2.13 DOE Disposal Box

The DOE Disposal Box was actually a small disposal trench with steel reinforced shoring, and not a box or dumpster as originally thought (PNNL, 1996). This trench contained laboratory waste, including both empty and approximately 70 liquid filled vials. The results of testing these materials confirmed the presence of low level radiologic chemicals in this trench.

2.2.2.14 Domestic Septic Systems

A typical Domestic Septic System (DSS) consists of a domestic septic tank (DST), leach field, and interconnecting piping. The locations of seven DSTs are shown on Figure 2. Liquid wastes and sewage were discharged to six of the seven DSTs (DSTs 1 through 6) from 1958 until the Site's connection to the UC Davis Wastewater Treatment Plant in 1971. DST 7 was installed adjacent to the Cobalt-60 (Co-60) Field to receive wastes from the irradiator building. This tank was reportedly never used, and was abandoned and backfilled with sand.

2.2.2.15 Undefined On-Site Areas

For purposes of the SWRA, on-site areas that are not included in any of the previously discussed OUs/areas of concern will be considered as a separate area of concern. Samples collected from these areas will be evaluated separately in the SWRA as an individual exposure area.

2.2.3 Removal Actions

UC Davis began planning a groundwater interim removal action (IRA) 1996. The engineering evaluation/cost analysis (EE/CA) for the groundwater IRA was completed in early 1997. The groundwater IRA began operation in May 1998, and is continuing to operate. UC Davis initiated a solid waste IRA in the Waste Burial Holes area in early 1999 and was completed in early 2000. DOE completed removal actions for the DOE Disposal Box in 1996 (PNNL, 1996), and initiated plans for removal actions for the Southwest Trenches, Ra/Sr Treatment Area, and Domestic Septic Systems in 1998. The Western Dog Pens removal action was initiated in 1999. The DOE has completed their removal actions for the Southwest Trenches (Weiss, 2001a), the Ra/Sr Treatment Area (Weiss, 2001b) and the Western Dog Pens (Weiss, 2002), and is in the process of completing the removal action for the Domestic Septic Systems.

2.3 EXTENT OF IMPACTS

Numerous investigations have been conducted at the Site to characterize the contamination, and are briefly summarized below.

2.3.1 Soil Investigations

Numerous soil investigations have been conducted from 1987 to the present at each area of concern. UC Davis and DOE have collected soils data as part of their removal actions as well. The DOE is preparing their Draft Remedial Investigation, which will summarize the soils data in the DOE areas due in March 2002. UC Davis will summarize the soil and water investigations of UC Davis areas in the Remedial Investigation/Feasibility Study Work Plan Addendum due in early April 2002.

2.3.2 Groundwater Investigations

Groundwater monitoring at the LEHR/SCDS was initiated in 1987 (Wahler, 1988) and subsequently formalized on a quarterly basis in 1990 as part of the Phase II Investigation (Dames & Moore, 1993). Changes in the sampling program were implemented beginning with the fall 1999. Specifics concerning the sampling program can be found in the 2000 Annual Water Monitoring Report (URS, 2001).

2.3.3 Other Media Investigations

Surface water and storm water monitoring was initiated in 1990 and continues to the present. Currently, there are three monitoring locations for surface water and three monitoring locations for storm water. In addition, a study of the sediment and bioaccumulation in fish in Putah Creek was conducted (ATSDR, 1998 and Slotten et al., 1999).

2.4 CONTAMINANT MIGRATION MECHANISMS

Ten potential migration mechanisms have been identified that could theoretically transport contaminant mass from a LEHR/SCDS source to a potential receptor. Evidence as to whether these mechanisms might result in complete exposure pathways is presented and discussed in the following sections, if known. In most cases, the evidence of chemical transport is in the form of chemical test results at the point of environmental contact (where the receptor might contact the chemical). However, in some cases, chemical fate and transport modeling would be necessary to determine potential magnitude and whether or not chemicals are being transported from source to receptor. Fate and transport modeling for these inter-media migration mechanisms are discussed in Section 5.3.

Some of these mechanisms discussed below are more significant than others, but are included herein for completeness. The CSMs for the Tier 1 risk assessments, and the refined CSMs for Tier 2 risk assessments, will show whether are not these pathways are complete and significant for each individual OU.

2.4.1 Migration from Soils to Groundwater

Contaminants that are soluble in water and have a low affinity for adsorption to soil particles may leach, infiltrate or percolate into groundwater. Measured concentrations of chemicals are available for on-site soil, on-site groundwater and off-site groundwater. This pathway is considered to be potentially complete for HSU-1/2 as evidenced by the presence of chemicals in HSU-1/2. The on-site workers and off-site residents are not currently exposed by this pathway. The pathway is potentially complete for hypothetical on-site residents. The pathway is also potentially complete for off-site residents only to the degree of the potential for chemicals to reach groundwater that is available to off-site residents. This pathway is further discussed in Section 5.3.6.

2.4.2 Migration from Groundwater to Surface Soil

Potential contaminants in off-site groundwater could be pumped to the surface by farmers and applied to the surface soil of agricultural fields. Thus, the contribution of groundwater to soil chemical concentration would require modeling to assess. However, off-site migration of chemicals in groundwater have been addressed by the on-going IRA, therefore; this pathway is considered incomplete.

2.4.3 Migration from Groundwater to Surface Water

Contaminants that reach groundwater may be transported to surface waters if the groundwater has a surface discharge point (*e.g.* a seep or spring). As described in Section 2.1.5, Putah Creek is a losing stream and groundwater does not have a surface discharge point. Therefore, this pathway is considered incomplete.

2.4.4 Migration from Groundwater to Air

Volatile contaminants may be released to outside air and transported by the wind. Also, volatile contaminants may be released to the air within an animal's burrow. For Landfill Unit No. 2, flux data are available to estimate on-site exposures to VOCs originating from groundwater to air. The flux data shows that migration of VOCs from the subsurface is a complete pathway. This is a pathway by which current workers and ecological receptors are possibly exposed.

2.4.5 Migration from Soils to Air

Volatile contaminants may be released to outside air and transported by the wind. Non-volatile contaminants with a moderate to strong adsorption affinity to soils may be transported via wind-borne fugitive dust. Volatile contaminants may be released to the air within an animal's burrow. For Landfill Unit No. 2, flux data are available to estimate on-site volatile chemical exposures from soil to air. The flux data shows that migration of VOCs from the subsurface is a complete pathway. This is a pathway by which current workers and ecological receptors are possibly exposed.

Volatilization of radionuclides will not be assessed in the risk assessment. However, external radiation exposures will be assessed. Estimation of off-site air concentrations will require modeling as discussed in Section 5.3.3.

2.4.6 Storm Water Discharges

Contaminants that are soluble in water and have a low adsorption affinity to soil particles may become dissolved in storm water runoff from the Site and may be discharged to surface water. Contaminants with a strong affinity for soils may be resuspended as sediment load and transported to stream sediments in surface runoff. Storm water monitoring data from LEHR/SCDS and surface water sampling data from Putah Creek are both available. This is considered a complete exposure pathway for current ecological receptors and off-site residents.

2.4.7 Inter-HSU Migration

Under some conditions, contaminants that are soluble in water and have a low adsorption affinity to soil particles may leach, infiltrate or percolate between stratigraphic groundwater units. Chemical data are available for each groundwater HSU. This pathway is considered to be potentially complete for HSU-1/2 as evidenced by the presence of chemicals in HSU-1/2. The pathway is potentially complete for transfer from HSU-2 to HSU-4. The likely source of chloroform currently in HSU-4 was the agricultural well 22N, which has been closed. The inter-HSU migration is potentially complete to hypothetical on-site residents. The pathway is also potentially complete for off-site residents only to the degree of the potential for chemicals that reach groundwater that is available to off-site residents.

2.4.8 Surface Water/Sediment Equilibrium

Contaminants in sediments may partition into pore waters based on their adsorption characteristics and sediment organic carbon levels, thus affording their availability to benthic invertebrates or bottom-dwelling fish. Chemicals in pore water may then become diluted in the water column thereby becoming available to water column-dwelling organisms.

Sediment data are available for estimating exposure to benthic invertebrates. Pore-water concentrations can be estimated using the equilibrium-partitioning model. Storm water monitoring data and surface water sampling data are both available for estimating chemical exposure to Putah Creek surface water. This is considered a complete exposure pathway for current ecological receptors and off-site residents.

2.4.9 Surface Water/Soil Chemical Transfer

Contaminants in surface soil may partition into puddles (transient water bodies), based on their adsorption characteristics and soil organic carbon levels, thus making them available to animals that may use the puddles for bathing, drinking or egg laying. Based on site observations, however, on-site standing water is storm-related and water percolates or evaporates before spring (Bold, 2002). Thus, on-site surface water is not expected to be relevant exposure pathway, but will be evaluated for completeness. No data is

currently available for on-site puddle water, but chemical concentrations in puddle water can be estimated using the equilibrium-partitioning model.

2.4.10 Food-Chain Transfer

Ecological and human receptors may be exposed to contaminants that are capable of biomagnification within the food chain; this indirect (secondary) exposure pathway may involve contaminants initially contained in any environmental media (soil, sediment, surface water, groundwater, and air). There are currently no data to adequately assess food chain transfer of site-related chemicals. Plant and animal tissue concentrations can be modeled, however, and plans for benthic invertebrate sampling in Putah Creek are underway. Current ecological receptors and future human receptors could be exposed through this pathway, therefore, this is pathway is considered complete.

2.5 POTENTIAL HUMAN AND ECOLOGICAL EXPOSURE SCENARIOS

The following section summarizes land use and the human and ecological exposure scenarios which will be assessed.

2.5.1 Current and Future Land Use

US EPA risk assessment guidance (US EPA, 1989) states that potential future land use should be considered in addition to current land use when evaluating the potential for human and/or ecological exposure at a site. Current land use was described in Section 2.1.1. The anticipated future land use for the Site is the same; a research facility. Although it is unlikely that land use at the Site will change, assessment of the Site under a hypothetical on-site residential land-use scenario will be included at the request of US EPA. Workers could also experience short-term exposure during construction activities for future development of the Site, if such development were to occur.

2.5.2 Potential Human Receptors and Exposure Pathways

A human health CSM will be developed for each of the 15 areas of concern (Section 2.2.2). Currently, and for the foreseeable future, access to the Site property is restricted during non-working hours. Adults involved in research activities, as well as construction and maintenance workers can move about the Site during working hours. Children may enter the Site under the supervision of adults during working hours; however, exposure to children under these conditions is likely to be limited. Therefore, potential human receptors include an on-site outdoor researcher, on-site indoor researcher, and on-site construction worker.

Farmland abuts three sides of the property. Farmland to the east and south is privately owned. UC Davis farmland and research facilities are located to the west and north of the Site. For the purpose of this initial CSM, potential human receptors include an off-site farm resident (east) and off-site farm resident (south). A farm resident living to the west of the property was not considered because consideration of the eastern and southern dwelling residents maximizes assumed exposures based on the predominant groundwater

and wind flow directions; consideration of the southern and eastern dwelling resident should be protective of the western dwelling resident. A researcher located to the north of the property is not considered relevant because potential exposure is considerably less than for on-site researchers.

Residences do not exist and are not planned for the Site property. A deed restriction prohibiting residential development is anticipated. However, at the request of US EPA and to evaluate the possibility of future unrestricted use of the site, a hypothetical on-site resident will be included.

2.5.3 Potential Ecological Receptors and Exposure Pathways

An ecological CSM will be developed for each area of concern (Section 2.2.2). The ecological CSM integrates the contaminant migration mechanisms (Section 2.4) with biological information (Section 2.1.6) to identify potentially complete exposure pathways between contaminants and ecological guilds (Tier 1 Screening Level Ecological Risk Assessment or SLERA) and/or specific receptors (Tier 2 Baseline ERA). The Tier 1 SLERA will identify all potentially complete pathways and exposure routes (*e.g.* inhalation, ingestion, etc.) within a site-specific food web, regardless of the magnitude of their contribution to the chemical dose. However, only those pathways that are complete, and expected to contribute substantially to exposures by ecologically important receptors, will be carried forward for quantitative analysis in the Tier 2 Baseline ERA.

3.0 DATA QUALITY OBJECTIVES

This section summarizes the DQOs that will be applied in the risk assessment process for the Site. Quality objectives are essential to ensuring that collected data are sufficient to meet the intended project goals. Quality objectives are pre-established goals or "bench marks" that are used to monitor and assess the progress of the project and the quality of the work performed on the project. Following the guidance presented in *Guidance for the Data Quality Objective Process* (US EPA, 2000a, hereinafter "DQO Guidance"), and as summarized below, the general seven step framework was followed in developing the DQOs for the Site project.

3.1 STATE THE PROBLEM (STEP 1)

The purpose of this step is to clearly and concisely state the problem for which the assessment has been initiated, to ensure that the focus of the assessment is unambiguous. It is important that collected data be of sufficient quantity and quality such that a risk assessment can be prepared that suitably characterizes the human health and ecological risks at the Site. As implied, these risks will be evaluated to assess whether a threat to human health and the environment exists at the Site. If suitable and adequate data has not been collected, additional collection/analyses may be required in order to assure that proper data are available for risk assessment. This iterative process will be followed until a final data set has been collected that meets the DQOs presented in this section, and therefore allows for completion of a risk assessment. Worded otherwise, the null hypothesis is that

site conditions exist that could pose an unacceptable risk to human health and the environment.

The goal of the sample collection and risk assessment is to collect and analyze sufficient data to reject the null hypothesis.

3.2 IDENTIFY THE DECISION (STEP 2)

The purpose of this step is to define the Principal Study Questions (PSQs) needing to be resolved in order to address the problem, and to identify alternative actions that may be taken, depending on the answer to the PSQs. The PSQ is whether conditions at the Site meet acceptable human-health and ecological risk levels. Prior to this, one must first determine whether sufficient data have been collected to perform a quantitative evaluation of the risks posed to potential receptors at the Site. The concept of sufficiency incorporates:

1. An analytical program that includes all relevant chemicals that have the potential to affect risk calculations; and
2. A spatial density of sampling points that provides confidence that the Site has been characterized and areas of local exceedance requiring remediation have not been missed.

3.3 INPUT TO THE DECISIONS (STEP 3)

The purpose of this step is to identify the types of data needed to resolve the PSQs identified in Step 2. As summarized below, the types of data anticipated to be needed fall into the following broad classes: chemical quality (soil, groundwater, surface water, sediments, biota), and toxicology/exposure parameters.

Data Type	Description
Chemical:	The risk assessment data pool for each medium shall serve as the primary inputs to the PSQ. These data represent a broad suite of analyses, in which standard analyte lists have been measured. The detection limits for the selected analytical methods are adequately low such that chemical concentrations with the potential to pose an unacceptable threat to human health and the environment should not be missed. The risk assessment data pool will be reviewed with respect to data usability and adequacy, respectively, and the results will be presented to the risk assessors prior to use.
Toxicology/Exposure Parameters	Toxicological properties of chemicals evaluated in the risk assessment will be obtained from US EPA, Oak Ridge National Laboratory (ORNL) or other applicable sources. As discussed in Sections 5.4 and 5.5, the exposure parameters used in the risk assessment will be conservative default values based on US EPA or other applicable guidance.

3.4 DEFINE THE STUDY BOUNDARIES (STEP 4)

In this Step, the target populations of interest are identified, as well as the spatial and temporal features of that population that are pertinent for the risk assessment.

Spatial Boundaries:	In this case, the "target population" refers to the universe of environmental samples that constitute the geographic area of interest (the Site, as defined in Section 1) and are evaluated in the risk characterization. The Site boundaries are as defined in Section 1. Each area of concern will be considered an exposure area. In addition, the Site as a whole will also be considered as an exposure area. The risk assessment and statistical evaluation is designed to fully characterize human health and ecological risks posed by the Site.
Temporal Boundaries:	Current environmental conditions during risk characterization (unless additional remediation is subsequently performed) will be considered reflective of conditions to which all future site receptors will be exposed. Because groundwater is currently being investigated and remedial systems are in place, groundwater conditions are assumed to conservatively reflect future exposures. That is, chemical concentrations measured during the RI (or earlier) should represent the highest concentrations to which future Site receptors could be exposed in groundwater.

3.5 DEVELOP A DECISION RULE (STEP 5)

In this Step, decision rules for the SWRA are developed to guide the risk assessment process for the Site.

Decision	Parameter of Interest
Related to Risk Assessment	
Consideration of populations and relevant exposure pathways	All relevant populations and exposure pathways are to be accounted for in the risk assessment.
Evaluation of potential threat to human health	Predicated on having previously demonstrated data adequacy/usability
Evaluation of potential threat to ecological receptors	Predicated on having previously demonstrated data adequacy/usability

3.6 LIMITS ON DECISION ERRORS (STEP 6)

US EPA's DQO Guidance emphasizes the need to specify tolerable limits on decision errors. As discussed in that guidance, "A decision error occurs when the sample data set misleads you into making the wrong decision and, therefore, taking the wrong response action." The possibility of a decision error is the result of using sample data that are incomplete and never perfect because of factors such as the inherent variability of the population over space and time, sampling design, number of samples, and random/systematic measurement errors introduced during sample collection, handling, preparation, and analysis, data reduction, transmission, and storage.

3.7 OPTIMIZE THE DESIGN FOR OBTAINING DATA (STEP 7)

The tiered risk assessment approach provides opportunities for effective evaluation in an optimal manner. The sampling programs incorporate site-specific features, historical usage, and known chemical occurrence patterns based on historical investigations, as well as the overall project considerations discussed in this DQO section.

4.0 DATA EVALUATION

This section describes the procedures that will be employed to evaluate the acceptability of data for use in the risk assessment. Overall quality of sample results is a function of proper sample management. Management of samples begins at the time of collection and continues throughout the analysis process. Standard Operating Procedures (SOPs) presented in other Site documents have been followed to ensure samples are collected and managed properly and consistently and to optimize the likelihood that the resultant data will be valid and representative.

4.1 DETERMINATION OF BACKGROUND CONCENTRATIONS

Some chemicals at the Site, particularly metals and radionuclides, are known to be naturally-occurring constituents of soils and groundwater. A risk assessment should consider the contribution of background concentrations to overall site risks, as differentiated from those concentrations associated with historic Site operations or regional anthropogenic conditions. Therefore, it is necessary to establish site-specific background conditions to support the risk assessment.

Background soil concentrations of target metals and radionuclides considered representative of the Site have been evaluated (Weiss, 1998). Background groundwater concentrations are being addressed as part of the UC Davis Remedial Investigation. Once background groundwater levels have been established and agreed to by the RPMs, these levels will be incorporated into the risk assessment.

Regional anthropogenic use of chemicals, unrelated to Site operations can also contribute to Site soil and groundwater chemical concentrations. The existing background data has shown that nitrates and pesticides are present in soils (Weiss, 1998) and groundwater (URS, 2001) upgradient and adjacent to LEHR from regional agricultural use of pesticides and fertilizers. Separating the Site related and non-Site related concentrations of pesticides and nitrates may be complex. Therefore, the Tier 1 screening assessment will assume that soil and groundwater background for pesticides and nitrates is zero. Tier 2 and 3 risk assessments will consider ambient or regional concentrations of pesticides and nitrates supported by background soils and groundwater data as discussed in Section 5.7.

4.2 DATA USABILITY EVALUATION PROCEDURES

Prior to performing the risk assessment, one must first determine whether: (1) the data are of a quality that is appropriate for use in risk assessment, and (2) sufficient data have been collected to perform a quantitative evaluation of the risks posed to potential receptors within each area. This section summarizes the procedures to make this determination, including QA/QC review of the data quality relative to the project-specific DQOs, incorporation of background conditions, and the statistical techniques that will be used to determine data adequacy.

4.2.1 Data Reduction, Validation, and Reporting

The pool of data to be used in the risk assessment will be subjected to the data review procedures described in this section, subject to the DQOs identified in Section 3.0. Only the data passing this evaluation will be considered in the risk assessment. The objective of data reduction, validation, and reporting procedures is to document the history of a sampling or measurement activity to ensure that data containing typographical errors or miscalculated results are not used for decision-making. A standardized system has been developed for reducing both raw field and laboratory data, for validating data, and for reporting analytical results in a consistent, reproducible format.

4.2.2 Evaluation of Background Data

The ranges of detections for the background data will be reviewed and outliers will be removed from the data pool. Descriptive statistics and confidence intervals for the mean of each sub-population will be computed. Upon establishing the background data pool, the risks associated with background conditions will be calculated and factored into the risk calculations using the techniques presented in Section 5.0.

4.2.3 Data Usability Review

Prior to completing the risk assessment, the data pool will be subjected to a rigorous scrutiny regarding its usability and adequacy. This section describes the procedures used to evaluate data usability and the results of that evaluation. According to the *Guidance for Data Usability in Risk Assessment, Final* (US EPA, 1992d; hereinafter "US EPA Data Usability Guidance"), there are six principal criteria by which data are determined usable for risk assessment. The six criteria are:

- Reports to the risk assessor;
- Documentation;
- Data sources;
- Analytical methods and detection limits;
- Data review; and
- Data quality indicators, which include completeness, comparability, representativeness, precision, and accuracy.

4.2.3.1 Reports to the Risk Assessor

US EPA's guidance recommends that preliminary data reports be reviewed to identify sampling or analytical problems and to ensure sufficiency of information provided to the risk assessor. The laboratory reports will be reviewed to confirm the validity of the data using procedures defined in the Project Work Plan, the *US EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (US EPA, 1999c), and the *US EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (US EPA, 1994) (hereinafter "National Functional Guidelines"). Data qualifiers will be presented in the data tables for risk assessment.

4.2.3.2 Documentation

US EPA's Data Usability Guidance recommends that data collection and analysis procedures be accurately documented to substantiate how the samples were analyzed, conclusions derived from the data, and the reliability of the reported analytical data. Documentation can be used to evaluate completeness, comparability, representativeness, precision, and accuracy of a combination of data sets. Types of documentation may include project work plans, QA/QC reviews, field and analytical records, and COC records. Consistent with this guidance, the LEHR/SCDS data have been collected following standardized procedures consistent with EPA quality assurance guidelines for conducting RI/FS investigations under CERCLA (Dames & Moore, 1994). The data review will include identification and documentation of any significant non-conformances (*e.g.*, those that would affect data usability) during the sampling events or in laboratory records, if any.

4.2.3.3 Data Sources

US EPA's Data Usability Guidance recommends that all data sources intended for use in the risk assessment be identified whether historical or current. All data used for the quantitative risk assessment should have comparable sampling and analytical techniques, have comparable detection limits, have undergone a sufficient review, and should characterize the Site and all potential exposure pathways to receptors.

4.2.3.4 Analytical Methods and Detection Limits

US EPA's Data Usability Guidance recommends that appropriate analytical methods and associated detection limits meet risk assessment requirements for chemicals and have sufficient QC measures to quantify target compound identification and measurement. Whenever possible, methods should not be used if the detection limits are above the relevant concentrations of concern. The analytical methods that have been and will be used in generating the risk assessment data pool are widely-used industry standards with recognized QA/QC procedures.

Based on comparison to screening criteria, the detection limits for the selected methods are appropriate for the project goals. As part of the data review process, the detection limits achieved in the risk assessment data pool will be compared to the relevant concentrations of concern. Detection limits in excess of these levels of concern will be identified, and the associated results will be evaluated to determine whether they could affect the data usability or risk assessment validity.

4.2.3.5 Data Review

US EPA's Data Usability Guidance recommends that all data have a minimum level of review as soon as the data become available. The data review can range from a full review of all Site samples and all Site data to specific key analytes and samples. Consideration must be given to the level of review to be consistent with the data quality requirements. Generally, the more in-depth the review, the more confidence can be placed in the usability of the data. Review and validation of all chemistry data collected

at the Site has been and will be performed in accordance with project requirements to ensure that data are of acceptable quality and that any limitations to data usability are identified prior to making decisions associated with the risk assessment that are based on these data.

4.2.3.6 Data Quality Indicators

The US EPA Data Usability Guidance recommends that data quality indicators be identified during the development of DQOs to provide quantitative measures of the achievement of quality objectives. The data quality indicators (for completeness, comparability, representativeness, precision, and accuracy) that will be used for this project are defined in the Project QAPP.

4.2.3.7 Summary Evaluation

Using the above criteria, an evaluation of the risk assessment data pool will be conducted. The Data Usability Worksheet from the *Risk Assessment Guidance for Superfund Part D* (US EPA, 1998b), which succinctly summarizes the criteria used to identify data usability, will be incorporated into the risk assessment report.

4.2.3.8 Data Adequacy

The concept of data adequacy incorporates: (1) an analytical program that seeks to quantify all relevant Site chemicals that have the potential to affect risk calculations, and (2) a spatial density of sampling points that provides confidence that the Site has been sufficiently characterized and that local exceedance areas requiring remediation have not been missed. The risk assessment analytical program for the Site represents a broad suite of analyses that cover all chemicals that might be reasonably expected to be present at elevated levels at the Site as a result of historical operations.

5.0 RISK ASSESSMENT METHODOLOGY

As presented in Section 1, the SWRA process described herein will consist of three tiers, which is consistent with US EPA (1999b) recommendations. Tier 1 is an initial risk screening, followed by a Tier 2 deterministic point estimate risk assessment, and then a Tier 3 probabilistic risk assessment, if deemed appropriate.

The SWRA will address potential human and ecological risks for each identified exposure area as well as for the Site wide exposure. The exposure areas to be evaluated were identified in Section 2.2.2, and include the UC Davis and DOE OUs, non-OU areas of the Site, and off-site areas.

5.1 TIER 1 SCREENING-LEVEL / SELECTION OF CONSTITUENTS OF POTENTIAL CONCERN FOR RISK ASSESSMENT

In order to ensure that a risk assessment focuses on those substances that contribute the greatest to the overall risk (US EPA, 1989), three procedures will be used to identify the chemical and radiologic constituents of potential concern (COPCs) for quantitative evaluation in the Tier 2 and 3 risk assessments. These procedures include comparison with naturally occurring or background concentrations where applicable, identification of chemicals that are infrequently detected at the Site, and comparison with appropriate human health and ecological risk-based screening concentrations.

5.1.1 Evaluation of Detections Relative to Background Conditions

US EPA (1989) guidance allows for the elimination of COPCs from further quantitative evaluation if detected levels are not significantly elevated above naturally-occurring levels. Background concentrations of target metals and radionuclides considered representative of the Site soils have been evaluated. A comparison of site-related soil concentrations to background levels will be conducted using the existing soils background data set presented in Weiss, 1998. These comparisons will be performed for each exposure area using the Wilcoxon rank sum test. COPCs for the human health and ecological evaluations will include only metals and radionuclides for which measured concentrations in Site soils are greater than background.

The Wilcoxon rank-sum test is a nonparametric alternative to the *t* test. That is, the test is distribution free, thus an assumption of whether the data are normally or lognormally distributed is not necessary. The null hypothesis evaluated is whether two independent samples come from the same population. The computer statistical software program SPSS® (2001), which identifies the Wilcoxon rank-sum test as the Mann-Whitney test, will be used to perform the calculations, with decision errors of alpha = 0.2 and beta = 0.1. The test also examines whether one sample is either larger or smaller than the other sample. Therefore, although a result may indicate a difference between the two samples, a determination as to whether concentrations of a constituent at an exposure area are above or below the background level will also be made. This is accomplished by comparing the corresponding mean rank values. Where the

Wilcoxon rank sum test indicates a difference between the two populations, *and* if the mean rank value for the exposure area is greater than the background value, that constituent is considered to exist above its background value in that particular exposure area.

Also consistent with US EPA guidance, human health background risks associated with COPCs will be separated from site-related risks in order to help identify those risks directly attributable to site-related operations. This will be done by developing total human health risk estimates for a particular exposure area and then subtracting out those risks associated with background conditions. For COPCs determined to exist above their respective background levels, the risks associated with the background levels will be subtracted out, and the remaining risks will be included in the site-related risks. The background concentrations determined in Section 4.1 will be subtracted from COPC concentrations in each exposure area in order to delineate naturally-occurring from potentially site-related concentrations. Therefore, the results of the human health risk assessment will present both the total risk estimates (*i.e.*, background plus site-related) and the incremental risk estimates from potentially site-related chemicals alone.

5.1.2 Frequency of Detection Evaluation

In general, chemicals exhibiting a low frequency of detection (FOD) do not contribute significantly to risk estimates. US EPA (1989) suggests that chemicals with a FOD less than or equal to five percent may be considered for elimination. For the human health risk assessment, US EPA Class A carcinogens will not be eliminated as COPCs based on FOD evaluation. Prior to eliminating a COPC based on the FOD criteria, (1) any elevated detection limits will be addressed and (2) data distributions within exposure areas must be considered (*e.g.*, address potential hot spots). Additionally, the detection of the COPC in all sampled media will be considered. For example, US EPA recommends that a chemical infrequently detected in soil should not be eliminated if it is frequently detected in groundwater and exhibits mobility in soil.

5.1.3 Comparison to Human Health Screening Benchmark Values

For the human health risk assessment, comparison of COPC concentrations with benchmark values allows screening of substances that are well below levels of human health concern. The US EPA Region 9 Preliminary Remediation Goals (PRGs, US EPA, 2000b) for residential exposures to soil and groundwater will be used as Tier 1 benchmark values. The use of the PRGs for this purpose is consistent with US EPA's intended use of the PRGs for site "screening" (US EPA, 2000b).

The available PRG values are generic and based on simplistic, easy to use equations. The same methodologies will be used to calculate residential PRGs for a COPC that is not already listed in the Region 9 PRG table. Similarly, applicable pathway-specific benchmark (or PRG equivalent) values will be derived as needed. For example, because off-site receptors do not have any complete direct soil contact exposure pathways, an inhalation pathway-specific benchmark will also be established for applicable COPCs.

For radionuclides, recent US EPA risk assessment methodologies will be used for the Tier 1 screening assessment (US EPA, 2000c). Exposure equations and parameter values used will be the typical US EPA (2000c) default values.

Maximum detected concentrations of each COPC in each exposure area will be compared to the appropriate benchmark. Tier 1 evaluation for surface soil exposures for the hypothetical on-site residential and researcher receptors will consist of comparing soil data from zero to 0.5 bgs with appropriate benchmark values. Tier 1 evaluation for surface and subsurface soil exposures to construction worker receptors will consist of comparing soil data from zero to three feet bgs with benchmark values. Tier 1 evaluation for groundwater exposures will consist of comparing the maximum groundwater concentrations from the most recent four quarters of monitoring data with benchmark values. If the maximum concentration of a COPC exceeds the corresponding residential PRG, the COPC will be recommended for further evaluation in Tier 2.

5.1.4 Comparison to Ecological Screening Benchmark Values

For the ecological risk assessment, at the request of US EPA (de Vries, 2001), the Tier 1 Screening Level Ecological Risk Assessment (SLERA) toxicity screen to identify chemicals of potential ecological concern (COPECs) will be performed as outlined below. This approach is similar to Concentration Toxicity-Screen methodology presented in RAGS Part I (US EPA 1989, p. 5-23).

5.1.4.1 Ecological Concentration-Toxicity Screen

Maximum concentrations of chemicals detected in each exposure area's surface water, sediment and/or soil will be compared to media-specific screening values.

For sediment and surface water, these values will be obtained from one or more of the following sources:

- Ecotox Thresholds (ET) provided in US EPA's *Eco Update Volume 3 Number 2* (US EPA, 1996a);
- Toxicological benchmarks provided in ORNL's *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment Associated Biota* (ORNL, 1997a);
- *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota* (ORNL, 1996a); and
- *Linkage of Effects to Tissue Residues: Development of A Comprehensive Database for Aquatic Organisms Exposed to Inorganic and Organic Chemicals (Jarvinen and Ankley, 1998).*

For soil, these values will be obtained from one or more of the following sources:

- Mammalian and avian Toxicity Reference Values (TRVs; mg/kg-d) provided in the Navy's *Development of Toxicity Reference Values for Conducting Ecological Risk Assessments at Naval*

Facilities in California (Engineering Field Activity, West, 1998), otherwise known as the US EPA Region IX Biological Technical Advisory Group (BTAG) TRVs;

- Toxicological benchmarks provided in ORNL's *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates.* (ORNL, 1997b);
- Toxicological benchmarks provided in ORNL's *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants.* (ORNL, 1997c); and
- Toxicological benchmarks provided in ORNL's *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Wildlife* (ORNL, 1996b).

The comparison of maximum concentrations with the screening numbers yields a chemical specific ecological HQ as follows:

$$HQ = \frac{Max_I}{SN_I}$$

where:

HQ	=	Hazard quotient (unitless)
Max_I	=	Maximum measured concentration in any media (mg/kg, mg/L)
SN_I	=	Toxicity screening number for guild (mg/kg, mg/L, mg/kg-d)

HQ values less than 1 are generally considered to be indicative of negligible potential biological or ecological effects on biota.

Following the Tier 1 SLERA, UC Davis and EPA will meet to decide whether there is sufficient basis to determine that ecological threats are negligible, or if further analysis is necessary. If the analysis indicates that there is or might be a risk of adverse ecological effects, the ecological risk assessment will advance to a Tier 2 Baseline ERA and the Site understanding derived from the Tier 1 SLERA may be used as justification for elimination of any contaminants or pathways from the Tier 2 Baseline ERA (US EPA, 1997a).

5.1.4.2 Ecological Radionuclide Screening Assessment

DOE's Biota Dose Assessment committee has developed a tiered approach for assessing ecological risks due to radionuclides, which will be followed for this assessment. This approach is contained in the DOE Technical Standard "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE, 2000; http://homer.ornl.gov/oepa/public/bdac) and is designed to be used in evaluations of compliance with the following technical standards:

- Aquatic animals. The absorbed dose to aquatic animals should not exceed 1 rad/day from exposure to radiation or radioactive material releases into the aquatic environment; (

- Terrestrial plants. The absorbed dose to terrestrial plants should not exceed 1 rad/day from exposure to radiation or radioactive material releases into the terrestrial environment; and
- Terrestrial animals. The absorbed dose to terrestrial animals should not exceed 0.1 rad/day from exposure to radiation or radioactive material releases into the terrestrial environment.

DOE has considered proposing these dose standards under proposed 10 CFR 834, but has delayed promulgating these standards until methods have been developed to demonstrate compliance (DOE, 2000).

A summary of DOE's three-step process is provided in Table 1. The Data Assembly and General Screening steps follow the SLERA process described above. After compiling the appropriate data, in the General Screening Step, maximum measured radionuclide concentrations in environmental medium (*i.e.*, water, sediment, and soil) are compared with a set of Biota Concentrations Guides (BCGs; Table 2 and Table 3). Each radionuclide-specific BCG represents the limiting radionuclide concentration in an environmental-medium that would not result in the recommended dose standards for biota to be exceeded. The BCG values are provided in the standard.

Hazard quotients are calculated using the maximum concentration and BCG. Following the calculation of hazard quotients, the fractions of each radionuclide and medium are summed. If the sum of the fractions is less that 1.0, no further action is recommended. If the sum of the fractions is greater than 1.0, further analysis is warranted.

5.2 DETERMINATION OF REPRESENTATIVE EXPOSURE CONCENTRATIONS FOR TIERS 2/3

A representative exposure concentration is a COPC-specific and media-specific concentration value used in each of the risk assessment tiers. In the risk assessment, these exposure concentrations are values incorporated into the exposure assessment equations from which potential baseline human and ecological exposures are calculated. As described below, the methods, rationale, and assumptions employed in deriving these concentration values are consistent with US EPA guidance and reflect site-specific conditions.

5.2.1 Soil

Due to the uncertainty associated with determining the true average concentration of a chemical at a site, the US EPA recommends using the lower of the maximum detected concentration or the 95 percent UCL as the concentration of a chemical to which an individual could be exposed over time (US EPA, 1992b). The 95 percent UCL is defined as the value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95 percent of the time (US EPA, 1992b). The purpose for using the 95 percent UCL is to take into account the different concentrations a person may be exposed to on any given day. Use of the 95 percent UCL concentration (as representative of the average

concentration), instead of the maximum concentration is recommended by the US EPA because "*...average concentration is most representative of the concentration that would be contacted at a site over time...*" (US EPA, 1992b). That is, an individual will not be exposed to a single (*e.g.*, maximum) concentration over the entire duration of exposure. Rather, an individual will be exposed to a range of concentrations that exist at the exposure area, from non-detect to the maximum concentration, over the entire exposure period. Non-detect sampling results will be incorporated to determine the 95 percent UCL soil concentrations at each source area. Based on US EPA (1989) guidance, for COPCs in soil the non-detects for the COPC will be assigned a value of half the detection limit. For uncensored data, such as radionuclide analytical results, the actual reported value will be used, unless the reported value is negative. Negative values will be reported, but will not be used for the calculation of the 95 percent UCL. For the UCL calculation a 0 will be substituted for any reported negative value.

Prior to determining the 95 percent UCL for each COPC in soil, the distribution of each combined dataset for each COPC will be characterized. For each dataset containing less than 50 samples, the Shapiro-Wilk W Test (W-Test) will be used. For each dataset containing greater than 50 samples, the D'Agnostino Test (D-Test) will be performed (Gilbert, 1987). Three different types of distribution profiles are possible: normal distribution, lognormal distribution, and non-parametric (*i.e.*, neither normal nor lognormal).

The measure of central tendency for non-parametric data is the median. The median is determined by ordering the data and identifying the concentration in the middle; therefore, 50 percent of the concentrations are below the median and half are above the median. A cumulative distribution function of the binomial distribution was used to determine the 95 percent UCL (Gilbert, 1987). The calculation of the 95 percent UCL is then based on the size of the sample, the Z1-α value of 1.282, and the standard deviation, which is the square root of np(1-p) where n is the size of the sample and p is the proportion of interest (*i.e.*, the median = 50 percent). The result of the equation is the number of the observation corresponding to the 95 percent UCL concentration. However, because of the number of non-detect sample results typically obtained from a site, the 95 percent UCL concentration for each COPC using this method is very low. In some cases this concentration was at or slightly above the median concentration, which was itself below the calculated average concentration. Therefore, the 95 percent UCL for a normal distribution may be used as a better and more conservative estimator of the upper bound of the average concentrations at each exposure area. For normally distributed data, the 95 percent UCL is calculated using the following equation (US EPA, 1992b; Gilbert 1987):

$$UCL = \mu + t\left(\frac{s}{\sqrt{n}}\right)$$

where:

UCL = 95 percent upper confidence limit

μ	=	mean of the data
t	=	Student-t statistic (from Gilbert, 1987)
s	=	standard deviation of the data
n	=	number of samples

For lognormally distributed data, the following equation is used:

$$UCL = e^{(\mu + 0.5s^2 + sH/\sqrt{n-1})}$$

where:

UCL	=	95 percent upper confidence limit on the arithmetic mean
e	=	constant (base of the natural log, equal to 2.718)
μ	=	mean of the transformed data
s	=	standard deviation of the transformed data
H	=	H-statistic (taken from Gilbert, 1987)
n	=	number of samples

Exposure point concentrations are based on the potential exposure depth for each of the receptors. For on-site research workers and potential residents, which are exposed to surface soils, data from the top 0.5 feet of soil will be used. For construction workers and ecological receptors, which are exposed to on-site surface and sub-surface soils, data from the surface to three feet bgs will be used.

5.2.2 Groundwater

For direct contact with groundwater exposures (hypothetical on-site residents and off-site farm residents to the east only), the representative exposure concentration will be the lower of the maximum detected concentration or the 95 percent UCL as the concentration for each detected chemical. In order to evaluate exposures based on the data that is representative for a given receptor, data collected from the most recent four quarters of groundwater monitoring events will be used. The data from HSU-2 will be used for determination of exposure point concentrations. Based on US EPA (1989) guidance, non-detects for COPCs are assigned a value of one-half the detection limit. For uncensored data, such as radionuclide analytical results, the actual reported value will be used, unless the value is negative, where a 0 will be substituted for the UCL calculation.

5.2.3 Surface Water

For direct contact with surface water exposures, the representative exposure concentration will be the lower of the maximum detected concentration or the 95 percent UCL as the concentration for each detected chemical. Non-detects for COPCs will be assigned a value of one-half the detection limit. For uncensored data, such as radionuclide analytical results, the actual reported value will be used, the actual reported value will be used, unless the value is negative, where a 0 will be substituted for the UCL

calculation. For COPCs that represent a biomagnification concern, are detected in Putah Creek sediment, but have not been detected in surface water, the surface water concentration may need to be estimated to address potential bioaccumulation in surface water fish (see Section 5.3 below).

5.2.4 Air

5.2.4.1 Indoor Air

No VOC sources under existing buildings have been identified. Concentrations of VOCs in soil and groundwater that may infiltrate future buildings that may be constructed at the Site will be estimated using existing data from surface emission isolation flux chamber (flux chamber) measurements previously collected at the Site. The flux chamber is used to measure the emission rates from surfaces emitting VOCs. Use of the flux chamber reduces the need for modeling or estimation, which reduces the uncertainty in the risk assessment. Test data indicate that the flux chamber is a reliable assessment technology. Because the flux chamber measurements have been conducted outdoors on open soil, an "infiltration factor" will be applied to the outdoor flux data to generate data supporting the inhalation of indoor air exposure pathway (Section 5.3.1).

Future potential household use of impacted groundwater may also contribute to indoor air concentrations of VOCs. Indoor air concentrations of VOCs associated with the household use of groundwater will be estimated using a methodology developed by the California Environmental Protection Agency (Cal/EPA) for the CalTOX model (Cal/EPA, 1994) as discussed below.

5.2.4.2 Outdoor Air

Exposure to COPCs bound to dust particles will be evaluated using the US EPA's Particulate Emission Factor (PEF) approach (1996b, 2001a). The US EPA guidance for dust generated by construction activities (1996b, 2001a) will be used for assessing construction worker exposures. Input soil concentrations for the model will be the 95 percent UCL concentrations as described in Section 5.2.1 above. For exposures to VOCs in outdoor air, the flux chamber measurements as described above will be used.

5.2.4.3 Burrow Air

Volatile contaminants may be released to the air within an animal's burrow. The exposure concentrations within an animals burrow will be estimated from subsurface soil and/or groundwater concentrations (Section 5.3.4).

5.2.5 Sediments

For direct contact with sediment exposures, the representative exposure concentration will be the lower of the maximum detected concentration or the 95 percent UCL as the concentration for each detected chemical. Non-detects for COPCs will be assigned a value of one-half the detection limit. For uncensored

data, such as radionuclide analytical results, the actual reported value will be used, the actual reported value will be used, unless the value is negative, where a 0 will be substituted for the UCL calculation.

5.2.6 Biota

Direct measurement of chemicals in benthic organisms in Putah Creek is being planned as part of UC Davis Remedial Investigation activities. The maximum or 95 percent UCL concentration of each COPEC in the benthic organisms will be assumed to be the exposure point concentration for estimating doses to higher trophic levels. All other biota exposure point concentrations will be modeled.

5.3 FATE AND TRANSPORT MODELING FOR TIERS 2/3

5.3.1 Indoor Air Modeling from Subsurface Volatilization

Although there are no current sources of VOCs under existing structures, indoor air will be assessed for future hypothetical on-site residents. An "infiltration factor" will be applied to the outdoor flux data to generate data supporting the inhalation of indoor air exposure pathway. The "infiltration factor" is based on ASTM's *Standard Guide for Risk Based Corrective Action* (2000). The indoor air concentrations will be determined from the following:

$$C_a = \frac{J \times 86{,}400\,\mathrm{sec}/day}{L \times ER}$$

where:

C_a	=	indoor air concentration (mg/m^3)
J	=	measured flux of chemical (g/m^2-sec)
L	=	enclosed space volume/infiltration area ratio (m)
ER	=	enclosed space air exchange rate (1/day)

Generic, default parameter values from ASTM (2000) will be used where site-specific data are unavailable.

5.3.2 Indoor Air Modeling from Groundwater Domestic Use

For future hypothetical on-site residents, indoor air concentrations associated with the household use of groundwater will be estimated using a methodology developed by Cal/EPA in the CalTOX model (Cal/EPA, 1994). The significance of this pathway for VOCs has led to the development of several models to estimate the impact of VOC concentrations in water on household air concentrations (McKone, 1987; McKone and Knezovich, 1991; and Giardino and Andelman, 1996). The work of McKone (1987) and McKone and Knezovich (1991), in particular, have been incorporated into the multi-media exposure and risk assessment CalTOX model for Cal/EPA (1994).

Estimates of VOCs in household air will be based on the method in the CalTOX model (Cal/EPA, 1994) for predicting steady-state air concentrations from chemicals in water. This method relates the ratio of the air concentration to the water concentration based on the air ventilation rate, water use rate, and chemical specific transfer efficiency from shower water to air. The relationship used is:

$$\frac{C_h}{C_w} = \frac{(W_{house} \times \phi_x)}{VR_{house}}$$

where:

C_h	=	Indoor air concentration (mg/m^3)
C_w	=	Water concentration (mg/L)
W_{house}	=	Household water use rate (L/hr)
VR_{house}	=	Household ventilation rate (m^3/hr)
ϕ_x	=	Mass transfer efficiency of chemical from water to air (unitless)

The model will be used to evaluate indoor air impacts from the potential residential use of existing groundwater. The default household water use rate in CalTOX of 40 L/hr will be used (Cal/EPA, 1994). The household ventilation rates will be calculated using the following equation:

$$VR_{house} = V_h \times ACH_{house}$$

where:

V_{house}	=	Household air volume (m^3)
ACH_{house}	=	Household air exchange rate (1/hr)

The mass transfer efficiency for each of the COPCs is estimated using the method outlined by McKone (1987) and recommended by Cal/EPA (1994):

$$\phi_x = 0.7 \times \frac{3 \times 10^6 (m^2/s)^{-2/3}}{\left[\frac{2.5}{D_l^{2/3}} + \frac{RT}{H \times D_a^{2/3}}\right]}$$

where:

R	=	The universal gas constant 8,319 (Pa-L/mol-K)
T	=	Temperature in Kelvin 273.16 (K) as recommended (McKone, 1987)
D_l	=	Chemical-specific diffusion coefficient in water (m^2/sec)

D_a	=	Chemical-specific diffusion coefficient in air (m^2/sec)
H	=	Chemical-specific Henry's law constant (Pa-L/mol)

5.3.3 Outdoor Air Modeling for Volatiles

The box model developed by Hanna *et al.* (1982) will be used to assess the volatilization of chemicals from the sub-surface to ambient outdoor air. The results from the outdoor sub-surface vapor flux will be used to estimate outdoor air concentrations using the Hanna *et al.* model.

The box model assumes steady and spatially uniform conditions of dispersion so that the emissions from an area source are uniformly distributed throughout a box defined by the area of the source and the height of the box. The application of the box model for air dispersion requires steady-state emission rates, a constant wind vector, and a crosswind area source length that is large relative to the downwind distance to the receptor. The on-site ambient air concentrations will be determined from (Hanna *et al.*, 1982):

$$C_n = \frac{Q \times X}{A \times u \times H}$$

where:

C_a	=	On-site ambient air concentration (mg/m^3)
X	=	Crosswind width of box (m)
H	=	Effective mixing height (m)
Q	=	Emission rate of a chemical (mg/sec)
A	=	Total area (m^2)
u	=	Mean wind speed (m/sec)

and

$$Q = J \times A \times CF$$

where:

J	=	Measured flux of chemical (g/m^2-sec)
CF	=	Conversion factor (1,000 mg/g)

5.3.4 Subsurface Burrow Air Modeling

The concentration of a volatile contaminant in subsurface burrow air will be estimated by applying the method described by Hope (1995). The method assumes that the COPEC is in equilibrium with the bulk soil, soil water, and soil vapor:

$$C_{ba} = \frac{H/(R \times T)}{\rho_s \times K_{oc} \times f_{oc}} \times C_s \times \rho_a$$

where:

C_{ba}	=	Estimate burrow air concentration of COPEC (mg/m^3)
H	=	Henry's law constant ($Pa\text{-}m^3/mol$)
R	=	Universal gas constant (8.314 $Pa\text{-}m^3/mol/K$)
T	=	Temperature (K)
ρ_s	=	Bulk soil density (kg/cm^3)
K_{oc}	=	Soil-water partition coefficient normalized for organic carbon content (L/kg)
f_{oc}	=	Soil fraction organic carbon (unitless)
C_s	=	COPEC soil concentration (mg/kg)
ρ_a	=	Air density (kg/cm^3)

The model assumes that the COPEC is in steady-state equilibrium with the surrounding soil matrix and there is no dilution or mixing of the burrow air with ambient air. Where it is appropriate based on the life history of an ecological receptor and data are available, a dilution factor may be applied to the estimated burrow air concentration.

5.3.5 Fugitive Dust Generation, Dispersion, and Deposition

COPCs entrained on soil particles can potentially become airborne, resulting in possible exposure of receptors and/or migration and off-site deposition and accumulation in soil. Fugitive dust concentrations will be estimated using equations from US EPA (1996b, 2001a). Dispersion of fugitive dust to off-site areas over time will be estimated using the Gaussian algorithm developed by Baker and MacKay (1985). Fugitive dust deposition in off-site areas and contaminant loss via degradation and volatilization will be estimated using a model provided by US EPA (1990b).

5.3.6 Soil to Groundwater Modeling

Additional contribution of the vadose zone to groundwater contamination will not be evaluated. Previous modeling exercises and monitoring data indicate that the transport of mobile COPCs from vadose zone soil to groundwater has already peaked. The vadose modeling conducted for the Waste Burial Holes evaluated the leaching potential of COPCs in on-site soils using average rainfall for the area and soil data from the site. The analysis estimated that soluble COPCs originally discharged in surface or near surface soils would reach groundwater in over 12 years (Montgomery Watson, 2001). The results suggested that mobile compounds placed in the Waste Burial Holes area in the 1960's and 1970's were flushed through the vadose zone into the groundwater in the mid to late 1980's. To support this modeling, the groundwater monitoring for tritium and chloroform indicate the groundwater concentrations in the source areas are decreasing since the early 1990's. Therefore, for this assessment exposures to groundwater will be based on current groundwater concentrations rather then modeling future decreases in groundwater concentrations.

5.3.7 Groundwater Modeling

Groundwater flow and transport modeling will not be performed for the Tier 1 Human Health Screening. Ingestion and dermal contact with HSU-2 and HSU-4 groundwater are potential exposure routes for the hypothetical future potential on-site resident and the off-site farm resident (east). These scenarios will be evaluated in the Tier 1 Human Health Screening using the available historical data for HSU-2 and HSU-4. These data indicate that the concentrations of most COPCs are declining in HSU-2 and HSU-4 as the result of interim remedial actions in the source areas and for HSU-1 and HSU-2 groundwater.

Groundwater flow and transport modeling may be required as part of the Tier 2 Deterministic Risk Assessment if the historic maximum concentrations used in Tier 1 and the 95 percent UCL concentrations used in Tier 2 indicate potential for an unacceptable level of risk for any of the COPCs or if the historic data are insufficient to calculate a representative 95 percent UCL for use in Tier 2 for any of the COPCs. If either of these situations occurs for particular COPCs, flow and transport modeling will be considered as a means of simulating future COPC concentrations for the hypothetical on-site resident and the off-site farm resident (east) scenarios.

If necessary, the simulated concentrations would be used in conjunction with the historical data to calculate the 95 percent UCL for use as the exposure concentrations used in Tier 2. The existing MODFLOW flow model developed for the Groundwater Interim Remedial Action Engineering Evaluation/Cost Analysis (Dames & Moore, 1997) and updates (Dames & Moore, 1999) would be evaluated for use in this application. The existing model would be used, if possible, with the appropriate modifications needed for the risk assessment scenarios (*e.g.*, hypothetical supply well locations, flow rates and duration). Transport of the specific COPCs identified in Tier 1 would be simulated using MT3D for each of the exposure scenarios. The specific setup of the models would depend on the outcome of the Tier 1 Human Health Screening, since the screening will be applied to HSU-1 and HSU-4 separately and may have different outcomes for each of the two units.

5.3.8 Sediment/Surface Water Partition Equation

If on-site soil/surface water is considered to be a complete pathway for ecological receptors, a partitioning model will be used to estimate surface water concentrations in on-site puddles, as well. The water concentration can be estimated using the following equation:

$$C_w = [C_{sed} / (K_{oc} \times f_{oc})]$$

where:

C_{sed}	=	Chemical concentration in soil/sediment (mg/kg)
K_{oc}	=	Chemical-specific organic carbon partitioning coefficient for non-polar organic compounds (L/Kg)
f_{oc}	=	Fraction organic carbon in soil/sediment (unitless)

The product ($K_{oc} \times f_{oc}$) approximates the sediment-interstitial water partition coefficient (Di Toro *et al.*, 1991 as cited in US EPA, 1995a). If it is necessary to estimate Putah Creek surface water concentrations from sediment data a dilution factor may be necessary. A dilution factor would be applied because contaminants in sediment and interstitial water and in overlying water are not in equilibrium (Parkerton *et al.*, 1993 Thibodeaux, 1996). In fact, equilibrium even between sediment and interstitial water is rarely achieved because actual sediment/water systems are open, not closed. Because the Putah Creek is and will be an open, vertically well-mixed system, extensive dilution of concentrations in water at the sediment-water interface will occur.

5.3.9 Biota

5.3.9.1 Terrestrial Biota

Transfer coefficients from soil-to-biota and sediment-to-biota will be used to estimate exposure point concentrations in plants and animals based on concentrations measured in site-specific media (*i.e.*, air, soil, surface water, sediment and benthos). Transfer coefficients for inorganic COPECs will be derived from Sample *et al.* (1998), for terrestrial invertebrates, and Bechtel Jacobs (1998b) for terrestrial plants.

For organic COPECs, transfer coefficients will be obtained from the literature (*i.e.*, US EPA, 1999d), or from linear regression equations based on chemical-specific octanol-water partition coefficients (Cal/EPA, 1994; Travis and Arms, 1988). The linear regression equation proposed for calculating soil-to-plant transfer coefficient for organic COPECs is the following:

$$TC_{s\text{-}p} = 7.7 \times (K_{ow})^{-0.58}$$

where:

$TC_{s\text{-}p}$ = Transfer coefficient from soil to above-ground plant parts (unitless)
K_{ow} = Octanol-water partition coefficient (unitless)

The linear regression equation proposed for calculating plant-to-animal transfer coefficient for organic COPECs is the following:

$$TC_{p\text{-}a} = 0.17 \times K_{ow}$$

where:

$TC_{p\text{-}a}$ = Transfer coefficient from plants to animal tissues (unitless)
K_{ow} = Octanol-water partition coefficient (unitless)

Where transfer factors are not available, unity will be assumed between the measured environmental media and the organism.

5.3.9.2 *Fish Tissue Concentration*

Fish in Putah Creek represent an exposure media for both potential human and ecological receptors. Since site-specific fish tissue data is limited (Slotten et al., 1999), fish tissue concentrations will be estimated for constituents when site-specific fish tissue data is not available. Several different models are available to estimate fish tissue concentrations. The models shown are taken from the US EPA Hazardous Waste Identification Rule (HWIR) methodologies (US EPA, 1999d). The model used for each COPC and COPEC will depend on the available data. Models will be selected in order to maximize the use of existing data when available. The following equation may be used to calculate the concentrations in fish tissues for a chemical if a bioaccumulation factor (BAF), which takes into portioning, food chain magnification as well as metabolism, is available:

$$C_f = BAF \times C_w$$

where:

C_f	=	Concentration in fish tissue (mg/kg wet weight)
C_w	=	Freely dissolved concentration in surface water (mg/L water)
BAF	=	Bioaccumulation factor (mg/kg tissue per mg/L water)

If a BAF is not available, the following equation may be used for hydrophobic organics (Kow ≥ 10,000):

$$C_f = \frac{k_1 \times C_w + k_D \sum Frac_{Biota} \times C_{Biota}}{(k_2 + k_E + k_M + k_G)}$$

where:

C_f	=	Concentration in fish tissue (mg/kg wet weight)
C_w	=	Freely dissolved concentration in surface water (mg/L water)
C_{Biota}	=	Concentration in biota type in diet (mg/kg wet weight)
$Frac_{Biota}$	=	Fraction of biota type in diet (unitless)
k_1	=	Rate constant for chemical uptake from water (1/kg-day)
k_2	=	Rate constant for chemical elimination to water (1/day)
k_D	=	Rate constant for chemical uptake from food (1/day)
k_E	=	Rate constant for chemical elimination from faecal egestion (1/day)
k_M	=	Rate constant for metabolic transformation of chemical (1/day)
k_G	=	Rate constant for growth dilution (1/day)

If a BAF is not available, the following equation may be used for hydrophilic organics (K_{ow} < 10,000):

$$C_f = BCF \times C_w$$

where:

C_f	=	Concentration in fish tissue (mg/kg wet weight)
C_w	=	Freely dissolved concentration in surface water (mg/L water)
BCF	=	Bioconcentration factor (mg/kg tissue per mg/L water)

Since human receptors typically eat the fish filet rather than the whole fish, the whole body concentration will be used to estimate the filet concentration for hydrophobic chemicals. The following equation will be used (US EPA 1999d):

$$C_{filet} = C_{fish} \times FiletFrac$$

where:

C_f	=	Concentration in fish tissue (mg/kg wet weight)
C_{filet}	=	Concentration in fish filet tissue (mg/kg wet weight)
FiletFrac	=	Ratio of lipid fraction in filet to lipid fraction in whole fish (unitless)

The chemical and biota parameters needed for the modeling will be selected from the HWIR documents (US EPA, 1999d) or other available literature.

5.4 TIERED HUMAN HEALTH RISK ASSESSMENT APPROACH

The tiered approach for the risk assessment follows the US EPA recommendations (US EPA, 1999b). The tiered risk assessment approach will be conducted for all COPCs. For a complete exposure pathway to exist, each of the following elements must be present (US EPA, 1989):

- A source and mechanism for chemical release;
- An environmental transport medium (*i.e.*, air, water, soil);
- A point of potential human contact with the medium; and
- A route of exposure (*e.g.*, inhalation, ingestion, dermal contact).

Section 2 and Figure 4 present the CSM with the primary exposure pathways for each of the potential receptors at the Site. These populations and relevant exposure pathways for each of these receptors will be evaluated in the risk assessment.

5.4.1 Tier 2 (Baseline) Deterministic Exposure Assessment

The Tier 2 Deterministic Risk Assessment will follow basic procedures outlined in the US EPA's *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (US EPA, 1989).

Other guidance documents that will be consulted include:

- US EPA. 1992a. *Guidelines for Exposure Assessment.*
- US EPA. 1991a. *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual.* Supplemental Guidance.

The Tier 2 Deterministic Risk Assessment will be conducted using the 95 percent UCL for each COPC for each exposure area.

5.4.1.1 Deterministic Exposure Parameters

The exposure parameters proposed to be used in the Tier 2 Deterministic Risk Assessment are presented in Tables 4 through 6. These conservative default values are based on standard US EPA guidance values. Chemical-specific dermal absorption values from US EPA guidance will be used in the risk assessment.

5.4.1.2 Quantification of Exposure

Reasonable maximum exposure levels to chemicals will be calculated for each receptor of concern, using the exposure parameters identified in Tables 4 through 6. Because the Tier 3 risk assessment, if needed, will be conducted probabilistically, a Tier 2 central tendency exposure (CTE) will not be evaluated. The methodology used to estimate the average daily dose (ADD) of the chemicals via each of the complete exposure pathways will be based on US EPA (1989, 1992a) guidance. For carcinogens, lifetime ADD (LADD) estimates are based on chronic lifetime exposure extrapolated over the estimated average 70-year lifetime (US EPA, 1989). This is performed in order to be consistent with cancer slope factors, which are based on chronic lifetime exposures. For non-carcinogens, ADD estimates will be averaged over the estimated exposure period. The generic equation for calculating the ADDs and LADDs is:

$$Dose = \frac{C \times IR \times ED \times EF \times BIO}{BW \times AT \times 365\ d/yr}$$

where:

Dose	=	ADD for non-carcinogens and LADD for carcinogens (in mg/kg-day)
C	=	chemical concentration in the contact medium (mg/kg soil)
IR	=	intake rate (*e.g.*, mg/day soil ingestion and dermal contact; m^3/day for inhalation)
ED	=	exposure duration (years of exposure)
EF	=	exposure frequency (number of days per year)
BW	=	average body weight over the exposure period (kilograms)
BIO	=	relative bioavailability (unitless)
AT	=	averaging time; same as the ED for non-carcinogens and 70 years (average lifetime) for carcinogens

Exposure levels of any potentially carcinogenic and non-carcinogenic chemicals will be calculated separately because different exposure assumptions apply. Exposure levels will be estimated for each relevant exposure pathway (*i.e.*, soil, air), and for each exposure route (*i.e.*, oral, inhalation). For non-carcinogens, ADDs will be derived for both child (zero to six years of age) and adult (seven to 30 years of age) receptors. For carcinogens, LADDs will be derived for an age-adjusted receptor (zero to 30 years of age). Daily doses for the same route of exposure will be summed. Total dose of each chemical is the sum of doses across applicable exposure routes.

The results of the exposure assessment are then compared with information on the toxicity of the COPCs in the risk characterization step of the risk assessment to estimate the potential risks to human health posed by exposure to the COPCs. This process is discussed in Section 5.4.3.

5.4.2 Human Health Toxicity Criteria

This section identifies where toxicity values to be used for the risk assessment will be obtained. Cancer slope factors (CSFs) are chemical-specific and experimentally derived potency values that are used to calculate the risk of cancer resulting from exposure to potentially carcinogenic chemicals. A higher value implies a more potent carcinogen. Reference doses (RfDs) are experimentally derived "no-effect" levels used to quantify the extent of toxic effects other than cancer due to exposure to chemicals. With RfDs, a lower value implies a more potent toxicant. These criteria are generally developed by US EPA risk assessment work groups and listed in the US EPA risk assessment guidance documents and databases. Toxicity criteria will not be developed for compounds that do not have criteria published in the above sources. Should COPCs be found without established toxicity criteria (*e.g.*, titanium), these will be discussed on a case-by-case basis with US EPA and qualitatively addressed in the uncertainty section of the risk assessment report.

Like any biological reaction, the toxicity of a chemical can be described as a range of possible values (severities and levels that cause an endpoint of interest). The uncertainty in the toxicity values is an important source of uncertainty in most risk assessments and would be an appropriate parameter to be modeled probabilistically. However, for the purposes of both the Tier 2 and Tier 3 assessments, the toxicity values used will be point estimates (deterministic). Available toxicity values for all Site COPCs to be used in the risk assessment will be obtained from the following hierarchy:

1. Integrated Risk Information System (IRIS; US EPA, 2002)
2. National Center for Environmental Assessment (NCEA, or other current US EPA sources; and
3. California Office of Environmental Health Hazard Assessment (OEHHA) Cancer Potency Factors (Cal/EPA, 2002).
4. Health Effects Assessment Summary Tables (HEAST; US EPA, 1997b).

For carcinogens, the US EPA weight-of-evidence classification will be identified for each carcinogenic COPC. Available RfDs will be obtained for all COPCs, including carcinogens.

Although route-to-route extrapolation is inappropriate without adequate toxicological information, route-to-route extrapolation will be applied based on US EPA's approach (US EPA, 2000b). The uncertainties associated with this approach will be addressed in the risk assessment report.

5.4.3 Risk Characterization

In the last step of a risk assessment, the estimated rate at which a receptor intakes a chemical is compared with information about the toxicity of that COPC to estimate the potential risks posed by exposure to the COPC. This step is known as risk characterization. The methods used for assessing cancer risks, non-cancer adverse health effects, and ecological effects are discussed below.

5.4.3.1 Methods for Assessing Cancer Risks

In the risk characterization, carcinogenic risk is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of a chemical exposure. Carcinogenic risks will be evaluated by multiplying the estimated average exposure rate (*i.e.*, LADD calculated in the exposure assessment) by the chemical's CSF. The CSF converts estimated daily doses averaged over a lifetime to incremental risk of an individual developing cancer. Because cancer risks are averaged over a person's lifetime, longer-term exposure to a carcinogen will result in higher risks than shorter-term exposure to the same carcinogen, if all other exposure assumptions are constant. Theoretical risks associated with low levels of exposure in humans are assumed to be directly related to an observed cancer incidence in animals associated with high levels of exposure. According to US EPA (1989), this approach is appropriate for theoretical upper-bound incremental lifetime cancer risks of less than 1×10^{-2}. The following equations will be used to calculate chemical-specific risks and total risks:

$$Risk = LADD \times CSF$$

where:

LADD	=	lifetime average daily dose (mg/kg-d)
CSF	=	cancer slope factor $(mg/kg\text{-}d)^{-1}$

and

$$Total\ Carcinogenic\ Risk = \Sigma\, Individual\ Risk$$

It will be assumed that cancer risks from various exposure routes are additive. Thus, the result of the assessment is a high-end estimate of the total carcinogenic risk. High-end carcinogenic risk estimates will be compared to the US EPA acceptable risk range of 1 in 10,000 (10^{-4}) and 1 in 1 million (10^{-6}). If the estimated risk falls within or below this risk range, the chemical is considered unlikely to pose an

unacceptable carcinogenic risk to individuals under the given exposure conditions. A risk level of 1×10^{-5} (1 E-5) represents a probability of 1 in 100,000 that an individual could develop cancer from exposure to the potential carcinogen under a defined set of exposure assumptions.

5.4.3.2 Methods for Assessing Non-Cancer Health Effects

Non-cancer adverse health effects are estimated by comparing the estimated average exposure rate (*i.e.*, ADDs estimated in the exposure assessment) with an exposure level at which no adverse health effects are expected to occur for a long period of exposure (*i.e.*, the RfDs).

ADDs and RfDs are compared by dividing the ADD by the RfD to obtain the ADD:RfD ratio, as follows:

$$Hazard\ Quotient = \frac{ADD}{RfD}$$

where:

ADD	=	average daily dose (mg/kg-d)
RfD	=	reference dose (mg/kg-d)

The ADD-to-RfD ratio is known as an HQ. If a person's average exposure is less than the RfD (*i.e.*, if the HQ is less than 1), the chemical is considered unlikely to pose a significant non-carcinogenic health hazard to individuals under the given exposure conditions. Unlike carcinogenic risk estimates, a HQ is not expressed as a probability. Therefore, while both cancer and non-cancer risk characterizations indicate a relative potential for adverse effects to occur from exposure to a chemical, a non-cancer adverse health effect estimate is not directly comparable with a cancer risk estimate.

If more than one pathway is evaluated, the HQs for each pathway will be summed to determine whether exposure to a combination of pathways poses a health concern. This sum of the HQs is known as an HI.

$$Hazard\ Index = \Sigma\, Hazard\ Quotients$$

Any HI less than 1 indicates the exposure is unlikely to be associated with a potential health concern.

<u>*Segregation by Target Organs*</u>. Because toxicological effects associated with exposure to multiple chemicals may not be additive, the total HI may overestimate the potential for non-carcinogenic health effects. Therefore, for any HI that exceeds 1.0, the potential for adverse health effects is further evaluated by considering the organs upon which each chemical could have an adverse effect. The target organ specific HIs will be summed for both organic and inorganic COPCs. The segregation of HI by target organ is consistent with US EPA guidance for non-carcinogens, including metals (US EPA, 1989).

5.4.3.3 Determination Whether to Proceed to a Tier 3 Risk Assessment

The determination whether the Tier 2 Deterministic Risk Assessment results indicate that the Site conditions do not present unacceptable adverse human health risks will be made based on the non-cancer HI and total cancer risk for each exposure area, and the site as a whole. If both the non-cancer HI and the total cancer risk are below their respective acceptable levels (*i.e.*, a target organ HI of 1.0 and a cancer risk of 10^{-6}), remediation will be determined not to be necessary. If not below acceptable levels, a decision to proceed to a higher tiered risk assessment (Tier 3), or to perform additional soil removal and/or sampling, will be conducted. If a Tier 3 risk assessment is conducted for a particular exposure area, all chemicals will be included (*i.e.*, no further selection of COPCs will be conducted).

5.4.4 Radionuclide Risk Assessment Methodology

Risks associated with radionuclides in soil will be assessed both separately from and together with chemical contaminants. There are several important differences between evaluating risks to radionuclides and chemical contaminants. These differences include:

- Concentrations are based on units of activity (*e.g.*, pCi) instead of units of mass (*e.g.*, mg) in soil;
- Only the carcinogenic effects of radionuclides due to ionizing radiation are considered; and
- Cancer slope factors (CSFs) are based on the total theoretical age-averaged incremental lifetime cancer risk per intake of the radionuclide, or per unit external radiation exposure.

The Argonne National Laboratory (ANL, 2001) RESRAD computer code will be used for assessing risks to radionuclides. All applicable exposure pathways and fate and transport modeling are accounted for in the RESRAD code. RESRAD has been used widely by the both DOE and US EPA for calculating doses and risks from radionuclides in environmental media. Default parameter values in the RESRAD code and exposure pathways consistent with those in Figure 4 will be used.

Radionuclides toxicity criteria will be obtained from the US EPA's April 2001 *Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors* (US EPA, 2001b). For some radionuclides, two different toxicity criteria are available from this table: One for that radionuclide only and one for the radionuclide and associated short-lived radioactive decay products (*i.e.*, those decay products with radioactive half-lives less than or equal to 6 months). To be conservative, the toxicity criteria that include radioactive decay products will be used. If the decay product is out of equilibrium with its parent, the daughter's toxicity will be evaluated separately. The uncertainties associated with the approach will be addressed in the risk assessment report.

5.4.5 Site-Wide Risk Assessment Approach

The previous risk characterization section (Section 5.4.3) focused on estimating human health risks for each area of concern. However, several human receptors have the potential to be exposed to more than

one exposure area as well as the whole Site. Therefore, for those receptors that potentially could be exposed to the whole site, site-wide risks will also be evaluated.

The human receptors that could be exposed to the whole Site include the on-site researcher and construction worker. The risk characterization for these receptors for individual exposure areas assumed that the receptor spent all of their exposure time in a single exposure area. Therefore, the Site-wide risks would not be represented by summing risks from all the exposure areas, but rather would be represented by an average of risks from the exposure areas, as weighted by the fraction of the receptor's assumed exposure to each exposure area. For each receptor, it will be assumed there is an equal probability of exposure to any individual location throughout the site. Therefore, the fraction of the total Site represented by each exposure area will be used to weight the contribution of exposure from each exposure area. The sum of the weighted exposures for each of the areas is the assumed Site-wide exposure:

$$SiteWideRisk = \sum CancerRisk_i (orHI_i) \times AreaFraction_i$$

where:

SiteWideRisk	=	Total site cancer risk or HI
$CancerRisk_i$	=	Exposure area-specific cancer risk
HI_i	=	Exposure area-specific non-carcinogenic HI
$AreaFraction_i$	=	Ratio of exposure area-specific area to total Site area

5.4.6 Tier 3 Probabilistic Human Health Risk Assessment Methodology

As discussed previously, the Tier 3 probabilistic risk assessment will be performed if warranted and will follow basic procedures outlined in US EPA (1989 and 1999b). Other guidance documents that will be consulted include:

- US EPA. 1992a. *Guidelines for Exposure Assessment.*
- US EPA. 1997c *Guiding Principles for Monte Carlo Analysis*

Because of the overall size of the Site and the scale of potential impacts associated with the results of the risk assessment, the Tier 3 risk assessment will be conducted probabilistically to provide more information and flexibility for remedial decisions. Due to the uncertainty of whether a Tier 3 risk assessment will be necessary, this work plan does not address the specific methodology for a Tier 3 risk assessment. Prior to conducting a Tier 3 risk assessment a more detailed work plan will be submitted to US EPA.

5.5 TIERED ECOLOGICAL RISK ASSESSMENT APPROACH

The purpose of the Tier 2 Baseline ERA is to determine whether or not the Site, if left unremediated, would pose unacceptable current or likely future risks to critical species currently residing on the Site or

reasonably expected to reside on the Site in the future. The Tier 2 Baseline ERA differs from the Tier 1 SLERA in that assumptions made for the Tier 2 Baseline ERA are more site-specific and include less uncertainty than the Tier 1 SLERA.

5.5.1 Tier 2 (Baseline) Problem Formulation

The problem formulation step includes information on the following: (1) identification of indicator receptors for evaluating the assessment and measurement endpoints; (2) identification of COPECs; (3) identification of complete and significant exposure pathways, and (4) the assessment endpoints selected for evaluation.

5.5.1.1 Identification of Representative Ecological Receptors

Using the biological resource information described in Section 2.1.6, the valued or 'critical' receptors to be used in evaluating exposures will be selected. Valued or 'critical' receptors are defined as:

- Federal or State listed special status species;
- migratory species;
- game or commercially important species;
- species integral to a healthy food web.

From this list of 'critical' receptors, representative receptors will be selected for quantitative risk calculations. For the representative receptors, estimates of current habitat size and of population abundance will be made.

5.5.1.2 Constituents of Potential Ecological Concern

For each media (surface water, sediment, soil), detected chemicals and radionuclides with maximum concentrations above both the screening benchmarks and background concentrations will be carried into the Tier 2 Baseline ERA as COPEC.

5.5.1.3 Identification of Complete and Significant Exposure Pathways

The CSMs developed for the Tier1 SLERA will need to be refined for the more detailed Tier 2 Baseline ERA. For individual COPECs, the number of exposure pathways to be addressed will be focused on a few "critical exposure pathways" which reflect maximum exposures of receptors in an ecosystem and/or constitute exposure pathways to sensitive ecological receptors (US EPA, 1997a). The following will be considered when identifying "critical exposure pathways:"

- Contaminant fate and transport information (*e.g.* mobility, lipophilicity)
- Critical or at-risk habitats present at the Site.

Rationale for exclusion of any pathway will be included in the Tier 2 Baseline ERA text.

5.5.1.4 Identification of Assessment Endpoints

Assessment endpoints require the site-specific knowledge of the biological resources and the selection of representative receptors. Assessment endpoints will be selected in consultation with the risk managers, in accordance with the guidance provided in US EPA's *Eco Update Volume 1 Number 1* (US EPA, 1991b)

For this assessment, an "assessment endpoint" is defined as "an explicit expression of a specific ecological receptor and an associated function or quality that is to be maintained or protected." Each assessment endpoint will be presented in the following format: Protect/maintain *function or quality* of *specific ecological receptor* from adverse effects due to the presence of *a given COPEC or class of COPEC.*

5.5.2 Exposure Assessment

A deterministic approach to predicting risks will be employed for the Tier 2 Baseline ERA. For quantifying food chain exposures, simplified exposure models have been developed for terrestrial and aquatic food webs. The terrestrial exposure model consists of plant uptake of chemicals from soil; ingestion of plants by a primary consumer; and ingestion of the primary consumer by a secondary consumer. Uptake of chemicals by producer species, such as plants, is generally dependent upon root uptake and translocation of soil contaminants. Consumer species receive exposure through the diet, as well as direct exposure to soil COPECs through dermal contact and incidental ingestion. Higher trophic level receptors potentially receive increased relative exposures to COPECs due to the number of chemical transfers through the food chain. Thus, exposure modeling for these receptors allows for an evaluation of the impacts of potential biomagnification.

As discussed in Section 5.3.9, transfer coefficients from soil-to-biota will be used to estimate COPEC exposure point concentrations in the dietary items of indicator receptors (*i.e.*, plants and small mammals). The methods used to estimate dietary concentrations are described in the following subsections.

5.5.2.1 Receptor-Specific Exposure Parameters

Exposure parameters for each indicator receptor will be required to estimate the exposure dose. Exposure parameters will be obtained from US EPA's *Wildlife Exposure Factors Handbook* (US EPA, 1993), the National Audubon Society's *Field Guide to North American Birds* (Whitaker, 1977) and *Field Guide to North American Mammals* (Whitaker, 1996), and *California's Wildlife* (Zeiner *et al.*, 1990) and other literature sources as appropriate. The exposure parameters required for the quantitative dose estimate include the representative receptors:

- Body weight;
- Ingestion rate of biotic and abiotic media;
- Dermal contact rates with abiotic media (*e.g.*, soil);
- Site utilization factor (the area of contamination in relation to the receptor's home range);

- Exposure duration (time in a year that a receptor is exposed to site COPECs);
- Skin surface area;
- Chemical-specific dermal absorption factors; and
- Soil adherence factors.

The assumptions to be used for each of these exposure parameters are detailed in the following subsections.

Body Weight. An average of the body weights reported for both males and females will be used for each indicator receptor.

Biotic Ingestion Rates. Food ingestion rates (FIR) for each indicator receptor will be obtained directly from the literature, or calculated using allometric equations provided in US EPA's *Wildlife Exposure Factors Handbook* (US EPA, 1993) that are based on established relationships between body size and metabolic requirements. Food ingestion rates expressed in grams of food per day will be calculated based on Equations 3-3 (birds) and 3-9 (mammals) of US EPA (1993). Ingestion rates will be converted to milligrams of food per day, prior to input to the dose calculation.

Abiotic Ingestion Rates. The abiotic ingestion rates (for incidental soil or sediment ingestion) will be obtained from US EPA (1993). When an ingestion rate for a receptor species is not available, a suitable substitute will be selected. Soil/sediment ingestion rates are expressed in grams of soil/sediment ingested per day and will be converted to milligrams of soil/sediment ingested per day prior to input to the dose equation.

Site Utilization Factor. The site utilization factor (SUF) describes the area of contamination that a receptor potentially contacts relative to its home range. Home range is the area of habitat required by an ecological receptor to meet its dietary needs. Home ranges vary between species depending upon differences in dietary requirements, and within a species depending upon the relative abundance of food items in a particular area in which the receptor feeds. Home range values will be obtained from the literature sources described previously.

Comparison of a receptor's home range to the areal extent of contamination of a site is used to determine the relative amount of potentially contaminated diet the receptor is exposed to. The SUF is calculated as the ratio of the area of contamination to a receptor's home range. When the receptor's home range is greater than the area of contamination, the SUF is less than one. When a receptor's home range is less than or equal to the area of contamination the SUF will be assumed to equal one.

Exposure Duration. The exposure duration (ED) refers to the fraction of the year that a receptor is likely to spend utilizing a site. This is frequently a function of migration and/or hibernation potential.

Skin Surface Area. The skin surface area (SSA) is an exposure parameter used to estimate dermal exposure of indicator receptors to soil or sediment COPECs. This parameter will be calculated based on methods outlined in *Wildlife Exposure Factors Handbook* (US EPA, 1993), which include:

- allometric equations for estimating the total skin surface area beneath fur or feathers; and
- the percentage of body not covered by fur or feathers.

For this assessment it will be assumed that fur and feathers would prevent exposure from soil/sediment and exposure is limited to those parts of the body not covered by fur or feathers (*e.g.* feet, beak).

Chemical-Specific Dermal Absorption Fraction. The chemical-specific dermal absorption fraction (ABS) is used in the estimate of dermal exposure to contaminants in soil or sediment. The ABS represents the ratio of the absorbed dose to the applied dose of a chemical (US EPA, 1992a). An average dermal absorption fraction of 0.1 (*i.e.*, 10 percent) for organic chemicals, and 0.01 (*i.e.*, 1 percent) for inorganic chemicals, has been published by US EPA (1992a) for use in human health risk assessment. These dermal absorption fractions will also be used in this ERA for estimating doses to biota derived from dermal exposures.

Soil Adherence Factor. The soil-to-skin adherence factor (AF) will be used in the estimation of dermal exposure to contaminants in soil. This parameter depends in part on chemical properties and in part on soil characteristics, such as total organic carbon and particle size.

Ventilation Rate. The ventilation rate will be used to estimate inhalation exposure for burrowing animals to volatile compounds.

5.5.2.2 Exposure Dose Calculation

This phase of the exposure assessment consolidates the exposure pathways and exposure routes, exposure point concentrations, and exposure parameters into an equation that provides an exposure dose estimate in units of milligrams of COPEC per kilogram body weight per day (mg/kg-day). Ingestion dose estimates will be calculated using the following general equation derived from US EPA's *Wildlife Exposure Factors Handbook* (US EPA, 1993):

$$\text{Dose}_{\text{Ingestion}} = \frac{[(\text{IR}_{\text{Biotic}} \times \text{EPC}_{\text{Biotic}}) + (\text{IR}_{\text{Abiotic}} \times \text{EPC}_{\text{Abiotic}})] \times \text{ED} \times \text{SUF} \times \text{UC}}{\text{BW}}$$

where:

$\text{Dose}_{\text{Ingestion}}$	=	Estimated exposure dose from ingestion of food and ingestion of abiotic media (mg/kg-day)
$\text{IR}_{\text{Biotic}}$	=	Food ingestion rate (milligrams per day [mg/day])

$IR_{Abiotic}$	=	Abiotic media ingestion rate (mg/day)
EPC_{Biotic}	=	Concentration of COPEC in food item (milligrams per kilogram [mg/kg])
$EPC_{Abiotic}$	=	Concentration of COPEC in abiotic media (mg/kg)
ED	=	Exposure Duration (unitless)
SUF	=	Site Utilization Factor (unitless)
UC	=	Unit Conversion, 10^{-6} kilograms per milligram (kg/mg)
BW	=	Body weight (kilograms [kg])

Dermal exposure estimates will be calculated for indicator receptors using the following general equation:

$$Dose_{Dermal} = \frac{EPC_{Abiotic} \times SSA \times AF \times ABS \times ED \times SUF \times UC}{BW}$$

where:

$Dose_{Dermal}$	=	Estimated dose from dermal contact with soil (mg/kg-day)
$EPC_{Abiotic}$	=	Exposure point concentration in soil (mg/kg)
SSA	=	Skin Surface Area (square centimeters [cm^2])
AF	=	Soil adherence factor (unitless)
ABS	=	Chemical-specific dermal absorption fraction (unitless)
ED	=	Exposure Duration (unitless)
SUF	=	Site Utilization Factor (unitless)
UC	=	Unit Conversion, 10^{-6} (kg/mg)
BW	=	Body Weight (kg)

When VOCs are present in surface soil, an additional factor, an inhalation dose, will be added for burrowing animals (Hope, 1995).

$$Dose_{Inhalation} = \frac{EPC_{Abiotic} \times IR \times EPC_{abiotic} \times SUF \times B_t}{BW}$$

where:

$Dose_{Inhalation}$	=	Estimated dose from inhalation of soil vapor (mg/kg-day)
EPCAbiotic	=	Exposure point concentration in soil (mg/kg)
IR	=	Inhalation rate of resting receptors (m^3/day)
ED	=	Exposure Duration (unitless)
SUF	=	Site Utilization Factor (unitless)
Bt	=	Fraction of day spent in burrow (unitless)

The daily dose of a COPEC for a given receptor is then simply the sum of the ingested, dermal and, if appropriate, inhalation doses.

5.5.3 Ecological Toxicity Reference Values

The literature search conducted for the Tier 1 SLERA will need to be expanded to obtain the information needed for the more detailed Tier 2 Baseline ERA. For those pathways and COPEC carried forward from the Tier 1 SLERA, toxicological profiles will be developed and appropriate toxicological benchmarks extracted, as per Appendix C of US EPA (1997a) for the receptors of interest (See 5.6.1). It is purposed that:

- For special status species, the highest no-observable-effects level (NOAEL) that considered effects on reproductive success be adopted for risk characterization; and,
- For common species, the LD50 or EC50, as applicable, which considers effects on the population's reproductive success be adopted for risk characterization.

If a NOAEL, LD50 or EC50 is not available for the species of interest, the uncertainty factors provided in US EPA (1997a) will be used to convert other toxicological endpoints to a NOAEL, LD50 or EC50.

5.5.4 Ecological Risk Characterization

The ecological risk characterization will use the information that was previously gathered to determine the potential ecological risks resulting from exposures to COPECs in Site media. Information regarding the presence and attributes of Site receptors as well as the chemistry, toxicology, and distribution of Site chemicals will be synthesized in an evaluation of the potential for adverse effects to ecological receptors.

The measurement endpoint of this ERA involves comparison of modeled exposure doses with toxicity reference values for indicator receptors. The comparison with toxicity reference values yields a chemical specific HQ as follows:

$$HQ = \frac{Dose_I}{TRV_I}$$

where:

HQ	=	Hazard quotient (unitless)
$Dose_I$	=	Modeled chemical exposure dose to the indicator receptor (mg/kg-day)
TRV_I	=	Toxicity reference value for the indicator receptor (mg/kg-day)

To estimate cumulative effects of COPECs, an ecological HI will be calculated for each indicator receptor. This HI will be determined by adding the HQs obtained from food chain modeling for all COPECs identified at the Site for each indicator receptor. Ecological HQ or HI values exceeding 1.0 are

generally considered to be indicative of potential biological or ecological effects on representative receptors. These values do not necessarily indicate that a biological or ecological effect will occur, but only that a lower threshold has been exceeded (Menzie *et al.*, 1992).

Additionally, to estimate effects of COPECs to receptors potentially using the whole Site, Ecological HQs and HIs calculated from each of the sub-sites will be summed, with consideration given to the target organs associated with the COPECs. From the risk characterization step, constituents of ecological concern (COEC) will be identified. If the results of the Tier 2 Baseline ERA indicate potentially high ecological risk, a validation study will be considered to refine assumptions and decrease uncertainty in the assessment.

5.5.5 Radionuclide Risk Assessment Methodology

DOE's Biota Dose Assessment committee has developed a tiered approach for assessing ecological risks due to radionuclides, which will be followed for this assessment. This approach is contained in the DOE Technical Standard "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE, 2000; http://homer.ornl.gov/oepa/public/bdac) and is designed to be used in evaluations of compliance with the following technical standards:

- Aquatic animals. The absorbed dose to aquatic animals should not exceed 1 rad/day from exposure to radiation or radioactive material releases into the aquatic environmental
- Terrestrial plants. The absorbed dose to terrestrial plants should not exceed 1 rad/day from exposure to radiation or radioactive material releases into the terrestrial environment; and
- Terrestrial animals. The absorbed dose to terrestrial animals should not exceed 0.1 rad/day from exposure to radiation or radioactive material releases into the terrestrial environment.

A summary of DOE's three-step process was given in Table 1. The "Analysis" step follows the Tier 2 Baseline ERA paradigm and the Tier 3 paradigm. In the Analysis phase, a site-specific screening is performed to identify COPECs. In this step, more realistic site-representative parameters (*e.g.*, bioaccumulation factors) are used in place of the default parameters used in the Screening step (Section 5.1.4.2). After the site specific screening step, a site-specific analysis is performed to estimate doses to aquatic and terrestrial receptors and hazard quotients are again estimated. The BCGs used for the SLERA may be modified after considering site-specific receptors or concerns, as well. Following the calculation of hazard quotients, the fractions of each radionuclide and medium are summed. If the sum of the fractions is less that 1.0, no further action is recommended. If the sum of the fractions is greater than 1.0, a risk management decision is warranted.

5.5.6 Site-Wide Risk Assessment Approach

The previous risk characterization section focused on estimating ecological risks for each exposure area. However, several ecological receptors have the potential to be exposed to more than one exposure area as

well as the whole Site. Therefore, for those receptors that potentially could be exposed to the whole site, site-wide risks will also be evaluated.

The risk characterization for ecological receptors considered both an area use factor and a seasonality factor and assumed that the receptor spent only a fraction of their exposure time in a single exposure area. Therefore, the Site-wide risks would be represented by summing risks from all the exposure areas.

$$SiteWideRisk = \sum HQi$$

where:

SiteWideRisk = Risk to ecological receptor from exposure to multiple exposure areas

HI_i = Exposure area-specific HQ

This value will be calculated for those receptors that would reasonably be expected to use the whole site, such as raptors, and not for the receptors that would not use the whole site, such as plants.

5.6 UNCERTAINTY ANALYSIS

Risk estimates are values that have associated uncertainties. These uncertainties, which arise at every step of a risk assessment, are evaluated to provide an indication of the relative degree of uncertainty associated with a risk estimate. Consistent with US EPA (1989) guidance, for the Tier 2 Deterministic Risk Assessment, a qualitative discussion of the uncertainties associated with the estimation of risks for the Site will be presented in the risk assessment report. The uncertainty analysis will discuss uncertainties associated with each step of the risk assessment, including site characterization data, data usability, selection of COPCs, representative exposure concentrations, fate and transport modeling, exposure assessment, toxicity assessment, and risk characterization. For both non-carcinogens and carcinogens, the 'driver' COPCs and pathways will be identified.

Exposure models that predict adverse effects form COPEC exposure require many assumptions and therefore contain a lot of uncertainty. An uncertainty analysis will be performed that summarizes the assumptions made and evaluates the impact of the uncertainties on the assessment. Topics that will be covered in the uncertainty section include, but are not limited to: COPEC selection and quantification; representative receptor selection; exposure estimation; effects estimation; and risk characterization.

5.7 INTERPRETATION OF FINDINGS

The risk characterization results will be presented in tabular format in the SWRA report. Key exposure (*e.g.*, estimated intakes, important modeling assumptions, summary of exposure pathways for each receptor) and toxicity information (*e.g.*, CSFs, RfDs, and target organs) will be provided. In addition, the

risk characterization results will be placed into proper perspective, including a discussion of the concept of *de minimus* risk. The cancer risk assessment results will be presented for both the total cancer risk and incremental cancer risk estimates, as well as presentation of the percent contribution of the background cancer risk to the total cancer risk. In addition, those COPCs and exposure pathways having the greatest influence on the risk assessment results will be identified. Ambient chemical source influences on Site risk due to anthropogenic contributions, that are not Site related, will also be incorporated into the findings (See Section 4.1). Graphical presentation of the results will also be included in the SWRA report. In addition, risk assessment reports will follow the guidelines presented in US EPA's Reviewers Checklist (US EPA, 1989) to ensure that essential issues are adequately addressed in the SWRA.

6.0 REPORTING

This section presents the proposed outline for the SWRA, deliverables to be submitted during the course of the risk assessment process and the schedule for the SWRA. Table 7 provides a proposed outline for the Draft SWRA report.

The Draft SWRA submittal will consist of two volumes: Volume 1–Human Health SWRA; and Volume 2–Ecological SWRA. Both volumes of the draft SWRA will include the results of Tier 1/Tier 2 assessments for both human health (Volume 1) and ecological (Volume 2) risk assessments.

The proposed schedule for the draft SWRA will meet the requirements stated in the AOC. The draft SWRA (Volumes 1 and 2) will be submitted 90 days after final DOE risk assessment input is submitted to UC Davis. Final DOE risk assessment input is tentatively scheduled for September 30, 2002.

The interim milestones for the SWRA are presented in Figure 3. Figure 3 shows that UC Davis will meet with the EPA/RPM risk assessors at major decision points during the risk assessment process. The first meeting will be to discuss the results of the preliminary Tier 1 SLERA and scope the Tier 2 Baseline ERA. Additional meetings may be arranged to discuss whether a Tier 3 probabilistic human health and/or ecological risk assessments should be conducted. Arrangement of these meetings will be conditional on the Tier 2 risk assessment results. These meetings will be scheduled prior to completion of the Draft SWRA, and allow integration of EPA/RPM comments prior to issuing the Draft SWRA.

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Table 1. Summary of DOE's Three-Step Process for Evaluating Radation Doses to Aquatic and Terrestrial Biota

1. Data Assembly	Knowledge of sources, receptors, and routes of exposure for the area to be evaluated is summarized. Measured radionuclide concentrations in water, sediment, and soil are assembled for subsequent screening.
2. General Screening	Maximum measured radionuclide concentrations in an environmental medium (*i.e*., water, sediment, soil) are compared with a set of Biota Concentration Guides (BCGs). Each radionuclide-specific BCG represents the limiting radionuclide concentration in an environmental medium which would not result in recommended dose standards for biota to be exceeded.
3. Analysis	This phase consists of three increasingly more detailed steps of analysis.
(a) Site-Specific Screening	Site-specific screening, using more realistic site-representative lumped parameters (*e.g.* , bioaccumulation factors) in place of conservative default parameters. Use of mean radionuclide concentrations in place of maximum values, taking into account time dependence and spatial extent of contamination, may be considered.
(b) Site-Specific Analysis	Site-specific analysis employing a kinetic modeling tool (applicable to riparian and terrestrial animal organism types) provided as part of the graded approach methodology. Mulitple parameters which represent contributions to the organism internal dose (*e.g.* , body mass, consumption rate of food/soil, inhalation rate, lifespan, biological elimination rates) can be modified to represent site and organism-specific characteristics. The kinetic model employs allometric equations relating body mass to these internal dose parameters.
(c) Site-Specific Biota Dose Assessment	An actual site-specific biota dose assessment involving the collection of biota samples, which would involve a problem formulation, analysis, and risk characterization protocol similar to that recommended by the U.S. EPA.

Table 2. Biota Concentration Guides (BCGs) for Water and Sediment (in SI Units) for Use in Aquatic System Evaluations[a]

Nuclide	BCG (water), Bq/m^3	Organism Responsible for Limiting Dose in Water	BCG (sediment), Bq/kg	Organism Responsible for Limiting Dose in Sediment
^{241}Am	2 E+4	Aquatic Animal	2 E+5	Riparian Animal
^{144}Ce	6 E+4	Aquatic Animal	1 E+5	Riparian Animal
^{135}Cs	2 E+4	Riparian Animal	2 E+6	Riparian Animal
^{137}Cs	2 E+3	Riparian Animal	1 E+5	Riparian Animal
^{60}Co	1 E+5	Aquatic Animal	5 E+4	Riparian Animal
^{154}Eu	8 E+5	Aquatic Animal	1 E+5	Riparian Animal
^{155}Eu	1 E+7	Aquatic Animal	1 E+6	Riparian Animal
^{3}H	1 E+10	Riparian Animal	1 E+7	Riparian Animal
^{129}I	1 E+6	Riparian Animal	1 E+6	Riparian Animal
^{131}I	5 E+5	Riparian Animal	2 E+5	Riparian Animal
^{239}Pu	7 E+3	Aquatic Animal	2 E+5	Riparian Animal
^{226}Ra	6 E+0	Riparian Animal	2 E+2	Riparian Animal
^{228}Ra	6 E+0	Riparian Animal	1 E+2	Riparian Animal
^{125}Sb	1 E+7	Aquatic Animal	3 E+5	Riparian Animal
^{90}Sr	1 E+4	Riparian Animal	2 E+4	Riparian Animal
^{99}Tc	2 E+7	Riparian Animal	2 E+6	Riparian Animal
^{232}Th	1 E+4	Aquatic Animal	5 E+4	Riparian Animal
^{233}U	7 E+3	Aquatic Animal	2 E+5	Riparian Animal
^{234}U	7 E+3	Aquatic Animal	2 E+5	Riparian Animal
^{235}U	8 E+3	Aquatic Animal	1 E+5	Riparian Animal
^{238}U	8 E+3	Aquatic Animal	9 E+4	Riparian Animal
^{65}Zn	5 E+2	Riparian Animal	5 E+4	Riparian Animal
^{95}Zr	3 E+5	Aquatic Animal	9 E+4	Riparian Animal

[a]For use with radionuclide concentrations from co-located water and sediment.

Table 3. Biota Concentration Guides (BCGs) for Water and Sediment (in SI Units) for Use in Terrestrial System Evaluations

Nuclide	BCG (water), Bq/m^3	Organism Responsible for Limiting Dose in Water	BCG (sediment), Bq/kg	Organism Responsible for Limiting Dose in Sediment
^{241}Am	7 E+6	Terrestrial Animal	1 E+5	Terrestrial Animal
^{144}Ce	1 E+8	Terrestrial Animal	5 E+4	Terrestrial Animal
^{135}Cs	3 E+8	Terrestrial Animal	1 E+4	Terrestrial Animal
^{137}Cs	2 E+7	Terrestrial Animal	8 E+2	Terrestrial Animal
^{60}Co	4 E+7	Terrestrial Animal	3 E+4	Terrestrial Animal
^{154}Eu	8 E+7	Terrestrial Animal	5 E+4	Terrestrial Animal
^{155}Eu	1 E+9	Terrestrial Animal	6 E+5	Terrestrial Animal
^{3}H	7 E+8	Terrestrial Animal	2 E+6	Terrestrial Animal
^{129}I	2 E+8	Terrestrial Animal	2 E+5	Terrestrial Animal
^{131}I	7 E+7	Terrestrial Animal	3 E+4	Terrestrial Animal
^{239}Pu	7 E+6	Terrestrial Animal	2 E+5	Terrestrial Animal
^{226}Ra	1 E+4	Terrestrial Animal	9 E+1	Terrestrial Animal
^{228}Ra	9 E+3	Terrestrial Animal	8 E+1	Terrestrial Animal
^{125}Sb	3 E+8	Terrestrial Animal	1 E+5	Terrestrial Animal
^{90}Sr	2 E+6	Terrestrial Animal	8 E+2	Terrestrial Animal
^{99}Tc	6 E+8	Terrestrial Animal	2 E+5	Terrestrial Animal
^{232}Th	2 E+6	Terrestrial Animal	6 E+4	Terrestrial Animal
^{233}U	1 E+7	Terrestrial Animal	2 E+5	Terrestrial Animal
^{234}U	1 E+7	Terrestrial Animal	2 E+5	Terrestrial Animal
^{235}U	2 E+7	Terrestrial Animal	1 E+5	Terrestrial Animal
^{238}U	2 E+7	Terrestrial Animal	6 E+4	Terrestrial Animal
^{65}Zn	6 E+6	Terrestrial Animal	2 E+4	Terrestrial Animal
^{95}Zr	8 E+7	Terrestrial Animal	4 E+4	Terrestrial Animal

Table 4. Tier 2 Exposure Factors – On-Site Researcher

Parameter	Abbrev.	Value	Units	Reference
Dermal absorption fraction	ABS	--chemical-specific--		US EPA, 2001b
Dermal adherence factor, soil	AF_{mw}	0.2	mg/cm^2	US EPA, 2001a,b
Averaging time, carcinogenic	AT_c	70	years	US EPA, 1991a, 2001a,b
Averaging time, non-carcinogenic	AT_{nc}	25	years	Based on ED_{mw}
Adult body weight	BW_a	70	kg	US EPA, 1991a, 2001a
Researcher exposure frequency	EF_{cmw}	250	days/year	US EPA, 2001a,b
Exposure duration	ED	25	years	US EPA, 2001a,b
Adult inhalation rate	IR_a	20	m^3/day	US EPA, 2001a,b
Researcher exposed surface area, soil	SA_{mw}	3,300	cm^2/day	US EPA, 2001a,b
Researcher soil ingestion rate	$IR_{s,cmw}$	50	mg/day	US EPA, 2001a

Table 5. Tier 2 Exposure Factors – On-Site Construction Worker

Parameter	Abbrev.	Value	Units	Reference
Dermal absorption fraction	ABS	--chemical-specific--		US EPA, 2001b
Dermal adherence factor, soil	AF_s	0.3	mg/cm^2	US EPA, 2000, 2001a,b
Averaging time, carcinogenic	AT_c	70	years	US EPA, 1991a, 2001a,b
Averaging time, non-carcinogenic	AT_{nc}	1	years	Based on ED_{cw}
Adult body weight	BW_a	70	kg	US EPA, 1991a, 2001a
Exposure frequency, soil	$EF_{s,cw}$	250	days/year	US EPA, 1991a, 2001a,b
Exposure duration	ED_{cw}	1	years	(1)
Adult inhalation rate	IR_a,	20	m^3/day	US EPA, 1991a, 1997, 2001a,b
Construction worker exposed surface area, soil	$SA_{cw,s}$	3,300	cm^2/day	US EPA, 2001a,b
Construction worker soil ingestion rate	$IR_{s,cw}$	330	mg/day	US EPA, 2001a

(1) Based on site data. A one-year exposure duration is appropriate for carcinogenic effects, because the methodology averages exposures over a lifetime (US EPA, 2001a).

Table 6. Tier 2 Exposure Factors – Residential

Parameter	Abbrev.	Value	Units	Reference
Dermal absorption fraction	ABS	--chemical-specific--		US EPA, 2001b
Dermal adherence factor, adult	AF_a	0.07	mg/cm^2	US EPA, 2001a,b
Dermal adherence factor, child	AF_c	0.2	mg/cm^2	US EPA, 2001a,b
Dermal adherence factor, sediment	AF	0.3	mg/cm^2	US EPA, 1997, US EPA, 2001b
Averaging time, carcinogenic	AT_c	70	years	US EPA, 1991a
Averaging time, non-carcinogenic	AT_{nc}	30	years	Based on ED_r
Adult body weight	BW_a	70	kg	US EPA, 1991a, 2001a
Child body weight	BW_c	15	kg	US EPA, 1991a, 2001a
Exposure frequency	EF_r	350	days/year	US EPA, 1991a, 2001a,b
Exposure frequecy, sediment contact	EF_s	65	days/year	(1)
Exposure frequency, surface water contact	EF_{sw}	12	days/year	US EPA, 1997, 1998
Exposure time, surface water contact	ET_{sw}	1	hours/day	US EPA, 1997
Exposure duration	ED_r	30	years	US EPA, 1991a, 2001a,b
Adult total skin surface area	$SA_{T,a}$	18,150	cm^2/day	US EPA, 2001b
Child total skin surface area	$SA_{T,c}$	6,600	cm^2/day	US EPA, 2001b
Available skin surface area, soil contact adult	SA_a	5,700	cm^2/day	US EPA, 2001a,b
Available skin surface area, soil contact child	SA_c	2,800	cm^2/day	US EPA, 2001a,b
Fruit/vegetable ingestion rate, aboveground, child	$CR_{ag,c}$	0.0609	kg DW/d	US EPA, 1997b
Fruit/vegetable ingestion rate, belowground, child	$CR_{bg,c}$	0.0033	kg DW/d	US EPA, 1997b
Fruit/vegetable ingestion rate, aboveground, adult	$CR_{ag,a}$	0.0179	kg DW/d	US EPA, 1997b
Fruit/vegetable ingestion rate, belowground, adult	$CR_{bg,a}$	0.0098	kg DW/d	US EPA, 1997b
Contaminated plant fraction from the site	CPF	0.4	--	US EPA, 1996
Adult soil/sediment ingestion rate	$IR_{s,a}$	100	mg/day	US EPA, 1991a, 2001a

Table 6. Tier 2 Exposure Factors – Residential

Parameter	Abbrev.	Value	Units	Reference
Dermal absorption fraction	ABS	--chemical-specific--		US EPA, 2001b
Child soil/sediment ingestion rate	$IR_{s,c}$	200	mg/day	US EPA, 1991a, 2001a
Adult inhalation rate	$IR_{a,a}$	20	m^3/day	US EPA, 1991a, 2001a
Child inhalation rate	$IR_{a,c}$	10	m^3/day	US EPA, 1991a
Tap water ingestion rate, adult	$IR_{w,a}$	2	L/day	US EPA, 1991a, 2001a
Tap water ingestion rate, child	$IR_{w,c}$	1	L/day	US EPA, 1991a
Fish ingestion rate	IF	23.3	g/day	(2)
Water ingestion rate, surface water contact	$IR_{w,sw}$	0.05	L/hour	US EPA, 1989
Fraction of total skin surface exposed, sediment	FOSE	0.15	--	US EPA, 1992e
Adult skin surface area exposed, sediment	$SA_{e,a}$	2,723	cm^2/day	$= SA_{T,a} \times FOSE$
Child skin surface area exposed, sediment	$SA_{e,c}$	990	cm^2/day	$= SA_{T,c} \times FOSE$

(1) Assumes exposure to sediments three times per week during summer months (three months), and one time per week during spring and fall months (six months).

(2) Based on the average of recommended upper percentile fish ingestion for recreational freshwater anglers (US EPA, 1997b).

Table 7. Site-Wide Risk Assessment Report Outline

Volume 1: Site-Wide Human Health Risk Assessment

1.0 INTRODUCTION
- 1.1 Purpose of Human Health SWRA
- 1.2 Methodology
- 1.3 Relationship to Ecological SWRA
- 1.4 Report Organization

2.0 SITE DESCRIPTION
- 2.1 Site Background and History
- 2.2 Environmental Setting
- 2.3 Identification of Areas of Concern
- 2.4 Summary of Previous Investigations

3.0 DATA EVALUATION
- 3.1 Determination of Background Concentrations
- 3.2 Data Usability Evaluation
- 3.3 Statistical Analyses

4.0 CONCEPTUAL SITE MODEL
- 4.1 Potentially Exposed Populations
- 4.2 Potential Pathways of Human Exposure

5.0 TIER 1 RISK ASSESSMENT/SELECTION OF CHEMICALS OF POTENTIAL CONCERN
- 5.1 Frequency of Detection Evaluation
- 5.2 Evaluation of Detections Relative to Background Conditions
- 5.3 Comparison to Human Health Screening Benchmark Values
- 5.4 Results of Tier 1 Human Health Risk Assessment

6.0 TIER 2 RISK ASSESSMENT
- 6.1 Determination of Exposure Point Concentrations
- 6.2 Fate and Transport Modeling
- 6.3 Exposure Assessment
- 6.4 Toxicity Assessment
- 6.5 Risk Characterization

7.0 TIER 3 RISK ASSESSMENT (IF WARRANTED)

8.0 UNCERTAINTY ANALYSIS

9.0 SUMMARY OF RESULTS

10.0 REFERENCES

Table 7. Site-Wide Risk Assessment Report Outline

Volume 2: Site Wide Ecological Risk Assessment

1.0 INTRODUCTION
- 1.1 Purpose of Ecological SWRA
- 1.2 Methodology
- 1.3 Relationship to Human Health SWRA
- 1.4 Report Organization

2.0 SITE DESCRIPTION
- 2.1 Physical Description
- 2.2 Biological Characterization
- 2.3 Identification of Areas of Concern
- 2.4 Summary of Previous Investigations

3.0 DATA EVALUATION
- 3.1 Determination of Background Concentrations
- 3.2 Data Usability Evaluation
- 3.3 Statistical Analyses

4.0 ECOLOGICAL CONCEPTUAL SITE MODEL
- 4.1 Identification of Habitats and Biota
- 4.2 Identification of Potential Receptors of Concern

5.0 TIER 1 RISK ASSESSMENT/SELECTION OF CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN
- 5.1 Frequency of Detection Evaluation
- 5.2 Evaluation of Detections Relative to Background Conditions
- 5.3 Comparison to Ecological Screening Benchmark Values
- 5.4 Results of Tier 1 Ecological Risk Assessment

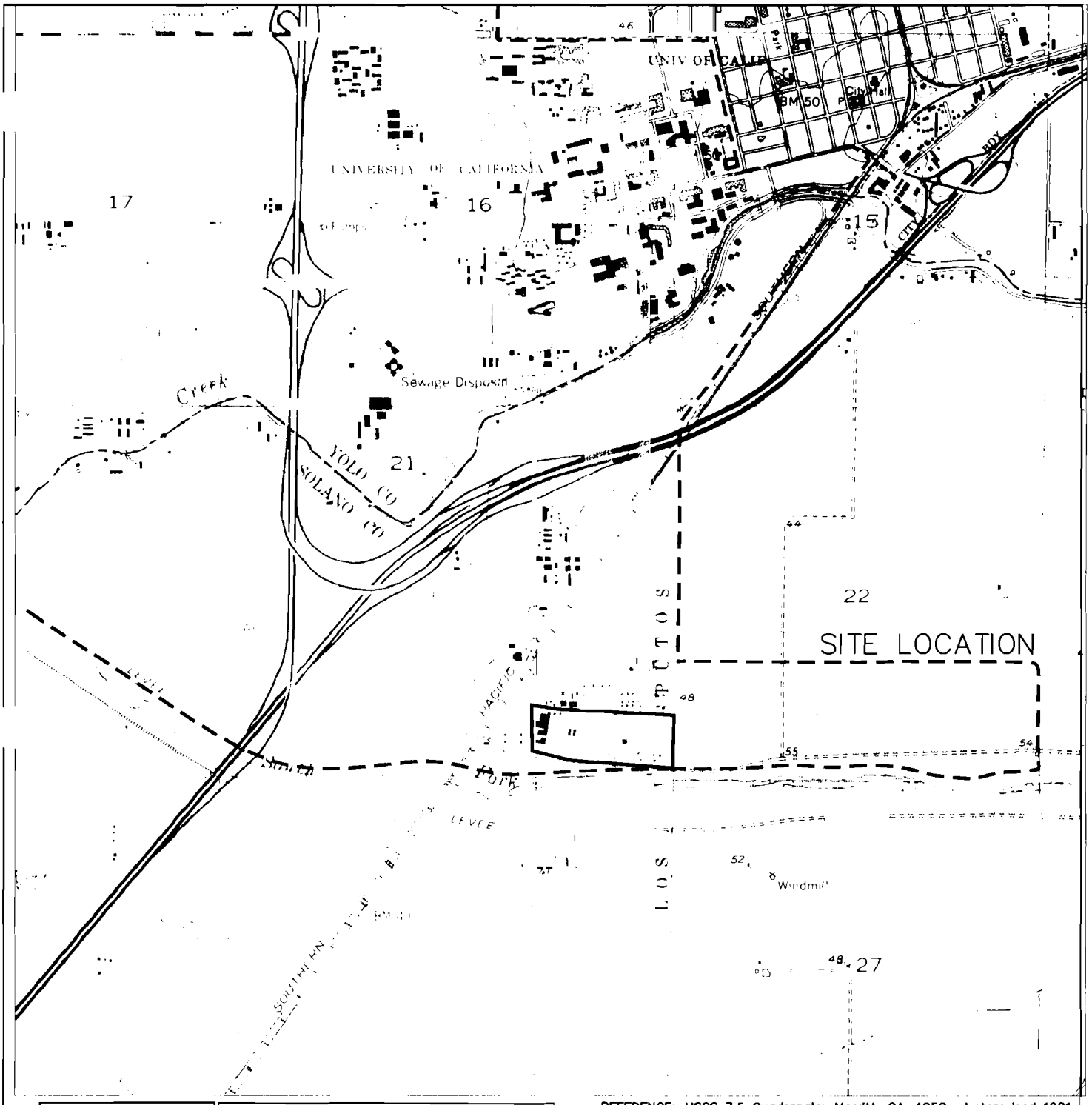
6.0 TIER 2 RISK ASSESSMENT
- 6.1 Selection of Receptor Species
- 6.2 Problem Formulation
- 6.3 Fate and Transport Modeling
- 6.4 Exposure Assessment
- 6.5 Toxicity Assessment
- 6.6 Risk Characterization

7.0 TIER 3 RISK ASSESSMENT (IF WARRANTED)

8.0 UNCERTAINTY ANALYSIS

9.0 SUMMARY OF RESULTS

10.0 REFERENCES



REFERENCE: USGS 7.5 Quadrangle; Merritt, CA, 1952, photorevised 1981; and Davis, CA, 1952, photorevised 1981.

EXPLANATION

- Campus Boundary
- Project Boundary

N

0 2000

Scale in Feet

MWH

MONTGOMERY WATSON HARZA

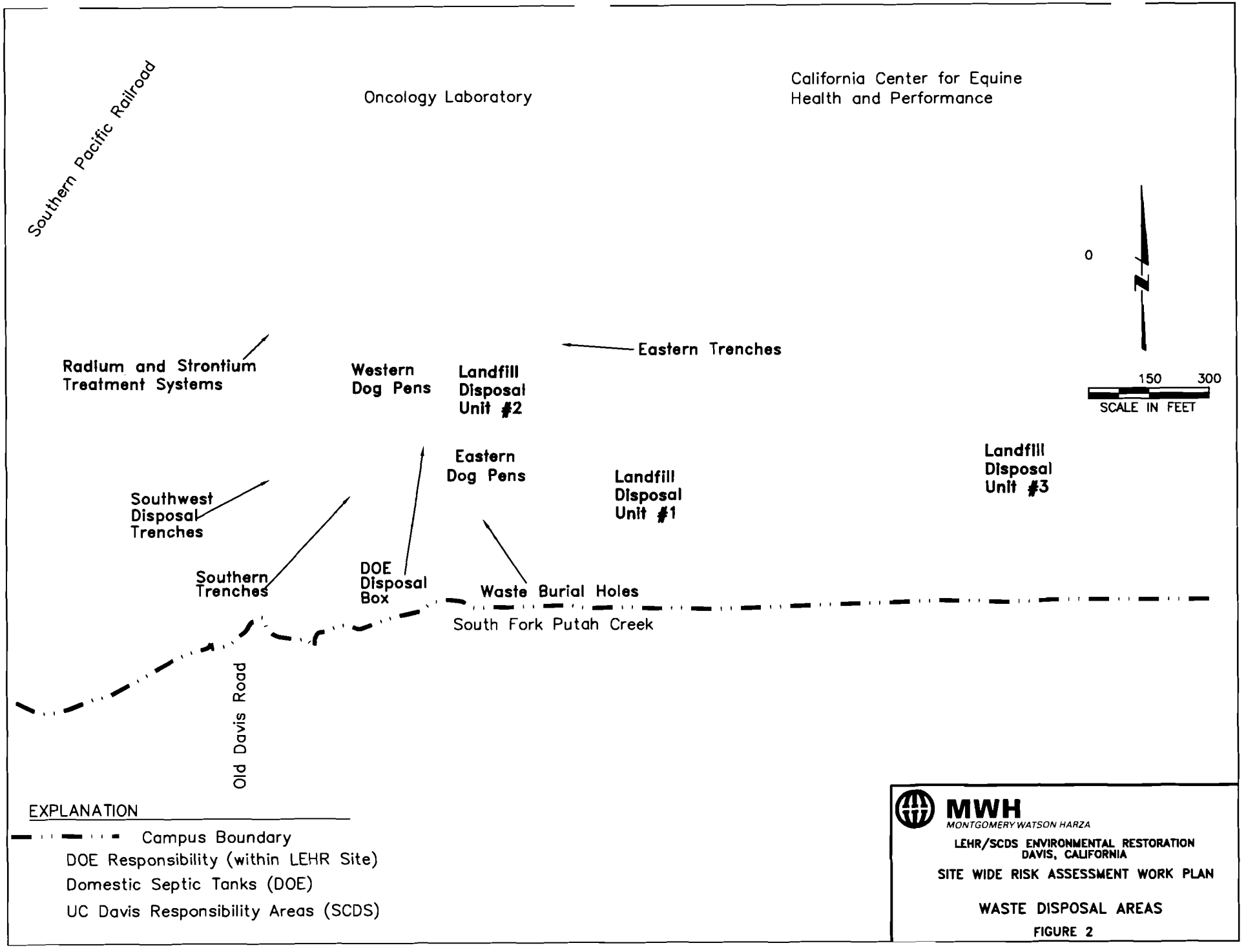
LEHR/SCDS ENVIRONMENTAL RESTORATION
DAVIS, CALIFORNIA

SITE WIDE RISK ASSESSMENT WORK PLAN

SITE VICINITY MAP

FIGURE 1

JOB No. 3R50099 FILE: PROJECT\LEHR\SWRA WORK PLAN\CADD\LEHRSiteMap.DWG SAC LJP REV. 1/14/02



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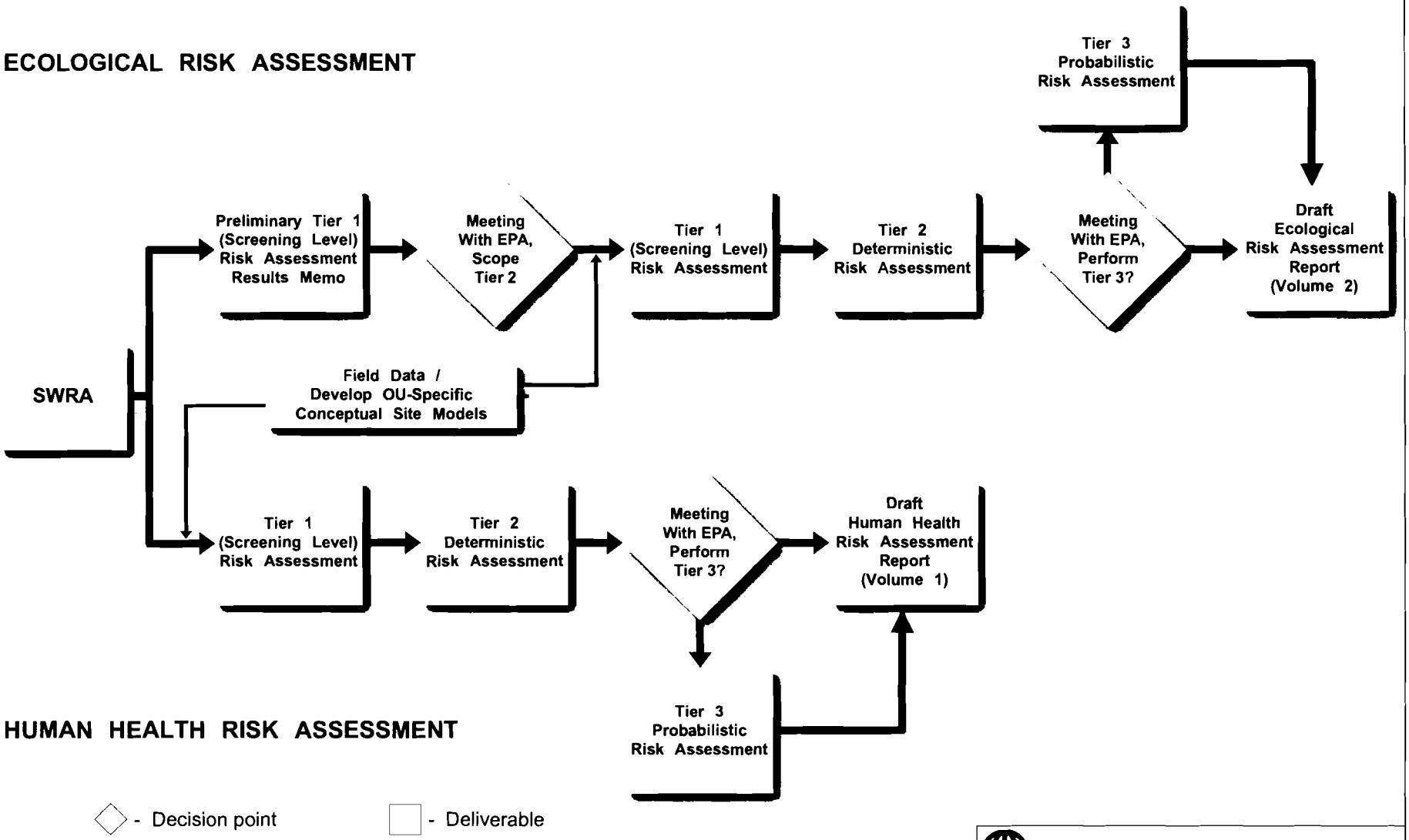


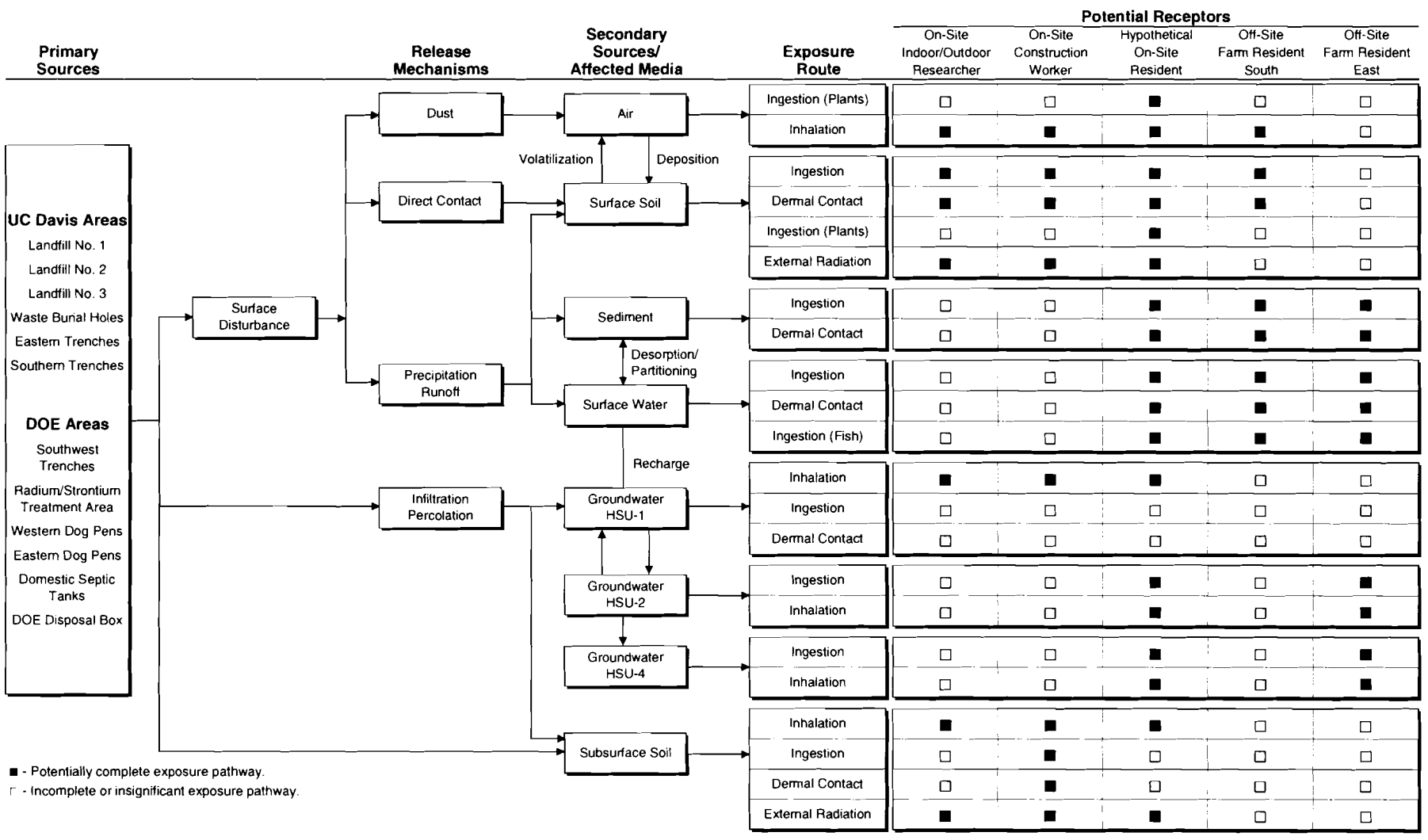
MWH
MONTGOMERY WATSON HARZA

LEHR/SCDS ENVIRONMENTAL RESTORATION
DAVIS, CALIFORNIA

SITE WIDE RISK ASSESSMENT WORK PLAN

RISK ASSESSMENT PROCESS

FIGURE 3



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SITE WIDE RISK ASSESSMENT WORK PLAN

HUMAN HEALTH
CONCEPTUAL SITE MODEL

FIGURE 4

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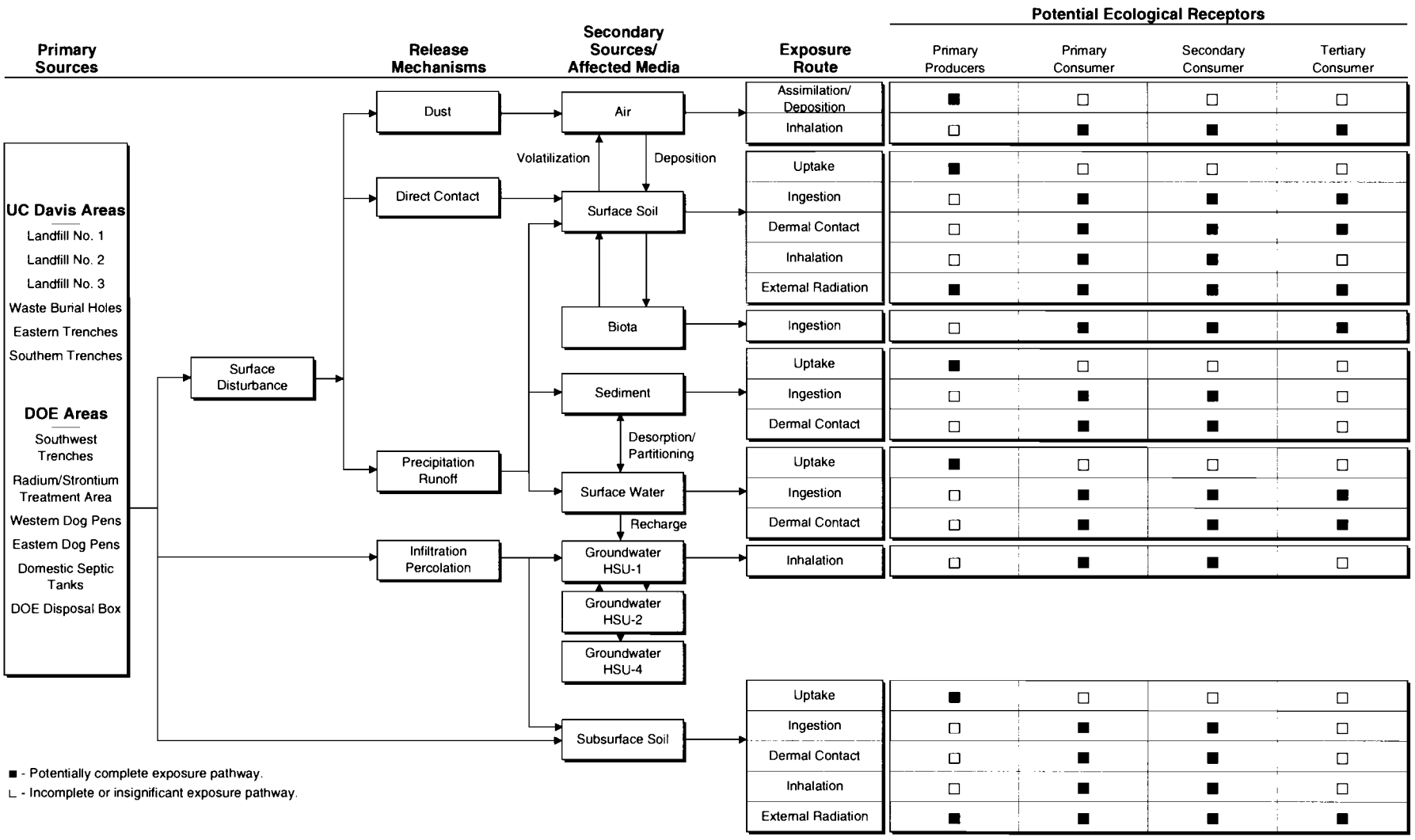

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SITE WIDE RISK ASSESSMENT WORK PLAN

ECOLOGICAL
CONCEPTUAL SITE MODEL

FIGURE 5

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