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FINAL FEASIBILITY STUDY FOR THE UNIVERSITY OF CALIFORNIA, DAVIS AREAS VOLUME 1: SOIL/SOLID WASTE AND SOIL GAS

at the

Laboratory for Energy-related Health Research/ Old Campus Landfill Superfund Site University of California, Davis

prepared for

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April 30, 2012
Rev. 0

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Weiss Associates' work for the Laboratory for Energy-related Health Research/Old Campus Landfill was conducted under my supervision. To the best of my knowledge, the data contained herein are true and accurate and satisfy the scope of work prescribed by the client for this project. The data, findings, recommendations, specifications or professional opinions were prepared solely for the use of the University of California, Davis in accordance with generally accepted professional geologic practice. We make no other warranty, either expressed or implied, and are not responsible for the interpretation by others of the contents herein.

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ACRONYMS AND ABBREVIATIONS

AE	assessment endpoint
ANL	Argonne National Laboratory
AOC	*Administrative Order on Consent for Removal Action and Remedial Investigation/Feasibility Study*
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
BBL	Blasland, Bouck, & Lee, Incorporated
BC	Brown and Caldwell
bgs	below ground surface
BMP	best management practice
Cal/EPA	California Environmental Protection Agency
CAMU	corrective action management unit
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHE	Center for Health and the Environment
CHHSL	California Human Health Screening Level
COC	constituent of concern
COPC	constituent of potential concern
COPEC	constituent of potential ecological concern
CSM	conceptual site model
CWA	Clean Water Act
CY	cubic yard(s)

DDC	density-driven convection
DOE	United States Department of Energy
Eh	oxidization state
EPC	exposure point concentration
ET	Eastern Trenches
FEMA	Federal Emergency Management Agency
FS	Feasibility Study
FS – Volume 1	*Final Feasibility Study for the University of California, Davis Areas Volume 1: Soil/Solid Waste and Soil Gas*
FS – Volume 2	*Feasibility Study for the University of California, Davis Areas Volume 2: Groundwater*
GHG	greenhouse gas
GRA	general response action
HDPE	high-density polyethylene
HELP	Hydrogeologic Evaluation of Landfill Performance
HFSDA	Hopland Field Station Disposal Area
HHRA	human health risk assessment
HHRA - Part A	*Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part A – Risk Estimate) LEHR/SCDS Environmental Restoration*
HHRA - Part B	*Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part B – Risk Characterization for DOE Areas) at the Laboratory for Energy-related Health Research, University of California, Davis*
HHRA - Part C	*Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part C – Risk Characterization for UC Davis Areas)*
HI	hazard index
HQ	hazard quotient
HSU	hydrostratigraphic unit
IC	institutional control

K_d	soil/water partitioning coefficient
LCRS	leachate collection and removal system
LCY	loose cubic yard
LEHR	Laboratory for Energy-related Health Research
LFU	landfill unit
LLRW	low-level radioactive waste
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effect concentration
LRDP	UC Davis Long-Range Development Plan
LTW	low threat waste
LUC	land use covenant
MCL	Maximum Contaminant Level
ME	measurement endpoint
MMBTU	million British thermal units
MMP	Materials Management Plan
MOA	Memorandum of Agreement
MS4	municipal separate storm sewer system
MWH	Montgomery Watson Harza
NOAEL	no observed adverse effect level
NCP	*National Oil and Hazardous Substances Pollution Contingency Plan*
NO_x	nitrogen oxides
NPL	National Priorities List
NUFT	Non-isothermal Unsaturated Flow and Transport
O&M	operations and maintenance
OCL	Old Campus Landfill

OEHHA	Office of Environmental Health Hazard Assessment
OWTP	Old Wastewater Treatment Plant
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCG	preliminary cleanup goal
PM_{10}	particulate matter with a diameter less than 10 micrometers
PRG	Preliminary Remediation Goal
PRP	potentially responsible party
PTW	principal threat waste
RACER	Remedial Action Cost Engineering and Requirements
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD/RA	remedial design/remedial action
redox	reduction/oxidization
RI	*UC Davis Final Remedial Investigation Report*
ROD	Record of Decision
RSL	Regional Screening Level
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
Site	Laboratory for Energy-related Health Research/Old Campus Landfill Superfund Site
SO_x	sulfur oxides
ST	Southern Trenches
SWERA	*Site-Wide Ecological Risk Assessment*
SWRA	Site-Wide Risk Assessment

SWRCB	State Water Resources Control Board
TEV	total excavated volume
TPHRL	Toxic Pollutant Health Research Laboratory
TRV	toxicity reference value
UC ANR	University of California Agriculture and Natural Resources
UC Davis	University of California, Davis
UCOP	University of California Office of the President
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WBH	Waste Burial Holes
Weiss	Weiss Associates
ºF	degrees Fahrenheit

EXECUTIVE SUMMARY

In May 1994, the Laboratory for Energy-related Health Research (LEHR) and the Old Campus Landfill (OCL) Superfund Site (Site) were placed on the National Priorities List (NPL). As defined in the 1999 *Administrative Order on Consent for Removal Action and Remedial Investigation/Feasibility Study* (AOC) and the 1999 *Federal Facility Agreement for the Laboratory for Energy-Related Health Research and the South Campus Disposal Superfund Site*, the University of California, Davis (UC Davis) and the United States Department of Energy (DOE) are responsible for remediation of environmental impacts associated with past activities at the Site. In December 2009, DOE and the United States Environmental Protection Agency (US EPA) finalized the Record of Decision (ROD) for the DOE areas at the Site. The ROD included provisions for land use controls, long-term monitoring, and contingent remediation, should residual contamination in these areas impact groundwater. UC Davis has prepared this *Final Feasibility Study for the University of California, Davis Areas Volume 1: Soil/Solid Waste and Soil Gas* (FS – Volume 1) to identify remedial alternatives for the soil/solid waste/soil gas areas under their responsibility at the Site. A separate Feasibility Study (FS) that develops remedial alternatives for contaminants in groundwater at the Site will also be prepared (*Feasibility Study for the University of California, Davis Areas Volume 2: Groundwater* [FS – Volume 2]).

The *UC Davis Final Remedial Investigation Report* was completed in 2004. This report included data obtained from over 15 years of investigations conducted at the Site. These data formed the basis for the Site-Wide Risk Assessment (SWRA). The SWRA was completed in two volumes: Volume 1, the Human Health Risk Assessment (HHRA), and Volume 2, the Ecological Risk Assessment. Volume 1 consisted of three parts: the *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part A – Risk Estimate) LEHR/SCDS Environmental Restoration* (HHRA – Part A); the *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part B – Risk Characterization for DOE Areas) at the Laboratory for Energy-related Health Research, University of California, Davis* (HHRA – Part B); and the *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part C – Risk Characterization for UC Davis Areas)* (HHRA – Part C). Part A provided the human health risk assessment for the Site in its entirety, including areas under the responsibility of DOE, in accordance with the 1997 Memorandum of Agreement (MOA) between UC Davis and DOE. Human health risk characterizations were presented in Parts B and C for the areas that are under the responsibility of DOE and UC Davis, respectively. In 2006, the *Site-Wide Ecological Risk Assessment* (SWERA) was completed and superseded Volume 2 of the SWRA. In 2006, using data from these previous reports, UC Davis submitted the Draft Screening of Alternatives for the Feasibility Study. Since that time, the *Feasibility Study Data Gaps Technical Report* was completed (2010). This report presented findings from three additional investigations: development of a conceptual model for hexavalent chromium in groundwater; an examination of the soil-to-groundwater impact from constituents found at the Site; and an evaluation of vapor intrusion.

Purpose

This FS Report (FS – Volume 1) was prepared to fulfill the requirements of Section 300.430(e) of the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP). The specific objectives of FS – Volume 1 include:

- Summarizing the Site's history, nature and extent of contamination, risks to human health and the environment, potential impact to groundwater from constituents of concern (COCs) found at the Site, and fate and transport of COCs;
- Identifying remedial action objectives (RAOs) and applicable or relevant and appropriate requirements (ARARs);
- Developing general response actions and process options, and identifying and screening potential treatment technologies/containment/disposal requirements;
- Assembling the process options into remedial alternatives;
- Analyzing the alternatives against the nine NCP evaluation criteria for remedial action; and
- Comparing the alternatives with each other.

Following completion of the FS - Volume 1, the US EPA will present its preferred alternative in the Proposed Plan. Following a 30-day public comment period, the US EPA will select the final remedy and document the basis for its selection in the ROD.

Site History

UC Davis operated three land disposal units within the boundaries of LEHR/OCL: Landfill Unit (LFU) No. 1 was operated from the early 1940s through the mid-1950s; LFU-2 was operated from 1956 through 1967; and LFU-3 was operated from 1963 through 1967. These three units primarily received municipal-type waste from the main UC Davis campus. From 1956 through 1974, the Waste Burial Holes (WBH) area was primarily used to dispose of radioactive wastes from the UC Davis campus. From 1957 through 1965, laboratory waste was sent to the Eastern Trenches (ET) area; the Southern Trenches (ST) and Hopland Field Station Disposal Area (HFSDA) areas received minor amounts of experimental animal remains from UC Davis laboratories during the same time period. Between 1968 and 1970, the DOE constructed the Eastern Dog Pens on top of the southern portion of LFU-2; these dog pens were used by DOE to house research beagles until 1988, when research ceased. In the DOE ROD, the selected remedy for the Eastern Dog Pens was limited to implementing a soil management plan during future soil-disturbing activities.

Nature and Extent of Contamination

Table ES-1 lists FS – Volume 1 COCs and summarizes the nature and extent of contamination for land disposal units LFU-1, LFU-2, WBH, ET, LFU-3, and ST. Waste was last disposed of on-Site over 35 years ago. The extent of contamination in the land disposal units is illustrated on Figure ES-1. This figure shows locations of exploratory trenches and waste identified within the trenches, geophysical anomalies, and sample results greater than human health screening levels. Minimal potential principal threat waste (PTW) (waste that is considered highly toxic or highly mobile, or that would potentially present a risk to human health or the environment in the event of exposure) was found in some of the exploratory trenches. The magnitude of exceedance of a constituent over screening levels is depicted in different colors on this figure (i.e., between 1 and 10 times the screening level, between 10 and 100 times the screening level, or greater than 100 times the screening level).

Risks to Human Health and Potential Impact to Groundwater

Since the publication of the HHRA – Part C, where preliminary soil/solid waste and soil gas FS COCs were identified, additional data have been collected and the risk-based screening values for soil and soil gas constituents have been updated. Therefore, a re-evaluation of the previously-identified soil/solid waste and soil gas FS COCs was conducted and is presented in this document. Updated risks and hazards and the primary risk drivers (constituents contributing greater than 80 percent of the total risk) for unrestricted land use (age-adjusted adult [adult plus child]) at depths of 0 to 20 feet below ground surface (bgs) for soil/solid waste are:

Land Disposal Unit	Risk	Hazard	Risk/Hazard Drivers[1]
Eastern Trenches	8.2×10^{-5}	---	Tritium
LFU-1	1.4×10^{-4}	---	Arsenic
LFU-2	1.6×10^{-4}	---	Potassium-40
LFU-3	2.2×10^{-5}	2.2	Carbon-14, Manganese, Cesium-137, Strontium-90
Southern Trenches	1.1×10^{-5}	---	Carbon-14
Waste Burial Holes	2.1×10^{-2}	---	Cesium-137

[1]Lead was also present at concentrations that may pose a potential risk (blood-lead levels greater than one microgram per deciliter) at LFU-1, LFU-2, and LFU-3.

---: COCs not present

For unrestricted land use, the estimated cancer risk is within or near the NCP's cancer risk range of 10^{-4} and 10^{-6} and near the hazard index of 1.0 for each of the land disposal units, except the WBH, where the estimated risk is 2×10^{-2}. A removal action was conducted at the WBH in 1999. The majority of solid waste was removed; however, soil from the removal action was placed back into the excavated areas. The estimated risk at the WBH is due to two detected values of cesium-137 at a depth of 7 feet bgs at the same sample location. These are conservative estimates, since the long-range plan for the Site does not include residential use. Moreover, the disposal sites are currently covered with compacted soil and vegetation; therefore, potential exposure of humans, burrowing animals, and deep-rooted vegetation to contaminated soil/solid waste is minimized.

In 2008, soil gas samples were collected at depths of 5, 15, and 25 feet bgs; the updated cancer risk for the vapor intrusion pathway for the five foot depth and the depth with the highest risk and associated risk drivers are:

Land Disposal Unit	Risk at 5 feet bgs	Risk Driver at 5 feet bgs	Highest Risk/Depth (feet bgs)	Risk Driver
Eastern Trenches	1.9×10^{-5}	Chloroform	7.0×10^{-5}/15	Chloroform
LFU-1	5.3×10^{-7}	Formaldehyde	5.7×10^{-6}/15	1,3-Butadiene
LFU-2	1.6×10^{-4}	Chloroform	1.6×10^{-4}/5	Chloroform
LFU-3	4.6×10^{-7}	Formaldehyde	1.2×10^{-6}/25	Formaldehyde
Southern Trenches	1.8×10^{-7}	Chloroform	1.8×10^{-7}/5	Chloroform
Waste Burial Holes	1.4×10^{-6}	Formaldehyde	1.4×10^{-6}/5	Formaldehyde

For the vapor intrusion pathway, the estimated cancer risk for unrestricted land use is at or within the NCP's cancer risk range. Non-cancer risks were less than the hazard index of 1.0.

Although formaldehyde was the risk driver in LFU-3 and the WBH, the risk estimated from formaldehyde at each of these locations was near or below 1×10^{-6} (see Table B-8, Appendix B); therefore, formaldehyde is not considered a COC for this FS. In addition, since the vapor intrusion pathway was evaluated, recommended attenuation factors have been updated in the California Department of Toxic Substances' 2011 *Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance)*. 1,3-Butadiene in LFU-1 and the ET and formaldehyde in the WBH would not have been identified as COCs if these attenuation factors had been used. However, use of the new values does not impact the overall scope or evaluation of the alternatives in this FS; therefore, corresponding COC changes have not been made. 1,3-Butadiene should be eliminated as a COC in the Proposed Plan and ROD.

The Site-wide cancer risk was calculated by summing the total risk at each of the six land disposal units for soil/solid waste and soil gas with the Site-wide cancer risk from groundwater. The cancer risk from groundwater was calculated as 1.3×10^{-3} for age-adjusted residential adults in the HHRA – Part A. The Site-wide cancer risk is estimated to be 2.3×10^{-2}. Approximately 88 percent of this risk comes from the two cesium-137 samples in the WBH, as discussed above. The Site-wide non-cancer hazard was calculated in a similar manner as above and is estimated to be 9.3. Approximately 63 percent of the total hazard is derived from the estimated groundwater hazard (primarily due to chromium and chloroform); 24 percent of the total hazard is from manganese in LFU-3 (hazard index 2.2).

The potential impact to groundwater was evaluated in the *2010 Feasibility Study Data Gaps Technical Report*. COCs identified in this report that have the potential to impact groundwater from residual contamination in soil/solid waste include:

Land Disposal Unit	Constituent
Eastern Trenches	Tritium, Carbon-14
LFU-1	Copper, Selenium, Carbon-14
LFU-2	Cadmium, Carbon-14
LFU-3	Barium, Cadmium, Copper, Carbon-14
Southern Trenches	Carbon-14[1]
Waste Burial Holes	Tritium, Carbon-14

[1]Based on information provided in HHRA-Part C, carbon-14 is designated a constituent of potential concern; subject to change based on additional investigation included in the remedial alternatives.

COCs with the potential to impact groundwater from soil gas include: chloroform and 1,2-dichloroethane in the ET and chloroform in LFU-2.

Remedial Action Objectives

RAOs for the Site were developed for the protection of human health, the environment, and groundwater quality, as listed below:

- Prevent human contact with contamination in soil/solid waste and soil gas that may pose excess cumulative cancer risk greater than the lower bound of the risk range, 1×10^{-4} to 1×10^{-6}.
- Prevent human contact with contamination in soil/solid waste and soil gas that may pose a non-cancer hazard with a hazard index greater than 1.0.
- Prevent potential future impacts to groundwater above Maximum Contaminant Levels or Maximum Contaminant Level Goals (chloroform only) from landfill waste and affected soil/soil gas.
- Minimize threats to the environment by limiting ecological receptor exposure, including, but not limited to, sensitive and critical habitats of species protected under the state and federal Endangered Species Acts.
- Prevent contact of surface water or storm water with landfill waste or impacted soil.

Site-specific preliminary cleanup goals (PCGs) for soil/solid waste and soil gas were developed for the protection of human health and groundwater resources in this FS. Protection of the environment has been evaluated qualitatively due to the order-of-magnitude level of uncertainty in the ecological risk assessment. Cleanup levels for the Site will be established in the ROD.

General Response Actions/Selected Process Options

UC Davis evaluated a full range of general response actions and process options for the solid waste areas at the Site. The selected response actions and process options included:

General Response Action	Process Option
No Action/No Further Action	No Action/No Further Action
Institutional Controls	Land Use Restrictions Subsurface Hazard Notification Groundwater Monitoring Storm Water Monitoring
Containment	Storm Water Runoff Diversion/Collection Extended Detention Basin Storm Water Lift Station Asphalt/Concrete Cap, Single-Layer Evapotranspiration Cap Clay Cover, Single-Layer Multiple-Layer Cap Geomembrane Liner Geosynthetic Clay Liner Leachate Collection and Removal System
Removal	Excavation Using Conventional Heavy Equipment Principal Threat Waste Removal
Ex Situ Physical/Chemical Treatment	Solidifying/Stabilizing Additive
Disposal	On-Site Reuse

General Response Action	Process Option
	On-Site Disposal Off-Site Disposal

Development and Detailed Analysis of Remedial Alternatives

The alternatives developed to remediate soil/solid waste and soil gas for the six land disposal units are:

- SW-1: No Action/ No Further Action;
- SW-2: Institutional Controls and Groundwater Monitoring;
- SW-3: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-4: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-5: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-6: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-7: VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
- SW-8: VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-9: Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring; and
- SW-10: Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Each of these alternatives, with the exception of "No Action/No Further Action," was designed to meet the RAOs. A corrective action management unit (CAMU) is defined by the US EPA as an area within a facility that is used only for managing remediation wastes for implementing corrective action or cleanup at a facility. Table ES-2 presents a matrix showing the elements involved in each alternative.

The NCP identifies nine criteria to be used in the detailed analysis of alternatives. These are categorized into three groups as follows:

Threshold Criteria - Criteria that must be met in order for an alternative to be selected:

- Overall protection of human health and the environment; and
- Compliance with ARARs.

Balancing Criteria - Primary considerations in selecting an alternative:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

Modifying Criteria - Criteria that must be considered in the remedy selection:

- State acceptance; and
- Community acceptance.

For each alternative, a detailed analysis was conducted with respect to the first seven NCP criteria (threshold and balancing criteria). The modifying criteria will be considered following the receipt of regulatory agency and public comments on the FS –Volume 1 and the Proposed Plan.

Evaluation of Remedial Alternatives

Alternatives were compared and ranked on a scale of 0 to 5, where a higher ranking represents a more favorable outcome for the two threshold criteria and five balancing criteria (Table ES-3). Each of the alternatives was developed to be compatible with DOE's land use control (soil management) remedy for the Eastern Dog Pens.

Overall Protection of Human Health and the Environment

Except for the No Action/No Further Action Alternative, each alternative developed in this FS would be protective of human health and the environment and meet RAOs, although nominal levels of COCs will remain on-Site. Updated estimated soil/solid waste cancer risks are currently within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except the WBH), and over 20 years of groundwater monitoring indicate limited migration of contamination from soil/solid waste to groundwater. Institutional controls (ICs) such as land use covenants would prohibit residential development and restrict non-residential development. Under Alternatives SW-3 through SW-10, the two volatile organic compound (VOC) "hot spot" areas would be removed, and increasing quantities of PTW and hazardous material would be sent off-Site for disposal. Graded covers and surface caps would isolate waste and prevent infiltration; storm water drainage enhancements would further limit infiltration over the land disposal units. Alternative SW-8 would provide greater protection than Alternatives SW-3 through SW-7 by enveloping soil/solid waste in the surface cap and a bottom liner with a leachate collection and removal system. Alternatives SW-9 and SW-10 would be the most protective because the majority of waste is excavated and removed off-Site; however, COCs would remain below 20 feet bgs.

Compliance with ARARs

Alternatives SW-2 through SW-10 would be compliant with ARARs. Alternative SW-1 would not comply with ARARs because remedial actions are not proposed under the No Action/No Further Action Alternative.

Long-Term Effectiveness and Permanence

Alternative SW-1 would not be effective in the long term, since soil/solid waste and soil gas would remain in place without a long-term management plan. ICs that limit exposure to the waste, including a land use covenant, would be effective in the long term under Alternatives SW-2 through SW-10, as long as enforcement of these controls is maintained. Excavation and off-Site disposal in Alternatives SW-3 through SW-10 would be effective in permanently removing soil/solid waste and soil gas from the Site. As more waste is progressively removed in each alternative, it is expected that long-term effectiveness and permanence would increase as reliance on ICs decreases. Furthermore, uncertainty with respect to unknown hazardous materials within the land disposal units decreases as more waste is removed and sent off-Site for disposal. Alternatives SW-3 through SW-9 would provide protection against remaining soil/solid waste by isolating waste with graded covers or surface caps, which would also limit infiltration and reduce the risk of leaching to groundwater. Alternatives SW-7, SW-8, and SW-9 also provide additional protection by consolidating waste from the ST, HFSDA, and LFU-3 into a CAMU, thereby eliminating exposure, risk, and COC migration in these areas.

Reduction of Toxicity, Mobility, or Volume through Treatment

For Alternatives SW-3 through SW-10, some waste sent off-Site for disposal could undergo on-Site *ex situ* solidification/stabilization prior to off-Site disposal. The actual amount of treated waste would depend on specific volumes of waste generated and its treatability based on its hazardous characteristics. Assuming that the total volume of *ex situ* treatment is proportional to the waste volume sent off-Site for disposal, Alternative SW-10 would involve the greatest potential reduction of toxicity, mobility, or volume of hazardous material, and Alternatives SW-1 and SW-2 would involve no reduction.

Short-Term Effectiveness

Alternative SW-1 would not add any short-term impacts to the public, on-Site workers, or the environment. Alternative SW-2 would involve minor short-term impacts associated with the installation of groundwater monitoring wells. Alternatives SW-3 through SW-10 would involve similar types of community, worker, and environmental risks, with the total risk proportional to the time to completion. In addition, as transportation of material on-Site and waste disposal off-Site increases from Alternative SW-2 (approximately 1 truck trip and 450 miles) to Alternative SW-10 (approximately 12,400 truck trips and 4,667,450 miles), local traffic congestion, air emissions, greenhouse gas emissions, and accident and emissions fatality risks would increase. Greenhouse gas emissions increase by over two orders of magnitude between SW-2 (42 metric tons) and SW-10 (15,200 metric tons). Similarly, common air pollutants (nitrogen oxides [NO_x], sulfur oxides [SO_x], and particulate matter less than 10 micrometers in diameter [PM_{10}]) increase from approximately 0.3 metric tons to 50 metric tons. Total energy use is estimated to increase by over two orders of magnitude between Alternatives SW-2 and SW-10; when converted to an equivalent volume of diesel fuel, the energy consumed ranges from approximately 4,000 gallons of diesel fuel under Alternative SW-2 to 1,674,500 gallons of diesel fuel under Alternative SW-10. The accident and emissions fatality risks from both on- and off-Site activities increase by over three orders of magnitude from SW-2 (2×10^{-4}) to SW-10 (7×10^{-1}).

The RAOs of preventing human and ecological exposure would be achieved at the completion of remedial activities. Alternative SW-1 would take no time to implement and would not provide any additional protection. Alternatives SW-2 through SW-7 would require one construction season, and Alternatives SW-8 through SW-10 would achieve protection in two construction seasons.

Implementability

There are no barriers to implementing Alternative SW-1. Alternative SW-2 would be relatively quick and easy to implement. Alternatives SW-3 through SW-7 would be more complex, in that soil/solid waste would be excavated, segregated, and covered/capped. Alternative SW-8 would be the most complex to implement because it requires the installation of a bottom liner and leachate collection and removal system. The large-scale removals proposed in Alternatives SW-9 and SW-10 would be relatively straightforward to implement because they include the fewest design requirements. Each alternative would be based on standard practices, and suitable landfill space is expected to remain available during remedial actions. Services and materials necessary for implementation are readily available. The administrative viability of each alternative is not a barrier, and suitable on-Site land is available for the storm water drainage enhancements proposed under Alternatives SW-3 through SW-10 and for the area between the ET and LFU-1 for Alternative SW-8.

Cost

Figure ES-2 summarizes the costs of each alternative. Total present value costs range from $6.5 million for Alternative SW-2 to $108.7 million for Alternative SW-10 (Figure ES-2). Periodic and operations and maintenance costs are similar among Alternatives SW-2 through SW-10, with differences in total cost related to differences in capital costs. The primary driver of capital cost is related to the total volume of excavated material sent off-Site for disposal, as well as the composition of that material (i.e., low-level radioactive waste or mixed waste). Since Alternatives SW-9 and SW-10 would involve the off-Site disposal of most soil/solid waste, the total costs are much higher than the other alternatives. Although similar amounts of soil/solid waste are sent off-Site for disposal under Alternatives SW-4 through SW-8, additional capital costs under Alternative SW-8 are associated with the much greater excavation volume and the installation of a bottom liner and leachate collection and removal system.

State and Community Acceptance

State and community acceptance of the alternatives will be established as part of the Comprehensive Environmental Responsiveness, Compensation, and Liability Act (CERCLA) public participation process. A summary of the remedial alternatives and the preferred remedy will be presented in the Proposed Plan. A public meeting will be held during the 30-day comment period for the Proposed Plan to receive comments from the public. Per the CERCLA process, public comments will be considered in the selection of the final remedy, and responses to the public comments will be presented in the ROD.

Green Remediation

Opportunities to evaluate and implement green remediation strategies exist throughout the project life cycle, and green practices may help support a protective remedy. During the design processes, opportunities for green design substitutions would be evaluated. Recommendations to evaluate and apply best management practices to the proposed alternatives in order to maximize environmental benefits, reduce project costs, and return sites to reuse consistent with cleanup goals could include:

- Use energy- and fuel-efficient equipment;
- Use alternative fuels;
- Reduce engine idling;
- Use native rather than imported vegetation;
- Implement recycle and reuse program for demolition debris;
- Reclaim and stockpile uncontaminated soil to use as fill;
- Locally source soil from campus and other nearby projects; and
- Utilize on-Site *ex situ* treatment to reduce trips to hazardous waste facilities.

EXECUTIVE SUMMARY FIGURES AND TABLES

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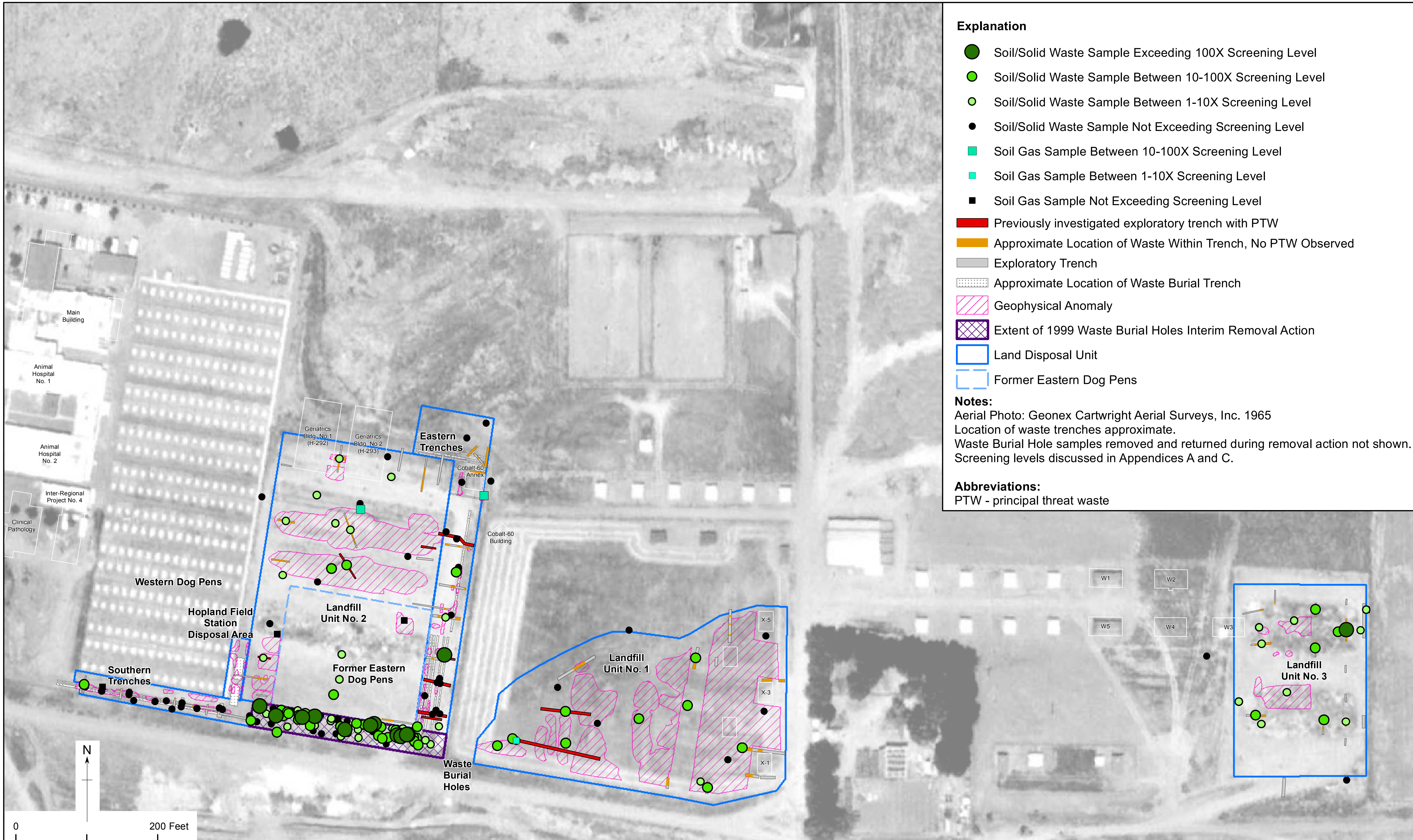

Figure ES-1. Extent of Contaminated Soil/Solid Waste and Soil Gas - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

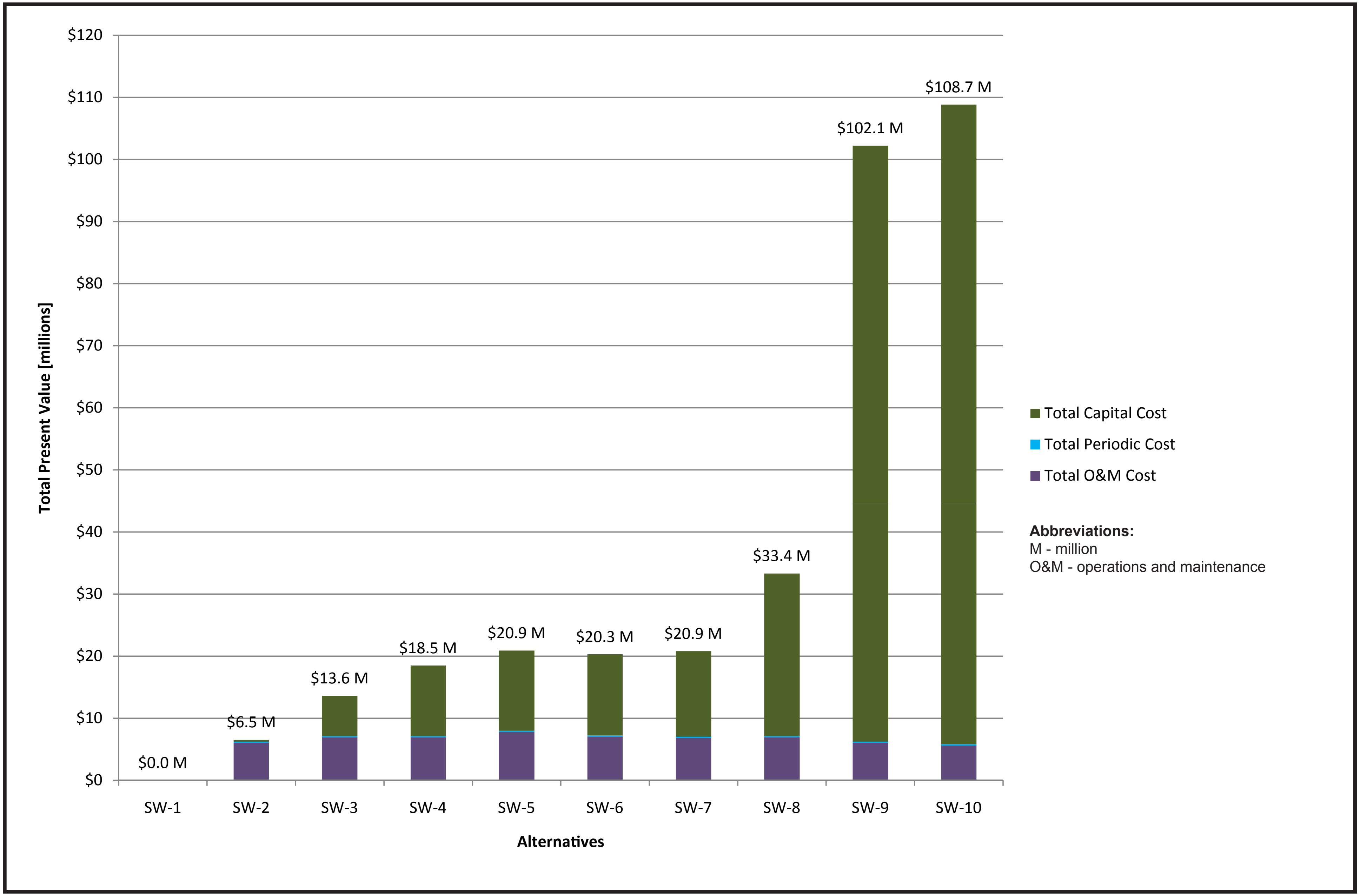

Figure ES-2. Total Present Value of Each Alternative - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

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Table ES-1. Summary of Nature and Extent of Contamination - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

			Landfill Unit No. 1	Landfill Unit No. 2	Waste Burial Holes	Eastern Trenches	Landfill Unit No. 3	Southern Trenches
	Waste Disposal Period		1940s and 1950s	1956 through 1967	1956 through 1974	1957 through 1965	1963 through 1967	1957 through 1965
Nature	Interim Removal/Remedial Actions		None	None	Underwent a removal action in 1999, due to high carbon-14 and tritium activities; waste removed to 12 feet below ground surface	None	North-south trending ditch along east side of unit was lined with concrete to prevent erosion of waste	None
Nature	Nature of Material Disposed		Campus wastes (mainly glass, metal, ash, and charcoal); potentially some chemical waste and sewage treatment plant sludge	General refuse, animal parts, and laboratory chemicals	Low-level radioactive material, contaminated soil placed back in holes after 1999 removal action	Low-level radioactive material, general laboratory chemicals, pesticides, bones, and dog pen waste	General municipal waste (mainly glass) and construction debris (mainly rusted metal, concrete, bricks, and ceramic material); potentially minor quantities of laboratory waste	Low-level radioactive materials, bones, animal feces, and laboratory waste mixed with gravel
Nature	Potential Principal Threat Waste Identified by Exploratory Trenching		Blue and green crystalline material	Lead (possibly a battery), ampules, and lead casing with white crystalline powder	Source material removal during 1999 removal action	Bottles/vials with clear/amber/reddish-brown liquids, orange/yellow/yellowish-olive/white powders, light green solid, jars with white crystalline powder, large ceramic crocks with whitish granular powder, olive-colored glass bottle with volatile liquid, wide-mouth bottles with thick liquid, 5-gallon bucket of "weedkiller," and large glass bottles containing fluid	None identified	None identified
Nature	COCs	Soil/solid waste COCs	Arsenic, lead, carbon-14, and benzo(a)pyrene	Lead, carbon-14, cesium-137, potassium-40, strontium-90, Aroclor 1260, benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene	Carbon-14, tritium, strontium-90, cesium-137, and naphthalene	Carbon-14 and tritium	Lead, manganese, carbon-14, cesium-137, strontium-90, and Aroclor 1260	Carbon-14
Nature	COCs	Soil gas COCs	1,3-Butadiene	1,2-Dichloropropane, chloroform, tetrachloroethene	None identified	1,2-Dichloroethane, 1,2-dichloropropane, 1,3-butadiene, and chloroform	None identified	None identified
Nature	COCs	Soil-to-groundwater COCs	Carbon-14, copper, and selenium	Cadmium, carbon-14, and chloroform	Carbon-14 and tritium	Carbon-14, tritium, chloroform, and 1,2-dichloroethane	Barium, cadmium, copper, and carbon-14	Carbon-14 [1]
Extent	Approximate Waste Orientation		North-south-trending trenches south of the former cobalt-60 field; east-west-trending trenches in eastern portion of unit	Twelve east-west-trending disposal trenches; HFSDA just outside of current area boundaries	Forty-nine 10-foot-deep holes that were filled with waste material (removed during removal action)	Six north-south-trending trenches; five east-west-trending trenches	Two east-west-trending cells approximately 60 feet wide by 120 feet long	Two east-west trending trenches, each approximately 250 feet long and 2 to 4 feet wide
Extent	Top of Waste Depth (feet below ground surface)		1 to 5	1 to 4	Not applicable, no waste present	Less than 1 to 4	1 to 4	0.5 to 1.5
Extent	Bottom of Waste Depth (feet below ground surface)		4 to 8	8 to 14	Not applicable, no waste present	5 to 6	3 to greater than 11	3 to 5.5
Extent	Estimated Volume of Contaminated Material		39, 204 LCY	41,095 LCY	3,488 LCY	5,777 LCY	12,153 LCY	1,274 LCY

Note:

[1] Based on information provided in HHRA-Part C (Brown and Caldwell, 2006), carbon-14 is designated a constituent of potential concern; subject to change based on additional investigation included in the remedial alternatives.

Acronyms/Abbreviations:

COC - constituent of concern

HHRA - Part C - *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment, (Part C – Risk Characterization for UC Davis Areas)*

LCY - loose cubic yards

HFSDA - Hopland Field Station Disposal Area

Reference:

Brown and Caldwell, 2006. *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment, (Part C – Risk Characterization for UC Davis Areas)* , April.

Table ES-2. Summary of Elements Included in Soil/Solid Waste Alternatives - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

Elements	**SW-2**	**SW-3**	**SW-4**	**SW-5**	**SW-6**	**SW-7**	**SW-8**	**SW-9**	**SW-10**
Planning and oversight documents (H&S, QA/QC, construction site environmental controls, Materials Management Plan)	X	X	X	X	X	X	X	X	X
Data gap trench investigations and sampling at the ST and the HFSDA	X	X	X	X	X				
Institutional controls	X	X	X	X	X	X	X	X	X
Decommission, replace, and install new groundwater wells	X	X	X	X	X	X	X	X	X
Post-remediation activities: storm water monitoring and maintenance, groundwater monitoring, five-year reviews	X	X	X	X	X	X	X	X	X
Demolish one on-Site building; recycling or off-Site disposal of hazardous waste		X							
Demolish nine on-Site buildings; off-Site disposal of hazardous waste and recycling or on-Site placement of non-hazardous waste in CAMUs			X	X	X	X	X	X[a]	X[a]
LFU-1: Install concrete-lined drainage channel along eastern edge of LFU-1		X							
LFU-3: Seal and annually maintain concrete-lined drainage channel		X							
LFU-3: Excavate soil/solid waste and contact soil below concrete-lined channel; segregate and dispose of PTW off-Site; place remaining waste under cap			X	X	X				
Confirmation-sampling and backfill with clean fill		X	X	X	X	X	X	X	X
Dispose of PTW off-Site from historical and proposed exploratory trenches; backfill remaining non-PTW and impacted soil within trenches		X	X	X	X[b]	X[b,c]			
Excavate VOC "hot spots"; dispose of hazardous material off-Site, backfill non-hazardous material		X	X	X	X	X	X	X[d]	X[d]
Install graded covers		X							
Install evapotranspiration caps			X						
Install HDPE liner and asphalt caps				X					
Install multiple-layer caps					X	X	X	X	
Surface water drainage enhancements, including installation of extended detention basin		X	X	X	X	X	X		
ET: Excavate soil/solid waste and contact soil, segregate and dispose of PTW off-Site, return non-PTW to excavation or beneath CAMU cap					X	X			
LFU-3: Excavate soil/solid waste and contact soil; segregate and dispose of PTW off-Site; place non-PTW in CAMU						X	X		
ST and HFSDA: Excavate soil/solid waste and contact soil; segregate and dispose of PTW off-Site; place non-PTW in CAMU						X	X		
Excavate soil/solid waste and contact soil from LFU-1, LFU-2, LFU-3, the ET, ST, and HFSDA and place in one lined CAMU at LFU-1/LFU-2/ET; WBH CAMU not lined; segregate and dispose of PTW off-Site							X		
Excavate ST and HFSDA; segregate and dispose of PTW off-Site; non-PTW waste placed in WBH CAMU								X	
Excavate soil/solid waste and contact soil from LFU-1, LFU-2, LFU-3, the ET, and the VOC "hot spots" and dispose of off-Site								X	X
Excavate soil/solid waste and contact soil from the WBH, the ST, and the HFSDA, and dispose of off-Site									X

Notes:

[a] Non-hazardous demolition waste would be sent off-Site for recycling or disposal.

[b] Does not include the known trenches with PTW or proposed trenches in the ET; under alternatives SW-6 and SW-7, these trenches would be included when the entire ET is excavated (ET excavation is included in separate elements).

[c] Does not include the proposed trenches in LFU-3; under alternative SW-7, these trenches would be included when the LFU-3 waste cells are excavated (LFU-3 waste cell excavation is included in separate elements).

[d] Non-hazardous material would be sent off-Site for disposal at licensed facilities as no capped CAMU would be present in the VOC "hot spot" areas; the VOC "hot spots" would be backfilled with clean, imported fill.

Acronyms/Abbreviations:

CAMU - corrective action management unit
ET - Eastern Trenches
HDPE - high-density polyethylene
HFSDA - Hopland Field Station Disposal Area
H&S - health and safety
LFU - landfill unit
PTW - principal threat waste
QA/QC - quality assurance/quality control
ST - Southern Trenches
VOC - volatile organic compound
WBH - Waste Burial Holes

Alternatives:

SW-1: No Action/No Further Action
SW-2: Institutional Controls and Groundwater Monitoring
SW-3: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-4: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-5: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-6: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-7: VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-8: VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-9: Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring
SW-10: Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

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Table ES-3. Relative Comparison of Alternatives - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

	Summary of Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Cost (Total Present Value)	Total Score[1]
SW-1	No Action/No Further Action	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). No monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative does not meet RAOs.		No remedial actions are proposed. Although this alternative may be effective in the long-term, no monitoring would be conducted to confirm long-term protection of human health and the environment.	No soil/solid waste would be treated, and thus there would be no reduction of toxicity, mobility, or volume.	There are no short-term risks to the community or workers since no remedial actions would be implemented.	Implementable since there are no technical or administrative components.	No costs associated with the No Action/No Further Action alternative.	
		NOT PROTECTIVE	**DOES NOT COMPLY**	**0**	**0**	**5**	**5**	**5**	**0.0**
SW-2	Institutional Controls and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. This alternative meets each RAO.		Sampling in the ST and HFSDA would better characterize risk in these disposal areas. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	No soil/solid waste would be treated, and thus there would be no reduction of toxicity, mobility, or volume.	There are minimal risks to the community, workers, and the environment due to well installation. 42 metric tons of GHGs, 0.2 metric tons of NO_x emissions, 0.1 metric tons of SO_x emissions, and 0.02 metric tons of PM_{10} emissions are estimated to be released. 550 MMBTU of energy are estimated to be used, equivalent to approximately 3,960 gallons of diesel. The estimated total fatality risk is 2E-04. This alternative would take one year to implement.	There are minimal technical and administrative components associated with well installation, monitoring, and sampling at the ST/HFSDA.	$6,510,297	
		PROTECTIVE	**COMPLIES**	**1**	**0**	**4**	**5**	**4**	**2.8**
SW-3	VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 38 LCY of PTW, removal of 2,394 LCY of hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via graded covers and storm water drainage enhancements. This alternative meets each RAO.		Hazardous material would be consolidated within three covered CAMUs. Sampling in the ST and HFSDA would better characterize risk in these disposal areas. The VOC "hot spot" areas would be excavated and hazardous material taken off-Site for disposal. PTW from historical and proposed trenches would be removed. Graded covers and storm water drainage enhancements would be installed to reduce infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 76 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 1,400 metric tons of GHGs, 1.8 metric tons of NO_x emissions, 0.8 metric tons of SO_x emissions, and 0.6 metric tons of PM_{10} emissions are estimated to be released. 22,400 MMBTU of energy are estimated to be used, equivalent to approximately 161,200 gallons of diesel. The estimated total fatality risk is 2E-02. This alternative would take one year to implement.	Technically and administratively feasible to implement in one year. The excavation, segregation, and disposal of soil/solid waste would be moderately complex to coordinate and implement. The installation of graded covers would be straightforward. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$13,571,030	
		PROTECTIVE	**COMPLIES**	**2**	**3**	**3**	**4**	**3.5**	**3.1**
SW-4	VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 150 LCY of PTW, removal of 2,516 LCY of hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via evapotranspiration caps and storm water drainage enhancements. This alternative meets each RAO.		Hazardous material would be consolidated within three CAMUs. Sampling in the ST and HFSDA would better characterize risk in these disposal areas. The VOC "hot spot" areas would be excavated and hazardous material taken off-Site for disposal. PTW from historical and proposed trenches would be removed. Evapotranspiration caps and storm water drainage enhancements would be installed to reduce infiltration; heavy precipitation may overwhelm the evapotranspiration barrier and result in infiltration. Periodic evapotranspiration cap maintenance would be required to limit infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 86 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 4,000 metric tons of GHGs, 2.8 metric tons of NO_x emissions, 1.0 metric tons of SO_x emissions, and 0.7 metric tons of PM_{10} emissions are estimated to be released. 69,200 MMBTU of energy are estimated to be used, equivalent to approximately 497,500 gallons of diesel. The estimated total fatality risk is 5E-02. This alternative would take one year to implement.	Technically and administratively feasible to implement in one year. The excavation, segregation, and disposal of soil/solid waste would be moderately complex to coordinate and implement. The installation of evapotranspiration caps would be more complex than the graded covers. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$18,500,777	
		PROTECTIVE	**COMPLIES**	**2**	**3**	**3**	**3**	**3**	**2.8**
SW-5	VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 150 LCY of PTW, removal of 2,516 LCY of hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via asphalt caps and storm water drainage enhancements. This alternative meets each RAO.		Hazardous material would be consolidated within three CAMUs. Sampling in the ST and HFSDA would better characterize risk in these disposal areas. The VOC "hot spot" areas would be excavated and hazardous material taken off-Site for disposal. PTW from historical and proposed trenches would be removed. Asphalt caps and storm water drainage enhancements would be installed to reduce infiltration. Periodic asphalt cap maintenance would be required to limit infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 86 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 3,000 metric tons of GHGs, 2.8 metric tons of NO_x emissions, 1.0 metric tons of SO_x emissions, and 0.7 metric tons of PM_{10} emissions are estimated to be released. 42,300 MMBTU of energy are estimated to be used, equivalent to approximately 304,600 gallons of diesel. The estimated total fatality risk is 3E-02. This alternative would take one year to implement.	Technically and administratively feasible to implement in one year. The excavation, segregation, and disposal of soil/solid waste would be moderately complex to coordinate and implement. The installation of asphalt caps would only be slightly more complex than the graded covers as the asphalt would be placed on top of a graded cover. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$20,893,851	
		PROTECTIVE	**COMPLIES**	**3**	**3**	**3**	**3**	**3**	**3.0**

Table ES-3. Relative Comparison of Alternatives - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

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SW-6	VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 261 LCY of PTW, removal of 2,626 LCY of hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via multiple-layer caps and storm water drainage enhancements. This alternative meets each RAO.		Hazardous material would be consolidated within three CAMUs. Sampling in the ST and HFSDA would better characterize risk in these disposal areas. The VOC "hot spot" areas would be excavated and hazardous material taken off-Site for disposal. PTW from historical and proposed trenches would be removed. The ET would be excavated and PTW sent off-Site for disposal; soil/solid waste would be completely removed from the ET North and consolidated within the CAMUs. Multiple-layer caps and storm water drainage enhancements would be installed to reduce infiltration; multiple-layer caps are more effective in the long-term than graded covers or evapotranspiration caps. Multiple-layer cap maintenance would be required to limit infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 95 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 3,600 metric tons of GHGs, 3.2 metric tons of NO_x emissions, 1.1 metric tons of SO_x emissions, and 0.7 metric tons of PM_{10} emissions are estimated to be released. 60,500 MMBTU of energy are estimated to be used, equivalent to approximately 435,300 gallons of diesel. The estimated total fatality risk is 4E-02. This alternative would take one year to implement.	Technically and administratively feasible to implement in one year. The excavation, segregation, and disposal of soil/solid waste would be moderately complex to coordinate and implement. The installation of multiple-layer caps would be more complex than the other cover/cap options. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$20,291,548	
		PROTECTIVE	**COMPLIES**	**3**	**3**	**3**	**3**	**3**	**3.0**
SW-7	VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 387 LCY of PTW, removal of 4,550 LCY of hazardous and non-hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via multiple-layer caps and storm water drainage enhancements. This alternative meets each RAO.		Hazardous material would be consolidated within two CAMUs. The VOC "hot spot" areas would be excavated and hazardous material taken off-Site for disposal. PTW from historical and proposed trenches would be removed. The ET, ST, HFSDA, and LFU-3 waste cells would be excavated and PTW sent off-Site for disposal. Non-PTW soil/solid waste from the ET North, LFU-3 waste cells, the ST, and HFSDA would be consolidated within the CAMUs, thereby permanently removing soil/solid waste from these areas. Multiple-layer caps and storm water drainage enhancements would be installed to reduce infiltration; multiple-layer caps are more effective in the long-term than graded covers or evapotranspiration caps. Multiple-layer cap maintenance would be required to limit infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 106 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 3,900 metric tons of GHGs, 3.7 metric tons of NO_x emissions, 1.2 metric tons of SO_x emissions, and 1.1 metric tons of PM_{10} emissions are estimated to be released. 66,600 MMBTU of energy are estimated to be used, equivalent to approximately 479,100 gallons of diesel. The estimated total fatality risk is 5E-02. This alternative would take one year to implement.	Technically and administratively feasible to implement in one year. The excavation, segregation, and disposal of soil/solid waste would be moderately complex to coordinate and implement. The installation of multiple-layer caps would be more complex than the other cover/cap options. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$20,860,309	
		PROTECTIVE	**COMPLIES**	**3**	**3**	**3**	**3**	**3**	**3.0**
SW-8	VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 1,116 LCY of PTW, removal of 21,471 LCY of hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via multiple-layer caps and storm water drainage enhancements. This alternative meets each RAO.		Hazardous material would be consolidated within one lined and capped CAMU. The VOC "hot spot" areas would be excavated and hazardous material taken off-Site for disposal. The ET, ST, HFSDA, LFU-1, LFU-2, and the LFU-3 waste cells would be excavated and segregated, and PTW would be sent off-Site for disposal. Non-PTW from the ET North, ST, HFSDA, and LFU-3 waste cells would be consolidated within the CAMU, thereby permanently removing soil/solid waste from these areas. A multiple-layer cap and storm water drainage enhancements would be installed to reduce infiltration; multiple-layer caps are more effective in the long-term than graded covers or evapotranspiration caps. Multiple-layer cap maintenance would be required to limit infiltration. Additional protection of groundwater would be achieved via the installation of a bottom liner and LCRS. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 168 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 5,200 metric tons of GHGs, 8.8 metric tons of NO_x emissions, 3.1 metric tons of SO_x emissions, and 4.5 metric tons of PM_{10} emissions are estimated to be released. 86,400 MMBTU of energy are estimated to be used, equivalent to approximately 621,300 gallons of diesel. The estimated total fatality risk is 7E-02. This alternative would take two years to implement.	Technically and administratively feasible to implement in two years. The excavation, segregation, and disposal of soil/solid waste would be moderately complex to coordinate and implement. The installation of a bottom liner, LCRS, and multiple-layer cap would be substantially more complex than the other alternatives. Required equipment and contractors are available. Additional land for storm water drainage enhancements and for the installation of the bottom liner and LCRS between LFU-1 and LFU-2/ET/WBH is readily available and would not pose a burden to the University's mission.	$33,368,762	
		PROTECTIVE	**COMPLIES**	**4**	**3**	**2**	**1**	**2**	**2.4**
SW-9	Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 1,116 LCY of PTW, removal of 115,231 LCY of hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via storm water drainage enhancements and a multiple-layer cap over the WBH. This alternative meets each RAO.		The VOC "hot spot" areas, ET, LFU-1, LFU-2 waste cells, and LFU-3 waste cells would be excavated and material sent off-Site for disposal, thereby permanently removing soil/solid waste from these areas. PTW from the ST and HFSDA would be sent off-Site for disposal, and non-PTW hazardous material would be consolidated within the WBH CAMU. A multiple-layer cap over the WBH and storm water drainage enhancements would be installed to reduce infiltration; multiple-layer caps are more effective in the long-term than graded covers or evapotranspiration caps. Multiple-layer cap maintenance would be required to limit infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 5,127 LCY of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 14,400 metric tons of GHGs, 17 metric tons of NO_x emissions, 7.2 metric tons of SO_x emissions, and 23 metric tons of PM_{10} emissions are estimated to be released. 222,000 MMBTU of energy are estimated to be used, equivalent to approximately 1,596,900 gallons of diesel. The estimated total fatality risk is 6E-01. This alternative would take two years to implement.	Technically and administratively feasible to implement in two years. The excavation, segregation, and disposal of hazardous material and multiple-layer cap installation over the WBH would be moderately easy to coordinate and implement. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$102,142,825	
		PROTECTIVE	**COMPLIES**	**5**	**5**	**1**	**4**	**1**	**3.2**

Table ES-3. Relative Comparison of Alternatives - Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

	Summary of Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Cost (Total Present Value)	Total Score[1]
SW-10	Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring	Currently, estimated cancer risks for residents are within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0 (except for the WBH). ICs would prohibit residential development and restrict non-residential development. Monitoring would confirm long-term protection of human health and the environment. Additional protectiveness would be achieved through removal of 1,116 LCY of PTW, removal of 124,269 LCY of hazardous and non-hazardous material (including the two VOC "hot spot" areas) and the reduction of infiltration via storm water drainage enhancements. This alternative meets each RAO.		The VOC "hot spot" areas, ET, ST, HFSDA, WBH, LFU-1, LFU-2 waste cells, and LFU-3 waste cells would be excavated and material sent off-Site for disposal, thereby permanently removing soil/solid waste from these areas. Storm water drainage enhancements would be installed to reduce infiltration. Monitoring would be conducted to confirm long-term protection of human health and the environment. This alternative is considered effective in the long-term.	A fraction of hazardous waste may be treated via *ex situ* solidification/stabilization prior to off-Site disposal; the actual amounts would depend on the hazardous characteristics of the waste. 5,129 LCY[3] of material are assumed to be treated.[2]	Risks are associated with construction site hazards, air emissions, fugitive dust emissions, and vehicular traffic. 15,200 metric tons of GHGs, 18 metric tons of NO_x emissions, 7.6 metric tons of SO_x emissions, and 25 metric tons of PM_{10} emissions are estimated to be released. 232,800 MMBTU of energy are estimated to be used, equivalent to approximately 1,674,500 gallons of diesel. The estimated total fatality risk is 7E-01. This alternative would take two years to implement.	Technically and administratively feasible to implement in two years. The excavation, segregation, and disposal of hazardous material would be moderately easy to coordinate and implement. Required equipment and contractors are available. Additional land for storm water drainage enhancements is readily available and would not pose a burden to the University's mission.	$108,685,985	
		PROTECTIVE	**COMPLIES**	**5**	**5**	**1**	**4**	**1**	**3.2**

Notes:

Relative comparison: the rankings reflect the relative differences between the alternatives and are ranked on a scale of 0-5, where a higher ranking reflects a more favorable outcome for that category

- Long-term effectiveness and permanence: a low ranking reflects lower long-term effectiveness/permanence relative to other alternatives
- Reduction of toxicity, mobility, or volume by treatment: a lower ranking reflects a smaller volume treated and a higher ranking reflects a larger treated volume
- Short-term effectiveness: a lower ranking reflects greater risks to the community than a higher ranking
- Implementability: a lower ranking reflects greater technical and administrative challenges than a higher ranking, which would be easier to implement
- Cost: ranking of high for cost refers to Alternatives that have low costs and thus perform well for this category; high total costs would have a lower ranking in this category

The Community Acceptance section will be completed upon receipt of community comments on the Proposed Plan.

The State Acceptance section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

[1] The total score is an average of the five numerical rankings. A score of zero (0) is applied if the alternative is not protective or does not comply with ARARs.

[2] The estimated volume of waste treated *ex situ* is ten percent of the mixed and RCRA hazardous waste characterization volumes.

[3] The estimated *ex situ* treatment volume for Alternative SW-10 is similar to Alternative SW-9 because the majority of waste in the WBH, ST, and HFSDA sent off-Site for disposal under SW-10 is categorized as LLRW, not mixed or RCRA hazardous waste.

Acronyms/Abbreviations:

ARAR - applicable or relevant and appropriate requirement
CAMU - corrective action management unit
ET - Eastern Trenches
FS - Feasibility Study
GHG - greenhouse gas
HFSDA - Hopland Field Station Disposal Area
IC - institutional control
LCRS - lea
LCY - loose cubic yards
LFU - landfill unit
LLRW - low-level radioactive waste
MMBTU - million British thermal units
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
NO_x - nitrogen oxides
PM_{10} - particulate matter with a diameter less than 10 micrometers
PTW - principal threat waste
RAO - remedial action objective
RCRA - Resource Conservation and Recovery Act
SO_x - sulfur oxides
ST - Southern Trenches
VOC - volatile organic compound
WBH - Waste Burial Holes

1. INTRODUCTION

This *Final Feasibility Study for the University of California, Davis Areas Volume 1: Soil/Solid Waste and Soil Gas* (FS – Volume 1) was prepared for the Laboratory for Energy-related Health Research (LEHR) and the Old Campus Landfill (OCL) Superfund Site, collectively referred to as the "Site," which is located at the University of California, Davis (UC Davis). The Site is situated approximately one mile south of the main campus, east of Old Davis Road and ¾ mile south of Interstate 80 (Figure 1-1). The Site was placed on the United States Environmental Protection Agency (US EPA) National Priorities List (NPL) on May 31, 1994. Investigations and remediation of the Site conducted by UC Davis are directed by the *Administrative Order on Consent for Removal Action and Remedial Investigation/Feasibility Study* (AOC), issued by the US EPA in 1999 (US EPA, 1999a). Supporting agencies include the California Environmental Protection Agency (Cal/EPA) – Department of Toxic Substances Control, the Central Valley Region of the Regional Water Quality Control Board (RWQCB), the Radiological Health Branch of the California Department of Public Health, and the United States Department of Energy (DOE). In December 2009, DOE and the US EPA finalized the Record of Decision (ROD) for the DOE areas at the Site; the ROD included provisions for land use controls, long-term monitoring, and contingent remediation should residual contamination in these areas impact groundwater.

The *UC Davis Final Remedial Investigation Report* (RI) was presented to the US EPA and supporting agencies on December 29, 2004. This report included information obtained from over 15 years of investigations conducted at the Site (Geomatrix, 2004) and was accepted by the US EPA on August 31, 2006. Data used in the RI formed the basis for the Site-Wide Risk Assessment (SWRA). The SWRA was completed in two volumes: Volume 1, the Human Health Risk Assessment (HHRA) and Volume 2, the Ecological Risk Assessment. These documents were approved by the US EPA on August 1, 2006. Volume 1 consisted of three parts, *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part A – Risk Estimate) LEHR/SCDS Environmental Restoration* (HHRA – Part A), *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part B – Risk Characterization for DOE Areas) at the Laboratory for Energy-related Health Research, University of California, Davis* (HHRA – Part B), and *Site-Wide Risk Assessment, Volume I Human Health Risk Assessment (Part C – Risk Characterization for UC Davis Areas)* (HHRA – Part C). HHRA – Part A (MWH, 2004) provided the human health risk assessment for the Site in its entirety, including areas under the responsibility of DOE, in accordance with the 1997 Memorandum of Agreement (MOA) between UC Davis and DOE. Human health risk characterizations were presented in HHRA – Part B (Weiss, 2005) and HHRA – Part C (BC, 2006a) for the areas that are under the responsibility of DOE and UC Davis, respectively. HHRA – Part A included risk and hazard estimates for constituents of potential concern (COPC). Proposed lists of constituents of concern (COC) for inclusion in the feasibility study (FS) were presented in HHRA – Part B and HHRA – Part C and were based solely on protection of human health. In 2006, the *Site-Wide Ecological Risk Assessment* (SWERA) (BBL, 2006) was completed and superseded Volume 2 of the SWRA. The SWERA presented constituents of potential ecological concern (COPEC) for inclusion in the FS.

Using data from these previous reports, UC Davis submitted a *Draft Screening of Alternatives for the Feasibility Study* in 2006 (BC, 2006b). The *Data Gaps Technical Report* was submitted in February 2010 (Appendix A), which included the findings for three additional investigations: development of a conceptual model for hexavalent chromium in groundwater; an examination of the soil-to-groundwater impact from constituents found at the Site; and an evaluation of vapor intrusion. This FS also provides revised vapor risk estimates (Appendix B) and an updated human health risk characterization and COC screening (Appendix C). Risk estimates presented in Appendix B supersede the results presented in Appendix A, as more recent toxicity values were used.

This FS is Volume 1 of the overall UC Davis FS and addresses the following environmental media: soil, solid waste (i.e., waste material and associated contact soil), and soil gas. The *Feasibility Study for the University of California, Davis Areas Volume 2: Groundwater* (FS - Volume 2) will address Site groundwater. Following completion of the feasibility studies, the US EPA will present the preferred alternatives in the Proposed Plan(s). Following a 30-day public comment period, the US EPA will select the final remedies and document the basis for their selection in the ROD(s).

1.1 Purpose

This Soil/Solid Waste and Soil Gas FS was prepared to fulfill the requirements of Section 300.430(e) of the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP). The NCP provides for efficient, coordinated, and effective response to discharges of oil and releases of hazardous substances, pollutants, and contaminants, in accordance with the authorities of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Clean Water Act (CWA). According to the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*, the purpose of the FS is to develop, screen, and evaluate remedies for a given site (US EPA, 1988). The FS – Volume 1 is based upon data collected as part of the RI and subsequent data collected from ongoing Site monitoring and data gap investigations. The specific objectives of FS – Volume 1 include:

- Summarizing the Site's history, nature and extent of contamination, risks to human health and the environment, potential COC impact to groundwater, and fate and transport of COCs;
- Identifying remedial action objectives (RAOs) and applicable or relevant and appropriate requirements (ARARs);
- Developing general response actions and process options and identifying and screening potential treatment technologies/containment/disposal requirements;
- Assembling the process options into remedial alternatives;
- Analyzing the alternatives against the nine NCP criteria; and
- Comparing alternatives against each other.

The nine NCP criteria are divided into three groups, as listed below. The threshold criteria are statutory requirements of the NCP. As such, these criteria must be achieved by each alternative except the "No Action/No Further Action" alternative. The five primary balancing factors form the basis for the FS analysis. The final two modifying criteria are typically addressed following receipt of public and state agency comments on the Proposed Plan.

Threshold Criteria

1. Overall protection of human health and the environment
2. Compliance with ARARs

Primary Balancing Criteria

3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost

Modifying Criteria

8. State acceptance
9. Community acceptance

1.2 Organization

This FS generally follows the format suggested in Table 6-5 of the US EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (US EPA, 1988). This FS includes the following sections:

- Section 2.0 – Background. This section describes the Site and its history; summarizes the nature and extent of contamination and the human health and ecological risks previously estimated for the Site; and discusses the fate and transport of COCs.
- Section 3.0 – Remedial Action Objectives and Applicable or Relevant and Appropriate Requirements. This section identifies the COCs that may result in adverse human health effects from exposure to soil/solid waste, soil gas, or environmental impacts to groundwater. RAOs and ARARs are presented based on federal (or state, where more stringent or implemented by the state and legally applicable) standards/requirements/criteria/limitations, COCs, potential exposure pathways, and remediation goals.
- Section 4.0 – Identification and Screening of Technologies. This section classifies 11 general response actions to achieve the RAOs established in

Section 3.0 for soil/solid waste and soil gas. Remedial technologies for each general response action are identified, evaluated, and selected.

- Section 5.0 – Description of Remedial Alternatives. This section uses the retained process options to develop ten remedial alternatives for soil/solid waste and soil gas.
- Section 6.0 – Detailed Analysis of Alternatives. This section analyzes, in detail, the final remedial alternatives for the nine NCP criteria.
- Section 7.0 – Comparative Analysis of Remedial Alternatives. This section compares the different remedial alternatives with one another.
- Section 8.0 – References. This section lists references used to prepare this report.
- Appendix A – Feasibility Study Data Gaps Technical Report. This appendix presents the findings for three additional investigations conducted after the RI was complete: development of a conceptual model for hexavalent chromium in groundwater; an examination of the soil-to-groundwater impact from COCs found at the Site; and an evaluation of vapor intrusion.
- Appendix B – Vapor Intrusion Risk Assessment. This appendix provides the human health vapor intrusion risk assessment based on the soil gas data collected in September 2008. Results in this appendix supersede the results presented in Appendix A.
- Appendix C – Update – Soil/Solid Waste Risk Characterization and Human Health Constituents of Concern. This appendix updates the UC Davis COCs using the SWRA dataset, in addition to data collected since the SWRA was completed (i.e., data collected post-2004) and provides a risk screening for soil/solid waste based on updated toxicity data and exposure assumptions.
- Appendix D – Applicable or Relevant and Appropriate Requirements. This appendix provides the chemical-specific, location-specific, and action-specific ARARs for the Site.
- Appendix E – Volume Estimates. This appendix provides supplemental information for the volume estimates used in this report.
- Appendix F – Cost Estimates. This appendix contains the cost assumptions and itemized cost estimates used in this report.
- Appendix G – Post-Construction Storm Water Control Analysis. This appendix develops post-construction storm water control requirements for the remedial alternatives.
- Appendix H – Methodology for Development of Cleanup Goals for New Constituents of Potential Concern. This appendix provides a methodology for identifying cleanup goals for constituents that may be detected during implementation of the selected remedy but are not currently identified as COCs in FS – Volume 1.

- Appendix I – Green and Sustainable Remediation Footprint Analysis. This appendix provides results from a green and sustainable remediation footprint analysis for each of the remedial alternatives.
- Appendix J – Responses to Regulatory Agency Comments on Previous Revisions of the Feasibility Study. This appendix includes the previously submitted comments and responses to comments on the Draft FS (Rev. C), Draft Final FS (Rev. E), and Preview Final FS (Rev. F).

2. BACKGROUND

This section provides information on the description and history of the Site, summarizes the nature and extent of contamination and the results from previous human health and ecological risk assessments, and provides information on the fate and transport of COCs at the Site. Detailed information regarding Site use and the physical characteristics of the Site can be found in the RI (Geomatrix, 2004) and the annual water monitoring reports prepared for the Site since 1994, the most recent of which is the *2010 Comprehensive Annual Water Monitoring Report* (Weiss, 2012).

2.1 Site Description

LEHR/OCL is located in Solano County, California, in the southeast quarter of Section 21, Township 8 North, Range 2 East, Mount Diablo Base and Meridian (Figure 1-1). It is approximately 1.5 miles south of the City of Davis and is bounded by UC Davis research facilities, farmland, and the South Fork of Putah Creek. The southern boundary of the Site is the northern levee of the South Fork of Putah Creek.

LEHR/OCL covers approximately 25 acres. It contains laboratory buildings and undeveloped land; Figure 2-1 shows the spatial distribution of the buildings. Of the 25 acres, approximately 35 percent is paved or covered by structures; approximately 55 percent is unpaved and relatively free of vegetation; and approximately 10 percent is covered by large, deep-rooted vegetation. The land and buildings are owned and maintained by the Regents of the University of California.

The Site was added to the NPL on May 31, 1994. Both UC Davis and DOE were recognized as potentially responsible parties (PRPs) to remediate the Site under the CERCLA process. In March 1990, UC Davis and DOE entered into an MOA that divided the responsibilities for the Site and offered a plan for coordinating environmental restoration and decontamination. This memorandum has been amended four times since 1990. Most recently, in 2009, the MOA was updated to include long-term surveillance, maintenance, and contingent remediation, should residual contamination in DOE areas impact groundwater (DOE, 2009a). The ROD for the DOE areas was finalized in December 2009 (DOE, 2009b), and remedial actions consisting of land use controls and groundwater monitoring began in January 2011.

Specific Site responsibilities of UC Davis and DOE were formalized in an AOC (US EPA, 1999a) and *Federal Facility Agreement for the Laboratory for Energy-Related Health Research and the South Campus Disposal Site Superfund Site* (US EPA, 1999b), respectively. The AOC defines the UC Davis Areas and assigns cleanup responsibilities to UC Davis for these areas. The following were identified as UC Davis areas in the AOC:

- UC Davis Campus Landfill Unit (LFU) No. 1 (LFU-1);

- UC Davis Campus LFU-2;
- UC Davis Campus LFU-3;
- Waste Burial Holes (WBH);
- Eastern Trenches (ET);
- Southern Trenches (ST);
- Groundwater;
- Putah Creek; and
- Old Wastewater Treatment Plant (OWTP).

Areas within LEHR/OCL that were not classified as either UC Davis or DOE areas, known as the "Non-OU" areas, were evaluated in the HHRA – Part A as directed by the US EPA.

The OWTP was evaluated in the RI and HHRA – Part A. Results from the human health risk assessment indicated that exposure to COPCs at the OWTP would not result in adverse health effects (HHRA – Part A). Therefore, the OWTP was not evaluated further in the HHRA – Part C. Putah Creek was evaluated in the HHRA – Part C and the SWERA. However, none of the preliminary COCs or COPECs in the Putah Creek area were proposed for further consideration. As such, neither the OWTP nor Putah Creek are evaluated in this FS. Also, FS – Volume 1 specifically addresses soil, solid waste, and soil gas; groundwater will be evaluated in the forthcoming FS – Volume 2. The areas evaluated in this FS include LFU-1, LFU-2, LFU-3, WBH, ET, and ST.

The locations of the areas under the responsibility of UC Davis, except groundwater, Putah Creek, and the OWTP, are shown on Figure 2-1. These areas are described in detail in Section 2.4.

2.2 Physical Setting

The following sections summarize the physical setting at the Site, including a summary of the Site's topography, climate, geology, hydrogeology, surface water, and storm water drainage. Additional information can be found in the *Draft Data Summary and Data Gaps Report and Remedial Investigation/Feasibility Study Work Plan Addendum for LEHR/SCDS Environmental Restoration* (MWH, 2002) and the RI (Geomatrix, 2004).

2.2.1 Topography

Land at the Site is typical of the broad, relatively flat Sacramento Valley. Ground surface elevations are approximately 50 feet above mean sea level, and relief across the Site is approximately two feet. According to the *Federal Emergency Management Agency* (FEMA) *Flood Insurance Map*, updated in May 2009, the Site is within a Zone A area, meaning it is subject to inundation by the one-percent annual chance flood event. This conclusion was made using approximate methodologies; no detailed hydraulic analyses have been performed (FEMA, 2010).

2.2.2 Climate

The temperate climate of the Sacramento Valley area is characterized by warm summers and mild winters. Average summer and winter temperatures are 72.9 degrees Fahrenheit (ºF) and 49.8 ºF, respectively (Western Regional Climate Center, 2011). The prevailing wind direction is north to south during the fall and winter and south to north during the spring and summer. The average annual wind speed is approximately six miles per hour (UC ANR, 2011). Normal annual rainfall in the area is approximately 17.6 inches, according to the nearest weather station (Davis 1 WSW) (Western Regional Climate Center, 2011).

2.2.3 Geology and Soils

Subsurface geology below the Site consists of two units: the Putah Creek Fan and the Pliocene-Pleistocene Tehama Formation. The Putah Creek Fan consists primarily of silt and clay, with coarse-grained sediments occurring locally. The Tehama Formation, which lies beneath the Putah Creek Fan, primarily consists of clayey silt to silty clay, with deeper coarse-grained sand and gravel (Figure 2-2). A more detailed discussion of Site geology is presented in Section 1.5.3 of the RI (Geomatrix, 2004).

2.2.4 Hydrogeology

This section describes the general framework of the hydrogeological model of the Site.

2.2.4.1 Surface Water

There are no surface water bodies located on the Site. The nearest surface water body is the South Fork of Putah Creek, an east-flowing, engineered channel that lies 250 feet from the southern boundary of the Site and is separated from the Site by a levee that was constructed during the 1940s and 1950s (Figure 2-1). This levee is approximately 30 feet high, forms the southern boundary of the Site, and is used as a road for vehicular traffic. The southern levee of the creek is located several hundred feet south of the Site. The creek flow rate is regulated by releases from the Monticello Dam and the Putah Creek Diversion Dam. The South Fork of Putah Creek receives a minimum water flow rate of 31,000 acre-feet during non-dry years, as required in the settlement agreement between the Solano County Water Agency (and other Solano parties) and the Putah Creek Council (and other Yolo parties) (BBL, 2006). The UC Davis wastewater treatment plant discharges up to 2.7 million gallons per day of treated wastewater to the South Fork of Putah Creek at a location just west of the Old Davis Road Bridge (RWQCB, 2003). The South Fork of Putah Creek is a losing stream that recharges shallow (hydrostratigraphic unit [HSU]-1) groundwater (Geomatrix, 2004). The Creek serves as habitat for many aquatic and riparian biota, including amphibians, fish, birds, and benthic invertebrates.

2.2.4.2 Storm Water Drainage

Runoff at the Site occurs at three locations: storm water sampling locations LS-01, LF-01, and LF-03 (Figure 2-1). Water flows in these areas only after moderate to heavy winter storms. LS-01 captures runoff from buildings and parking lots; when runoff is present, it is pumped to a drainage swale along Old Davis Road. The occasional runoff from the other two surface drainages (LF-01 and LF-03) eventually flows through discharge pipes into Putah Creek. It is estimated that the pipe from LF-01 discharges an average of eight days per year into Putah Creek; discharges from LF-03 occur less frequently (Geomatrix, 2004). A concrete-lined drainage channel overlays the eastern portion of LFU-3 (Figure 2-1).

2.2.4.3 Groundwater

The HSUs at the Site include, in descending order, HSU-1, HSU-2, HSU-3, HSU-4, and an unnamed aquitard. HSU-2 and HSU-4 are the most permeable of these HSUs, consisting predominantly of sand and gravel deposits. 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 (Figure 2-2). HSU-1, HSU-3, and the unnamed aquitard are generally composed of silt and clay and are less permeable than the other two HSUs. Hydraulic conductivity is estimated to be between two and 11 feet per day in HSU-1, and the horizontal seepage velocity is estimated to be approximately four feet per year. HSU-2 is estimated to have a hydraulic conductivity of approximately 1,020 feet per day and a horizontal seepage velocity of 1,500 feet per year (Geomatrix, 2004).

Groundwater levels have been monitored in Site wells for over 20 years. Levels are typically highest in March (first quarter) and April (second quarter), decline rapidly from April (second quarter) to August (third quarter), and recover from September (third quarter) to March (first quarter) (Figures 2-3 and 2-4). During this annual cycle, groundwater depths in HSU-1 and HSU-2 wells typically fluctuate between 20 and 40 feet below ground surface (bgs) (Weiss, 2012).

The groundwater flow direction is generally northeast in HSU-1, east/northeast in HSU-2, and east in HSU-4, but can be locally influenced by irrigation wells during the agricultural pumping season. In 2010, horizontal groundwater gradients varied between 0.0001 feet per foot (winter) and 0.01 feet per foot (fall) in HSU-1; between 0.0003 feet per foot (winter) and 0.003 feet per foot (fall) in HSU-2; and between 0.0001 feet per foot (winter) and 0.001 feet per foot (spring/summer) in HSU-4 (Weiss, 2012).

Seasonal trends show upward vertical gradients between HSU-1 and HSU-2 in the fall and downward gradients in the spring (Weiss, 2012). The variation in vertical groundwater gradients by season is largely attributable to seasonal and weather-related use of irrigation wells in the area.

Figures 2-3 and 2-4 show the 2010 groundwater elevation maps for HSU-1 and HSU-2, respectively (Weiss, 2012). In HSU-1, flow is generally northeast, although seasonal impacts are readily apparent (e.g., third quarter 2010). For HSU-2, groundwater predominantly flows toward the east.

2.3 Site History

The following sections describe historical operations, investigations, and remedial actions at the Site.

2.3.1 Summary of Historical Operations

UC Davis operated three land disposal units within the boundaries of LEHR/OCL: LFU-1 was operated from the early 1940s through mid-1950s; LFU-2 was operated from 1956 through 1967; and LFU-3 was operated from 1963 through 1967 (Figure 2-1). These three units mainly received municipal-type waste from the main campus (BC, 2006b). The WBH area was primarily used to dispose of chemical, laboratory, and radioactive wastes from the UC Davis campus from 1956 through 1974 (BC, 2006b). From 1957 through 1965, additional laboratory waste was sent to the ET area (Geomatrix, 2004). The ST area received minor amounts of experimental animal remains from the UC Davis laboratories during the same period (DOE, 1988). Between 1968 and 1970, the Eastern Dog Pens were constructed on top of the southern portion of LFU-2. These dog pens were used to house research beagles until 1988, when research ceased. The Eastern Dog Pens were included in the ROD for the DOE areas at the Site (DOE, 2009b).

The Atomic Energy Commission (now DOE) began conducting radiological studies at UC Davis on laboratory animals, primarily beagles, in the early 1950s. Initial studies were conducted on the main UC Davis campus and involved the irradiation of beagles to simulate health effects of radiation on humans. DOE-funded research activities began at LEHR/OCL in 1958 and focused on the health effects from chronic exposure to radionuclides, mainly strontium-90 and radium-226. In the early 1970s, a cobalt-60 irradiator facility was constructed by DOE northwest of LFU-1 to study the effects of chronic exposure to gamma rays on the bone marrow cells of beagles (Figure 2-1). In 1975, the Energy Research and Development Administration (now DOE), supported by the US EPA, initiated a program in basic aerosol science to utilize cellular and animal models to evaluate airborne materials on-Site. Research activities in this program focused on the potential health effects of the atmospheric release of combustion products from fossil fuel power plants, with emphasis on coal fly ash (DOE, 1988). In 1983, DOE began operating the Toxic Pollutant Health Research Laboratory (TPHRL) at LEHR/OCL. Studies at the TPHRL included the use of americium-241 and plutonium-241 on beagles and monkeys and other toxic and carcinogenic aerosols on beagles (DOE, 1988). DOE-funded research activities at LEHR/OCL had ceased by 1988. During the 30-plus years of research and experimentation, over 1,000 beagles were housed at the Site.

2.3.2 Review of Historical Aerial Photographs

Aerial photographs available for review are listed in Table 2-1. Photographs selected to provide information on former Site conditions for this FS included those from 1937, 1952, 1957, 1964, 1965, and 1973 (Figures 2-5 through 2-10); to illustrate former Site conditions with respect to the land disposal units, the FS-defined boundaries have been added to these figures.

The 1937 aerial photograph (Figure 2-5) shows the LEHR/OCL Site location prior to land disposal activities. At the time, the Site was used as a portion of a golf course. The OWTP was present within a group of trees along the southern boundary adjacent to the South Fork of Putah Creek.

In August 1952 (Figure 2-6), the LEHR/OCL Site location was primarily open grassland with a few developing roads. The photograph on Figure 2-6 shows east-west-trending surficial disturbances within the east side of LFU-1, but there is no distinct evidence of excavation or waste disposal activities.

By June 1957 (Figure 2-7), new roads had been established throughout the Site, and there is evidence of grading or excavation activities within LFU-2 and possibly within the WBH and ET areas.

By May 1964 (Figure 2-8), LEHR buildings and a portion of the Western Dog Pens, as well as a large barn and small buildings located in the eastern half of the photograph, had been erected. Waste cells appear to be present throughout LFU-2 and within the southern half of LFU-3. In addition, some evidence of grading or excavation activity is possibly present in the ST, WBH, and ET areas, and in the area north of LFU-1 and LFU-2.

By 1965 (Figure 2-9), the Western Dog Pens had been completed, new roads had been established, and many old roads had been expanded. New buildings existed north of LFU-1 and along Caprine Drive between LFU-1 and LFU-3. A possible trench may be present in the southeast part of the ST, and waste cells appear to be present in LFU-2 and LFU-3.

By July 1973 (Figure 2-10), the Eastern Dog Pens had been completed on top of the southern portion of inactive LFU-2. The waste cell present in the 1965 aerial photo of the northern portion of LFU-2 is covered and a road is present on the north and west sides of this land disposal unit. The cobalt-60 field is present to the northwest of LFU-1, and each of the five X-buildings had been constructed on the east side of LFU-1. The cobalt-60 annex building and paved section in the northern part of the ET had been constructed, as was the drainage channel along the eastern edge of LFU-3.

An aerial photograph taken in 2006 shows a relatively current layout of the Site (Figure 2-11). The Western and Eastern Dog Pens have been removed and the two geriatrics buildings at the northwest corner of LFU-2 are present. Heavy vegetation covers most of LFU-1 and the WBH and ST areas. The portion of the north-south trending drainage channel along the eastern edge of LFU-3 has been lined with concrete.

2.3.3 Historical Investigations and Remediation Summary

Characterization investigations began at the Site in 1984 and have been ongoing. Studies began with an Initial Assessment Survey in 1984 (Rockwell International, 1984). The most recent investigation, the *Feasibility Study Data Gaps Technical Report* (Appendix A), was performed in 2009 to study chromium contamination in groundwater and general groundwater and soil gas impacts from the UC Davis solid waste disposal sites. These studies, as well as removal actions and other major environmental activities, are summarized in Table 2-2.

In December 2009, DOE finalized the ROD for the DOE-responsible areas. The selected remedy for the Eastern Dog Pens is land use restrictions, including implementation of a soil management plan (DOE, 2009b). Remedial alternatives presented in FS – Volume 1 are consistent with this remedy, as the Eastern Dog Pens area is included within the LFU-2 footprint.

2.3.4 Current and Future Use

UC Davis currently operates the Center for Health and the Environment (CHE) at the former LEHR/OCL facility. Research activities at CHE focus on the effect of environmental agents, including chemicals and radiation, on the health of humans, animals, and other organisms (UC Davis, 2010a). Also, currently located on the Site is the California Raptor Center, an educational and research facility dedicated to the rehabilitation of injured and orphaned birds of prey (UC Davis, 2010b). These organizations are likely to continue their activities for the foreseeable future.

The Site is located at the southern extent of the 5,300-acre UC Davis Campus, in an area designated for low-density academic and support uses, known as "South Campus." The Site currently houses one- and two-story laboratory and office buildings, animal handling facilities, and vegetated open areas. Specific land uses on the Site and in the immediate adjacent areas are under the control of UC Davis and are consistent with the *UC Davis Long-Range Development Plan Final Environmental Impact Report* (LRDP) (UC Davis, 2003). The LRDP indicates that the Central Campus area, two miles to the north of the Site and separated from the Site by a waterway, an interstate highway, and railroad tracks, will continue to be the portion of campus most intensely developed for academic and co-curricular activities. Figure 2-12 shows the LRDP proposed land use, as updated in November 2006. Note the LEHR/OCL Site is proposed for low-density academic/administrative purposes.

2.4 Nature and Extent of Contamination

The following subsections summarize the nature of contamination for the UC Davis solid waste areas (Figure 2-1). The extent of contamination for soil/solid waste is depicted in the tables and figures presented in Appendix C of this FS. Since the initial identification of FS COCs in the 2006 HHRA – Part C, additional data have been collected and the risk-based screening values have been updated (Appendix C). Characterization data summaries, including minimum and maximum concentrations, location of the maximum concentration, frequency of detection, range of detection limits, and human health screening values, are provided in Appendix C tables for each land disposal unit, as noted in the following subsections.

Table 2-3 summarizes the nature and extent of contamination and sampling history for land disposal units LFU-1, LFU-2, WBH, ET, LFU-3, and ST. The extent of contamination in the land disposal units is illustrated on Figures 2-13, 2-14, and 2-15. These figures show data from exploratory trenches excavated in 1988, 1989, 1995, and 1996; geophysical studies conducted in 1994 and 1996; and chemical analyses performed between 1994 and 2008, superimposed on the 1965 aerial photo. The exploratory trenches shown on these figures were not surveyed, and as such, their locations are approximate. The areas marked as geophysical anomalies are combined outlines from magnetic, electromagnetic, and ground penetrating radar surveys. Historical Site boundaries have been modified, where appropriate, to encompass Site disturbances or anomalies observed in historical aerial photographs and geophysical studies (specifically, the Site boundary for LFU-1 was extended north and west).

The magnitude of exceedance of a constituent over screening levels (Appendix C) is depicted in different colors on Figures 2-13, 2-14, and 2-15 (i.e., between 1 and 10 times the screening level, between 10 and 100 times the screening level, or greater than 100 times the screening level).

The potential principal threat waste (PTW) that has been identified during exploratory trenching is listed in Table 2-3. PTW is waste that is considered highly toxic, highly mobile, or potentially presents a risk to human health or the environment in the event of exposure. Few analytical data are available for solid waste items found during exploratory trenching; therefore, considerations for identifying waste as PTW were made based on descriptions of waste from available trench logs and assumed mobility of the identified waste material (e.g., bottles and vials with unidentified liquids, unidentified powders, colored crystalline material, ampules, lead casing, and pottery with elevated beta counts were assumed to present a potential threat to human health [Appendix E; Table E-9]).

2.4.1 Landfill Unit No. 1

No inventory records are available for LFU-1. Geophysical anomalies were identified throughout the unit; waste was identified in the exploratory trenches, and samples exceeding chemical screening levels correlate with the geophysical data. Waste is presumed to be located throughout the entirety of this unit (Figure 2-13). Tables C-5 and C-6 provide summary statistics for LFU-1.

2.4.2 Landfill Unit No. 2

According to UC Davis employee responses to a 1986 questionnaire, 19,260 cubic yards (CY) of waste were placed within 12 east-west trending cells in this area (DOE, 1988). Records were not kept of the types of wastes placed in these trenches; however, UC Davis personnel noted that municipal, construction, laboratory, chemical, petroleum, and campus incinerator wastes were likely disposed of in this area (Dames & Moore, 1990). Subsequent geophysical anomalies and evidence of waste cells in aerial photographs and during exploratory trenching confirm that waste is located in these east-west trending cells (Figure 2-14). Geophysical surveys were not conducted in the majority of the southern part of this unit because, at the time of the survey, the Eastern Dog Pens were located in the area. However, geophysical anomalies identified towards the southwestern part of the unit indicate that waste likely continues beneath the former Eastern Dog Pens. In addition, evidence of waste cells can be seen in the 1965 aerial photo (Figure 2-9). Soil samples representative of the potential LFU-2 waste were collected from three locations within the former Eastern Dog Pens area. Results for each of the three samples exhibited constituent concentrations exceeding screening levels. Waste found in trench logs primarily correlates with the geophysical data. Waste is presumed to be located in east-west trending cells separated by relatively undisturbed soils (Figure 2-14). Tables C-7 and C-8 provide summary statistics for LFU-2.

In addition to soil/solid waste, elevated volatile organic compound (VOC) concentrations in soil gas samples (specifically chloroform) suggest the presence of a VOC “hot spot” in the northern region of LFU-2, south of Geriatrics Building H-293 (Figure 2-14). Figure 2-16 shows the chloroform plume in HSU-1 and HSU-2 groundwater. The plume profile suggests a source zone within HSU-1 in the northern region of LFU-2, as well as in the northern region of the ET (see below).

As noted previously, the Eastern Dog Pens, formerly used to house beagles for radioactive experimentation, overlies LFU-2. The primary sources of contamination in the Eastern Dog Pens were related to feces and urine (containing radioactive material) and flea control material (containing pesticides). In 1999, samples were collected from the upper two feet of soil but did not include waste associated with LFU-2 underneath; gravel and concrete curbing materials were also sampled. Residual cancer risk for the hypothetical on-Site resident at the Eastern Dog Pens was estimated at 4×10^{-6} (DOE, 2009b). The Eastern Dog Pens is included in the ROD for the DOE areas with a selected remedy of land use restrictions, including implementation of a soil management plan (DOE, 2009b).

2.4.3 Eastern Trenches

Little sampling or exploratory trenching has been performed in the northern portion of the ET. However, in the southern portion of the area, north-south-trending geophysical anomalies are common. Eleven waste burial trenches are known to exist in the ET and received low-level radioactive waste (LLRW); the approximate locations of the trenches are shown on Figure 2-14 (DOE, 1988). Waste was found in exploratory trenches in this area and chemical analytical results from many sampling locations exceeded screening levels for at least one constituent. Waste is presumed to be located throughout the entirety of this unit (Figure 2-14). Elevated VOC concentrations in soil gas samples (specifically chloroform) suggest the presence of a second VOC "hot spot" in the northern portion of the ET (Figures 2-14 and 2-16). Tables C-3 and C-4 provide characterization data summaries for the ET.

2.4.4 Waste Burial Holes

According to historical records, LLRW material was buried in 49 ten-foot-deep holes within this area (Geomatrix, 2004). In 1985, UC Davis compiled an inventory of radioactive wastes potentially discarded in each hole (UC Davis, 1985). Waste was removed from 32 of the 49 discrete waste burial holes during the 1999 removal action, sorted, and sent for off-Site disposal (some of the holes may have converged over the years). The waste included PTW, LLRW, laboratory chemicals, vials, syringes, laboratory glassware, and animal carcasses (Geomatrix, 2004). Contact soil from the removal action was placed back into the excavated areas, and the area was covered with four to 12 inches of clean, imported soil. Many samples were collected during both removal action pre-characterization and confirmation sampling events. Post-removal action samples taken from locations throughout the disposal unit exhibited concentrations that exceeded screening levels (Figure 2-14). No geophysical surveys were performed in the WBH area after completion of the interim removal action. Tables C-13 and C-14 provide characterization data summaries for the WBH.

2.4.5 Landfill Unit No. 3

Aerial photographs of this unit show clear delineations of two distinct waste cells (Figure 2-15). Geophysical data were obtained from the west side of the unit. Trench logs correlate well with the aerial photographs. Locations sampled within the unit exhibited constituent concentrations that exceeded screening levels. Two samples were collected just outside of the unit boundary; constituent concentrations were below screening levels in these areas. It is likely that waste is not widespread throughout the unit boundary but exists primarily within the two cell boundaries (Figure 2-15). Tables C-9 and C-10 provide characterization data summaries for LFU-3.

2.4.6 Southern Trenches and Hopland Field Station Disposal Area

Geophysical anomalies were found in the ST disposal unit, indicating the likely presence of disposal trenches. Elevated reporting limits were present for most samples due to matrix interference. This unit consists of mostly gravel and sand with some bones; only limited waste was found during exploratory trenching (Figure 2-14). Historically, LLRW was discarded in three radioactive waste burial trenches (DOE, 1988). The southwestern corner of the historical boundary of the ST (on Figure 2-14 outside the ST boundary, but exhibiting geophysical anomalies) was removed during the 1998 DOE Southwest Trenches Removal Action (DOE, 2001). As such, this area is not addressed in this FS. Tables C-11 and C-12 provide characterization data summaries for the ST.

In 1965 and 1968, two experiments, including radionuclide injections into deer and sheep, were performed at the Hopland Field Station, a 5,300-acre UC Davis research facility approximately 120 miles northwest of the main campus. Historical information suggests that animals from the 1968 experiment were buried on-Site. The location of these carcasses is presumably to the east of the ST, adjacent to the southwestern edge of LFU-2 (DOE, 1988) (Figure 2-14). Sampling has not been performed in this area, and the single trench that crosses from LFU-2 into the Hopland Field Station Disposal Area (HFSDA) does not indicate the presence of waste. Geophysical anomalies suggest that disturbance to the soil has occurred (DOE, 1988).

2.5 Risk Assessment

The baseline risk assessment provides the basis for taking action at a site and identifies particular exposure pathways and COCs to be addressed by the remedial alternatives. It gives a baseline to indicate the potential risks if no action was taken. This section summarizes the results of the risk assessments conducted for the Site. Additional details can be found in the HHRA – Part A (MWH, 2004), the HHRA – Part C (BC, 2006a), the SWERA (BBL, 2006), and Appendix C of this FS.

2.5.1 Human Health Risk Assessment

The human health risk assessment evaluated potential current and future risks to human health and impact to groundwater quality, assuming no further cleanup or remediation at the Site.

The HHRA – Part A identified COPCs by comparing the maximum detected concentrations of each constituent in each land disposal unit to its available 2002 US EPA Region 9 Preliminary Remediation Goal (PRG). Those that exceeded their respective PRGs were considered COPCs. Constituents that lacked the appropriate toxicity criteria for the development of screening criteria and constituents that were not detected within a certain area were not considered COPCs. After COPCs were identified, an exposure point concentration (EPC) representative of each constituent within each area was developed. Fate and transport modeling was used to predict concentrations when direct measurements were not available. These EPCs were evaluated for various receptors present in each area, and toxicity values were assigned to each constituent. Cancer risk and non-cancer hazards were then calculated.

HHRA – Part C combined the risk and hazard estimates developed in the HHRA – Part A with other factors, such as spatial distribution, percentage of samples above background, analytical bias in the data, degradation and decay patterns, relationship to LEHR/OCL operations, and contribution of naturally-occurring chemicals and radionuclides, to create potential COCs to be addressed in the FS. For these COCs, cancer risks and non-cancer hazards calculated in the HHRA – Part A for the soil and solid waste COCs are presented in Tables 2-4 and 2-5, respectively. Similarly, cancer risks and non-cancer hazards calculated in the HHRA – Part A for groundwater COCs are presented in Tables 2-6 and 2-7, respectively. Cancer risks and non-cancer hazards were summarized for on-Site age-adjusted adults, on-Site residents, on-Site resident children, on-Site indoor researchers, on-Site outdoor researchers, and on-Site construction workers.

Tables 2-8 and 2-9 show the cumulative cancer risks and non-cancer hazards by exposure route for each receptor within each land disposal unit, respectively. For each land disposal unit, the cumulative cancer risks and non-cancer hazards for the non-resident receptors (i.e., on-Site indoor researcher, on-Site outdoor researcher, and on-Site construction worker) are currently within the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and below the hazard index (HI) of 1.0. The cumulative cancer risks for the age-adjusted adult, on-Site resident, and on-Site resident child are above the NCP's designated cancer risk range. For these receptors, inhalation of vapors from groundwater used for domestic purposes (e.g., showers, sinks) is the predominant driver of the cumulative cancer risk, with indoor air inhalation of vapors derived directly from groundwater also contributing. For LFU-1, LFU-2, and LFU-3, aboveground and belowground plant ingestion also contribute to the cumulative risk for the resident receptors, but in lesser amounts. Cumulative non-cancer hazards for the age-adjusted adult, on-Site resident, and on-Site resident child are above the HI of 1.0. Aboveground plant ingestion is the primary exposure pathway contributing to the hazard at LFU-1, LFU-2, and LFU-3; ingestion of groundwater through domestic use is the primary pathway at the ET and WBH and is also a contributor to the overall HI at each LFU.

Since the 2005 publication of the HHRA – Part C, additional environmental data have been collected, and the risk-based screening values for soil and soil gas constituents have been updated. Therefore, the previously-identified soil/solid waste and soil gas FS COCs were reevaluated using methodology based on the HHRA's screening process. The screening values used for this evaluation were the US EPA Regional Screening Levels (RSL) for non-radiologic constituents and PRGs for radionuclides, updated in November 2011 (US EPA, 2011c) and August 2010 (US EPA, 2010a), respectively. Appendix C of this FS serves as the update to the HHRA – Part C. Table 2-10 provides a comparison of which COCs identified in the HHRA – Part C have been retained or eliminated as COCs and the corresponding rationale. It also identifies new COCs as a result of acquisition of additional data or changes to risk-based screening values. Risks presented by the new soil/solid waste and soil gas FS – Volume 1 COCs were estimated by dividing the EPC for each constituent within a given area and depth interval by the respective screening level for residents (both adult and child). For carcinogens, this ratio was then multiplied by 10^{-6}; for non-carcinogens, the ratio is equal to the hazard quotient (HQ). Tables 2-11 and 2-12 summarize the risk and hazard results calculated in Appendix C of this FS for a hypothetical on-Site resident. The residential receptor was chosen because the HHRA – Part A indicated that this receptor was the most sensitive in comparison to the on-Site indoor researcher, the on-Site outdoor researcher, or the on-Site construction worker.

2.5.2 Ecological Risk Assessment

In 2006, a SWERA was conducted for 14 on-Site areas, including the LEHR/OCL Site (BBL, 2006). The primary objective of the SWERA was to evaluate potential ecological risks associated with the Site, using existing Site data and characterization reports.

The SWERA consisted of problem formulation for Tier 1 and Tier 2 evaluations, and, for Tier 2, an exposure and effects assessment, a risk characterization, and an uncertainty analysis.

2.5.2.1 Tier 1

The Tier 1 problem formulation defined the goals and objectives of the SWERA and included the selection of: 1) COPECs; 2) assessment endpoints (AE) and measurement endpoints (ME); and 3) representative receptors (including identification of special-status species). In addition, the Tier 1 problem formulation provided a discussion of the conceptual site model (CSM) for exposure to ecological species.

COPECs were selected based on a comparison of maximum detected concentrations to benchmarks protective of ecological receptors. Both inorganic and organic compounds were identified as COPECs and were referred to as List 1 COPECs for each Site area. For the soil/solid waste areas, the CSM identified the following exposure pathways and receptors:

Exposure Pathway	Receptor
Direct contact with soil	Terrestrial plants and soil invertebrates
Inhalation of soil gas	Burrowing animals
Ingestion of impacted plant, invertebrate, or other prey	Herbivorous, insectivorous, and carnivorous birds and mammals

Based on the complete exposure pathways identified in the CSM, AEs were developed to identify the ecological entities and attributes that require protection. Ten AEs were identified for the terrestrial habitat observed on-Site. The MEs were developed to aid in assessing potential ecological effects and to evaluate whether potential risk is associated with the COPEC concentrations in each media. Lastly, the Tier 1 problem formulation identified receptors of concern that are representative species for each AE. Receptors of concern were selected conservatively with consideration of their life history characteristics to maximize estimates of potential exposure.

2.5.2.2 Tier 2

In the Tier 2 problem formulation, the inorganic List 1 COPECs were evaluated against Site-specific background concentrations. In addition, an exposure and effects assessment was conducted. For the soil/solid waste areas, the exposure assessment included the development of EPCs in soil and soil gas (for LFU-2). EPCs were used: 1) to evaluate direct contact for plants and invertebrates, and 2) in a food web model to calculate a daily dose to birds and mammals. In the effects assessment, toxicological effects data were used to compare to Site COPEC concentrations or modeled doses. Benchmarks were selected as conservative estimates of potential toxic effects to minimize the possibility of reaching a finding of no risk when risk actually exists.

The risk characterization integrated the results of the exposure and effects assessments to characterize risk to the receptors of concern. The MEs were evaluated using a hazard quotient approach.

Risk estimates (e.g., hazard quotients) were calculated for List 1 COPECs using the lowest observed effect concentration (LOEC) low benchmarks and no observed adverse effect level (NOAEL) toxicity reference values (TRV). The LOEC-based low benchmarks and NOAEL-based TRVs represent a toxicological threshold below which there is high confidence in a finding of no risk.

To refine these risk estimates for birds and mammals, HQs were also calculated using lowest observed adverse effect level (LOAEL) TRVs for those List 1 COPECs that were found to be greater than background and that had NOAEL-based HQs greater than one. The LOAEL-based TRVs represent a value above which risk may be possible or further evaluation is needed. In between the LOAEL and NOAEL, the exact concentration at which a toxicological effect might be observed is uncertain. These COPECs were referred to as List 2 COPECs.

Uncertainties were inherent in each phase of the SWERA process, including the exposure assessment, effects assessment, and risk characterization. However, the ecological risk values are likely to overestimate the true risk associated with the Site because protective assumptions were made at many different steps during the ecological risk evaluation process and are compounded in calculation of the risk estimate.

Ecological risks were found to be acceptable for the ET and ST, and no further evaluation of ecological receptors was recommended. Ecological risk was found to be *de minimus* at the WBH (with the possible exception of the special-status California horned lark). However, no further evaluation was recommended from an ecological perspective. Ecological risks identified for List 2 COPECs in soil are summarized for LFU-1, LFU-2, and LFU-3 in Tables 2-13, 2-14, and 2-15, respectively. In addition to the risks calculated for soil in LFU-2, a hazard quotient of 3.6 was calculated for chloroform in soil gas for the burrowing mammal receptor. This was the only COPEC for soil gas.

2.6 Fate and Transport

This section summarizes the fate and transport of identified COCs for this FS (Appendix C).

2.6.1 Fate

An overview of the fate of human health and soil-to-groundwater COCs (Appendix C) is provided in this section, as well as brief descriptions of general transport properties. Section 2.6.2 and Table 2-16 describe transport properties, Site modeling exercises, and Site trends.

2.6.1.1 Inorganic Compounds in Soil

The fate of metal FS – Volume 1 COCs in soil, including their rate of biodegradation, is controlled by the physical and chemical properties of the soil, including particle size, cation exchange capacity, reduction/oxidation (redox) potential, pH, binding site competition, and the presence and content of organic material. Human health FS – Volume 1 metal COCs are arsenic, lead, and manganese; soil-to-groundwater FS – Volume 1 metal COCs are barium, cadmium, copper, and selenium.

Arsenic is a naturally occurring metal that is widely and uniformly distributed and exists in a variety of oxidation states (-3, 0, +3, +5) (ATSDR, 2007a; Kabata-Pendias, 2001). It cannot be destroyed in the environment, only transformed between different organic or inorganic compounds. Partitioning and transport of arsenic is largely controlled by the oxidation state (Eh). Arsenic binds strongly to sediment under oxidizing conditions, with adsorption largely controlled by the iron content of the soil. Under reducing conditions, adsorbed arsenic may be released and mobilized. In addition to the oxidation state, other soil characteristics account for the specific arsenic compound, including soil pH, temperature, salinity, distribution and composition of biota, and metal sulfide and sulfide ion concentration (ATSDR, 2007a).

Lead is a naturally occurring metal, but most elevated levels are by-products of human activity (ATSDR, 2007b). Elemental lead does not break down, but air, sunlight, and water can transform lead compounds. Lead is highly mobile in the air, and atmospheric deposition can be a major source of lead to the environment. Once deposited, lead adsorbs strongly to soil particles and organic matter, where it can be transformed into other inorganic and organic compounds. Solubility increases with acidity (lower pH) (ATSDR, 2007b), but the presence of sulfate and carbonate ions limit lead in solution (Kabata-Pendias, 2001). The transport of lead from soil to groundwater is dependent on the type of lead compound and soil characteristics (pH, cation exchange capacity, amount of organic matter, and the presence of other ions) (ATSDR, 2007b).

Manganese is one of the most abundant trace elements in the lithosphere, forming numerous compounds, including oxides, hydroxides, and oxyhydroxides, that in turn form adsorption sites for other metals. Manganese can exist in several oxidation states, and the soil Eh and pH conditions are important controls on which form manganese will take (Kabata-Pendias, 2001). Cation exchange and adsorption are the two primary mechanisms controlling the fate of manganese in the environment; some evidence suggests that microbes may also play a role in its availability (ATSDR, 2008a). Manganese is often associated with other heavy metals, and manganese oxides likely control the oxidation of other heavy metals (Kabata-Pendias, 2001).

Barium is a naturally occurring, highly reactive metal that forms a variety of compounds in the environment. Barium only exists in the 2+ oxidation state. Partitioning in the environment is affected by pH, the oxidation-reduction potential, cation exchange capacity, and the presence of sulfate, carbonate, and metal oxides. In the subsurface, barium primarily exists as insoluble barium sulfate and barium carbonate compounds. Barium compounds are also found adsorbed to sediment. Most barium compounds exhibit low mobility in the subsurface, but under lower pH conditions, barium compounds can be more soluble. Barium chloride and barium complexes with fatty acids are also more mobile forms, although they do not last long in solution before barium is scavenged by naturally occurring carbonate or sulfate (ATSDR, 2007c).

Cadmium is a naturally occurring metal and is commonly extracted during the production of other metals like zinc, lead, and copper. Once released into the environment, cadmium primarily partitions into the soil (80-90 percent). Cadmium can be released to the atmosphere from both natural and anthropogenic sources, where it can undergo long-range transport before removal via wet and dry deposition. In the subsurface, cadmium can exist as the hydrated ion (Cd^{2+}) or in ionic complexes with both organic and inorganic substances; pH plays a large role in controlling the form of cadmium. Cadmium is more mobile than other heavy metals, but generally forms immobile compounds or is adsorbed to sediment. Cadmium binds strongly with organic matter; adsorption increases with pH and organic content. Consequently, leaching is more common under lower pH conditions. Under reducing conditions, cadmium may be transformed into poorly soluble cadmium sulfide, which tends to precipitate. Many cadmium compounds are readily available to plants, and uptake is especially efficient under lower pH conditions (ATSDR, 2008b).

Copper is a naturally occurring metal that does not degrade in the environment; it tends to bind strongly to organic matter, clay, or sediment rather than migrate. Copper can exist in four oxidation states: Cu(0), Cu(I), Cu(II), and Cu(III). Cu(II) is the typical oxidation state in water. Transport of copper is dependent on its specific form; most copper forms organic and inorganic complexes and binds strongly to organic matter, carbonate minerals, clay minerals, hydrous manganese oxides, and iron oxides. The binding affinities of copper depend on pH, oxidation-reduction potential, and the presence of competing metal ions and inorganic anions. Leaching to groundwater is most prominent at low pH; copper remains mobile in soil with a pH below 5. In anaerobic sediments, copper forms insoluble cuprous (Cu(I)) salts (ATSDR, 2004a).

Selenium is a naturally occurring metal that is common in the environment and resembles sulfur in the forms and compounds in which it is found. The environmental fate of selenium is largely controlled by its oxidation state and soil pH conditions. Selenium has four stable oxidation states: heavy metal selenides (2-) and elemental selenium (0) are insoluble in water, whereas the inorganic alkali selenites (4+) and selenates (6+) are soluble and mobile in water. The soluble forms are favored under aerobic and high pH conditions. Under acidic conditions, selenium may be reduced to the insoluble and stable elemental form or form insoluble compounds (ATSDR, 2003). Sulfates and phosphates reduce adsorption and can mobilize selenium (Kabata-Pendias, 2001). Some evidence suggests that microbe-mediated reduction and precipitation may strongly retard selenium transport in groundwater (ATSDR, 2003).

2.6.1.2 Radionuclides in Soil

The fate of radionuclides in soil is dependent upon the site soil conditions and the half-lives of the constituent. With the exception of potassium-40 (1.3×10^9 years) and carbon-14 (5,730 years), FS – Volume 1 COC radionuclides (cesium-137, strontium-90, and tritium) have half-lives of 30 years or less.

Carbon-14 is a naturally occurring radioactive isotope that decays to nitrogen-14 via beta decay. Its half-life is 5,730 years. Radioactive carbon can form organic and inorganic compounds and ultimately be converted to the gaseous phase as carbon dioxide or methane. In the subsurface, the transport of carbon-14 largely depends on the specific molecule where it is found. Transport may occur as carbonate or bicarbonate ions or as soluble organic compounds (US EPA, 1986).

Cesium-137, a fission product, is a radioactive isotope that decays via beta emission (with release of gamma particles) to non-radioactive barium-137 (ATSDR, 2004b). The half-life of cesium-137 is 30 years. Cesium can form compounds that tend to be highly soluble but generally have very low mobility in soils when compared to other metals. Mobility is especially reduced in potassium-rich clays that adsorb cesium as clay interlayer cations. Cesium also appears to have an affinity for organic matter (Kabata-Pendias, 2001). The fate of cesium-137 does not respond substantially to pH, cation exchange capacity, or water availability (ATSDR, 2004b).

Potassium-40 is a naturally occurring radionuclide with a very long half-life (1.3 billion years). The predominant (~90 percent) decay pathway is to calcium-40 via beta emission. Potassium is very reactive and is frequently incorporated into plant and animal tissue (ANL, 2005a).

Strontium-90 is a fission product and is typically soluble and moderately mobile in the subsurface (ATSDR, 2004c). Radioactive strontium-90 decays via beta emission to radioactive yttrium-90, which in turn decays via beta emission and some gamma emission to the stable isotope zirconium-90. The half-life of strontium-90 is 29 years. In the environment, strontium typically exists as Sr^{2+} and is moderately mobile (ATSDR, 2004c). Strontium is geochemically and biochemically similar to calcium, and thus is often associated with calcium and, to a lesser extent, magnesium (Kabata-Pendias, 2001). Sorption and desorption reactions mediate the transformation of Sr^{2+} in soil and are controlled by pH, ionic strength, solution speciation, mineral composition, organic matter, biological organisms, and temperature (ATSDR, 2004c). Organic matter and ion-exchangeable Ca^{2+} in soil reduce strontium mobility, whereas nitrate fertilizers and salinity increase strontium mobility (ATSDR, 2004c).

Tritium (H-3) is a naturally-occurring radioactive isotope of hydrogen that is also produced in appreciable quantities by neutron bombardment of lithium-6 (US EPA, 2011b) or in heavy water-moderated reactors. Tritium decays to helium-3 via beta emission, with a half-life of 12.3 years. Tritium is often found in the environment incorporated into water molecules; its fate and transport is linked with water (ANL, 2005b; OEHHA, 2006).

2.6.1.3 Organic Compounds in Soil

Polychlorinated biphenyls (PCBs) refer to 209 different synthetic chlorinated compounds, known as congeners (ATSDR, 1995a). Aroclor is a former trade name for PCBs which precedes a number indicating the number of carbon atoms and percentage of chlorine by weight present among the mixture of individual congeners. For example, Aroclor 1260 is a mixture of different congeners with 12 carbon atoms and 60 percent chlorine by weight. PCBs are generally inert, hydrophobic, resist acids and alkalis, and are thermally stable. Consequently, PCBs are very persistent in the environment and tend to cycle between environmental media (air, soil, water) rather than degrade. They are generally insoluble in water, with insolubility increasing with the number of chlorine atoms. PCBs, however, are very soluble in organic solvents and adsorb strongly to organic matter, which limits their mobility in soil and cycling between environmental media. More highly chlorinated congeners sorb more strongly. PCBs may volatilize, with volatilization decreasing with increasing chlorine substitution. In sediment, decreasing moisture content will also decrease volatilization. The number of chlorine atoms plays a key role in partitioning between soil and air, with the less chlorinated congeners more likely to volatilize and higher chlorinated congeners more likely to sorb. Although rates are slow, aerobic and anaerobic biodegradation is the major degradation process in soil. The effectiveness of aerobic biodegradation increases with decreasing chlorine substitution, while anaerobic degradation is more important for the more highly chlorinated congeners. Anaerobic biodegradation transforms the PCB to a less chlorinated PCB rather than completely degrading the compound (ATSDR, 1995a).

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that form during incomplete combustion of organic substances (ATSDR, 1995b). Naphthalene, benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene are PAHs.

Benzo(a)pyrene ($C_{20}H_{12}$), benzo(a)anthracene ($C_{18}H_{12}$), and benzo(b)fluoranthene ($C_{20}H_{12}$) are categorized as high molecular weight compounds and behave similarly in the environment (ATSDR, 1995a). These PAHs have low solubility in water and occur either in the air or are bound to soil particles; each of these compounds has a high affinity for organic carbon. In soils, microbial metabolism is the primary degradation mechanism. Although abiotic degradation is typically not a significant degradation pathway, volatilization, oxidation, and photolysis are other potential removal mechanisms. The retardation factors listed in Table 2-16 indicate that benzo(a)pyrene, benzo(a)anthracene, and benzo(b)fluoranthene have very low mobility in the subsurface relative to other COCs (ATSDR, 1995a).

In contrast, naphthalene ($C_{10}H_8$) is a two-ring PAH that has a short environmental half-life, given its tendency to volatilize and biodegrade (ATSDR, 2005). Naphthalene evaporates easily; photochemical degradation often breaks down the compound within one day. Naphthalene can also dissolve into water, where evaporation and microbial degradation are common removal mechanisms. In soil, naphthalene binds weakly to sediment, with sorption controlled by organic content. Microbial degradation typically removes naphthalene within one to three months, where increasing organic content increases the time to biodegradation (ATSDR, 2005).

2.6.1.4 Volatile Organic Compounds in Soil Gas

Land disposal units are also suspected sources of VOCs in soil gas. Chloroform, 1,2-dichloroethane, 1,2-dichloropropane, 1,3-butadiene, and tetrachloroethene have been detected in soil gas in LFU-2 and the ET land disposal units. VOCs exhibit little to no natural attenuation in soil gas prior to being transported upward to the atmosphere (or indoor air) or downward to groundwater.

Chloroform is both a natural and synthetic compound that degrades very slowly in air, water, and sediment. It readily volatilizes in the atmosphere. It also dissolves easily into water, where it can migrate into the subsurface (ATSDR, 1997a).

1,2-Dichloroethane is a synthetic compound that readily volatilizes into the atmosphere from water and soil, where it undergoes photochemical oxidation with a residence time of 73 days. It is not expected to adsorb appreciably to sediment. Biodegradation occurs very slowly in water and sediment, and abiotic processes are not environmentally significant. 1,2-Dichloroethane can be found in groundwater, where its high density causes it to sink into the aquifer (ATSDR, 2001).

1,2-Dichloropropane is a synthetic compound that volatilizes into the atmosphere and dissolves in water. In the atmosphere, photochemical degradation is slow (greater than 23 days), and atmospheric dispersion can be considerable before degradation or removal via washout. In the subsurface, 1,2-dichloropropane does not adsorb appreciably to sediment and has a low affinity for organic content. Moderately soluble, 1,2-dichloropropane can enter groundwater, where it subsequently volatilizes or slowly degrades. Degradation takes place via hydrolysis, with a half-life of 25-200 weeks, and potentially via anaerobic biotransformation. Biotransformation rates have not been quantified but studies suggest low biotransformation potential (ATSDR, 1989).

1,3-Butadiene is a highly volatile hydrocarbon gas used in the production of commercial plastics and synthetic rubbers. Once in the atmosphere, it breaks down rapidly by photochemical reactions, with a half-life of approximately six hours. The partitioning of 1,3-butadiene is not well understood in the subsurface, although it is anticipated that it will volatilize rapidly. Experimental evidence suggests that it does not adsorb appreciably to soil or sediment. Experimental data also suggest the potential for moderate mobility in soil, but the high rate of volatilization and the possibility of rapid degradation in soil suggest a low potential for leaching (ATSDR, 2009).

Tetrachloroethene is a synthetic compound that readily volatilizes to the atmosphere. Tetrachloroethene can persist for several months in the atmosphere before it photochemically degrades, allowing long-range transport far from the source. In the subsurface, tetrachloroethene has demonstrated medium-to-high mobility through soil, with some sorption to sediment related to organic matter content. Tetrachloroethene has a relatively low solubility in water and is denser than water; volatilization is not a viable removal pathway for this compound in groundwater. Anaerobic microbes may play a role in groundwater degradation, although rates are estimated to be low and breakdown products may be of similar or greater toxicity (i.e., trichloroethene, dichloroethenes, and vinyl chloride) (ATSDR, 1997b).

2.6.2 Transport

The conceptual site model presented on Figure 2-17 summarizes the transport pathways and likely sources of contamination to soil, soil gas, and groundwater. When storm water infiltrates the land disposal units, mobile chemicals (VOCs, complex metal ions, carbon-14, and tritium) may leach to groundwater in HSU-1. HSU-1 is hydraulically connected to the more permeable HSU-2. Accordingly, chemicals in HSU-1 groundwater have the potential to flow downward to groundwater in HSU-2. HSU-2 and HSU-4 are separated by a 140-foot thick layer of clayey silt and silty clay (referred to as HSU-3). Thus, there is no natural hydraulic connectivity between HSU-2 and HSU-4. However, former irrigation well 22N provided a transport pathway for contaminants (predominantly chloroform) in HSU-2 to reach HSU-4. This well is now sealed and abandoned.

The following subsections summarize three major transport pathways from soil/solid waste.

2.6.2.1 Transport from Soil/Solid Waste to Groundwater

Constituent travel times from soil/solid waste to groundwater were estimated based on groundwater flow rates and representative soil/water partitioning coefficients (K_d) for each constituent. Groundwater flow rates through the vadose zone were estimated with the Hydrologic Evaluation of Landfill Performance (HELP) Version 3.0 model (Geomatrix, 2004), as well as the Non-isothermal Unsaturated Flow and Transport (NUFT) model (Appendix A). The distribution coefficients were used to calculate adsorption/retardation factors using the linear retardation factor model. Table 2-16 provides the calculated vadose zone travel times for the COCs identified in this FS. These estimated travel times update those from the RI (Geomatrix, 2004) by using more representative K_d values (Weiss, 2008) as well as soil and water parameters (documented in Appendix A).

Constituent mobility and time to reach groundwater were evaluated by defining mobility categories: high mobility means the constituent reaches groundwater in less than 100 years; intermediate mobility means the constituent reaches groundwater between 100 and 300 years; and low mobility means the constituent reaches groundwater in more than 300 years. As shown in Table 2-16, the constituent with the longest time to reach groundwater is Aroclor 1260 (approximately 2,350,000 years), and the constituents with the shortest time to reach groundwater are tritium, carbon-14, barium, cadmium, and selenium (0 years).

Barium, cadmium, and selenium were identified via NUFT modeling (Appendix A) as soil-to-groundwater FS – Volume 1 COCs; NUFT modeling results indicated that concentrations of these metals should currently be at concentrations greater than Maximum Contaminant Levels (MCLs). Modeling of copper suggests that the MCL will not be exceeded for over 700 years. Maximum concentrations for each of these constituents from the last five years of sampling are below MCLs.

Carbon-14 and tritium were selected as representative mobile constituents at the Site. Groundwater sampling data for these constituents were plotted to illustrate potential leachate release trends from landfill waste. HSU-1 wells downgradient of the land disposal units were selected as representative wells to display time trends (Figure 2-18):

- UCD-010 for LFU-3;
- UCD-011 for LFU-1;
- UCD-012 for the ET, LFU-2, and the WBH; and
- UCD-013 for the ET, LFU-2, and the WBH.

Historical trends of carbon-14 and tritium relative to groundwater levels are shown on Figures 2-19 through 2-22. Groundwater levels in monitoring wells measured since 1990 show that water levels in HSU-1 have rarely, if ever, reached the deepest extent of buried waste contained in the land disposal units, as documented in Table 2-3 and shown on Figures 2-19 to 2-22. For these wells, carbon-14 and tritium either were not detected in groundwater or show a noticeable decreasing trend towards lower concentrations over time. The wells with the highest current and historical concentrations of carbon-14 and tritium are located downgradient of LFU-2 (UCD1-012; Figures 2-18 and 2-20) and the ET/WBH (UCD1-013; Figures 2-18 and 2-21), and are also exhibiting a distinct trend of decreasing concentrations.

Several of the inorganic and radionuclide constituents the models estimated to have "low" and "intermediate" mobilities (arsenic, lead, manganese, cesium-137, potassium-40, strontium-90; Table 2-16) have occasionally been detected in groundwater at the Site; most groundwater samples show non-detectable concentrations, and detectable concentrations do not appear to show any temporal patterns and are interspersed with non-detectable results. Monitoring well UCD1-011, downgradient of LFU-1 (Figure 2-18), shows some arsenic concentrations near or below the background concentration.

Of the organic COCs listed in Table 2-16, none of the "low" mobility organic COCs have been detected in groundwater, and "high" mobility naphthalene has only been detected in two wells in May 2001 at concentrations near the detection limit. These two wells, UCD2-046 and UCD4-047, are both at least 1,500 feet downgradient of the Site to the northeast. This evidence suggests that naphthalene is not leaching from the landfill waste to groundwater, which is consistent with its short environmental half-life, as described above in Section 2.6.1.3.

2.6.2.2 Transport from Soil/Solid Waste to Surface Water

For Site constituents to reach surface water in Putah Creek, the nearest surface water body, the constituents must be present in surface soil, and a complete storm water pathway from surface soil to surface water must exist. Storm water on most of the Site infiltrates into soil; however, complete storm water runoff pathways to Putah Creek currently exist at the storm water culverts at the southern and eastern portions of both LFU-1 and LFU-3. Storm water runoff commonly enters Putah Creek from the LFU-1 area, but it has rarely been observed in LFU-3 since the eastern channel was lined with concrete in 1998 (Geomatrix, 2004).

2.6.2.3 Transport from Soil/Solid Waste to Soil Gas

VOCs transported to the atmosphere will be degraded by photochemically-produced hydroxyl radicals. Vapors could also be transported through subsurface soil into indoor air by advection and diffusion. VOCs in soil gas could also infiltrate to groundwater and migrate through the HSUs (Figure 2-17).

3. REMEDIAL ACTION OBJECTIVES AND APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

RAOs establish the chemicals and media of concern, the potential exposure pathways, and remediation goals for protecting human health and the environment. The chemicals and media of concern for human health and the environment are discussed below, followed by a discussion of ARARs and remedial action objectives.

3.1 Chemicals and Media of Concern

Since the publication of the HHRA – Part C, additional data have been collected and updates have been made to the human health toxicity screening values issued by the US EPA and the California Office of Environmental Health Hazard Assessment (OEHHA). Furthermore, reliance on the previous presumptive remedy (containment and capping) originally posited in the HHRA – Part C is no longer applicable. Consequently, a human health screening update was conducted for the FS - Volume 1 COCs for soil/solid waste (Appendix C) and soil gas (Appendix B). In addition to the updated human health screening, a groundwater impact assessment was performed (Appendix A). Details on the screening process and the updated FS – Volume 1 COCs are discussed below.

3.1.1 Soil/Solid Waste

The updated human health risk-based screening process described in Appendix C was based on an on-Site adult resident scenario and involved compilation of Site data for the six land disposal units. Soil/solid waste data were screened against the US EPA November 2011 RSLs for chemical COCs (US EPA, 2011c), the US EPA August 2010 PRGs for radiologic COCs (US EPA, 2010a), the California Human Health Screening Level (CHHSL) for lead (OEHHA, 2010), and background values. Constituents with concentrations exceeding screening and background values were designated as soil/solid waste COCs for this FS and are summarized in Table 3-1; COCs were determined for two depth ranges: 0 to 10 feet bgs and 10 to 20 feet bgs. Cancer risks and non-cancer hazards for these COCs are shown in Tables 2-11 and 2-12, respectively. Lead was also identified as a COC but is not shown on either table, as toxicity is measured by blood-lead levels (OEHHA, 2009) rather than cancer risk or non-cancer hazard.

According to the HHRA – Part C, human health risk-based screening (Appendix C), soil gas risk assessment (Appendix B), and groundwater impact assessment (Appendix A), data collected from the ST indicate that no constituents in soil or solid waste are present at concentrations that pose a risk to human health or a threat to groundwater quality. However, in this analysis, carbon-14 was retained as a COPC in the ST in the 0 to 10-foot depth interval because one detected value (out of 21 samples analyzed for carbon-14) was greater than the health-based screening value. In addition, of the 20 non-detects, each had a detection limit greater than the screening value, and uncertainty counts for each sample were greater than 50 percent of the result value. Because of the uncertainty surrounding the quality of these data, it is not possible to quantify the potential risk or impact to groundwater from carbon-14 in the ST; thus, this constituent was retained as a COPC until further evaluation.

Table 3-1 also lists ecological COCs for LFU-1, LFU-2, and LFU-3 for depths between 0 to 10 feet bgs. These COCs were identified in the SWERA (BBL, 2006). Ecological risks were not identified for the ET, ST, or WBH.

A groundwater impact assessment was performed as part of the 2010 Data Gaps Investigation (Appendix A). This assessment included a calculation of soil/solid waste designated levels to identify COCs at concentrations that could degrade groundwater quality. The COCs identified during this evaluation were:

- ET: carbon-14 and tritium;
- LFU-1: copper, selenium, and carbon-14;
- LFU-2: cadmium and carbon-14;
- LFU-3: barium, cadmium, copper, and carbon-14; and
- WBH: carbon-14 and tritium.

3.1.2 Soil Gas

Vapor intrusion risks were originally estimated in the HHRA – Part A. However, they have been reassessed as part of this FS to estimate risks in the six land disposal units from chemicals present in soil gas (Appendix B). The reassessment of vapor intrusion risks was necessary to incorporate soil gas data collected in 2008 during the FS data gaps investigation (Appendix A) and to account for new toxicity values released subsequent to the completion of the SWRA. Soil gas COCs associated with human health risk due to vapor intrusion are:

- ET: 1,2-Dichloroethane, 1,2-dichloropropane, 1,3-butadiene, and chloroform;
- LFU-1: 1,3-Butadiene;
- LFU-2: 1,2-Dichloropropane, chloroform, and tetrachloroethene;
- LFU-3: none identified;
- ST: none identified; and
- WBH: none identified.

Formaldehyde in the WBH was initially recommended as an FS COC in Appendix B; however, because the estimated risk is $1x10^{-6}$, it has been eliminated as a COC for this FS. In addition, since the vapor intrusion pathway was evaluated, recommended attenuation factors have been updated (DTSC, 2011). 1,3-Butadiene in LFU-1 and the ET and formaldehyde in the WBH would not have been identified as COCs if these attenuation factors had been used. However, use of the new values does not impact the overall scope or evaluation of the alternatives in this FS;

therefore, corresponding COC changes have not been made. 1,3-Butadiene should be eliminated as a COC in the Proposed Plan and ROD.

Soil gas COCs with the potential to impact groundwater were also recommended in the groundwater impact assessment (Appendix A). These recommended COCs were evaluated in conjunction with additional groundwater data collected during the first quarter of 2010. As a result of this evaluation, acetone, formaldehyde, 1,1-dichloroethane, 1,2-dichloropropane, and 1,4-dioxane were eliminated as FS – Volume 1 COCs. Soil gas COCs with potential impacts to groundwater are:

- ET: chloroform and 1,2-dichloroethane;
- LFU-1: none identified;
- LFU-2: chloroform;
- LFU-3: none identified; and
- WBH: none identified.

3.2 Applicable or Relevant and Appropriate Requirements

Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, requires attainment of ARARs in the remediation process. Section 121(d)(2)(A) states the following:

> "With respect to any hazardous substance, pollutant, or contaminant that will remain on-site, if – (i) any standard, requirement, criteria, or limitation under any Federal environmental law...; or (ii) any promulgated standard, requirement, or limitation under a state environmental or citing law that is more stringent than any Federal standard, requirement, criteria, or limitation ... and that has been identified ... in a timely manner, is legally applicable to the hazardous substance or pollutant or contaminant concerned or is relevant and appropriate under the circumstances of the release or threatened of such hazardous substance or pollutant or contaminant, the remedial action selected ... shall require, at the completion of the remedial action, a level or standard of control for such hazardous substance or pollutant or contaminant which at least attains such legally applicable or relevant or appropriate standard, requirement, criteria, or limitation."

The NCP describes the process for identifying ARARs in 40 Code of Federal Regulations (CFR) Section 300.400(g). This section provides general information regarding ARARs. Appendix D lists the ARARs for the Site, describes the individual ARARs, and lists whether it is applicable or relevant and appropriate to the land disposal units and the proposed remedial alternatives provided in Section 5.

3.2.1 Definitions

ARARs are federal standards, requirements, criteria, limitations, or state standards determined to be legally applicable or relevant and appropriate to the circumstances at a given

CERCLA site. Only those state standards that are promulgated and identified by the state in a timely manner and are more stringent than federal requirements may be ARARs.

Applicable requirements are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, or state environmental or facility citing laws that, while not "applicable" to the hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. In some cases, only a portion of the requirement may be relevant and appropriate. The lead and support agencies have the discretion to determine which requirements are relevant and appropriate to the project.

Substantive requirements are requirements that pertain directly to actions or conditions in the environment. On-site actions need to comply only with substantive requirements. "On-site" includes not only the aerial extent of contamination subject to CERCLA action, but also areas in close proximity to the contamination necessary for implementation of the response action.

Administrative requirements are mechanisms that facilitate the implementation of the substantive requirement of a statute or regulation; these requirements are interpreted broadly by the US EPA to include administrative provisions from other laws, such as recordkeeping, consultation, and reporting requirements. Administrative requirements are not applicable for on-site activities. In particular, federal, state, or local permits are not required for on-Site activities undertaken under CERCLA Sections 104, 106, 120, 121, or 122 (40 CFR Section 300.400(e)).

Activities conducted off-site must meet both the substantive and administrative requirements that are determined to be applicable.

3.2.2 Types of Applicable or Relevant and Appropriate Requirements

ARARs to be reviewed for CERCLA sites fall into three categories depending on the COCs, site location, site conditions, and the actions being considered. The three categories are:

- Chemical-specific ARARs - Usually, health- or risk-based requirements that define acceptable concentrations of a chemical in the environment.
- Location-specific ARARs - Requirements that restrict activities in certain environmentally sensitive areas, such as flood plains, wetlands, endangered species habitat, or historically significant areas.
- Action-specific ARARs - Requirements that are technology- or activity-based. These ARARs regulate discrete actions, or the design and use of certain equipment.

3.2.3 To-Be-Considered Guidelines

When ARARs are not fully protective of human health and the environment, the NCP allows for other local ordinances, unpromulgated criteria, advisories, or guidance documents to be identified to supplement the ARARs if they are helpful in achieving an acceptable level of risk (40 CFR Section 300). The identification of to-be-considered guidelines is not mandatory; however, it is recommended if it will assist in determining a level of cleanup that protects human health and the environment.

3.2.4 Risk-Based Requirements

In addition to meeting ARARs, RAOs must reduce risk from the Site to levels acceptable under CERCLA. As specified in 40 CFR Section 300.430 (e)(2)(i)(A)(2), the acceptable human exposure to carcinogens at CERCLA sites is an excess lower bound lifetime cancer risk between 1 in 10,000 (10^{-4}) and 1 in 1,000,000 (10^{-6}). For systemic toxicants, acceptable exposure levels represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety (40 CFR Section 300.430 (e)(2)(i)(A)(1)). This exposure is measured using an HI. An HI less than or equal to 1.0 represents an acceptable exposure.

3.3 Remedial Action Objectives

After consideration of CERCLA risk standards and ARARs, RAOs were developed for the LEHR/OCL Site. RAOs for the Site include those for the protection of human health, the environment, and groundwater quality, as described below:

- Prevent human contact with contamination in soil/solid waste and soil gas that may pose excess cumulative cancer risk greater than the lower bound of the risk range, 1×10^{-4} to 1×10^{-6}.
- Prevent human contact with contamination in soil/solid waste and soil gas that may pose a non-cancer hazard with a HI greater than 1.0.
- Prevent potential future impacts to groundwater above MCLs or Maximum Contaminant Level Goals (chloroform only) from landfill waste and affected soil/soil gas.
- Minimize threats to the environment by limiting ecological receptor exposure, including, but not limited to, sensitive and critical habitats of species protected under the state and federal Endangered Species Acts.
- Prevent contact of surface water or storm water with landfill waste or impacted soil.

Site-specific preliminary cleanup goals (PCGs) for soil/solid waste and soil gas were developed for protection of human health and groundwater resources. Development of these PCGs is discussed in the following subsections. Cleanup levels for the Site will be established in the ROD.

On the basis of the level of uncertainty (orders of magnitude) in the ecological risk assessment (BC, 2006b), protection of the environment has been evaluated qualitatively.

3.3.1 Preliminary Cleanup Goals – Soil/Solid Waste

PCGs were initially established for soil/solid waste in Appendices A and C for groundwater impact and human health, respectively. Tables 3-2 (for 0 to 10 feet bgs) and 3-3 (for 10 feet bgs and deeper) present proposed soil/solid waste constituent-specific PCGs protective of human health and groundwater quality. For each COC, the soil PCG was chosen by selecting the most conservative (the lowest) of human health RSLs (US EPA, 2011c) (PRGs for radionuclides [US EPA, 2010a]; CHHSL for lead [OEHHA, 2010]) for unrestricted land use or groundwater impact designated levels. This selected value was then compared to the constituent's background concentration, and the higher of the two values was designated as the PCG. Soil background values are those calculated in the 1998 background investigation (Weiss, 1998) and used in the 2004 human health risk assessment (MWH, 2004). Background values were used for depth intervals extending from ground surface to 40 feet bgs, as the background data set included samples within this depth range (Weiss, 1998). For constituents beyond 20 feet bgs, the higher of the background and groundwater impact designated level was selected as the PCG. Only groundwater impact COCs were considered beyond 20 feet bgs (Table 3-3).

PCGs were not developed for ecological receptors because of the uncertainty in the risk estimates. As presented in Tables 2-13 through 2-15 and summarized in Table 3-4 for each of the three LFUs, estimated HQs per receptor and constituent can range by orders of magnitude. As shown in Table 3-4, for most of the ecological COCs, HQs for the NOAEL and LOAEL values differ by about one to three orders of magnitude. Factors in the uncertainty of these estimates include uncertainties in the exposure assessment, effects assessment, and risk characterization, as discussed in detail in Section 2.5 of the SWERA (BBL, 2006). In addition, as noted in Section 1.3 of the SWERA, "The risk conclusions… were estimated based on modeled exposure and non-site-specific literature-based toxicity benchmarks… Any determinations of potential risk should not be considered definitive conclusions, but rather, they should be interpreted as conservative estimates of potential risk." As such, alternatives will be developed that focus on exposure prevention for ecological receptors.

3.3.2 Preliminary Cleanup Goals - Soil Gas

PCGs for soil vapor are provided in Table 3-5. For each COC, the PCG is the minimum of the risk-based concentration at a given depth that would achieve a cancer risk of $1x10^{-6}$ and the soil vapor designated level protective of groundwater quality.

3.3.3 Evaluation of Protectiveness of Preliminary Cleanup Goals

Tables 3-6 and 3-7 show the residual risks and hazards, respectively, in each area and depth interval, if the soil/solid waste cleanup goals are attained for each of the human health COCs. The tables also indicate the percent contribution each constituent makes to the total remaining post-remediation risk or hazard once the cleanup goals are achieved. The risks presented in each land disposal unit are within the NCP designated range of 10^{-4} and 10^{-6}, except LFU-2, where the estimated risk upon attainment of the cleanup goal is 1.3 x 10^{-4} in the 10-to-20-foot depth interval. This risk is driven by potassium-40, which has a cleanup goal equal to the Site background activity (14 picoCuries per gram); the LFU-2 risk is essentially equivalent to the 1.2 x 10^{-4} risk that is due to the background activity of potassium-40 only.

4. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section categorizes and screens remedial technologies for several response actions capable of achieving the RAOs identified in Section 3. Section 4.1 describes the general response actions (GRAs) available to address the RAOs. The remedial technologies and process options that may be included in the GRAs because of their applicability, effectiveness, implementability, and cost are screened in Section 4.2. Select response actions and technologies that pass the screening are combined to form the feasible remediation alternatives developed in Section 5.

4.1 General Response Actions

GRAs are media-specific groups of actions that may be able to achieve the RAOs established in Section 3.0. Soil/solid waste and soil gas are intermingled on-Site and have COCs in common. Thus, the GRAs are the same for each of these media. These GRAs also address infiltration of storm water into these media.

Eleven GRAs, including No Action/No Further Action, have been identified as potentially suitable for soil/solid waste and soil gas remediation at the Site:

- No Action/No Further Action – The NCP requires that this response action be considered to provide a comparison point for the other alternatives. This response indicates that no further measures would be taken to reduce contaminant exposure or migration.
- Institutional Controls (ICs) – This response action limits access to the Site and/or reduces exposure risk without addressing contaminant containment or treatment.
- Containment – This response action controls the exposure pathways, migration, and mobilization of contaminants.
- *In Situ* Physical/Chemical Treatment – This response action treats soil/solid waste and soil gas in place using the chemical and physical properties of the contaminants.
- *In Situ* Thermal Enhancement – This response action uses heat to increase the volatilization of semi-volatile organic compounds and facilitate extraction or to immobilize inorganic constituents.
- Removal – This response action requires excavation and characterization of contaminated media.
- *Ex Situ* Physical/Chemical Treatment – This response action treats excavated soil/solid waste and soil gas using the chemical and physical properties of the contaminants.

- *Ex Situ* Thermal Treatment – This response action treats excavated soil/solid waste and soil gas to desorb, stabilize, or burn off contaminants.
- *Ex Situ* Biological Treatment – This response action treats excavated soil/solid waste and soil gas by encouraging microbial activity within the media.
- Disposal – This response action requires transportation and disposal of contaminated soil either on- or off-Site.
- Vapor-phase Treatment – This response action applies to landfill gas, soil gas, and air emissions from other treatment process options. This process option potentially applies to new building construction; however, it is not carried through the FS as plans for any new construction are unknown at this time.

4.2 Identification and Screening of Technology Types and Process Options

For each GRA, one or more potential technologies were evaluated for the soil/solid waste and soil gas media. In the FS process, the term "technology type" is considered to be a general category of treatment or control, such as landfill capping, physical separation, or reuse/disposal. The term "process option" refers to a specific process within a technology type. For instance, the soil reuse/disposal technology type may include on-site reuse, on-site disposal, off-site reuse, and off-site disposal. Process options were evaluated against applicability (technical implementability), effectiveness, implementability (administrative feasibility), and relative cost.

4.2.1 Identification and Screening of Technologies

The identification and screening of technologies for the 11 GRAs is presented in Table 4-1. GRAs and process options deemed not applicable due to technical implementation challenges identified during this screening process are not discussed further. Options for six GRAs were retained for further analysis.

4.2.2 Evaluation and Selection of Representative Technologies

Table 4-2 details the screening criteria and evaluation of process options for soil/solid waste and soil gas. The applicable (technically implementable) process options were assessed on the basis of effectiveness, administrative implementability, and cost. According to US EPA guidance (US EPA, 1988), three specific criteria are to be used to judge effectiveness: 1) the potential effectiveness of the option(s) to address estimated volumes and meet remedial goals for soil/solid waste and soil gas; 2) the potential impacts to human health and the environment during the construction and implementation phase; and 3) how proven and reliable the process is with respect to the contaminants and conditions at the site. Administrative implementability at this level of screening focuses on institutional and administrative aspects, such as the ability to obtain necessary permits or the availability of necessary equipment and skilled workers. Finally, the cost analysis compares the relative capital and operations and maintenance (O&M) costs of the various process options. Under the cost criterion, a low degree of O&M intensity and capital investment corresponds to an above average comparative ranking of alternatives because low O&M and capital investment would result in an alternative being ranked more favorably than comparable alternatives. For this analysis, relative costs were roughly based on the Treatment Technologies Screening Matrix from the Federal Remediation Technologies Roundtable (U.S. Army Environmental Center, 2002), as summarized below:

	Relative Overall Costs Treatment Technologies Screening Matrix		
	Above Average/Low	**Average/Medium**	**Below Average/High**
O&M – Operations and Maintenance	Low degree of O&M intensity	Medium degree of O&M intensity	High degree of O&M intensity
Capital	Low degree of capital investment	Medium degree of capital investment	High degree of capital investment

This cost evaluation plays a minor role during this stage of evaluation. The costs of retained process options are analyzed in detail in Section 6 for each remedial alternative.

4.2.3 Selection of Representative Process Options

The representative process options selected for soil/solid waste and soil gas media are marked as "Retained" in Table 4-2. For each process option that was not retained, the rationale for elimination is presented. Process options were eliminated if, on the basis of professional judgment, they were not considered applicable, if at least one other process option was deemed more effective or more easily implemented, and/or if at least one other process option exhibited a lower estimated cost but was as effective, implementable, and protective as other options. The process options included for use in the assembly of remedial alternatives are listed in Table 4-3.

5. DESCRIPTION OF REMEDIAL ALTERNATIVES

In this section, remedial alternatives for soil/solid waste and soil gas have been developed from the remedial technologies identified and retained in Section 4. Each alternative, except the No Action/No Further Action Alternative, was assembled with the goal of achieving the RAOs.

The alternatives to remediate soil/solid waste and soil gas (to a maximum depth of 20 feet bgs) in the six land disposal units are:

- SW-1: No Action/No Further Action;
- SW-2: Institutional Controls and Groundwater Monitoring;
- SW-3: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-4: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-5: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-6: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-7: VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-8: VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring;
- SW-9: Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring; and
- SW-10: Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring.

A corrective action management unit (CAMU) is defined by the US EPA as an area within a facility that is used to consolidate, treat, store, and/or dispose of hazardous and non-hazardous waste in order to implement corrective action and site cleanup (40 CFR 264.552(a)). CAMU-eligible wastes are solid and hazardous wastes and media (e.g., soil and sediment) and debris that are managed for implementing cleanup (40 CFR 264.552(a)(1)). A review of ARARs related to shallow burial of LLRW, as well as LEHR Team discussions held on June 14, 2011, have supported that LLRW can be consolidated on-Site in a CAMU as part of the remedial alternatives (Appendix D Attachments D-2 and D-3). Additional information regarding CAMU implementation is provided in Appendix D.

The ten alternatives are described below; Alternatives SW-2 through SW-10 are graphically depicted on Figures 5-1 through 5-9. Components of each alternative are provided in Table 5-1, and a matrix showing the elements involved in each alternative is presented in Table 5-2. Table 5-3 presents a matrix of Site groundwater monitoring wells and indicates which wells are monitored, abandoned, or replaced under each alternative.

Appendix E provides the methodology and assumptions for calculating the volumes to be removed under each alternative. Total excavated volumes (TEVs) were estimated after defining the areas/subareas of the land disposal units known or suspected to contain waste and estimating the average depth of waste burial in each. Evidence used in support of estimated waste extent limits included historical aerial photographs, historical anecdotal evidence of the approximate location of waste trenches, geophysical anomalies identified in previous Site investigations, and waste logs produced during exploratory trenching investigations. Based on data review, the land disposal unit boundary for LFU-1 was modified to include geophysical anomalies outside the historical LFU-1 boundary. Table 5-4 summarizes the excavation areas/subareas designated for the Site and indicates the area and volume excavated under each alternative.

After estimating TEVs at each land disposal unit, sub-volumes were estimated by subdividing the TEV at each land disposal unit into individual waste streams: soil, low threat waste (LTW), principal threat waste (PTW), and biological waste (Appendix E). Exploratory trench waste logs, accounts of Site history, and observations from previous removal actions at the WBH were used to approximate volumes for each of these waste streams. When available, analytical data for each land disposal unit were evaluated to further refine the waste stream volumes into five waste characterization types: Resource Conservation and Recovery Act (RCRA) hazardous waste, non-RCRA hazardous waste (as defined by California state regulations), LLRW, mixed waste, and non-hazardous waste. Management and disposal of these five waste characterization types are key components of the alternatives that require excavation of Site soil/ solid waste.

Appendix F provides the detailed assumptions used in estimating costs for each alternative with the Remedial Action Cost Engineering and Requirements (RACER) cost estimating software tool.

5.1 Alternative SW-1: No Action/No Further Action

Alternative SW-1 provides a baseline for comparison with the other alternatives. Under this alternative, soil/solid waste, soil gas, and associated residual contaminants would be left in place in their existing configuration, and no action/no further action of any kind, such as grading, excavation, treatment, disposal, ICs, or environmental monitoring, would be performed. Monitoring well decommissioning would be deferred to the “No Action/No Further Action” alternative in the FS - Volume 2.

5.2 Alternative SW-2: Institutional Controls and Groundwater Monitoring

Alternative SW-2 consists of leaving soil/solid waste and soil gas undisturbed, implementing ICs, and monitoring groundwater (Figure 5-1). Signage would be posted to notify of potential subsurface hazards, and a land use covenant (LUC) would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would confirm the efficacy of groundwater protection under this alternative, inclusive of the installation and sampling of additional monitoring wells. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data would be evaluated to assess whether these areas should be included in the alternative. No buildings would be removed under this alternative.

Elements of SW-2 include (Table 5-2):

1. Planning and oversight activities would include document preparation of health and safety plans, construction quality assurance/quality control programs, and construction site environmental controls (Table 5-1). Pre-remediation elements would be implemented as described in Table 5-1 and would include performance of a land survey to develop a legal description of the impacted areas, a pre-construction biological survey, elderberry shrub cluster relocation, the establishment of decontamination facilities, and other Site environmental controls.

2. Data gap sampling via exploratory trenching would occur at the ST and the presumed location of the HFSDA to assess the necessity of including these areas in the alternative (Table 5-1; Figure 5-1). PTW encountered would be sent off-Site for disposal.

3. ICs would be implemented to prevent future Site development or activities incompatible with the designated land use (Table 5-1). An LUC prohibiting residential land use and restricting non-residential use of the approximately 6.4 acres of disposal areas would be recorded with Solano County, which includes LFU-1, LFU-2, LFU-3, the ET, ST, WBH, and any other co-located areas (such as the HFSDA). ICs included in the LUC would consist of: maintaining access to designated monitoring wells; restricting drilling or other subsurface penetration and access to groundwater; restricting surface changes affecting drainage, infiltration, and potential COC mobilization; and requiring assessment and mitigation of potential vapor intrusion hazards to buildings. A requirement for a soil management plan would also be identified as a requirement in the LUC for implementation during post-remediation earthwork and construction activities. Signage would be posted to notify workers of potential subsurface hazards both during remedial action phases and post-construction activities while ICs remain in place.

4. Groundwater samples would be collected from designated monitoring wells located downgradient of the land disposal units to evaluate the effectiveness of the remedial alternative, inclusive of new groundwater monitoring wells, as outlined in Tables 5-1 and 5-3 and shown on Figure 5-1.

5. Post-remediation activity would be conducted until cleanup goals are achieved, including storm water monitoring, maintenance of ICs, and five-year reviews (Table 5-1).

5.3 Alternative SW-3: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-3 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW and the two soil gas VOC "hot spot" areas), grading the CAMUs with compacted soil, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Figure 5-2; Tables 5-1, 5-2, and 5-3). One building would be removed; the demolition debris would be recycled or sent off-Site for disposal. Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded at a minimum 1.5 percent slope to facilitate drainage and covered with a low permeability soil cover to reduce infiltration (maximum thicknesses estimated between 2 and 3.25 feet). The covered areas would encompass approximately 2 acres of LFU-1, 3.5 acres of LFU-2/WBH/ET, and 0.7 acres of LFU-3. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and graded covers would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data evaluated to assess whether these areas should be included in the alternative (Figure 5-2; Tables 5-1, 5-2, and 5-3).

Alternative SW-3 would include elements 1 through 5 (Table 5-2), as well as the following elements:

6. One on-Site building (Cobalt-60 Annex) would be decommissioned and demolished, as described in Table 5-1 and shown on Figure 5-2. Demolition debris would be recycled or sent off-Site for disposal at licensed facilities. This building may be replaced based on future University needs.

7. A Materials Management Plan (MMP) would be developed for implementation during excavation and disposal phases of the alternative. The MMP would describe procedures for the sorting and screening of excavated materials (including PTW), stockpiling, sampling and analysis (i.e., waste characterization), potential treatment, and off-Site disposal at licensed facilities.

8. After waste excavation and before backfilling areas with clean fill, confirmation samples would be collected and data evaluated in accordance with a confirmation sampling protocol that would be developed and documented in the Remedial Design/Remedial Action (RD/RA) Work Plan for the Site (Table 5-1). Once COC

concentrations are within levels identified in the work plan, the excavated areas would be backfilled.

9. PTW previously identified during historical exploratory trench investigations in the ET, LFU-1, and LFU-2 would be removed, segregated, and sent off-Site for disposal at licensed facilities (Table 5-1 and Figure 5-2). The locations of the exploratory trenches with previously identified PTW were estimated based on geophysical anomalies identified in previous geophysical surveys. However, the locations of these trenches were not surveyed. To confirm the locations of these original exploratory trenches, new spatially-referenced geophysical surveys would be conducted. The results of these surveys would be compared to previous survey results to re-establish the locations of the original exploratory trenches and the potential location of PTW. After excavation, segregation, and off-Site disposal of PTW, the remaining non-PTW waste and impacted soil would be replaced within the excavated trenches. Excavation would continue in these trenches until no further PTW is encountered.

10. In areas of the ET, LFU-1, LFU-2, and LFU-3 where geophysical anomalies were/are observed, or where there is otherwise suspicion of the presence of waste based on review of historical photographs and documents, and where no previous exploratory trench investigations were conducted, additional exploratory trenches would be excavated (Figure 5-2). PTW encountered in these trenches would be segregated and sent off-Site for disposal at licensed facilities; non-PTW waste and impacted soil would be replaced within the trenches. Excavation would continue in these trenches until no further PTW is encountered.

11. The two VOC "hot spots," one south of the Geriatrics Buildings (H-292 and H-293) and one on the east side of the ET (Figure 5-2), would be excavated to 20 feet bgs to remove the soil and soil gas containing elevated concentrations of VOCs; this depth is five feet deeper than the measured maximum VOC concentration at 15 feet bgs. Excavated soil would be characterized; hazardous soil would be sent off-Site for disposal at licensed facilities and non-hazardous soil would be used to backfill the excavated area. Since the eastern half of the ET VOC "hot spot" would not be graded and covered, it would be backfilled with clean fill.

12. A fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability based on its hazardous characteristics (see Appendix E). Treatment would involve the solidification/stabilization of COC-impacted soil and solid waste, rendering the COCs less mobile. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment would reduce disposal costs, as waste would no longer be considered hazardous or mixed waste.

13. The ET, LFU-1, LFU-2, LFU-3, and the WBH areas would be graded with clean, low-permeability soil, as needed, to establish a minimum 1.5 percent slope to facilitate drainage. The newly graded areas would be replanted with a vegetative cover. Monitoring well casings within the covered area would be extended to the newly-graded ground surface. The cover construction adjacent to the northern landward levee toe of Putah Creek would comply with the levee maintenance easement requirements. While the density-driven convection (DDC) system, located in the northern part of the ET (ET North subarea [as defined in Appendix E]; Table 5-4), would be included in the graded area, it is assumed that the proper grade could be established without requiring modification of the current DDC system.

14. A storm water drainage system would be installed to route precipitation away from LFU-1 and the LFU-2/WBH/ET CAMUs (Figure 5-2; Appendix G). Small drainage depressions would be installed across the covered landfill surface to direct water to a perimeter collection system consisting of a series of drop inlets and underground storm drain pipes. The pipes would permit water to flow to a storm water lift station, where the water would be pumped to an extended detention basin for treatment. The basin would include a high-density polyethylene (HDPE) liner beneath three to five feet of soil to prevent infiltration. Water passing through the extended detention basin would be routed to a drainage conveyance channel that would be constructed along the eastern edge of LFU-1 (see next element). This system (as well as the system for LFU-3 discussed in element 18 below and the vegetated swale discussed in element 24 below) has been developed to meet the post-construction control requirements contained in the *Draft Waste Discharge Requirements (WDRs) for Storm Water Discharges From Small Municipal Separate Storm Sewer Systems* (MS4s) *(General Permit)*, published by the California State Water Resources Control Board in June 2011 and expected to be implemented prior to remediation construction activities (SWRCB, 2011). A detailed design of the storm water drainage system would be provided in the remedial design documents, presumably after the above-referenced permit is finalized (see Appendix G for preliminary calculations).

15. A concrete-lined drainage channel would be constructed along the eastern perimeter of LFU-1. Any excess water that is not evaporated from the drainage channel would enter outfall LF-01 and be transported to Putah Creek (Figure 5-2). Channel construction is estimated to be three feet bgs. It is not expected that PTW would be encountered at this depth; however, PTW identified during channel construction would be segregated and sent off-Site for disposal at a licensed facility. Remaining soil would be used to grade and cover the LFU-1 CAMU.

16. The concrete-lined drainage channel on the east side of LFU-3 would be sealed and maintained annually to limit infiltration through cracks.

17. The drainage ditch that currently passes through LFU-3 would be redirected south along the perimeter of LFU-3 and into outfall LF-03 (Figure 5-2).

18. An additional storm water drainage system would be installed to route precipitation away from the LFU-3 CAMU (Figure 5-2; Appendix G). Small drainage depressions would be installed across the covered landfill surface to direct water to a perimeter collection system consisting of a series of drop inlets and underground storm drain pipes. The pipes would permit water to flow to a storm water lift station, where the water would be pumped to an extended detention basin installed north of LFU-3 for treatment. The extended drainage basin would include an HDPE liner beneath three to five feet of soil to prevent infiltration. Water passing through the extended detention basin would be routed to the existing concrete-lined drainage channel.

19. Annual inspections and maintenance would be performed on the installed storm water infrastructure and land disposal unit graded and covered areas. Routine maintenance would be performed as needed.

Excavation, grading and covering, and associated activities would be conducted as described in Table 5-1.

5.4 Alternative SW-4: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-4 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW, the two soil gas VOC "hot spot" areas, and a portion of LFU-3 underlying the concrete-lined drainage channel), covering the CAMUs with evapotranspiration caps, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Figure 5-3; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded and covered with a 4.5-foot thick evapotranspiration cap to reduce infiltration. The capped areas would cover approximately 2 acres of LFU-1, 3.5 acres of LFU-2/WBH/ET, and 0.7 acres of LFU-3. In LFU-3, the portion of the waste cells underneath the concrete-lined drainage channel would be excavated and placed into the LFU-3 CAMU, and the concrete-lined drainage channel would be reconstructed to match original conditions. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and evapotranspiration caps would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data evaluated to assess whether these areas should be included in the alternative (Figure 5-3; Tables 5-1, 5-2, and 5-3).

Alternative SW-4 would include elements 1-5, 7-12, 14, and 17-19 (Table 5-2), as well as the following elements:

20. During pre-remediation activities, monitoring wells would be decommissioned and relocated, as appropriate (Figure 5-3; Tables 5-1 and 5-3). New groundwater monitoring wells would also be installed (element 4; Table 5-3). As the current DDC system lies within the boundaries of the ET North, implementation of the remedial action in this area may require its decommissioning. Although future configuration of the DDC system is subject to change upon further evaluation of HSU-1 groundwater treatment strategies, for alternative comparison and costing purposes, it was assumed that the wells within the ET North boundary would be decommissioned, and that three DDC wells and three nested piezometers would be replaced (Table 5-3).

21. Nine on-Site buildings would be decommissioned and demolished, as described in Table 5-1 and shown on Figure 5-3. Applicable non-hazardous material would be recycled. Remaining non-hazardous demolition debris would be disposed of within the CAMUs; hazardous demolition debris would be sent off-Site for disposal at licensed facilities. Some of these buildings may be replaced based on future needs of the University.

22. In LFU-3, areas of the concrete-lined drainage channel overlying the identified waste cells would be demolished and incorporated into the capped area of LFU-3. The waste and contaminated soil underlying the drainage channel would be excavated, including material as far as 10 feet from the channel's western edge. PTW encountered during excavation would be segregated and sent off-Site for disposal at licensed facilities (Table 5-1). After confirmation samples are collected and evaluated (element 8), the excavation would be backfilled with clean fill, and any demolished sections of the concrete channel would be reconstructed to match original conditions. The excavated waste/contaminated soil would be placed into the LFU-3 CAMU, beneath the LFU-3 cap.

23. LFU-1, LFU-2, LFU-3, the ET, and the WBH areas would be graded and receive a 4.5-foot thick evapotranspiration cap replanted with a vegetative cover. The cap construction adjacent to the northern landward levee toe of Putah Creek would comply with the levee maintenance easement requirements.

24. An unlined vegetated swale would be constructed along the eastern perimeter of LFU-1. Any excess water that is not evapotranspired from the swale would enter outfall LF-01 and be transported to Putah Creek (Figure 5-3). During construction, an area overlying the proposed channel location would be excavated to 10 feet bgs,

PTW would be segregated and sent off-Site for disposal, and non-PTW would be placed within the capped LFU-1 CAMU.

This alternative is compatible with future groundwater remedies in the DDC area since the cap can be designed to accommodate the DDC system, or be locally removed and reconstructed. Excavation, capping, and associated activities would be conducted as described in Table 5-1.

5.5 Alternative SW-5: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-5 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW, the two soil gas VOC "hot spot" areas, and a portion of LFU-3 underlying the concrete-lined drainage channel), covering the CAMUs with HDPE-lined asphalt pavement caps, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Figure 5-4; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded and covered with clean, compacted, low-permeability fill and base rock, lined with an HDPE liner and drainage mat (or equivalent), and capped with asphalt to reduce infiltration. The LFU-1, LFU-2/WBH/ET, and LFU-3 asphalt-capped CAMUs would cover areas of approximately 2 acres, 3.5 acres, and 0.7 acres, respectively. In LFU-3, the portion of the waste cells underneath the concrete-lined drainage channel would be excavated and placed into the LFU-3 CAMU, and the concrete-lined drainage channel would be reconstructed to match original conditions. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and asphalt caps would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data would be evaluated to assess whether these areas should be included in the alternative (Figure 5-4; Tables 5-1, 5-2, and 5-3).

Alternative SW-5 would include elements 1-5, 7-12, 14, 17-22, and 24 (Table 5-2), as well as the following element:

25. LFU-1, LFU-2, LFU-3, the ET, and the WBH areas would be graded and covered with clean, compacted, low-permeability soil and base rock, as needed, an HDPE liner and drainage mat (or equivalent), and an asphalt cap, as described in Table 5-1. Under this alternative, the VOC "hot spot" areas would also be covered with asphalt after excavation, waste disposal, and backfilling; the eastern half of the ET VOC "hot spot" would be backfilled with clean fill and not covered with asphalt. The cap construction adjacent to the northern landward levee toe of Putah Creek would comply with the levee maintenance easement requirements.

This alternative is compatible with future groundwater remedies in the DDC area since the cap can be designed to accommodate the DDC system, or can be locally removed and reconstructed. Excavation, capping, and associated activities would be conducted as described in Table 5-1.

5.6 Alternative SW-6: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-6 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW, the two soil gas VOC "hot spot" areas, the ET, and a portion of LFU-3 underlying the concrete-lined drainage channel), covering the CAMUs with multiple-layer caps, enhancing the existing storm water drainage system to divert water away from solid waste, implementing ICs, and monitoring groundwater (Figure 5-5; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The ET would be excavated and segregated, and PTW would be sent off-Site for disposal. At the ET North subarea (Figure 5-5; Table 5-4; Appendix E), non-PTW soil/solid waste would be placed within the footprint of the LFU-2/WBH/ET CAMU, and the subarea would be backfilled with clean fill. The remaining soil/solid waste and non-PTW material from the ET South would be placed back within the ET South excavation and capped as part of the LFU-2/WBH/ET CAMU (Figure 5-5; Table 5-4; Appendix E). Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded and covered with multiple-layer caps to reduce infiltration. The LFU-1, LFU-2/WBH/ET, and LFU-3 multiple-layer capped CAMUs would cover areas of approximately 2 acres, 3.4 acres, and 0.7 acres, respectively. In LFU-3, the portion of the waste cells underneath the concrete-lined drainage channel would be excavated and placed into the LFU-3 CAMU, and the concrete-lined drainage channel would be reconstructed to match original conditions. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and multiple-layer caps would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data would be evaluated to assess whether these areas should be included in the alternative (Figure 5-5; Tables 5-1, 5-2, and 5-3).

Alternative SW-6 would include elements 1-5, 7-12, 14, 17-22, and 24 (Table 5-2), as well as the following elements:

26. At the ET, soil/solid waste would be excavated within both the northern and southern sections. PTW would be segregated and sent for off-Site disposal at licensed facilities. The ET North would be excavated and backfilled with clean fill. Non-PTW material would be consolidated within the LFU-2/ET/WBH CAMU footprint. In the southern section of the ET (ET South subarea [as defined in Appendix E]; Table 5-4), non-PTW material would be used as backfill within the LFU-2/ET/WBH CAMU footprint.

27. A multiple-layer cap would be installed for the designated CAMUs (Table 5-1). Each multiple-layer cap would consist of a foundation layer, a low-permeability layer comprising a geomembrane over a compacted clay or geosynthetic clay liner, a drainage layer, a bio-barrier and protection layer, and an upper vegetated (topsoil) layer. The cap construction adjacent to the northern landward levee toe of Putah Creek would comply with the levee maintenance easement requirements.

This alternative is compatible with future groundwater remedies in the DDC area since the cap can be designed to accommodate the DDC system, or be locally removed and reconstructed. Excavation, capping, and associated activities would be conducted as described in Table 5-1.

5.7 Alternative SW-7: VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-7 consists of excavating known PTW; excavating the two soil gas VOC "hot spot" areas; consolidating soil/solid waste into two on-Site CAMUs (located at LFU-1 [approximately 2 acres] and LFU-2/WBH/ET [approximately 3.4 acres]); covering the CAMUs with multiple-layer caps; enhancing the existing storm water drainage system to divert storm water away from solid waste; implementing ICs; and monitoring groundwater (Figure 5-6; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. The LFU-3 waste cells would be excavated and any PTW found at LFU-3 would be sent for off-Site disposal at licensed facilities. Non-PTW waste from the LFU-3 excavation would be placed in one of the two CAMUs. The LFU-3 concrete-lined drainage channel would be demolished, the waste would be placed within the CAMU footprint, and the channel would be replaced with a vegetated drainage channel. Areas of known PTW identified during previous exploratory trench investigations in LFU-1 and LFU-2, as well as during additional proposed exploratory trenching in these areas, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. Additional unidentified PTW may be present in other areas of these disposal units and would be left in place. The ST and HFSDA would also be excavated and segregated, and PTW would be sent off-Site for disposal. The remaining soil/solid waste and non-PTW excavated material would be placed within the footprint of the appropriate LFU-1 or LFU-2/WBH/ET CAMU. The ET would be excavated and segregated, and PTW would be sent off-Site for disposal. At the ET North subarea (Figure 5-6; Table 5-4; Appendix E), non-PTW soil/solid waste would be placed within the footprint of the LFU-2/WBH/ET CAMU, and the subarea would be backfilled with clean fill. The remaining soil/solid waste and non-PTW material from the ET South would be placed back within the ET South excavation and capped as part of the LFU-2/WBH/ET CAMU (Figure 5-6; Table 5-4; Appendix E). The two VOC "hot spots" would be excavated to 20 feet bgs. The two CAMUs would be graded and covered with multiple-layer caps to reduce infiltration. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and multiple-layer caps would maintain the functionality of the remedy, as designed (Figure 5-6; Tables 5-1, 5-2, and 5-3).

Alternative SW-7 would include elements 1, 3-5, 7-12, 14, 17, 19-21, 24, and 26-27 (Table 5-2), as well as the following elements:

28. Waste would be entirely excavated from the LFU-3 waste cells. Removed waste and contact soil would be placed in one of the two CAMUs following segregation and off-Site disposal of PTW. The LFU-3 excavation would be backfilled with clean fill. No multiple-layer cap would be constructed over LFU-3 after excavation and importation of fill.

29. In LFU-3, the concrete-lined drainage channel would be completely demolished to facilitate excavation of the LFU-3 waste cells. Following excavation, a vegetated drainage channel would be constructed to replace the concrete-lined drainage channel. Demolition debris would be placed in one of the two CAMUs.

30. The ST and HFSDA would be excavated and, after segregation of PTW for off-Site disposal at licensed facilities, the remaining non-PTW material would be consolidated within one of the two CAMUs. After ST and HFSDA excavation is completed, they would be backfilled with clean fill.

This alternative is compatible with future groundwater remedies in the DDC area since the cap can be designed to accommodate the DDC system, or be locally removed and reconstructed. Excavation, capping, and associated activities would be conducted as described in Table 5-1.

5.8 Alternative SW-8: VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-8 consists of excavating known PTW and the two soil gas VOC "hot spot" areas, consolidating soil/solid waste into a single on-Site lined CAMU that overlaps portions of LFU-1 and LFU-2/ET/WBH, covering the CAMU with a multiple-layer cap, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Figure 5-7; Tables 5-1, 5-2, and 5-3). The single CAMU, covering approximately 6.7 acres, would have a multiple-layer cap, bottom liner, and a leachate collection and removal system (LCRS). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMU; hazardous debris would be sent off-Site for disposal. The LFU-3 waste cells would be excavated, PTW would be sent off-Site for disposal at licensed facilities, and non-PTW waste would be placed in the CAMU. The concrete-lined drainage channel would be demolished, the waste would be placed within the CAMU footprint, and the channel would be replaced with a vegetated drainage channel. The ST, HFSDA, and ET North would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. The remaining soil/solid waste and non-PTW material from these areas would be placed within the CAMU footprint and these areas would be backfilled with clean fill. Soil/solid waste within the CAMU footprint, including the two VOC "hot spot" areas and the areas of known PTW identified during previous exploratory trench investigations, would be excavated to 20 feet bgs to accommodate the bottom liner and LCRS. The excavation material would be segregated and PTW sent off-Site for disposal at licensed facilities. Clean fill from the area between the ET and LFU-1 would be used to backfill LFU-3 and other areas, as appropriate. The capped and lined CAMU area would incorporate soil/solid waste from each area except the WBH, which would be within the capped area but not excavated. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 20 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and multiple-layer caps would maintain the functionality of the remedy, as designed (Figure 5-7; Tables 5-1, 5-2, and 5-3).

Alternative SW-8 would include elements 1, 3-5, 7-8, 11-12, 14, 17, 19-21, 24, and 27-30 (Table 5-2), as well as the following elements:

31. The single CAMU would have a bottom liner and an LCRS, except in the WBH area. LFU-2, the ET South, LFU-1, and the area between LFU-1 and LFU-2 would be excavated to 20 feet bgs to remove waste and accommodate the liner, LCRS, and waste to be consolidated in the CAMU. The LFU-3 waste cells, the ET North, the ST, and the HFSDA would be excavated and backfilled with clean fill (Figure 5-7); PTW from each excavation would be segregated and sent off-Site for

disposal at licensed facilities. Remaining non-PTW material would be used as backfill in the lined CAMU.

32. Because the CAMU cap would cover a large area of clean soil between the ET and LFU-1, this soil would be stockpiled and used for backfill in the excavated areas. Prior to use as backfill, the soil from this area would be sampled and analyzed to verify that it meets clean fill requirements for the Site. If the soil does not meet clean fill requirements, it would be replaced within the CAMU or sent off-Site for disposal. Clean fill would be imported as needed.

This alternative is compatible with future groundwater remedies in the DDC area since the cap can be designed to accommodate the DDC system, or be locally removed and reconstructed. Excavation, capping, and associated activities would be conducted as described in Table 5-1.

5.9 Alternative SW-9: Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-9 consists of excavating most soil/solid waste for off-Site disposal (Figure 5-8; Tables 5-1, 5-2, and 5-3). Specifically, soil/solid waste (inclusive of PTW) from LFU-1, LFU-2 waste cells, LFU-3 waste cells and the ET, including the VOC "hot spot" areas, would be excavated, segregated, and characterized for transport to licensed off-Site facilities. These excavated land disposal units would be backfilled with clean fill. The WBH and a section of LFU-2 bordering the WBH to the north would be designated as a CAMU and would receive a multiple-layer cap covering approximately 0.6 acres (Figure 5-8). The ST and HFSDA would be excavated and the material consolidated into the WBH CAMU after segregation of PTW; these areas would be backfilled with clean fill. Nine buildings would be removed, and the demolition debris would be recycled or sent off-Site for disposal. The concrete-lined drainage channel on the east-side of LFU-3 would be demolished, debris would be sent off-Site for disposal, and the channel would be replaced with a vegetated drainage channel. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and WBH multiple-layer cap would maintain the functionality of the remedy, as designed (Figure 5-8; Tables 5-1, 5-2, and 5-3).

Alternative SW-9 would include elements 1, 3-5, 7-8, 11-12, 17, 19-21, 24, 27, and 29 (except that under element 21, demolition debris would be disposed of off-Site) (Table 5-2), as well as the following elements:

33. The ST and the HFSDA would be entirely excavated. PTW would be segregated and sent for disposal off-Site at licensed facilities, and the remaining non-PTW would be excavated and consolidated within the WBH CAMU. The land disposal units would be backfilled with clean fill.

34. Demolition debris and designated waste and soil from LFU-1, LFU-2 waste cells, LFU-3 waste cells, the ET, and the VOC "hot spots" would be excavated and recycled or sent for disposal off-Site at licensed facilities. The excavated areas would be backfilled with clean fill.

This alternative is compatible with future groundwater remedies in the DDC area since the DDC system can be relocated or reconstructed. Excavation, capping, and associated activities would be conducted as described in Table 5-1.

5.10 Alternative SW-10: Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-10 consists of excavating soil/solid waste for off-Site disposal (Figure 5-9; Tables 5-1, 5-2, and 5-3). Specifically, soil/solid waste from LFU-1, LFU-2 waste cells, LFU-3 waste cells, the ET, the ST, the WBH, and the HFSDA, including previously identified and newly identified PTW and the two soil gas VOC "hot spot" areas, would be excavated, segregated, and characterized for transport to licensed off-Site facilities. These excavated land disposal units would be backfilled with clean fill. Nine buildings would be demolished, and the demolition debris would be recycled or sent off-Site for disposal. The concrete-lined drainage channel on the east side of LFU-3 would be demolished, debris would be sent off-Site for disposal, and the channel would be replaced with a vegetated drainage channel. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative (Figure 5-9; Tables 5-1, 5-2, and 5-3). Clean-closure for unrestricted land use may not be attained under this alternative, as COCs would remain at depths below 20 feet bgs and in unexcavated areas of the land disposal units (e.g., in LFU-2 and LFU-3).

Alternative SW-10 would include elements 1, 3-5, 7-8, 11-12, 17, 19-21, 24, 29, and 34 (except that under element 21, demolition debris would be disposed of off-Site) (Table 5-2), with the following element:

35. The WBH, ST, and the HFSDA would be entirely excavated and material sent off-Site for disposal at licensed facilities. These areas would be backfilled with clean fill.

No cap monitoring or maintenance would be necessary, as the waste would be excavated. Groundwater monitoring and five-year reviews reporting the results of this monitoring would be included as post-remediation tasks. This alternative is compatible with future groundwater remedies in the DDC area since the DDC system can be relocated or reconstructed. Excavation and associated activities would be conducted as described in Table 5-1.

6. DETAILED ANALYSIS OF ALTERNATIVES

This section provides a detailed evaluation of each remedial alternative developed in Section 5. The alternatives have been assessed using criteria based on statutory requirements of CERCLA, as amended by SARA, Section 121; the NCP; and *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (US EPA, 1988).

The NCP specifies nine criteria to be used in the detailed analysis:

Overall Protection of Human Health and the Environment: This criterion addresses how each alternative, as a whole, protects human health and the environment and indicates how each hazardous substance source is to be eliminated, reduced, or controlled.

Compliance with ARARs: This criterion evaluates each alternative's compliance with requirements under federal and state environmental laws and facility citing laws, or, if an ARAR waiver is required, how the waiver is justified. ARARs reflect chemical-, location-, and action-specific concerns. FS – Volume 1-specific ARARs are provided in Appendix D.

Long-Term Effectiveness and Permanence: This criterion is used to evaluate the effectiveness of each alternative in protecting human health and the environment after the construction and implementation phase of the response action is complete. Factors considered include magnitude of residual risks and adequacy and reliability of controls.

Reduction of Toxicity, Mobility, or Volume through Treatment: This criterion is used to evaluate the anticipated capability of each alternative to reduce the toxicity, mobility, or volume of hazardous substances through treatment. Under the NCP definition, capping, excavation, and off-Site disposal are not classified as treatment.

Short-Term Effectiveness: This criterion addresses the effectiveness of each alternative in protecting human health and the environment during the construction and implementation phase. Factors considered include exposure of the community during implementation, exposure of the workers during construction, effects on the environment, and the time required to complete implementation of the remedial action.

Implementability: This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of the required services and materials during its implementation. Factors considered include the ability to construct the technology, reliability of the technology, monitoring considerations, and availability of equipment and specialists.

Cost: This criterion addresses the capital and O&M costs for each alternative. Capital and O&M cost estimates are order-of-magnitude-level estimates that have an expected accuracy of minus 30 to plus 50 percent (US EPA, 2000). Appendix F provides a detailed description of the cost estimation process and the RACER cost estimating tool. RACER was used to generate estimates for the multiple phases of remediation, which include pre-study, study, design, remedial action, operations and maintenance, and long-term monitoring.

Community Acceptance: This criterion is used to evaluate issues and concerns that the public may have regarding each alternative. This criterion will be applied following the receipt of public comments on the Proposed Plan.

State Acceptance: This criterion evaluates technical and administrative issues and concerns that the state regulatory agencies may have about each alternative. This criterion will be applied following the receipt of regulatory agency comments on the FS Report and the Proposed Plan.

The following subsections provide the detailed analysis of the alternatives outlined in Section 5. Clean-closure for unrestricted land use is not proposed because concentrations of COCs just above the PCGs would remain below 20 feet bgs. However, RAOs of preventing contact with COCs at this depth would be met; long-term groundwater monitoring is proposed for each alternative. Appendix H, *Methodology for Development of Cleanup Goals for New Constituents of Potential Concern*, is provided for cases where new constituents of potential concern may be identified during implementation of the selected remedy.

6.1 Alternative SW-1: No Action/No Further Action

Alternative SW-1 provides a baseline for comparison with the other alternatives. Under this alternative, soil/solid waste, soil gas, and associated residual contaminants would be left in place in their existing configuration, and no action/no further action of any kind, such as grading, excavation, treatment, disposal, ICs, or environmental monitoring, would be performed. Monitoring well decommissioning would be deferred to the "No Action/No Further Action" alternative in the FS – Volume 2 (groundwater).

6.1.1 Overall Protection of Human Health and the Environment

As presented in Tables 2-11 and 2-12 and detailed in Appendix C, the soil/solid waste cancer risks estimated for each land disposal unit except the WBH currently fall near or within the 10^{-4} to 10^{-6} NCP cancer risk range and near the hazard index of 1.0. Although risk was estimated at 2 x 10^{-2} for the WBH, this estimate was based on two samples from one location collected at seven feet bgs. Because of its depth, this area is not currently accessible to humans and is unlikely to be accessed by animals living in the area. In addition, numerical modeling (Appendix A) and over 20 years of groundwater monitoring have indicated that the soil/solid waste COCs are not migrating to groundwater in most locations within the land disposal units (Section 2.6.2.1; Figures 2-19 through 2-22). Exceptions include tritium and carbon-14 groundwater impacts from the WBH area. The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS – Volume 2 (groundwater). The "No Action/No Further Action" alternative would not eliminate, reduce, or control hazardous substances at the Site.

6.1.2 Compliance with ARARs

Under Alternative SW-1, no environmental actions, including groundwater monitoring of existing or potential future releases, would take place. As such, this alternative would not comply with the California Code of Regulations (CCR) Title 27. Basin Plan numerical water quality objectives (chemical-specific ARARs defined in Appendix D) could be exceeded; however, they would remain undetected, as no groundwater monitoring would occur.

6.1.3 Long-Term Effectiveness and Permanence

Under Alternative SW-1, concentrations of COCs greater than PCGs would remain in place. Table 6-1 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Numerical model-based estimates (Appendices A and B) suggest that if COCs migrate to groundwater, Basin Plan numerical water quality objectives (as identified in Appendix D) could be exceeded in the future; however, the modeling is based on conservative assumptions, and actual Site groundwater monitoring trends demonstrate that this occurrence is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22).

Alternative SW-1 is not effective in providing protection of human health and the environment over the long term, since contaminated soil/solid waste would remain as is on-Site, and no controls would be established to manage risks or protect groundwater.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative SW-1 would not involve treatment of any waste material, and toxicity, mobility, and volume would not be reduced. Constituent concentrations above PCGs would remain, and mobility of residual contamination would not be altered under this alternative.

6.1.5 Short-Term Effectiveness

Under Alternative SW-1, no short-term impacts would occur.

6.1.6 Implementability

There are no barriers to implementing Alternative SW-1.

6.1.7 Cost

There would be no cost to implement Alternative SW-1. Monitoring well abandonment and associated costs would be deferred to the "No Action/No Further Action" alternative in the FS - Volume 2 (groundwater).

6.1.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.1.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.2 Alternative SW-2: Institutional Controls and Groundwater Monitoring

Alternative SW-2 consists of leaving soil/solid waste and soil gas undisturbed, implementing ICs, and monitoring groundwater (Section 5.2; Figure 5-1; Tables 5-1, 5-2, and 5-3). Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would confirm the efficacy of groundwater protection under this alternative, inclusive of the installation and sampling of additional monitoring wells. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted, and the data would be evaluated to assess whether these areas should be included in the alternative (Section 5.2; Figure 5-1; Tables 5-1, 5-2, and 5-3). No buildings would be removed under this alternative.

6.2.1 Overall Protection of Human Health and the Environment

Under this alternative, overall protection of human health and the environment relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus would reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use and restrict non-residential use of the Site, as well as to prevent disturbance of the subsurface. A soil management plan would be developed to manage soil and waste should future excavation would be necessary.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}; the primary constituent contributing to the vapor intrusion risk is chloroform. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS – Volume 2 (groundwater). This alternative would control the potential for human exposure but would not eliminate or reduce hazardous substances at the Site.

6.2.2 Compliance with ARARs

Under Alternative SW-2, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if significant quantities of COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate that future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-2. Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during well construction activities.

6.2.3 Long-Term Effectiveness and Permanence

Under Alternative SW-2, no actions are proposed that would reduce or eliminate hazardous substances at the Site, and concentrations of COCs greater than PCGs would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. Table 6-1 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact would be achieved.

Long-term effectiveness of RAO achievement (i.e., preventing human and ecological exposure) would be enhanced because an LUC prohibiting residential land use and restricting non-residential land use would be implemented. According to the Long-Range Development Plan (UC Davis, 2003), the Site is currently proposed for low-density academic and administrative uses. This planned land use, coupled with the LUC, would further limit potential exposure to remaining on-Site contaminants. Although LUC breach is possible, current cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. The long-term effectiveness of this alternative relies on long-term monitoring and enforcement of ICs, as well as five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative SW-2 would not involve treatment of any waste material, and toxicity, mobility, and volume would not be reduced. Constituent concentrations above PCGs would remain, and mobility of residual contamination would not be altered under this alternative.

6.2.5 Short-Term Effectiveness

Under Alternative SW-2, groundwater monitoring well installation and data gap sampling in the ST and HFSDA would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. During construction, trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community. Workers conducting the remedial action would potentially be exposed to chemical, heat, and minor physical hazards during well sampling and trench investigations in the ST and HFSDA. Worker risks during remedial action would be mitigated through properly planned and implemented administrative controls, engineering controls, and personal protective equipment.

Truck-mile estimates were calculated for each alternative using the soil/solid waste volume estimates shown in Table 6-2 and were based on off-Site disposal of soil/solid waste, including PTW, and the import of clean backfill and capping materials (Table 6-3). It is estimated that approximately 450 truck-miles would be required to convey soil/solid waste off-Site. The accident fatality risks from construction and transportation under this alternative have been estimated at 2×10^{-4} (Table 6-4). Latent fatalities related to vehicle emissions and road dust are presented on Table 6-4. For Alternative SW-2, this transportation emissions fatality risk was estimated as 6×10^{-5}. When combined with the accident fatality risk, the total fatality risk is approximately 2×10^{-4}.

Table 6-4 also shows estimated emissions for greenhouse gases (GHG) and common air pollutants (nitrogen oxides [NO_x], sulfur oxides [SO_x], and particulate matter with a diameter less than 10 micrometers [PM_{10}]) (Appendix I). Activities conducted under Alternative SW-2 would result in an estimated 42 metric tons of GHG emissions and 0.3 tons of common air pollutants (Table 6-4). Total energy use is estimated to be 550 million British thermal units (MMBTUs), equivalent to approximately 3,960 gallons of diesel fuel.

The estimated time to complete implementation of this alternative is approximately one construction season. ICs such as signage and LUCs would be in effect until cleanup goals approved in the ROD are achieved.

6.2.6 Implementability

Under this alternative, no barriers to implementability are anticipated. Groundwater well installation and maintenance would follow established Site procedures. Contractors and materials to install additional monitoring wells are readily available.

Implementation of land-use restrictions would involve coordination with the UC Office of the President (UCOP) Real Estate Services Group and the UC Davis Office of Administrative and

Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. No additional land would be required to enact this remedial alternative.

6.2.7 Cost

The cost of Alternative SW-2 is summarized in Table 6-5.

6.2.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.2.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.3 Alternative SW-3: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Graded Covers, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-3 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW and the two soil gas VOC "hot spot" areas), grading the CAMUs with compacted soil, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Section 5.3; Figure 5-2; Tables 5-1, 5-2, and 5-3). One building would be removed; the demolition debris would be recycled or sent off-Site for disposal. About 5,900 loose cubic yards (LCY) of material would be excavated (Table 6-2). Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. An estimated 38 LCY of PTW would be sent off-Site for disposal under this alternative (Table 6-2). Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded at a minimum 1.5 percent slope to facilitate drainage and covered with a low permeability soil cover to reduce infiltration (maximum thicknesses estimated between 2 and 3.25 feet). The covered areas would encompass approximately 2 acres of LFU-1, 3.5 acres of LFU-2/WBH/ET, and 0.7 acres of LFU-3. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and graded covers would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data evaluated to assess whether these areas should be included in the alternative (Section 5.3; Figure 5-2; Tables 5-1, 5-2, and 5-3).

6.3.1 Overall Protection of Human Health and the Environment

Alternative SW-3 protects human health and the environment by removing the VOC "hot spot" areas and known PTW from historical exploratory trench investigations in the ET, LFU-1, and LFU-2. Additional PTW would also be removed during proposed exploratory trenching in the ET, LFU-1, LFU-2, and LFU-3. However, not all waste would be excavated and unidentified PTW may remain.

Drainage enhancements would control potential COC migration to surface water and reduce infiltration, and the installation of graded covers over the land disposal units would reduce potential COC migration to groundwater. The concrete-lined drainage channel on the east side of LFU-3 would be sealed and maintained annually to reduce infiltration through cracks. Although the graded covers incorporate low permeability soil designed to reduce infiltration, several studies have documented that graded covers of limited thickness, with only a compacted soil barrier, are susceptible to infiltration through cracks and other macropores, particularly in regions susceptible to dessication (e.g., Albright et al, 2004; Dwyer, 2003).

The graded covers would isolate the soil/solid waste, thereby limiting human exposure to COCs. However, these covers are susceptible to breaching by deep-rooted vegetation and burrowing animals, thereby providing potential access to contaminated material. O&M of the graded covers and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The soil vapor hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. These elevated risks would be eliminated by complete removal of the VOC "hot spot" areas to 20 feet bgs. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS - Volume 2 (groundwater).

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus would reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A soil management plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove known areas of PTW and the VOC "hot spot" areas, reduce potential COC migration to groundwater, and control potential migration to surface water. Although this alternative would reduce and control the potential for human exposure, it would not eliminate hazardous substances at the Site.

6.3.2 Compliance with ARARs

Under Alternative SW-3, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if significant quantities of COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are less likely under Alternative SW-3 because storm water drainage enhancements and graded covers over the land disposal units would limit infiltration of water. The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-3. It is expected that net storm water runoff would increase under this alternative, but the storm water drainage enhancements would be designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4s Permit (SWRCB, 2011) (additional explanation regarding post-construction storm water controls is provided in Appendices D and G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.3.3 Long-Term Effectiveness and Permanence

Under Alternative SW-3, PTW would be removed from known PTW trench areas and additional proposed exploratory trenches in the ET, LFU-1, LFU-2, and LFU-3. PTW would be taken off-Site for disposal, and a fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. Unidentified PTW may be present in other locations within the land disposal units and would be left in place. The VOC "hot spot" areas would be excavated, eliminating the potential for future vapor intrusion risk should buildings be built and occupied in the area. The VOC "hot spot" removal would also reduce the potential for downward VOC migration to groundwater. Additional information on the VOC "hot spot" areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. However, by reducing infiltration, the graded covers and drainage modifications would limit this possibility. Results from two demonstration projects (including sites in similar semi-arid regions) have shown that graded covers may not be effective at controlling infiltration because they are susceptible to cracking and macropore formation, which provide preferential flow pathways (e.g., Albright et al., 2004; Dwyer, 2003). Monitoring and maintenance of the covers are critical to ensuring the long-term effectiveness. Table 6-6 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact and preventing migration to surface water, storm water, and groundwater would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be further limited due to the graded cover. Under this alternative, the vegetation planted over the graded covers would provide some wildlife habitat.

The long-term effectiveness of this alternative relies on PTW and VOC source removal, containment of waste via the graded covers, and reduction of storm water infiltration. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; as-needed maintenance of the graded covers; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-3, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability based on its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste. Because excavation and off-Site disposal are limited under SW-3, the majority of the waste material would remain untreated on-Site (Table 6-2).

6.3.5 Short-Term Effectiveness

Under Alternative SW-3, earth-moving activities, building demolition, grading, and covering would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under Alternative SW-3, approximately 5,900 CY of potentially contaminated material would be excavated and approximately 2,400 LCY would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 140,900 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill and grading material to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 2×10^{-2} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 1,400 metric tons of GHG emissions and 3 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 22,400 MMBTUs, equivalent to approximately 161,200 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Workers conducting the remedial action would potentially be exposed to chemical, heat, and minor physical hazards during remedial actions. Worker risks during remedial action would be mitigated through properly planned and implemented administrative controls, engineering controls, and personal protective equipment.

Consultation with neighboring UC Davis facilities, such as the Raptor Center and Center for Equine Health, would assess potential disturbances to animals housed adjacent to work sites, and mitigation measures would be implemented, such as noise reduction or animal relocation. Mitigation measures would be applied to replace any habitat for special-status species affected on-Site, such as elderberry shrubs for the Valley Elderberry Longhorn Beetle.

It is anticipated that LLRW would be encountered during PTW removal. LLRW is defined by the Low-Level Radioactive Waste Policy Act of 1980 as “any waste which is not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act of 1954.” UC Davis currently has a state-administered license to receive, use, possess, transfer, or dispose of (at a licensed off-Site facility) radioactive material, pursuant to California Code of Regulations, Division 1, Title 17, Chapter 5, Subchapter 4, Group 2, Licensing of Radioactive Material. When LLRW is removed to a licensed off-Site location, shipments would comply with United States Department of Transportation packaging and transportation requirements and regulations. The need for engineering controls would be evaluated and implemented, if necessary, to protect on-Site workers and the public from LLRW exposure during remedial activities. In order to maintain protection of the public from radiological exposure when an immediate and serious threat to public health is deemed present, the California Department of Public Health Radiologic Health Branch may initiate and administer programs of surveillance and control, including, but not limited to, environmental and worker monitoring, inspections, and emergency access.

The estimated time to complete implementation of this alternative is approximately one construction season. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.3.6 Implementability

Alternative SW-3 requires standard demolition, excavation, construction, and surface grading techniques. Transportation and disposal of hazardous material from the VOC “hot spot” areas and PTW from the known and proposed exploratory trench locations would require a waste acceptance process. Suitable licensed landfill space is expected to remain available during the remedial action. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the graded covers and storm water drainage system. Graded covers and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Under this alternative, activities conducted in the building proposed for removal could be relocated to existing structures or are not mission-critical, and as such, the building could be demolished. Additional land would be required for construction of the extended detention basins north of LFU-2 and north of LFU-3, as well as to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.3.7 Cost

The cost of Alternative SW-3 is summarized in Table 6-7.

6.3.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.3.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.4 Alternative SW-4: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Evapotranspiration Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-4 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW, the two soil gas VOC "hot spot" areas, and a portion of LFU-3 underlying the concrete-lined drainage channel), covering the CAMUs with evapotranspiration caps, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Section 5.4; Figure 5-3; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. About 19,900 LCY of material would be excavated (Table 6-2). Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated. An estimated 150 LCY of PTW would be sent off-Site for disposal at licensed facilities under this alternative (Table 6-2). Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded and covered with a 4.5-foot-thick evapotranspiration cap to reduce infiltration. The capped areas would cover approximately 2 acres of LFU-1, 3.5 acres of LFU-2/WBH/ET, and 0.7 acres of LFU-3. In LFU-3, the portion of the waste cells underneath the concrete-lined drainage channel would be excavated and placed into the LFU-3 CAMU, and the concrete-lined drainage channel would be reconstructed to match original conditions. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and evapotranspiration caps would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data evaluated to assess whether these areas should be included in the alternative (Section 5.4; Figure 5-3; Tables 5-1, 5-2, and 5-3).

6.4.1 Overall Protection of Human Health and the Environment

Alternative SW-4 protects human health and the environment by removing the VOC "hot spot" areas and known PTW from historical exploratory trench investigations in the ET, LFU-1, and LFU-2. Additional PTW would also be removed during proposed exploratory trenching in the ET, LFU-1, LFU-2, and LFU-3, as well as during excavation of the area underlying the proposed LFU-1 vegetated drainage swale and the LFU-3 waste cells underlying the concrete-lined drainage channel. However, not all waste would be excavated and unidentified PTW may remain.

Drainage enhancements would control potential COC migration to surface water and reduce infiltration, and the installation of evapotranspiration caps over the land disposal units would reduce potential COC migration to groundwater. In general, evapotranspiration caps are expected to be applicable in semi-arid regions with a climate similar to Davis (US EPA, 2011a). Several studies have shown that properly designed evapotranspiration caps are as effective as conventional cap methods in limiting infiltration, with infiltration rates generally less than 2 millimeters per year in semi-arid climates similar to Davis (e.g., Albright et al., 2004; Dwyer, 2003).

The evapotranspiration caps would also isolate the soil/solid waste, thereby limiting human exposure to COCs, as well as deep-rooted vegetation and deep-burrowing animal access to contaminated material. O&M of the evapotranspiration cap and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The soil vapor hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. These elevated risks would be eliminated by complete removal of the VOC "hot spot" areas to 20 feet bgs. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS – Volume 2 (groundwater).

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus would reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A soil management plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove known areas of PTW and the VOC "hot spot" areas, reduce potential COC migration to groundwater, and control potential migration to surface water. Although this alternative would reduce and control the potential for human exposure, it would not eliminate hazardous substances at the Site.

6.4.2 Compliance with ARARs

Under Alternative SW-4, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if significant quantities of COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are less likely under Alternative SW-4 because storm water drainage enhancements and evapotranspiration caps over the land disposal units would limit infiltration of water. The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-4. It is expected that net storm water runoff would increase under this alternative, but the storm water drainage enhancements would be designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4 Permit (SWRCB, 2011) (additional explanation regarding post-construction storm water controls is provided in Appendices D and G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.4.3 Long-Term Effectiveness and Permanence

Under Alternative SW-4, PTW would be removed from known PTW trench areas and additional proposed exploratory trenches in the ET, LFU-1, LFU-2, and LFU-3, as well as the portion of the LFU-3 waste cells underlying the concrete-lined drainage channel and the area underneath the proposed vegetated drainage swale in LFU-1. PTW would be taken off-Site for disposal, and a fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. Unidentified PTW may be present in other locations within the land disposal units and would be left in place. The VOC “hot spot” areas would be excavated, eliminating the potential for future vapor intrusion risk should buildings be built and occupied in the area. The VOC “hot spot” removal would also reduce the potential for downward VOC migration to groundwater. Additional information on the VOC “hot spot” areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. However, by reducing infiltration, the evapotranspiration caps and drainage modifications would limit this possibility. Results from two demonstration projects in similar semi-arid regions have shown that properly designed evapotranspiration caps are as effective at controlling infiltration as conventional cap technologies (e.g., Albright et al., 2004; Dwyer, 2003). Monitoring and maintenance of the caps are critical to ensuring the long-term effectiveness (ITRC, 2003). However, due to the seasonal mismatch between peak precipitation and peak evapotranspiration, infiltration is possible during heavy rainfall events (Albright et al., 2004). Table 6-8 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact and preventing migration to surface water, storm water, and groundwater would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP’s designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be further limited due to the 4.5-foot thickness of the evapotranspiration cap. Under this alternative, the evapotranspiration caps would provide some wildlife habitat.

The long-term effectiveness of this alternative relies on PTW and VOC source removal, containment of waste via the evapotranspiration caps, and reduction of storm water infiltration. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; as-needed maintenance of the evapotranspiration caps; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-4, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability based on its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste. Because excavation and off-Site disposal are limited under SW-4, the majority of the waste material would remain untreated on-Site (Table 6-2).

6.4.5 Short-Term Effectiveness

Under Alternative SW-4, earth-moving activities, building demolition, and capping would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under Alternative SW-4, approximately 2,500 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 305,800 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill and evapotranspiration cap material to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 5×10^{-2} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 4,000 metric tons of GHG emissions and 5 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 69,200 MMBTUs, equivalent to approximately 497,500 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5; mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative is approximately one construction season. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.4.6 Implementability

Alternative SW-4 requires standard demolition, excavation, grading, construction, and evapotranspiration capping techniques. Transportation and disposal of hazardous material from the VOC "hot spot" areas, PTW from the known and proposed exploratory trench locations, PTW from the LFU-1 vegetated swale area, and LFU-3 waste cells underlying the concrete-lined drainage channel would require a waste acceptance process. Suitable licensed landfill space is expected to remain available during the remedial action. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the evapotranspiration caps and storm water drainage system. Evapotranspiration caps and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required for construction of the extended detention basins north of LFU-2 and north of LFU-3, as well as to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.4.7 Cost

The cost of Alternative SW-4 is summarized in Table 6-9.

6.4.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.4.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.5 Alternative SW-5: VOC "Hot Spot" Removal, Three On-Site Corrective Action Management Units with Asphalt Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-5 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW, the two soil gas VOC "hot spot" areas, and a portion of LFU-3 underlying the concrete-lined drainage channel), covering the CAMUs with HDPE-lined asphalt pavement caps, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Section 5.5; Figure 5-4; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. About 19,900 LCY of material would be excavated (Table 6-2). Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated. An estimated 150 LCY of PTW would be sent off-Site for disposal at licensed facilities under this alternative (Table 6-2). Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded and covered with clean, compacted, low-permeability fill and base rock, lined with an HDPE liner and drainage mat (or equivalent), and capped with asphalt to reduce infiltration. The LFU-1, LFU-2/WBH/ET, and LFU-3 asphalt-capped CAMUs would cover areas of approximately 2 acres, 3.5 acres, and 0.7 acres, respectively. In LFU-3, the portion of the waste cells underneath the concrete-lined drainage channel would be excavated and placed into the LFU-3 CAMU, and the concrete-lined drainage channel would be reconstructed to match original conditions. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and asphalt caps would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted, and the data would be evaluated to assess whether these areas should be included in the alternative (Section 5.5; Figure 5-4; Tables 5-1, 5-2, and 5-3).

6.5.1 Overall Protection of Human Health and the Environment

Alternative SW-5 protects human health and the environment by removing the VOC "hot spot" areas and known PTW from historical exploratory trench investigations in the ET, LFU-1, and LFU-2. Additional PTW would also be removed during proposed exploratory trenching in the ET, LFU-1, LFU-2, and LFU-3, as well as during excavation of the area underlying the proposed LFU-1 vegetated drainage swale and the LFU-3 waste cells underlying the concrete-lined drainage channel. However, not all waste would be excavated and unidentified PTW may remain. Drainage enhancements would control potential COC migration to surface water and would reduce infiltration, and the installation of asphalt caps over the land disposal units would reduce potential COC migration to groundwater. The asphalt caps would also isolate the soil/solid waste, thereby limiting human exposure to COCs, as well as deep-rooted vegetation and deep-burrowing animal access to contaminated material. O&M of the asphalt cap and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. These elevated risks would be eliminated by complete removal of the VOC "hot spot" areas to 20 feet bgs. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS – Volume 2 (groundwater).

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A Soil Management Plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove known areas of PTW and the VOC "hot spot" areas, reduce potential COC migration to groundwater, and control potential migration to surface water. Although this alternative would reduce and control the potential for human exposure, it would not eliminate hazardous substances at the Site.

6.5.2 Compliance with ARARs

Under Alternative SW-5, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are substantially less likely under Alternative SW-5 because storm water drainage enhancements and HDPE-lined asphalt caps over the land disposal units would limit infiltration of water. The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-5. It is expected that net storm water runoff would increase under this alternative, but the storm water drainage enhancements would be designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4 Permit (SWRCB, 2011) (additional explanation regarding post-construction storm water controls is provided in Appendices D and G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.5.3 Long-Term Effectiveness and Permanence

Under Alternative SW-5, PTW would be removed from known PTW trench areas and additional proposed exploratory trenches in the ET, LFU-1, LFU-2, and LFU-3, as well as the portion of the LFU-3 waste cells underlying the concrete-lined drainage channel and the area underneath the proposed vegetated drainage swale in LFU-1. PTW would be taken off-Site for disposal, and a fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. Unidentified PTW may be present in other locations within the land disposal units and would be left in place. The VOC “hot spot” areas would be excavated, eliminating the future potential for vapor intrusion risk should buildings be built and occupied in the area. The VOC “hot spot” removal also would reduce the potential for downward VOC migration to groundwater. Additional information on the VOC “hot spot” areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. However, by reducing infiltration, the actively maintained asphalt caps and drainage modifications would limit this possibility (U.S. Army Environmental Center, 2002). Table 6-10 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact, as well as preventing migration to surface water, storm water, and groundwater, would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP’s designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be further limited due to the installation of the asphalt cap consisting of low-permeability fill, base rock, and the HDPE liner. Under this alternative, the asphalt caps could provide future options for parking, the installation of solar panels over the asphalt, or the inclusion of buildings resting on top of the asphalt surface.

The long-term effectiveness of this alternative relies on PTW and VOC source removal, containment of waste via the asphalt caps, and reduction of storm water infiltration. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; annual O&M of the asphalt caps; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-5, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability based on its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste. Because excavation and off-Site disposal are limited under SW-5, the majority of the waste material would remain untreated on-Site (Table 6-2).

6.5.5 Short-Term Effectiveness

Under Alternative SW-5, earth-moving activities, building demolition, and capping would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under this alternative, approximately 2,500 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 197,300 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill and asphalt cover material to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 3×10^{-2} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 3,000 metric tons of GHG emissions and 5 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 42,300 MMBTUs, equivalent to approximately 304,600 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5; mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative is approximately one construction season. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.5.6 Implementability

Alternative SW-5 requires standard demolition, excavation, grading, construction, and asphalt paving techniques. Transportation and disposal of hazardous material from the VOC "hot spot" areas, PTW from the known and proposed exploratory trench locations, PTW from the LFU-1 vegetated swale area, and LFU-3 waste cells underlying the concrete-lined drainage channel would require a waste acceptance process. Suitable licensed landfill space is expected to remain available during the remedial action. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the asphalt caps and storm water drainage system. Asphalt caps and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available. If monitoring indicates that further remedial action is necessary, then the HDPE-lined asphalt cap could be either temporarily removed (at moderate to high cost) and replaced after the remedial action, or modified to accommodate most longer-term remedial actions (e.g., pump and treat, soil vapor extraction, in-situ bioremediation).

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University’s mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required for construction of the extended detention basins north of LFU-2 and north of LFU-3, as well as to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.5.7 Cost

The cost of Alternative SW-5 is summarized in Table 6-11.

6.5.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.5.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.6 Alternative SW-6: VOC “Hot Spot” Removal, Three On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-6 consists of leaving soil/solid waste largely undisturbed (with the exception of known PTW, the two soil gas VOC “hot spot” areas, the ET, and a portion of LFU-3 underlying the concrete-lined drainage channel), covering the CAMUs with multiple-layer caps, enhancing the existing storm water drainage system to divert water away from solid waste, implementing ICs, and monitoring groundwater (Section 5.6; Figure 5-5; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. About 27,900 LCY of material would be excavated (Table 6-2). Areas of known PTW identified during previous exploratory trench investigations, as well as during additional proposed exploratory trenching, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. The remaining soil/solid waste and non-PTW excavated material would be placed within the existing footprint of the appropriate LFU CAMU. The ET would be excavated and segregated, and PTW would be sent off-Site for disposal. At the ET North subarea (Figure 5-5; Table 5-4; Appendix E), non-PTW soil/solid waste would be placed within the footprint of the LFU-2/WBH/ET CAMU, and the subarea would be backfilled with clean fill. The remaining soil/solid waste and non-PTW material from the ET South would be placed back within the ET South excavation and capped as part of the LFU-2/WBH/ET CAMU (Figure 5-5; Table 5-4; Appendix E). An estimated 260 LCY of PTW would be sent off-Site to licensed facilities for disposal under this alternative (Table 6-2). Additional unidentified PTW may be present in other areas of the disposal units and would be left in place. The two VOC "hot spots" would be excavated to 20 feet bgs. Each of the three CAMUs would be graded and covered with multiple-layer caps to reduce infiltration. The LFU-1, LFU-2/WBH/ET, and LFU-3 multiple-layer capped CAMUs would cover areas of approximately 2 acres, 3.4 acres, and 0.7 acres, respectively. In LFU-3, the portion of the waste cells underneath the concrete-lined drainage channel would be excavated and placed into the LFU-3 CAMU, and the concrete-lined drainage channel would be reconstructed to match original conditions. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and multiple-layer caps would maintain the functionality of the remedy, as designed. Prior to remedial actions, data gap trenching and sampling of the ST and HFSDA areas would be conducted and the data would be evaluated to assess whether these areas should be included in the alternative (Section 5.6; Figure 5-5; Tables 5-1, 5-2, and 5-3).

6.6.1 Overall Protection of Human Health and the Environment

Alternative SW-6 protects human health and the environment by removing the VOC "hot spot" areas and known PTW from historical exploratory trench investigations in LFU-1 and LFU-2. Additional PTW would also be removed during proposed exploratory trenching in LFU-1, LFU-2, and LFU-3, the complete excavation of the ET, and excavation of the area underlying the proposed LFU-1 vegetated drainage swale and the LFU-3 waste cells underlying the concrete-lined drainage channel. However, not all waste would be excavated and unidentified PTW may remain.

Drainage enhancements would control potential COC migration to surface water and reduce infiltration, and the installation of multiple-layer caps over the land disposal units would reduce potential COC migration to groundwater. Several studies have shown that multiple-layer caps are effective at limiting infiltration in semi-arid environments (e.g., Dwyer, 2003; Albright and Benson, 2005). The multiple-layer caps would also isolate the soil/solid waste, thereby limiting human exposure to COCs, as well as deep-rooted vegetation and deep-burrowing animal access to contaminated material. O&M of the multiple-layer cap and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as discussed in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the soil vapor NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. These elevated risks would be eliminated by complete removal of the VOC "hot spot" areas to 20 feet bgs. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS – Volume 2 (groundwater).

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A Soil Management Plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove known areas of PTW and the VOC "hot spot" areas, reduce potential COC migration to groundwater, and control potential migration to surface water. Although this alternative would reduce and control the potential for human exposure, it would not eliminate hazardous substances at the Site.

6.6.2 Compliance with ARARs

Under Alternative SW-6, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are substantially less likely under Alternative SW-6 because storm water drainage enhancements and multiple-layer caps over the land disposal units would limit infiltration of water. The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-6. It is expected that net storm water runoff would increase under this alternative, but the storm water drainage enhancements would be designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4 Permit (SWRCB, 2011) (additional explanation regarding post-construction storm water controls is provided in Appendices D and G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.6.3 Long-Term Effectiveness and Permanence

Under Alternative SW-6, PTW would be removed from known PTW trench areas and additional proposed exploratory trenches in LFU-1, LFU-2, and LFU-3, as well as from the excavation of the ET, the portion of the LFU-3 waste cells underlying the concrete-lined drainage channel, and the area underneath the proposed vegetated drainage swale in LFU-1. PTW would be taken off-Site for disposal, and a fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. Unidentified PTW may be present in other locations within the land disposal units and would be left in place. The VOC “hot spot” areas would be excavated, eliminating the future potential for vapor intrusion risk should buildings be built and occupied in the area. The VOC “hot spot” removal also would reduce the potential for downward VOC migration to groundwater. Additional information on the VOC “hot spot” areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. However, by reducing infiltration, the multiple-layer caps and drainage modifications would limit this possibility. Results from two demonstration projects in similar semi-arid regions have shown that properly designed multiple-layer caps are effective at controlling infiltration (e.g., Dwyer, 2003; Albright and Benson, 2005). Studies have also shown that the long-term effectiveness of a geosynthetic clay liner may be limited by potential degradation within a few years of installation (Dwyer, 2003). The maintenance of cap integrity, however, should ensure the long-term effectiveness of multiple-layer caps. Table 6-12 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact, as well as migration to surface water, storm water, and groundwater, would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP’s designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be further limited due to the installation of the multiple-layer cap’s upper vegetated (topsoil) layer, bio-barrier and protection layer, drainage layer, and low-permeability layer, comprising a geomembrane and compacted clay or geosynthetic clay. Under this alternative, the multiple-layer caps would provide some wildlife habitat and could be developed for park space and recreation.

The long-term effectiveness of this alternative relies on PTW and VOC source removal, containment of waste via the multiple-layer caps, and reduction of storm water infiltration. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; annual O&M of the multiple-layer caps; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.6.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-6, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability due to its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste. Because excavation and off-Site disposal are limited under SW-6, the majority of the waste material would remain untreated on-Site (Table 6-2).

6.6.5 Short-Term Effectiveness

Under Alternative SW-6, earth-moving activities, building demolition, and capping would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under this alternative, approximately 2,600 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 267,900 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill and capping material to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 4×10^{-2} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 3,600 metric tons of GHG emissions and 5 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 60,500 MMBTUs, equivalent to approximately 435,300 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5. Mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative would be approximately one construction season. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.6.6 Implementability

Alternative SW-6 requires standard demolition, excavation, grading, construction, and multiple-layer capping techniques. Transportation and disposal of hazardous material from the VOC "hot spot" areas, PTW from known and proposed exploratory trench locations, PTW from the ET excavation, PTW from the LFU-1 vegetated swale area, and LFU-3 waste cells underlying the concrete-lined drainage channel would require a waste acceptance process; suitable licensed landfill space is expected to remain available during the remedial action. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the multiple-layer caps and storm water drainage system. Multiple-layer caps and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available. Should monitoring indicate that further remedial action is necessary, the multiple-layer cap could be compromised.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required for construction of the extended detention basins north of LFU-2 and north of LFU-3, as well as to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.6.7 Cost

The cost of Alternative SW-6 is summarized in Table 6-13.

6.6.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.6.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.7 Alternative SW-7: VOC "Hot Spot" Removal, Two On-Site Corrective Action Management Units with Multiple-Layer Caps, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-7 consists of excavating known PTW; excavating the two soil gas VOC "hot spot" areas; consolidating soil/solid waste into two on-Site CAMUs (located at LFU-1 [approximately 2 acres] and LFU-2/WBH/ET [approximately 3.4 acres]), covering the CAMUs with multiple-layer caps; enhancing the existing storm water drainage system to divert storm water away from solid waste; implementing ICs; and monitoring groundwater (Section 5.7; Figure 5-6; Tables 5-1, 5-2, and 5-3). Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMUs; hazardous debris would be sent off-Site for disposal. About 40,300 LCY of material would be excavated under this alternative (Table 6-2). The LFU-3 waste cells would be excavated and any PTW found at LFU-3 would be sent for off-Site disposal at licensed facilities. Non-PTW waste from the LFU-3 excavation would be placed in one of the two CAMUs. The LFU-3 concrete-lined drainage channel would be demolished, the waste would be placed within the CAMU footprint, and the channel would be replaced with a vegetated drainage channel. Areas of known PTW identified during previous exploratory trench investigations in LFU-1 and LFU-2, as well as during additional proposed exploratory trenching in these areas, would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. Additional unidentified PTW may be present in other areas of these disposal units and would be left in place. The ST and HFSDA also would be excavated and segregated, and PTW would be sent off-Site for disposal. The remaining soil/solid waste and non-PTW excavated material would be placed within the footprint of the appropriate LFU-1 or LFU-2/WBH/ET CAMU. The ET would be excavated and segregated, and PTW would be sent off-Site for disposal. At the ET North subarea (Figure 5-6; Table 5-4; Appendix E), non-PTW soil/solid waste would be placed within the footprint of the LFU-2/WBH/ET CAMU, and the subarea would be backfilled with clean fill. The remaining soil/solid waste and non-PTW material from the ET South would be placed back within the ET South excavation and capped as part of the LFU-2/WBH/ET CAMU (Figure 5-6; Table 5-4; Appendix E). It is estimated that approximately 390 LCY of PTW would be sent off-Site for disposal at licensed facilities under this alternative (Table 6-2). The two VOC "hot spots" would be excavated to 20 feet bgs. The two CAMUs would be graded and covered with multiple-layer caps to reduce infiltration. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 10 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped LFU-1 CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and multiple-layer caps would maintain the functionality of the remedy, as designed (Section 5.7; Figure 5-6; Tables 5-1, 5-2, and 5-3).

6.7.1 Overall Protection of Human Health and the Environment

Alternative SW-7 protects human health and the environment by removing the VOC "hot spot" areas and known PTW from historical exploratory trench investigations in LFU-1 and LFU-2. Additional PTW would also be removed during proposed exploratory trenching in LFU-1 and LFU-2, the excavation of the area underlying the proposed LFU-1 vegetated drainage swale, and the complete excavation of the ET, ST, and the LFU-3 waste cells. However, not all waste would be excavated in LFU-1 and LFU-2 and unidentified PTW may remain. Non-PTW from the LFU-3 waste cell excavation would be moved to one of the two CAMUs, virtually eliminating human and ecological contact, as well as the potential for future COC migration to groundwater in this area.

Drainage enhancements would control potential COC migration to surface water and reduce infiltration, and the installation of multiple-layer caps over the CAMUs would reduce potential COC migration to groundwater. Several studies have shown that multiple-layer caps are effective at limiting infiltration in semi-arid environments (e.g., Dwyer, 2003; Albright and Benson, 2005). The multiple-layer caps would also isolate the soil/solid waste, thereby limiting human exposure to COCs, as well as deep-rooted vegetation and deep-burrowing animal access to contaminated material. O&M of the multiple-layer cap and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The soil vapor hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. These elevated risks would be eliminated by complete removal of the VOC "hot spot" areas to 20 feet bgs. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS - Volume 2 (groundwater).

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use and restrict non-residential use of the Site, as well as to prevent disturbance of the subsurface. A Soil Management Plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove known areas of PTW and the VOC "hot spot" areas, consolidate waste into two capped CAMUs, reduce potential COC migration to groundwater, and control potential migration to surface water. Although this alternative would reduce and control the potential for human exposure, it would not eliminate hazardous substances at the Site.

6.7.2 Compliance with ARARs

Under Alternative SW-7, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are substantially less likely under Alternative SW-7 because storm water drainage enhancements and multiple-layer caps over the two CAMUs would limit infiltration of water. The location- and action-specific ARARs listed in Appendix D would be met under Alternative SW-7. It is expected that net storm water runoff would increase under this alternative, but the storm water drainage enhancements would be designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4 Permit (SWRCB, 2011) (additional explanation regarding post-construction storm water controls is provided in Appendices D and G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.7.3 Long-Term Effectiveness and Permanence

Under Alternative SW-7, PTW would be removed from LFU-3, the ET, the ST, and HFSDA as well as known PTW trench areas and additional proposed exploratory trenches in LFU-1 and LFU-2; PTW would also be removed from the area underneath the proposed vegetated drainage swale in LFU-1. PTW would be taken off-Site for disposal, and a fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. Unidentified PTW may be present in other locations within the land disposal units and would be left in place. Soil/solid waste would be removed from ET North, the LFU-3 waste cells, the ST, and HFSDA and consolidated into the CAMUs, thus permanently removing the waste in these areas. The VOC "hot spot" areas would be excavated, eliminating the future potential for vapor intrusion risk should buildings be built and occupied in the area. The VOC "hot spot" removal also would reduce the potential for downward VOC migration to groundwater. Additional information on the VOC "hot spot" areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. However, by reducing infiltration, the multiple-layer caps over the CAMUs and drainage modifications would limit this possibility. Results from two demonstration projects in similar semi-arid regions have shown that properly designed multiple-layer caps are effective at controlling infiltration (e.g., Dwyer, 2003; Albright and Benson, 2005). Studies have also shown that the long-term effectiveness of a geosynthetic clay liner may be limited by potential degradation within a few years of installation (Dwyer, 2003). The maintenance of cap integrity, however, should ensure the long-term effectiveness of multiple-layer caps. Table 6-14 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact and migration to surface water, storm water, and groundwater would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be further limited due to the consolidation of ET North, the LFU-3 waste cells, the ST, and HFSDA into the multiple-layer cap and the multiple-layer cap construction inclusive of an upper vegetated (topsoil) layer, a bio-barrier and protection layer, a drainage layer, and a low-permeability layer comprising a geomembrane and compacted clay or geosynthetic clay. Under this alternative, the multiple-layer caps would provide some wildlife habitat and could be developed for park space and recreation.

The long-term effectiveness of this alternative relies on PTW and VOC source removal, removal of waste from LFU-3 waste cells and consolidation into the two CAMUs, containment of waste via the multiple-layer caps, and reduction of storm water infiltration. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; annual O&M of the multiple-layer caps; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.7.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-7, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability due to its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste. Because excavation and off-Site disposal are limited under SW-7, the majority of the waste material would remain untreated on-Site (Table 6-2).

6.7.5 Short-Term Effectiveness

Under Alternative SW-7, earth-moving activities, building demolition, and capping would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under this alternative, approximately 4,600 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 308,500 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill and capping material to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 5×10^{-2} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 3,900 metric tons of GHG emissions and 6 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 66,600 MMBTUs, equivalent to approximately 479,100 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5. Mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative is approximately one construction season. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.7.6 Implementability

Alternative SW-7 requires standard demolition, excavation, grading, construction, and multiple-layer capping techniques. Transportation and disposal of hazardous material from the VOC "hot spot" areas and PTW from known and proposed exploratory trench locations and from the ET, ST, HFSDA, LFU-1 vegetated swale area, and LFU-3 waste cell excavations would require a waste acceptance process. Suitable licensed landfill space is expected to remain available during the remedial action. Clean fill is anticipated to be available in sufficient quantities. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the multiple-layer caps and storm water drainage system. Multiple-layer caps and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available. Should monitoring indicate that further remedial action is necessary, the multiple-layer cap could be compromised.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required for construction of the extended detention basin north of LFU-2, as well as to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.7.7 Cost

The cost of Alternative SW-7 is summarized in Table 6-15.

6.7.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.7.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.8 Alternative SW-8: VOC "Hot Spot" Removal, One On-Site Lined Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-8 consists of excavating known PTW and the two soil gas VOC "hot spot" areas, consolidating soil/solid waste into a single on-Site, lined CAMU that overlaps portions of LFU-1 and LFU-2/ET/WBH, covering the CAMU with a multiple-layer cap, enhancing the existing storm water drainage system to divert storm water away from solid waste, implementing ICs, and monitoring groundwater (Section 5.8; Figure 5-7; Tables 5-1, 5-2, and 5-3). The single CAMU, covering approximately 6.7 acres, would have a multiple-layer cap, bottom liner, and an LCRS. Nine buildings would be removed, and the demolition debris would be recycled or placed within the CAMU; hazardous debris would be sent off-Site for disposal. About 274,700 LCY of material, including clean fill, would be excavated under this alternative (Table 6-2). The LFU-3 waste cells would be excavated, PTW would be sent off-Site for disposal at licensed facilities, and non-PTW waste would be placed in the CAMU. The concrete-lined drainage channel would be demolished, the waste would be placed within the CAMU footprint, and the channel would be replaced with a vegetated drainage channel. The ST, HFSDA, LFU-1 vegetated drainage swale area, and ET North would be excavated and segregated, and PTW would be sent off-Site for disposal at licensed facilities. The remaining soil/solid waste and non-PTW material from these areas would be placed within the CAMU footprint, and these areas would be backfilled with clean fill. Soil/solid waste within the CAMU footprint, including the two VOC "hot spot" areas and the areas of known PTW identified during previous exploratory trench investigations, would be excavated to 20 feet bgs to accommodate the bottom liner and LCRS. The excavation material would be segregated, and PTW would be sent off-Site for disposal at licensed facilities. It is estimated that approximately 1,100 LCY of PTW would be sent off-Site for disposal under this alternative (Table 6-2). Clean fill from the area between the ET and LFU-1 would be used to backfill LFU-3 and other areas outside the CAMU footprint, as appropriate. The capped and lined CAMU area would incorporate soil/solid waste from each area except the WBH, which would be within the capped area but not excavated. Additional storm water drainage enhancements, including extended detention basins, would further reduce infiltration in the land disposal units. During construction of the vegetated drainage swale in LFU-1, an area overlying the proposed channel location would be excavated to 20 feet bgs and segregated, PTW would be sent for off-Site disposal, and the remaining soil/solid waste and non-PTW excavated material would be placed within the capped CAMU. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and would include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and multiple-layer caps would maintain the functionality of the remedy, as designed (Section 5.8; Figure 5-7; Tables 5-1, 5-2, and 5-3).

6.8.1 Overall Protection of Human Health and the Environment

Alternative SW-8 protects human health and the environment by removing the VOC "hot spot" areas, excavating waste in the ET, ST, HFSDA, LFU-1, LFU-2, and LFU-3, and segregating PTW for off-Site disposal. Remaining waste would be consolidated in the capped and lined CAMU, virtually eliminating human and ecological contact and the potential for future COC migration to groundwater in this area.

Drainage enhancements would control potential COC migration to surface water and reduce infiltration, and the installation of a multiple-layer cap, a bottom liner, and an LCRS within the CAMU would substantially reduce potential COC migration to groundwater. Several studies have shown that multiple-layer caps are effective at limiting infiltration in semi-arid environments (e.g., Dwyer, 2003; Albright and Benson, 2005).

The multiple-layer cap, liner, and LCRS would also isolate the soil/solid waste, thereby preventing human and ecological exposure to COCs. The WBH area would not be excavated but would be covered with the multiple-layer cap that would isolate the soil/solid waste, thereby limiting human exposure to COCs, as well as deep-rooted vegetation and deep-burrowing animal access to contaminated material. O&M of the multiple-layer cap, liner, LCRS, and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Currently, the estimated soil/solid waste cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1 (Tables 2-11 and 2-12; Appendix C). Numerical modeling results (Appendix A) and over 20 years of groundwater monitoring have demonstrated that most soil/solid waste COCs are not migrating to groundwater within the land disposal units, with the exception of carbon-14 and tritium (Section 2.6.2.1; Figures 2-19 through 2-22).

The potential vapor intrusion risk is near or below the NCP point of departure of 10^{-6} in LFU-1, LFU-3, the ST, and the WBH (Appendix B). The soil vapor hazard index is below 1.0 for each land disposal unit. At the VOC "hot spot" areas within LFU-2 and the ET, the potential vapor intrusion risk is within or near the NCP's upper bound of 10^{-4}. The primary constituent contributing to the vapor intrusion risk is chloroform. These elevated risks would be eliminated by complete removal of the VOC "hot spot" areas to 20 feet bgs. Chloroform has also been detected in Site groundwater in these areas. Chloroform in groundwater will be evaluated further in the FS – Volume 2 (groundwater).

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A Soil Management Plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove known areas of PTW and the VOC "hot spot" areas, consolidate waste into one lined and capped CAMU, reduce potential COC migration to groundwater, and control potential migration to surface water. Although this alternative would reduce and control the potential for human exposure, it would not eliminate hazardous substances at the Site.

6.8.2 Compliance with ARARs

Under Alternative SW-8, concentrations of COCs greater than PCGs would remain in place. Numerical model-based estimates (Appendices A and B) suggest that, if COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are substantially less likely under Alternative SW-8 because storm water drainage enhancements, a bottom liner and LCRS, and a multiple-layer cap over the single CAMU would limit infiltration of water. The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-8. It is expected that net storm water runoff would increase under this alternative, but the storm water drainage enhancements would be designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4 Permit (SWRCB, 2011) (additional explanation regarding post-construction storm water controls is provided in Appendices D and G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.8.3 Long-Term Effectiveness and Permanence

Under Alternative SW-8, the land disposal units would be excavated and segregated, and identified PTW would be sent off-Site for disposal. The non-PTW soil/solid waste would be consolidated within one lined and capped CAMU. A fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. Soil/solid waste would be removed from the ET North, ST, HFSDA, and LFU-3 waste cells and consolidated in the CAMU, thus permanently removing the waste in these areas. The VOC "hot spot" areas would be excavated during removal of LFU-2 and the ET, eliminating the future potential for vapor intrusion risk should buildings be built and occupied in the area. The VOC "hot spot" removal also would reduce the potential for downward VOC migration to groundwater. Additional information on the VOC "hot spot" areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, some soil/solid waste would remain in place. Although numerical modeling results (Appendix A) and over 20 years of groundwater monitoring data suggest that leaching of most COCs is unlikely (Section 2.6.2.1; Figures 2-19 through 2-22), COC migration to groundwater could occur, and non-compliance with Basin Plan numerical water quality objectives is possible. However, by reducing infiltration and isolating the remaining waste on-Site, the multiple-layer cap, bottom liner, LCRS, and drainage modifications would limit this possibility. Results from two demonstration projects in similar semi-arid regions have shown that properly designed multiple-layer caps are effective at controlling infiltration (e.g., Dwyer, 2003; Albright and Benson, 2005). Studies have also shown that the long-term effectiveness of a geosynthetic clay liner may be limited by potential degradation within a few years of installation (Dwyer, 2003). The maintenance of cap integrity, however, should ensure the long-term effectiveness of multiple-layer caps. Table 6-16 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact, as well as preventing migration to surface water, storm water, and groundwater, would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be further limited due to exhuming the waste in each of the land disposal units (except the WBH), consolidating the waste in the lined and capped CAMU, and cap construction inclusive of an upper vegetated (topsoil) layer, a bio-barrier and protection layer, a drainage layer, and a low-permeability layer comprising a geomembrane and compacted clay or geosynthetic clay. Under this alternative, the multiple-layer cap would provide some wildlife habitat and could be developed for park space and recreation.

The long-term effectiveness of this alternative relies on PTW and VOC source removal; removal of LFU-1, the ST, ET, HFSDA, and the LFU-2 and LFU-3 waste cells; consolidation of non-PTW soil/solid waste into one CAMU; containment of waste via the multiple-layer cap, bottom liner, and LCRS; and reduction of storm water infiltration. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; annual O&M of the multiple-layer cap, liner, and LCRS; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.8.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-8, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability due to its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste. Because off-Site disposal is limited under SW-8, the majority of the waste material would remain untreated on-Site (Table 6-2).

6.8.5 Short-Term Effectiveness

Under Alternative SW-8, earth-moving activities, building demolition, and capping would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under this alternative, approximately 21,500 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 434,100 truck-miles would be required to convey the soil/solid waste off-Site and to deliver capping material to the Site (Table 6-3). No trucks are expected to be needed for the import of clean fill because clean fill would be used from the area between the ET and LFU-1. The total fatality risks under this alternative have been estimated at 7×10^{-2} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 5,200 metric tons of GHG emissions and 16 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 86,400 MMBTUs, equivalent to approximately 621,300 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5. Mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative is approximately two construction seasons because of the complexity of waste excavation and sorting, and LCRS and liner construction. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.8.6 Implementability

Alternative SW-8 requires standard demolition, excavation, grading, construction, and multiple-layer capping techniques. Transportation and disposal of hazardous material from the VOC “hot spot” areas and PTW from the ET, ST, HFSDA, LFU-1, LFU-2, and LFU-3 excavations would require a waste acceptance process; suitable licensed landfill space is expected to remain available during the remedial action. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the multiple-layer cap and storm water drainage system. Multiple-layer caps, a bottom liner, an LCRS, and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available. Should monitoring indicate that further remedial action is necessary, the constructed liner, LCRS, and multiple-layer cap could be compromised.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required for construction of the extended detention basin north of LFU-2, as well as to relocate the drainage ditch south of LFU-3; this land is readily available.

Under this alternative, it is proposed that soil between the ET and LFU-1 be used as fill for LFU-3. However, should sampling indicate that this fill does not meet the clean fill requirements for the Site, other options for disposal of the material as well as acquisition of fill for excavated areas outside the CAMU boundaries (i.e., LFU-3 waste cells, ET North, ST, and HFSDA) would need to be explored. Use of land located between the ET and LFU-1 that has no history of waste disposal would be required to enact this remedial alternative; this land is available. No additional land would be required to enact this remedial alternative.

6.8.7 Cost

The cost of Alternative SW-8 is summarized in Table 6-17.

6.8.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.8.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.9 Alternative SW-9: Excavate and Dispose of Waste Off-Site, Waste Burial Holes Corrective Action Management Unit with Multiple-Layer Cap, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-9 consists of excavating most soil/solid waste for off-Site disposal (Section 5.9; Figure 5-8; Tables 5-1, 5-2, and 5-3). Specifically, soil/solid waste (inclusive of PTW) from LFU-1, LFU-2 waste cells, and LFU-3 waste cells and the ET, including the VOC “hot spot” areas, would be excavated, segregated, and characterized for transport to licensed off-Site facilities. These excavated land disposal units would be backfilled with clean fill. The WBH and a section of LFU-2 bordering the WBH to the north would be designated as a CAMU and would receive a multiple-layer cap covering approximately 0.6 acres (Figure 5-8). The ST and HFSDA would be excavated and the material consolidated into the WBH CAMU after segregation of PTW; these areas would be backfilled with clean fill. It is estimated that 1,100 LCY of PTW would be sent off-Site for disposal at licensed facilities (Table 6-2). About 117,200 LCY of material would be excavated (Table 6-2). Nine buildings would be removed, and the demolition debris would be recycled or sent off-Site for disposal. The concrete-lined drainage channel on the east-side of LFU-3 would be demolished, debris would be sent off-Site for disposal, and the channel would be replaced with a vegetated drainage channel. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative. Long-term O&M on the groundwater wells, storm water drainage system, and WBH multiple-layer cap would maintain the functionality of the remedy, as designed (Section 5.9; Figure 5-8; Tables 5-1, 5-2, and 5-3).

6.9.1 Overall Protection of Human Health and the Environment

Alternative SW-9 protects human health and the environment by removing most soil/solid waste and disposing of this material off-Site, thereby virtually eliminating human and ecological contact and the potential for future COC migration to groundwater in these areas. Only COCs present at the WBH and non-PTW from the ST and HFSDA would remain on-Site. Drainage enhancements would control potential COC migration to surface water and reduce infiltration, and the installation of a multiple-layer cap over the WBH CAMU would reduce potential COC migration to groundwater where waste remains on-Site. Several studies have shown that multiple-layer caps are effective at limiting infiltration in semi-arid environments (e.g., Dwyer, 2003; Albright and Benson, 2005). The multiple-layer cap over the WBH would also isolate the soil/solid waste at this location, thereby limiting human exposure to COCs, as well as deep-rooted vegetation and deep-burrowing animal access to contaminated material. O&M of the multiple-layer cap over the WBH and drainage enhancements, as well as groundwater monitoring, would help maintain the continued protection of human health and the environment.

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A soil management plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove most soil/solid waste, transport most hazardous material off-Site, reduce potential COC migration to groundwater, and control potential migration to surface water. In addition to reducing and controlling the potential for human and ecological exposure, this alternative would also substantially reduce hazardous substances at the Site.

6.9.2 Compliance with ARARs

Under Alternative SW-9, concentrations of COCs greater than PCGs would remain in place, specifically at the WBH and at depths greater than 20 feet bgs; however, this area would be designated a CAMU and capped. Numerical model-based estimates (Appendices A and B) suggest that, if COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate that future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are substantially less likely under Alternative SW-9 because most soil/solid waste would be removed from the land disposal units and sent off-Site for disposal, and storm water drainage enhancements and a multiple-layer cap over the remaining waste in the WBH would limit infiltration of water. The location-specific and action-specific ARARs listed in Appendix D would be met under Alternative SW-9. Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.9.3 Long-Term Effectiveness and Permanence

Under Alternative SW-9, most soil/solid waste and soil gas from the land disposal units would be excavated and transported off-Site. PTW from the WBH was removed during the WBH removal action in 1999. PTW would be removed from the ST and HFSDA and sent off-Site for disposal before the remaining waste is placed in the WBH CAMU. Excavated material, including PTW, from LFU-1, LFU-2, LFU-3, and the ET would be segregated and sent for off-Site disposal. A fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. The VOC "hot spot" areas would be excavated during removal of LFU-2 and the ET, eliminating the future potential for vapor intrusion risk should buildings be built and occupied in the area. The VOC "hot spot" removal also would reduce the potential for downward VOC migration to groundwater. Additional information on the VOC "hot spot" areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would be removed from the Site. Although concentrations of COCs greater than PCGs would remain in place at the WBH and limited locations at other land disposal units, human and ecological exposure would be limited by source removal and installation of the multiple-layer cap at the WBH. The multiple-layer cap and drainage modifications would limit the possibility of groundwater contamination by reducing infiltration. Results from two demonstration projects in similar semi-arid regions have shown that properly designed multiple-layer caps are effective at controlling infiltration (e.g., Dwyer, 2003; Albright and Benson, 2005). Studies have also shown that the long-term effectiveness of a geosynthetic clay liner may be limited by potential degradation within a few years of installation (Dwyer, 2003). The maintenance of cap integrity, however, should ensure the long-term effectiveness of multiple-layer caps. Table 6-18 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact, as well as migration to surface water, storm water, and groundwater would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1; potential contact with soil/solid waste contaminants would be substantially less with the implementation of excavation and off-Site disposal and the multiple-layer cap covering the WBH. Since waste is excavated under this alternative, buildings could be constructed within the land disposal units, which would permit academic, administrative, and research buildings in addition to park and recreation space. The multiple-layer cap over the WBH would provide some wildlife habitat.

The long-term effectiveness of this alternative relies on the removal of most COC source material. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; annual O&M of the WBH multiple-layer cap; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.9.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-9, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability due to its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste.

6.9.5 Short-Term Effectiveness

Under Alternative SW-9, earth-moving activities, building demolition, and capping would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under this alternative, approximately 115,200 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 4,337,600 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill and capping material to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 6×10^{-1} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 14,400 metric tons of GHG emissions and 48 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 222,000 MMBTUs, equivalent to approximately 1,596,900 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5; mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative is approximately two construction seasons because of the volume of material proposed for excavation and off-Site disposal and installation of the multiple-layer cap at the WBH. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.9.6 Implementability

Alternative SW-9 requires standard demolition, excavation, grading, construction, and multiple-layer capping techniques. Transportation and disposal of soil/solid waste, PTW, and hazardous material from land disposal unit excavations would require a waste acceptance process. Suitable licensed landfill space is expected to remain available during the remedial action. Clean fill is anticipated to be available in sufficient quantities. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to prevent disturbance to animals housed near the work site.

ICs and long-term O&M activities would be used to maintain the WBH CAMU multiple-layer cap and storm water drainage system. Multiple-layer caps and storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available. Should monitoring indicate that further remedial action is necessary in the WBH, the multiple-layer cap over the WBH could be compromised.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.9.7 Cost

The cost of Alternative SW-9 is summarized in Table 6-19.

6.9.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.9.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

6.10 Alternative SW-10: Excavate and Dispose of Waste Off-Site, Institutional Controls, Drainage Enhancements, and Groundwater Monitoring

Alternative SW-10 consists of excavating soil/solid waste for off-Site disposal (Section 5.10; Figure 5-9; Tables 5-1, 5-2, and 5-3). Specifically, soil/solid waste from LFU-1, LFU-2 waste cells, LFU-3 waste cells, the ET, the ST, the WBH, and the HFSDA, including previously identified and newly identified PTW and the two soil gas VOC "hot spot" areas, would be excavated, segregated, and characterized for transport to licensed off-Site facilities. About 123,400 LCY of material would be excavated (Table 6-2). It is estimated that approximately 1,100 LCY of PTW would be disposed of under this alternative (Table 6-2). These excavated land disposal units would be backfilled with clean fill. Nine buildings would be demolished, and the demolition debris would be recycled or sent off-Site for disposal. The concrete-lined drainage channel on the east side of LFU-3 would be demolished, debris would be sent off-Site for disposal, and the channel would be replaced with a vegetated drainage channel. Signage would be posted to notify of potential subsurface hazards, and an LUC would be recorded to prohibit residential land use, restrict non-residential land use, and include a requirement for a soil management plan for post-remediation earthwork activities. Long-term groundwater monitoring would verify the efficacy of groundwater protection under this alternative (Section 5.10; Figure 5-9; Tables 5-1, 5-2, and 5-3). Clean-closure for unrestricted land use may not be attained under this alternative, as COCs would remain at depths below 20 feet bgs and in unexcavated areas of the land disposal units (e.g., in LFU-2 and LFU-3).

6.10.1 Overall Protection of Human Health and the Environment

Alternative SW-10 protects human health and the environment by removing the majority of soil/solid waste and disposing of this material off-Site, thereby virtually eliminating human and ecological contact and the potential for future COC migration to groundwater in these areas. This alternative does not address COCs below 20 feet bgs. Groundwater monitoring would help maintain the continued protection of human health and the environment.

Under this alternative, overall protection of human health and the environment also relies on implementing and enforcing ICs that would control human exposure to Site contaminants and thus reduce potential human health risks and hazards. Signage would be posted to notify of potential subsurface hazards, and LUCs would be recorded to prohibit residential land use, restrict non-residential use of the Site, and prevent disturbance of the subsurface. A soil management plan would be developed to manage soil and waste should future excavation be necessary.

This alternative would remove most soil/solid waste and transport the majority of hazardous material off-Site, reduce potential COC migration to groundwater, and control potential migration to surface water. In addition to reducing and controlling the potential for human and ecological exposure, this alternative would also substantially reduce hazardous substances at the Site.

6.10.2 Compliance with ARARs

Under Alternative SW-10, concentrations of COCs greater than PCGs would remain in place, but at depths greater than 20 feet bgs. Numerical model-based estimates (Appendices A and B) suggest that, if COCs migrate to groundwater, Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future; however, historical groundwater monitoring trends indicate future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Such impacts to groundwater are substantially less likely under Alternative SW-10 because the land disposal units would be excavated and soil/solid waste sent off-Site for disposal, thereby removing the source for migration of COCs from soil/solid waste to groundwater. The location- and action-specific ARARs listed in Appendix D would be met under Alternative SW-10. Action- and chemical-specific ARARs for air emissions would be met by developing and implementing controls during removal, construction, and maintenance activities.

6.10.3 Long-Term Effectiveness and Permanence

Under Alternative SW-10, soil/solid waste and soil gas from each land disposal unit would be excavated and transported off-Site, permanently removing these potential sources. PTW from each land disposal unit would be excavated, segregated, and sent for off-Site disposal. A fraction of the hazardous and mixed waste sent off-Site for disposal may be treated via *ex situ* solidification/stabilization. The VOC "hot spot" areas would be excavated during removal of LFU-2 and the ET, eliminating the future potential for vapor intrusion risk should buildings be built and occupied in the area. The VOC "hot spot" removal also would reduce the potential for downward VOC migration to groundwater, thus preventing potential future impacts to groundwater from landfill waste and affected soil and soil gas. Additional information on the VOC "hot spot" areas and vapor intrusion risk is provided in Appendix B.

Under this alternative, most soil/solid waste would be removed from the Site. Concentrations of COCs greater than PCGs would remain in place at depths greater than 20 feet bgs. Table 6-20 shows post-remediation concentrations and associated depths where COCs would remain at levels above PCGs. Although COCs would remain, RAOs preventing human and ecological contact, as well as preventing migration to surface water, storm water, and groundwater, would be achieved.

The long-term prevention of human and ecological exposure would be maintained through an LUC prohibiting residential land use and restricting non-residential land use. Although LUC failure is possible, current cancer risk is within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} and near the hazard index of 1.0, with the exception of the WBH, as described in Section 6.1.1. Potential contact with soil/solid waste contaminants would be substantially less with the implementation of excavation and off-Site disposal. Since waste is excavated under this alternative, buildings could be constructed within the land disposal units, which would permit academic, administrative, and research buildings in addition to park and recreation space.

The long-term effectiveness of this alternative relies on the removal of the majority of the COC source material. Long-term effectiveness would be confirmed by enforcement of ICs; long-term storm water and groundwater monitoring and management controls, including annual visual inspections and O&M of the storm water drainage enhancements; and five-year reviews. If water quality objectives are not met, additional remedial action(s) may be required.

6.10.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative SW-10, a fraction of the hazardous and mixed waste could undergo on-Site *ex situ* treatment to render it non-hazardous, prior to off-Site disposal. The actual amount of waste to be treated would depend on specific volumes of waste generated and its treatability due to its hazardous characteristics. Treatment would most likely involve the solidification/stabilization of COC-impacted soil and solid waste. The processes and procedures for *ex situ* solidification/stabilization would be documented in the MMP (element 7; Table 5-2). For costing purposes (Appendix F), it was assumed that the hazardous and mixed waste would be taken to licensed facilities capable of accepting such waste; however, it is anticipated that on-Site treatment could be implemented to reduce disposal costs, as the treated waste would no longer be considered hazardous or mixed waste.

6.10.5 Short-Term Effectiveness

Under Alternative SW-10, earth-moving activities and building demolition would be implemented. Short-term risks to the community and workers are those common to construction projects, including heavy equipment use, equipment and fugitive dust emissions, and noise. There is the potential for increased traffic accidents on roads and highways associated with the transport of soil/solid waste, imported fill, and construction equipment and supplies. Under this alternative, approximately 124,300 CY of potentially contaminated material would be sent off-Site for disposal (Table 6-2). It is estimated that approximately 4,667,000 truck-miles would be required to convey the soil/solid waste off-Site and to deliver clean fill to the Site (Table 6-3). The total fatality risks under this alternative have been estimated at 7×10^{-1} (Table 6-4). On-Site and off-Site activities associated with this alternative would result in an estimated 15,200 metric tons of GHG emissions and 51 metric tons of common air pollutant emissions (Table 6-4). Total energy use is estimated to be approximately 232,800 MMBTUs, equivalent to approximately 1,674,500 gallons of diesel fuel. Trucks would follow dust-suppression measures and would be routed to minimize noise and traffic impacts to the community.

Short-term risks for humans present at the work site, on-Site animals, and other ecological receptors are consistent with those described in Section 6.3.5. Mitigation measures would be imposed in a similar fashion.

The estimated time to complete implementation of this alternative is approximately two construction seasons because of the volume of material proposed for excavation and off-Site disposal. ICs, such as signage and LUCs, would be in effect until cleanup goals approved in the ROD are achieved.

6.10.6 Implementability

Alternative SW-10 requires standard demolition and excavation techniques. Transportation and disposal of soil/solid waste, PTW, and hazardous material from land disposal unit excavations would require a waste acceptance process. Suitable licensed landfill space is expected to remain available during the remedial action. Clean fill is anticipated to be available in sufficient quantities. The level of difficulty and cost for implementation of this remedial action increase substantially in wet conditions; therefore, this alternative should be implemented during the dry season. Construction activities related to remedial action may require accommodations to be made for animals housed near the work site to prevent disturbance.

ICs and long-term O&M activities would be used to maintain the storm water drainage system. Storm water drainage controls are proven technologies, and there is considerable experience with the maintenance and repair of these systems. Contractors and necessary materials are readily available.

Implementation of land-use restrictions would entail coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under this alternative could be relocated in existing structures or are not mission-critical, and as such, the structures could be demolished. Additional land would be required to relocate the drainage ditch south of LFU-3; this land is readily available. No additional land would be required to enact this remedial alternative.

6.10.7 Cost

The cost of Alternative SW-10 is summarized in Table 6-21.

6.10.8 Community Acceptance

This section will be completed upon receipt of community comments on the Proposed Plan.

6.10.9 State Acceptance

This section will be completed upon receipt of regulatory agency comments on the FS Report and Proposed Plan.

7. COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The comparative analysis of remedial alternatives provides information on the relative performance of the alternatives in relation to each other for the two threshold and five balancing criteria. Table 7-1 provides an alternative comparison summary table that ranks each alternative on a scale of 0 to 5, where a higher ranking reflects a more favorable outcome for that category.

7.1 Overall Protection of Human Health and the Environment

The primary considerations for this criterion are how risks to human health and the environment, including groundwater impacts, are eliminated, reduced, or controlled.

Human health and ecological risks from contaminants in the environment can be considered "eliminated" when there is no exposure. Alternatives were developed such that RAOs to prevent human and ecological contact with contaminated waste are met by applying land use controls, physical barriers, and varying levels of removal and off-Site disposal (Table 7-1). Estimated soil/solid waste and vapor intrusion cancer risks are currently within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6}, except for the WBH (Table 7-2), and near the hazard index of 1.0. Implementation of Alternative SW-1 would provide no additional protection of human health and the environment. Under this alternative, monitoring would be discontinued, and potential future releases of COCs would be undetected.

Alternative SW-2 relies on ICs such as LUCs and signage to meet RAOs. In addition to the ICs, further levels of protection under Alternatives SW-3 through SW-10 are achieved through physical removal and off-Site disposal of material and the isolation of contaminated waste via graded covers or surface caps. Alternative SW-2 would be most reliant on the ICs because there would be no removal, off-Site disposal, or capping, whereas Alternative SW-10 would be the least reliant on ICs since the majority of waste is removed and sent for off-Site disposal (Table 7-1).

Increasing volumes of heterogeneous waste, including PTW, would be removed and sent for off-Site disposal under Alternatives SW-3 through SW-10 (Table 7-1); limited concentrations of COCs would remain at depths greater than 20 feet bgs. As greater quantities are sent for off-Site disposal, the threat of future unknown hazardous conditions would be reduced. Furthermore, the future potential of COC leaching to groundwater would be reduced by source removal, including removal of the two VOC "hot spot" areas.

Under Alternatives SW-3 through SW-9, some waste would remain on-Site in designated CAMUs. This waste would be further contained and isolated from human contact by engineered surface covers/caps. The graded covers and evapotranspiration, multiple-layer, and asphalt caps would provide increasing levels of containment and isolation between waste and human and ecological exposure. Furthermore, the bottom liner and LCRS proposed under Alternative SW-8 would provide additional containment and isolation between the soil/solid waste and environment.

Alternatives SW-3 through SW-9 propose graded covers or surface caps and storm water drainage enhancements to limit infiltration and potential subsequent leaching of COCs to groundwater. The asphalt caps would provide the greatest protection against infiltration (Alternative SW-5). The graded covers (Alternative SW-3) would provide the least amount of protection against infiltration because they only provide a single low permeability barrier against infiltration. This soil barrier could be compromised through macropore formation (e.g., dessication, cracking, root growth, and animal burrowing). The evapotranspiration caps (Alternative SW-4) may fail as a result of a seasonal mismatch between peak precipitation and peak evapotranspiration. As such, the evapotranspiration cap may allow infiltration during heavy precipitation events. The multiple-layer cap (Alternatives SW-6 through SW-9) would provide increased protection when compared to the graded cover and evapotranspiration cap. In the event of cap failure under Alternative SW-8, the bottom liner and LCRS would capture potentially leaching COCs and prevent their release to groundwater. Since the Site is located within the inundation area of a one-percent annual chance flood (100-year flood), the graded covers and surface caps would be designed to resist washout but may remain vulnerable to flood damage. Flooding could overwhelm the infiltration barriers, and subsequent infiltration could mobilize remaining COCs left in place under Alternatives SW-1 through SW-9. Alternatives SW-9 and SW-10 should provide the most protection against potential flooding by removing most of the waste from the land disposal units.

Proposed groundwater monitoring would increase the probability of detecting potential COC leaching; as such, actions to address the source could be implemented. It is unlikely that Basin Plan numerical groundwater quality objectives would be exceeded in the future under any of the alternatives. Alternatives SW-2 through SW-7 are deemed to have a low possibility of groundwater impacts, while SW-8 through SW-10 have an even lower possibility of groundwater impacts because the waste is either fully contained or removed.

7.2 Compliance with ARARs

The primary consideration for this criterion is compliance with federal, state, and local environmental laws and facility siting laws. Under Alterative SW-1, “No Action/No Further Action”, no remedial actions have been recommended, and therefore, this alternative would not comply with ARARs; specifically, this alternative would not comply with the CCR Title 27, Corrective Action Program.

Alternatives SW-2 through SW-10 are compliant with ARARs listed in Appendix D. However, under each alternative, some level of COCs greater than PCGs would remain in place. If appreciable quantities of COCs migrate to groundwater, it is possible that Basin Plan numerical water quality objectives (chemical-specific ARARs identified in Appendix D) could be exceeded in the future. However, numerical modeling (Appendix A) and over 20 years of historical groundwater monitoring trends indicate that future exceedances are unlikely to occur (Section 2.6.2.1; Figures 2-19 through 2-22). Furthermore, under Alternatives SW-3 through SW-10, potential vertical migration of COCs would be curtailed by limiting infiltration, isolating waste, and removing COC source material. In the unlikely event that such potential migration occurred, compliance with

ARARs could be achieved through the Site's groundwater remedy or, if a new remedy is warranted, through a ROD amendment.

Under Alternatives SW-2 through SW-10, the action- and location-specific ARARs listed in Appendix D would be met. ARARs for designating and installing CAMUs at the Site would be met for Alternatives SW-3 through SW-9. Although it is expected that net storm water runoff would increase under Alternatives SW-3 through SW-8, each alternative would involve several storm water drainage enhancements designed to treat these increases and meet the post-construction requirements of the Draft 2011 MS4 permit (SWRCB, 2011; Appendix G). Action- and chemical-specific ARARs for air emissions would be met by developing and implementing appropriate engineering and administrative controls during demolition, excavation, grading, construction, covering/capping, and maintenance activities, including compliance with levee access requirements (CCR Title 23 §112, §115, §116, and §120).

7.3 Long-Term Effectiveness and Permanence

The primary considerations for this criterion are the magnitude of residual risks and the adequacy and reliability of controls.

Except for the WBH, estimated soil/solid waste and vapor intrusion cancer risks are currently within or near the NCP's designated cancer risk range of 10^{-4} to 10^{-6} (Table 7-2) and near the hazard index of 1.0. Under Alternative SW-2, implementation of ICs would continue to maintain soil/solid waste and vapor intrusion cancer risks within or near the cancer risk range. Increasing volumes of waste removal (including PTW and the VOC "hot spot" areas) and installation of surface covers/caps under Alternatives SW-3 through SW-10 would lessen the reliance on ICs and reduce potential exposure to hazardous material, thus reducing the potential for residual risk. Furthermore, in the event of IC failure, these additional remedial actions would lessen the potential for future exposure to hazardous material and the potential for leaching to groundwater. Uncertainty with respect to unknown hazardous materials within the land disposal units also would decrease as more waste is removed and sent off-Site for disposal.

Excavation and off-Site disposal of PTW and the VOC "hot spot" areas in Alternatives SW-3 through SW-10, and most soil/solid waste under Alternatives SW-9 (except for the WBH) and SW-10 would be effective in permanently removing waste from the Site. Table 7-3 summarizes the concentration of COCs remaining above PCGs under each alternative. Alternatives SW-1 and SW-2 do not include any removal actions, so there would be no change from the baseline COC concentrations and associated exposure to, and estimated risks from, COCs. Alternatives SW-3 through SW-10 would increasingly lower the amount of soil/solid waste with COC concentrations exceeding PCGs. Alternative SW-10 would provide the greatest long-term effectiveness and permanence, since the majority of waste would be removed and sent off-Site for disposal, although some risks would be transferred to the receiving facilities.

In addition to the off-Site disposal of waste, Alternatives SW-3 through SW-9 would include on-Site consolidation of waste in CAMUs. Under Alternatives SW-7, SW-8, and SW-9, the ST and HFSDA would be excavated, and soil/solid waste would be consolidated within a capped CAMU after off-Site disposal of PTW. Under Alternatives SW-7 and SW-8, soil/solid waste within the

LFU-3 waste cells would be excavated and consolidated within the capped CAMUs over LFU-1 and LFU-2/ET/WBH after segregation of PTW. Consolidation under these alternatives would lead to greater long-term effectiveness and permanence at the ST, HFSDA, and LFU-3 by eliminating future exposure, potential risk, and COC migration in these areas. It is anticipated that LLRW and hazardous waste would be encountered during the excavation of the land disposal units. Under Alternatives SW-3 through SW-9, LLRW and hazardous waste would likely remain on-Site but within the designated CAMUs. These areas would be isolated from human and ecological exposure via engineered surface covers/caps.

Disposal of waste material, either on-Site or off-Site, and consolidation of soil/solid waste under graded covers, evapotranspiration caps, asphalt caps, or multiple-layer caps are standard and well-proven technologies. There is an increased likelihood of graded cover failure (Alternative SW-3) when compared to the surface caps (Alternatives SW-4 through SW-9); the potential for landfill cap failure, resulting in exposure of the public or ecological receptors to COCs, is considered unlikely. The adequacy and reliability of controls for Alternatives SW-3 through SW-10 would be approximately the same, as long as the integrity of the landfill covers/caps is maintained and ICs enforced. Alternatives SW-3 through SW-9 would require periodic O&M on the storm water drainage enhancements and land disposal caps; Alternative SW-10 would include O&M on the storm water drainage enhancements. Alternative SW-5 would require the greatest long-term O&M and periodic requirements due to maintenance of the asphalt caps. Alternative SW-8 would provide additional protection to groundwater if cap failure occurs due to the bottom liner and LCRS, but these would require additional O&M as well. Alternative SW-1 is not effective because soil/solid waste would remain in place without a long-term management plan. Alternative SW-10 would be the least reliant on controls, since most waste is removed from the Site.

Alternative SW-1 would provide the least number of future land use options because potential human exposure to COCs would be higher than the other alternatives. Alternatives SW-2 through SW-8 provide moderate future land use options due to the requirement to maintain the covered/capped areas. Under Alternatives SW-9 and SW-10, the greatest volume of soil/solid waste would be removed, thus providing for additional land use options because there would be fewer land use restrictions, and potential human exposure to residual contamination would be lower than other alternatives. The asphalt caps (Alternative SW-5) would allow for additional land use options not provided with the vegetative surfaces.

7.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Primary considerations for this criterion include the reduction in toxicity, mobility, or volume through treatment. Since it is technically infeasible to treat heterogeneous waste like that found in the LEHR/OCL disposal units, none of the alternatives presented in this FS include *in situ* treatment as part of the remedy. For Alternatives SW-3 through SW-10, some waste sent off-Site for disposal could undergo on-Site *ex situ* solidification/stabilization to render it non-hazardous, prior to off-Site disposal. The actual amount of treated waste would depend on specific volumes of waste generated and its treatability due to its hazardous characteristics. Assuming that the total volume of *ex situ* treatment is proportional to the waste volume sent off-Site for disposal (Table 6-2), Alternative SW-10 would involve the greatest potential reduction of toxicity, mobility, or volume of hazardous material, and Alternatives SW-1 and SW-2 would involve no reduction (Table 7-1). However, because of the general heterogeneous nature of the waste, and limited treatability of such waste, the volume of waste undergoing *ex situ* treatment is expected to be a low percentage of the total waste volume for each of the alternatives.

7.5 Short-Term Effectiveness

Primary considerations for this criterion include protection of the community, protection of workers, potential environmental impacts during construction and implementation, and the time required to construct and implement the response actions.

Alternative SW-1 would not add any short-term impacts to the public, on-Site workers, or the environment. Short-term impacts under Alternative SW-2 would be associated with the installation of groundwater monitoring wells; only minor short-term impacts would be anticipated. Short-term impacts from Alternatives SW-3 through SW-10 include fugitive dust generation, air emissions, vehicular traffic, and construction site hazards. Site construction impacts, including localized noise and ground vibrations, would persist for several months during the excavation of PTW, the VOC “hot spot” areas, and contaminated soil/solid waste in Alternatives SW-3 through SW-7, and, potentially, for up to two construction seasons for Alternatives SW-8 through SW-10. Air monitoring, dust control, and personal protective equipment would be required to identify and mitigate these effects.

Figure 7-1 shows the total fatality risk for each alternative, as calculated in Appendix I and presented on Table 6-4. Although there is some risk associated with on-Site construction activities, the total fatality risk is primarily driven by the accident and latent fatality risks associated with transportation of materials, equipment, and waste to and from the Site during construction activities. The majority of transportation risk stems from the latent fatality risk due to vehicle emissions and road dust (Figure 7-1); for Alternatives SW-3 through SW-10, latent fatality risks are an order of magnitude greater than the accident fatality risks (Table 6-4). Alternative SW-2 has the least number of truck trips (1) and travel miles (450), and therefore, the least risk of fatality: 2×10^{-4} (Table 6-3; Table 6-4). The total fatality risk increases by over three orders of magnitude from Alternative SW-2 to Alternatives SW-9 and SW-10, with the greatest number of truck trips (12,400), travel miles (4,667,000), and associated fatality risk of 7×10^{-1}. The number of truck trips, total mileage, and fatality risk increases from Alternatives SW-5 through SW-8 due to the greater volume of LLRW and hazardous waste sent off-Site for disposal and increasing volume of imported fill and cap materials. When compared to Alternatives SW-3, SW-5, and SW-6, Alternative SW-4 has a higher number of truck trips, total mileage, and fatality risk due to the volume of imported material necessary for the 4.5-foot thick evapotranspiration caps. The estimated soil/solid waste cancer risk currently is within or near the NCP’s designated cancer risk range of 10^{-4} to 10^{-6} (with the exception of the WBH), whereas the estimated total fatality risks for Alternatives SW-3 through SW-10 (Table 6-4) are an order of magnitude or more higher than the estimated cancer risks. In addition to fatality risks, as more waste is removed and disposed of off-Site, total truck trips and transportation mileage would increase, leading to greater local traffic congestion and air emissions, with Alternatives SW-9 and SW-10 leading to the greatest impact on traffic congestion.

Figures 7-2 and 7-3 illustrate greenhouse gas emissions and total energy use, respectively, for each alternative. Greenhouse gas emissions are similar for Alternatives SW-4 through SW-8.

Emissions increase by almost a factor of three for Alternatives SW-9 and SW-10, primarily due to the substantial increase in transportation mileage associated with off-Site disposal of waste. There is also a notable increase in emissions associated with residual handling; residual handling is associated with emissions generated at the final disposal landfills after waste is received at the disposal facilities. Under Alternatives SW-3 through SW-10, appreciable emissions are generated during the life-cycle production and consumption of consumable materials (e.g., PVC for wells, concrete, steel, etc.). The total energy use (Figure 7-3) shows a similar pattern to the greenhouse gas emissions (Figure 7-2).

NO_x, SO_x, and PM_{10} emissions are shown on Figures 7-4, 7-5, and 7-6, respectively. Emissions of these common air pollutants are relatively low under Alternatives SW-2 through SW-7 (less than five metric tons for each pollutant). Total emissions more than double under Alternative SW-8, and increase by more than a factor of four under Alternatives SW-9 and SW-10. The dominant driver of NO_x and SO_x emissions for Alternatives SW-2 through SW-8 is on-Site use of equipment. Since Alternatives SW-8 through SW-10 would take two years to complete construction, NO_x and SO_x emissions attributed to on-Site equipment use approximately double when compared to the alternatives that would be completed in one year (Alternatives SW-3 through SW-7). The largest increase in NO_x and SO_x emissions under Alternatives SW-9 and SW-10 are attributable to activities at the final disposal landfills. While on-Site equipment use contributes to PM_{10} emissions, the dominant source of PM_{10} emissions is related to activities at the final landfill destinations.

The RAOs of preventing human and ecological exposure would be achieved at the completion of remedial activities (e.g., well installation, excavation, and capping) (Table 7-1). Alternative SW-1 requires no time to implement and would not provide any additional protection. Protection would be achieved for Alternative SW-2 in less than one year. Alternatives SW-3 through SW-7 would achieve protection in one construction season, and Alternatives SW-8 through SW-10 would achieve protection in two construction seasons.

7.6 Implementability

This evaluation criterion addresses the technical and administrative feasibility of implementing each alternative and the availability of services and materials necessary for implementation.

Technical feasibility includes the ability to construct and operate the remedy, the reliability of the technology, the ease of undertaking additional remedial actions, if necessary, and monitoring considerations. There are no barriers to implementing Alternative SW-1. Alternative SW-2 would be relatively quick and easy to implement. Alternatives SW-3 through SW-8 are more complex, in that soil/solid waste would be excavated, segregated, and capped (either under three graded covers [Alternative SW-3], three evapotranspiration caps [Alternative SW-4]; three asphalt caps [Alternative SW-5]; three multiple-layer caps [Alternative SW-6]; two multiple-layer caps [Alternative SW-7]; or one multiple-layer cap [Alternative SW-8]). The large-scale removals proposed in Alternatives SW-9 and SW-10 would be relatively straightforward to implement because they include the fewest design requirements. Since Alternative SW-9 includes a multiple-layer cap over the WBH CAMU, this alternative is more complex than Alternative SW-10, which involves the excavation and off-Site disposal of each land disposal unit.

Alternative SW-8 is the most complex of the alternatives, as it would require the most soil/solid waste excavation (to 20 feet bgs), as well as the subsequent installation of a bottom liner and LCRS. It is proposed that the soil between the ET and LFU-1 be used as fill during the remedial action. However, should sampling indicate that this fill does not meet the clean fill requirements for the Site, other options for disposal of the material, as well as acquisitions of fill for excavated areas outside the CAMU boundaries, would need to be explored. In addition, should monitoring indicate that further remedial action is necessary, implementation of this alternative would be difficult, because the constructed liner, LCRS, and CAMU cap could be compromised.

The administrative feasibility of each alternative is not a barrier to implementability. Each alternative (SW-2 through SW-10) would require coordinating with the UCOP Real Estate Services Group and UC Davis Office of Administrative and Resource Management to gain approval for recording the required LUC. Since the Site is located at the southern end of the property, removed from the Main Campus, the implementation of the proposed ICs is not identified as a burden to the University's mission. Additionally, activities conducted in the nine structures that are proposed for removal under Alternatives SW-4 through SW-10 (one structure under Alternative SW-3) could be relocated in existing structures or are not mission-critical, and as such the structures could be demolished. Some additional land at the Site would be required to implement the storm water drainage enhancements for Alternatives SW-3 through SW-10 (Alternatives SW-9 and SW-10 would require land for the drainage channel relocated to the south of LFU-3). Alternative SW-8 would require the use of additional land between the ET and LFU-1 that has no history of waste disposal. This additional land is readily available. However, the off-Site disposal proposed in Alternatives SW-3 through SW-10 may expose the University to future CERCLA liability at the off-Site disposal facilities.

7.7 Cost

The cost evaluation is based on capital costs, long-term O&M costs, and periodic costs, as detailed in Appendix F. Under the NCP, the FS should provide a "study estimate" cost with an expected accuracy between -30 percent to +50 percent. The cost estimates were calculated over a 100-year time period (Appendix F). For this FS, the cost criterion yields the greatest differences between the remedial alternatives developed for the Site.

Table 7-4 compares alternative costs. Except for Alternative SW-1, the "No Action/No Further Action" alternative, Alternative SW-2 has the lowest overall cost to complete, approximately $6.5 million; Alternative SW-10 has the highest cost to complete, approximately $108.7 million.

The primary driver of total cost is related to the total volume of excavated material sent for off-Site disposal (Figures 7-7 and 7-8). Because each of the four unlined capping alternatives (Alternatives SW-4, SW-5, SW-6, and SW-7) would include the off-Site disposal of similar volumes of soil/solid waste (2,500 LCY to 4,600 LCY), overall estimated costs are in a narrow range of $18.5 million to $20.9 million (Figure 7-8; Table 6-2). Under Alternative SW-3, similar volumes of hazardous material are sent off-Site for disposal, but overall costs are lower ($13.6 million) due to lower costs associated with graded covers rather than evapotranspiration, asphalt, and multiple-layer caps; in addition, substantially less on-Site disposal of material and the removal of fewer buildings contributes to the lower costs (Table 6-2). Alternative SW-8 has a higher estimated cost of approximately $33.4 million, reflecting capital costs associated with the much greater excavation volume (Table 6-2), as well as the installation of a bottom liner and LCRS. Alternatives SW-9 and SW-10, with overall costs of approximately $102 and $109 million, respectively, are about 3 to 17 times more costly than the other alternatives, reflecting the high cost of excavation, import of clean backfill, and off-Site disposal of nearly all waste.

The total disposal cost estimates are sensitive to the waste characterization assumptions described in Appendix E (Figure 7-8). In particular, the unit disposal costs of LLRW and mixed waste are over five times greater than the unit disposal costs of RCRA-hazardous, non-RCRA-hazardous, and non-hazardous wastes. As such, a small change in the volume of LLRW and mixed waste sent for off-Site disposal could result in a large increase or decrease in disposal cost. The spike in costs for Alternatives SW-9 and SW-10 is largely driven by the increase in LLRW and mixed waste sent for off-Site disposal (Figure 7-8; Table 6-2). Given the cost sensitivity to waste characterization type, if the assumptions regarding the waste characterization proportions are incorrect (Appendix E), the overall total costs may change more than the +50/-30 percent objective.

Long-term O&M and periodic costs play a secondary role in the difference in total cost between each alternative (Figure 7-8). Comparison of O&M costs shows that there is an approximate 1.4 times difference in these costs: minimum estimated O&M cost of $5.6 million for Alternative SW-10 and maximum estimated O&M cost of $7.8 million for Alternative SW-5. Alternative SW-5 has the highest O&M cost because of the overall maintenance required for the asphalt cap and the need to periodically resurface or repave the asphalt. Total O&M costs for Alternative SW-2 are more than Alternative SW-10, due to three additional monitoring wells included in the groundwater monitoring program (Table 5-3). Periodic costs are low relative to the total cost of each alternative and involve approximately three percent or less of the total cost.

7.8 State and Community Acceptance

A final assessment of these two modifying NCP criteria will be made in the final FS Volume 1, based on comments received, input from the public comment period, and a public meeting held for the Proposed Plan.

7.9 Green Remediation Evaluation

Although green remediation is not considered one of the nine criteria based on statutory requirements of CERCLA, according to the *Superfund Green Remediation Strategy* (US EPA, 2010b), the use of green remediation practices falls within the statutory and regulatory framework of the Superfund Remedial Program. According to the US EPA, "Green remediation comprises a range of best practices that may be applied throughout the Superfund cleanup process … The best management practices of green remediation provide potential means to improve waste management; conserve or preserve energy, fuel, water, and other natural resources; reduce [greenhouse gas] emissions; promote sustainable long-term stewardship; and reduce adverse impacts on local communities during and after remediation activities."

A green and sustainable remediation footprint analysis, conducted with the SiteWise™ Version 2 Green and Sustainable Remediation Tool, is presented in Appendix I. Several of the sustainability metrics resulting from this analysis are discussed above in Section 7.5, Short-term Effectiveness, and are presented on Figures 7-1 through 7-6. Results of this analysis show that the predominant drivers of GHG emissions and energy consumption for Alternatives SW-2 through SW-8 are related to life-cycle materials production for the materials used in these alternatives. Fuel consumption, inclusive of both on-Site earth moving equipment and off-Site transportation of materials, equipment, and waste, accounts for the majority of GHG emissions and energy consumption for Alternatives SW-9 and SW-10. On-Site equipment activities comprise over 80 percent of NO_x and SO_x emissions for Alternatives SW-2 through SW-8. On-Site equipment activities and off-Site landfill operations at the final disposal facilities contribute over 85 percent of NO_x and SO_x emissions under Alternatives SW-9 and SW-10. PM_{10} emissions are primarily driven by off-Site landfill operations at the final disposal facilities. In addition, as increasing quantities of waste are taken off-Site for disposal, not only is valuable landfill space consumed, but the total fatality risks increase. Alternatives SW-2 and SW-3 involve the least amount of on-Site and off-Site earth-moving activities, resulting in substantially lower emissions, fuel consumption, and fatality risks than Alternatives SW-4 through SW-10.

Opportunities to evaluate and implement green remediation strategies exist throughout the project life cycle. Table 7-5 provides a list of best management practices that could be implemented as part of each alternative and could improve the sustainability of the proposed remedial actions. This list is not exhaustive, and additional opportunities would be evaluated throughout the remedial process.

Alternative SW-1, the "No Action/No Further Action" alternative, would not include any components that could be conducted in a more sustainable manner.

Alternative SW-2 would involve the installation of additional monitoring wells. The sustainability of this alternative could be improved through best management practices (BMPs) related to the drilling and installation of wells, and potential reuse of investigation-derived waste. For example, idling could be reduced and equipment operated using alternative fuels (e.g., biodiesel, ultra-low sulfur diesel, and fuel additives).

Alternatives SW-3 through SW-10 involve the import of clean fill for backfill. To reduce truck miles, fuel consumption, and the generation of GHG emissions, emphasis could be placed on sourcing backfill soil from locations as close to the Site as feasible, with priority given to excess soil from campus and other nearby projects. In addition, excavated clean soil from the Site could be segregated and re-used to the extent practicable.

The graded covers in Alternative SW-3, the evapotranspiration caps in Alternative SW-4, and the multiple-layer caps in Alternatives SW-6 through SW-9 could include native vegetation that would require little or no irrigation. These natural vegetation caps would represent a more sustainable alternative than the asphalt caps proposed in Alternative SW-5. In addition, vegetated caps would serve as Site wildlife habitat and provide a more aesthetically pleasing feature to Site occupants. The design of evapotranspiration caps are listed by the US EPA as a BMP for alternative cover design (US EPA, 2008; US EPA, 2011d).

Solar panels could be installed over the excavated and capped areas in Alternatives SW-7 through SW-10 and over the asphalt caps in Alternative SW-5 to generate electricity for nearby University buildings or to return to the power distribution grid. In addition, under Alternative SW-5, asphalt rubber sourced from recycled materials could be substituted for conventional asphalt (US EPA, 2011d).

Most of the remedial actions would be implemented during the dry season, so there is little potential to capture and reuse storm water, although the use of reclaimed or other non-potable supplies could be explored for dust control and equipment washdown.

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