

# **FINAL REPORT**

## **REMEDIAL INVESTIGATION / FOCUSED FEASIBILITY STUDY (RI/FS)**

**PACIFIC COAST PIPELINE (PCPL) SUPERFUND SITE  
FILLMORE, CALIFORNIA**

*Submitted to*

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REMEDIAL INVESTIGATION /  
FOCUSED FEASIBILITY STUDY (RI/FS)

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This report describes the results of a Remedial Investigation / Focused Feasibility Study (RI/FS) implemented at the Chevron Environmental Management Company (Chevron) Pacific Coast Pipeline (PCPL) Superfund Site (Site) located in Fillmore, California. The purpose of this report was to (1) provide sufficient background information to understand the current conditions and (2) ensure that appropriate remedial alternatives were evaluated such that relevant information concerning the remedial action options are presented to a decision-maker for appropriate remedy selection for full-scale design. This report was developed in general accordance with *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988).

No express or implied representation or warranty is included or intended in this report except that the work was performed within the limits prescribed by Chevron with the customary thoroughness and competence of professionals working in the same area on similar projects.



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**LIST OF ABBREVIATIONS AND ACRONYMS**

ABS	Absorption factor
AC	Average concentration
ADI	Average daily intake
AF	Adherence factor
ALM	Adult lead model
amsl	Above mean sea level
ANOVA	Analysis of variance
AOC	Area of concern
API	American Petroleum Institute
ARARs	Applicable or relevant and appropriate requirements
AST	Aboveground storage tank
AT	Averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BA	Bachelor of Arts
bgs	Below ground surface
BMP	Best Management Practice
BPD	Barrels per day
BS	Bachelor of Science
BTEX	Benzene, toluene, ethylbenzene, and total xylenes
BW	Body weight
Cal/EPA	California Environmental Protection Agency
Caltrans	California Department of Transportation
CAM	California Assessment Metals
cPAHs	Carcinogenic polynuclear aromatic hydrocarbons
CD	Consent Decree
CDFG	California Department of Fish and Game
CDWR	California Department of Water Resources
CEC	Cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CF	Conversion factor
CFR	Code of Federal Regulations
CGWP	Certified Groundwater Professional
Chevron	Chevron Environmental Management Company
CH <sub>4</sub>	Methane
CHG	Certified Hydrogeologist
CHHSL	California Human Health Screening Level
CIH	Certified Industrial Hygienist
CMT	Continuous Multichannel Tubing
CNDDB	California Natural Diversity Database



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CNPS	California Native Plant Society
CO <sup>2</sup>	Carbon dioxide
COC	Chemical of Concern or Constituent of Concern
COPC	Constituent of potential concern
COPEC	Constituent of potential ecological concern
CSF	Cancer slope factor
CSM	Conceptual site model
CTR	California Toxics Rule
DAF	Dilution Attenuation Factor
db	Decibel
1,2-DCA	1,2-Dichloroethane
DCS	Document control system
DEQ	Oregon Department of Environmental Quality (also ODEQ)
DHS	Department of Health Services
dL	Deciliter
DO	Dissolved oxygen
DQO	Data Quality Objective
DTSC	Department of Toxic Substances Control
E&A	England and Associates
EcoSSL	Ecological soil screening level
ED	Exposure duration
EF	Exposure frequency
EMC	Environmental Management Company
ENSR	ENSR Corporation
EPA	U.S. Environmental Protection Agency (also U.S. EPA, USEPA, or Region 9)
EPC	Exposure point concentration
Equilon	Equilon Pipeline LLC
ERA	Ecological risk assessment
ESI	Environmental Solutions, Inc.
ESL	Ecological screening level
FRTR	Federal Remediation Technologies Roundtable
FS	Feasibility Study
ft	Feet
ft/ft	Foot per foot
g/m <sup>2</sup>	Grams per square meter
GHG	Greenhouse gas
GIS	Geographic information system
GPC	Gel Permeation Chromatography
GPM	Gallons per minute
GRA	General response action
GUI	Geographical user interface



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GWTS	Groundwater treatment system
HASP	Health and safety plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HI	Hazard index
HPAH	High molecular weight PAHs
HQ	Hazard quotient
HRA	Health risk assessment
HHRA	Human health risk assessment
H <sub>2</sub> S	Hydrogen Sulfide
ICS	Interference check samples
IRIS	Integrated Risk Information System
IUR	Inhalation unit dose
J&E	Johnson and Ettinger
kg/m <sup>3</sup>	Kilogram per cubic meter
LAC	Lifetime average concentration
LADI	Lifetime average daily intake
LANL	Los Alamos National Laboratory
LARWQCB	Los Angeles Regional Water Quality Control Board
LCS	Laboratory control sample
L/kg	Liters per kilogram
LNAPL	Light non-aqueous phase liquid
LNAST	LNAPL Dissolution and Transport Screening Tool
LPAH	Low molecular weight PAHs
µg/L	Micrograms per liter
µg/kg	Microgram per kilogram
M&CSP	Monitoring and Confirmation Sampling Plan
MBT	Molecular Biological Tool
MCL	Maximum contaminant level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
mg/m <sup>3</sup>	Milligrams per cubic meter
mL/Min	Milliliters per Minute
MNA	Monitored Natural Attenuation
MRL	Method reporting limit
MSCFH	Million Standard Cubic Feet per Hour
MS/MSD	Matrix spike/matrix spike duplicate
N <sub>2</sub> O	Nitrous oxide
NAPL	Non-aqueous phase liquid
NCP	National Contingency Plan
NOAEL	No-observable-adverse-effects-level
NPL	National Priorities List



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NPDES	National Pollutant Discharge Elimination System
NPV	Net present value
NELAC	National Environmental Laboratory Accreditation Conference
NELAP	National Environmental Laboratory Accreditation Program
ODEQ	Oregon Department of Environmental Quality (also DEQ)
OEHHA	Office of Environmental Health Hazard Assessment
ORC <sup>®</sup>	Oxygen Release Compound
P&T	Pump and treat
PAHs	Polynuclear aromatic hydrocarbons
Pb	Inorganic lead
PCB	Polychlorinated biphenyl
PCPL	Pacific Coast Pipeline
PDF	Portable document format
PE	Performance evaluation
PEF	Particulate emission factor
%R	Percent Recovered
PG	Professional Geologist
PID	Photoionization detector
K <sub>3</sub> PO <sub>4</sub>	Potassium Phosphate
POTW	Publicly Owned Treatment Works
ppb	Parts per billion
ppmv	Parts per million volume
PRG	USEPA Region 9 Preliminary remediation goal
QA/QC	Quality assurance/quality control
QAPP	Quality Assurance Project Plan
Q/C	Dispersion coefficient
RAO	Remedial Action Objective
RBC	Risk-based concentration
Redox	Reduction/oxidation
RfD	Oral reference dose
RfC	Inhalation reference concentration
RME	Reasonable maximum exposure
RIF	Route-specific intake factor
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of decision
RPD	Relative Percent Difference
RSL	Regional screening level
SA	Skin surface area
SCADA System	Supervisory Control and Data Acquisition System
SESOIL	Seasonal Soil Compartment Model
Site	Pacific Coast Pipeline Superfund Site



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SF	Slope factor
SLERA	Screening-level ecological risk assessment
SLV	Screening level value
SO <sub>2</sub>	Sulfur dioxide
SOW	Statement of work
SPRR	Southern Pacific Railroad
SSL	Soil screening level
STC	Source term concentration
STLC	Soluble threshold limit concentration
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
SWRCB	State Water Resources Control Board
TBC	To be considered
TCLP	Toxicity characteristic leaching procedure
TEAP	Terminal electron accepting process
TPH	Total petroleum hydrocarbon
TQ	Toxicity quotient
TRV	Toxicity reference value
TTLC	Total threshold limit concentration
TTTI	Texaco Trading and Transportation, Inc.
UAO	Unilateral Administrative Order
UCL	Upper confidence limit
URS	URS Corporation
USA	Underground Service Alert of Southern California
USCS	Unified Soils Classification System
USEPA	United States Environmental Protection Agency (also EPA)
USGS	United States Geologic Survey
UST	Underground storage tank
VCDEH	County of Ventura, Environmental Health Department
VCWPD	Ventura County Watershed Protection District
VDEQ	Virginia Department of Environmental Quality
VF	Volatization factor
VOC	Volatile organic compound
WDR	Waste Discharge Requirements
WMI	Waste Management, Incorporated



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## EXECUTIVE SUMMARY

### ***Site Background***

This Remedial Investigation / Focused Feasibility Study (RI/FS) report was prepared for the Pacific Coast Pipeline (PCPL) Superfund Site (Site) located in Fillmore, California. The purpose of this study is to (1) provide sufficient background information to understand the current conditions at the Site and (2) ensure that appropriate remedial alternatives for both shallow soil and groundwater are evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker for appropriate remedy selection for full-scale design.

The Site was formerly an oil refinery from circa 1915 until 1950. Texaco acquired the existing refinery in 1928. The refinery was shutdown in 1950, dismantled by 1951 leaving approximately eight (8) aboveground storage tanks (AST), and converted to a crude oil pumping station by 1952. Pumping station operations discontinued in 2000 and nearly all of the remaining facilities were dismantled and removed by July 2002. The last remaining AST was removed in August 2004.

In 1992, the U.S. Environmental Protection Agency (USEPA or EPA) issued its remedy decision in a Record of Decision (ROD) for the Site. The selected remedy for soil (as a preventative measure for groundwater) was Soil Vapor Extraction (SVE). Pump and Treat (P&T) was the selected remedy for groundwater at the Site. The SVE / P&T system operated for several years before reaching asymptotic conditions, and its operation was discontinued with agency concurrence in 2002. Contaminant concentration levels in groundwater remained above cleanup goals established in the ROD.

A secondary treatment process was evaluated for groundwater in 2003/2004 by conducting a pilot test using oxygen release compound (ORC<sup>®</sup>). The pilot test was not successful, but further evaluation of natural attenuation parameters indicate that impacted groundwater is being remediated in-situ by a naturally-occurring sulfate-reducing environment present beneath the Site. Monitored Natural Attenuation (MNA) became a preferred logical remedy as stated in the EPA's Second Five Year Review in 2006, but needed further evaluation since it was not selected as a contingent remedy in the initial ROD.

The 1992 ROD did not include a remedy for shallow soils, which will be needed for potential redevelopment of the Site as a commercial/industrial property, because (1.) the Site was still an operating crude oil pumping station at that time and (2.) the waste pits, unused since 1950, were remediated in 1986. Chevron initiated a three-phased investigation with agency concurrence to address shallow soils within the upper 10 feet below ground surface (ft bgs). The soil results were used in a risk assessment (human and ecological) to establish site-specific remediation goals. This, along with an updated groundwater remedy, is the focus of this RI/FS report for inclusion in an upcoming revision to the ROD.

### ***Nature and Extent of Contamination***

The recent shallow soil investigations identified contaminants typical of petroleum industry operations which were ongoing at the Site since circa 1915: polynuclear aromatic hydrocarbons (PAHs), including benzo[a]pyrene and naphthalene, and lead. Although few volatile organic compounds (VOCs) were detected in shallow soil, residual petroleum hydrocarbons remain in the saturated zone. The chemicals of

contaminants in groundwater are comprised of dissolved phase petroleum hydrocarbons that are degrading naturally at the Site. Light non-aqueous phase liquid (LNAPL) petroleum hydrocarbons are trapped in sediment pores and sorbed to sediment grains within a smeared zone above and below the water table. The residual LNAPL is an ongoing source of dissolved benzene in groundwater. In addition to groundwater impacts associated with historical operations, groundwater is also impacted by the presence of naturally-occurring petroleum hydrocarbons in soils and the underlying geologic strata.

Two distinct groundwater contaminant plumes (northern and southern) of dissolved benzene exist beneath the Site (Figure E-1). Groundwater in the southern plume is approximately 55 ft bgs. Groundwater in the northern plume is approximately 85 ft bgs. The southern plume has consistent detection of LNAPL trapped by fine-grained sediments present at the water table in wells EW-1 and EW-4. The maximum benzene concentration in the southern plume is typically in the 300-400 µg/L range. Dissolved benzene concentrations in the northern plume are typically lower. The maximum benzene concentration in the past year was 210 µg/L and LNAPL has not been detected in any northern plume wells since 2003.

The 1992 ROD cleanup goals for groundwater include five chemicals of concern (COCs): benzene, toluene, ethylbenzene, 1,2-dichloroethane (1,2-DCA), and methylene chloride. Since 1990, detectable concentrations of ethylbenzene have never exceeded its cleanup goal. Methylene chloride and 1,2-DCA have not been detected since 1991. Toluene is significantly less abundant in groundwater beneath the Site than benzene. In the few wells where the toluene concentration exceeds its ROD cleanup goal of 100 µg/L, benzene concentration also exceeds its ROD cleanup goal of 1 µg/L. **Therefore, of the five ROD COCs, benzene is the primary concern in groundwater and benzene and toluene are the only COCs that need consideration in an amended ROD.** A recent, two-year groundwater monitoring program (2007 through 2008) conducted for naphthalene found no results exceeding the State of California notification level of 17 µg/L. Therefore, naphthalene is not a COC in groundwater at the Site.

Recent studies have contributed multiple lines of evidence for intrinsic biodegradation of dissolved benzene that prevents migration of the contaminant plumes at the Site. **Municipal drinking water wells in the City are not threatened.** Evidence for biodegradation includes:

- ◆ Time-series plots that demonstrate continued decline in dissolved benzene concentrations.
- ◆ Time-series isopleth maps that demonstrate the dissolved plumes are stable and shrinking.
- ◆ Benzene mass calculations that demonstrate the dissolved plumes are stable and shrinking.
- ◆ Geochemical indicators of biodegradation, specifically sulfate reduction across both dissolved plumes.
- ◆ Stable isotope ratios for carbon ( $^{13}\text{C}/^{12}\text{C}$ ) vs. hydrogen ( $^2\text{H}/^1\text{H}$ ) demonstrate a biodegradation signature.
- ◆ Vertical concentration profiles of soil vapor that demonstrate natural attenuation within the vadose zone above the groundwater plumes.
- ◆ Reduction in the mole fraction of benzene in LNAPL in the smear zone.

A vapor study conducted in the unsaturated zone above the groundwater contaminant plumes demonstrated that natural attenuation in the unsaturated zone is preventing migration of contaminants in soil vapor from groundwater to ground surface (i.e., vapor intrusion is not occurring).

### ***Contaminant Fate and Transport Modeling***

Contaminant fate and transport modeling was conducted for key COCs in groundwater (benzene) and soil (lead and PAHs). In situ remedial options for treating lead, naphthalene, and benzo(a)pyrene in shallow soil is feasible and impacts to groundwater are unlikely. The groundwater modeling results provide insight as to what remedial techniques might be effective in cleaning up groundwater beneath the Site. The modeling results also indicate that given the subsurface geologic conditions along with a submerged smear zone, progress would be slow with respect to any groundwater remedy selected. Remedial options for groundwater should focus on changing LNAPL composition in the smear zone beneath the water table using technologies that can strip volatile constituents (i.e., benzene) such as air sparging. Upon completion of air sparging for the LNAPL objective, naturally occurring sulfate in groundwater could be circulated within the remaining dissolved plume to enhance biodegradation until such a point when the program may be transitioned to long-term MNA.

### ***Risk Assessments***

A human health risk assessment (HHRA) and an ecological screening-level assessment (SLERA) for shallow soil and soil gas were performed. Given the size of the Site and complexity of past operations, chemical releases, and geography, it was determined that evaluating the Site as individual AOCs would help to focus the health risk evaluations on specific units amenable to discrete risk-management or remedial actions. Criteria used to group sample locations into defined AOCs included similarities in historical uses, chemical releases, geographical proximity, terrain, and potential future land use. The Site was divided into 14 areas of concern (AOCs) for evaluating human health risks. Only AOC 1 (hillside) was determined to have suitable habitat for evaluating ecological risks. The HHRA was based on a commercial/industrial future land use scenario (the outcome of a thorough reuse assessment), although a residential screening-level risk assessment was also performed for comparison with cleanup costs developed for the focused feasibility study. The risk assessments identified specific locations that exceeded preliminary target concentrations established for both human and ecological receptors to guide cleanup of the shallow soil. Soil vapor detections resulted in a few locations that present unacceptable risks for either human or ecological receptors. COCs in shallow soil identified by the HHRA include inorganic lead, carcinogenic PAHs [benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, chrysene, dibenz(a,h)anthracene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, and naphthalene], and benzene, ethylbenzene, and naphthalene (in soil vapor). Organic lead was initially thought to be of greater concern than inorganic lead, however, additional **geochemical characterization found no alkylated lead species at the Site**. The organic lead appears to be inorganic lead adsorbed to soil organic matter and, based on bioavailability testing, it behaves like inorganic lead. Inorganic lead is the risk driver identified in the SLERA. Figure E-2 presents the COCs by areas of concern.

### ***Risk-Based Concentrations***

The derivation of site-specific risk-based concentrations (RBCs) for the COCs based on the risk assessments was an initial step for developing remedial action objectives (RAOs) and developing

information (impacted soil locations and volumes) for technical feasibility and cost-estimate evaluations needed for remedial decision-making within the Superfund program. RBCs are concentrations in environmental media that are derived to be protective of human health or the environment at specified 'acceptable' levels (in contrast to the HHRA and SLERA methods, which used specific environmental concentrations to predict the health or environmental threat level. For this Site, a range of target cancer risks of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$  and a target noncancer hazard index of 1.0 were used for the combined multiple pathways of exposure to COCs by commercial/industrial and construction worker receptors. RBCs were calculated for COCs for which cleanup criteria were not otherwise defined. Using the EPA Adult Blood Lead model, OEHHA methods, and a target blood lead concentration of an incremental change of 1  $\mu\text{g}/\text{dL}$  in worker receptors, the RBC for inorganic lead in soil would be 320 mg/kg (the California Human Health Screening Level). For AOC 1, the ecological benchmark for lead was set at the maximum background concentration of 26 mg/kg in 0- to 1-ft bgs soils and 56 mg/kg in 1- to 6- ft bgs soils.

### ***Remedial Action Objectives***

In accordance with the National Contingency Plan, site-specific RAOs were developed for soil and groundwater. The site-specific RAOs were developed to address (1) contaminants of concern, (2) media of concern (3) potential exposure pathways, and (4) preliminary remediation levels. The RAOs are based on applicable or relevant and appropriate requirements (ARARs) and site-specific RBCs (cleanup criteria). The RAOs are:

### ***Protection of Human Health***

- ◆ Prevent ingestion of groundwater containing constituent concentrations above state/federal maximum contaminant levels (MCLs).
- ◆ Prevent shallow soil-related exposures (i.e., incidental ingestion, direct dermal contact, particulate inhalation and outdoor vapor inhalation of VOCs adhering to soil) to constituent concentrations exceeding a selected commercial/industrial land use designation cancer risk threshold of  $1 \times 10^{-5}$  or  $1 \times 10^{-6}$  and a non-cancer hazard index of 1.
- ◆ Prevent indoor inhalation through vapor intrusion of constituent concentrations exceeding a selected commercial/industrial land use designation cancer risk threshold of  $1 \times 10^{-5}$  or  $1 \times 10^{-6}$  and a non-cancer hazard index of 1.

### ***Protection of the Environment***

- ◆ Restore water quality, at a minimum, to water quality objectives that are protective of beneficial uses within a reasonable timeframe.
- ◆ Prevent constituent soil concentrations from degrading groundwater in excess of state/federal MCLs.
- ◆ Maintain communities of terrestrial plants and soil invertebrates at AOC 01 by achieving soil concentrations below toxicity threshold levels protective of these receptor groups.
- ◆ Maintain Site conditions suitable for populations of terrestrial birds and mammals at AOC 01 by achieving soil and dietary tissue concentrations below toxicity threshold levels protective of these receptor groups.

***Institutional Controls***

EPA, the City of Fillmore, and Chevron agree that limiting future development at the site to commercial/industrial uses only (as opposed to residential or similar uses) makes sense, based on both historical use and reasonably anticipated future uses. EPA and Chevron consider institutional controls (ICs) to be an essential part of the remedial action.

The RI/FS report includes an in-depth analysis of institutional controls, including:

- ◆ Type of institutional control and the relationship of the control to the remedy,
- ◆ The objective to be obtained by each institutional control,
- ◆ The performance standard associated with each institutional control (e.g., prohibit well drilling to prevent exposure to contaminated groundwater),
- ◆ An institutional control monitoring plan, and
- ◆ The entity responsible for implementing, maintaining, and enforcing each institutional control.

***Remedial Alternatives***

The next step in the feasibility study involved screening remedial technologies based on effectiveness, implementability, and cost. The Site was divided into three broad categories requiring remedial actions: shallow soil to 10 ft bgs, the southern groundwater plume, and the northern groundwater plume. Different remedial technologies for soil and groundwater retained during the screening step were evaluated in detail for final selection based on relevance to RAOs.

The remedial alternatives evaluated for each category are:

***Shallow Subsurface Soils to 10 ft bgs***

- ◆ Alternative 1: No Action—Monitoring Only
- ◆ Alternative 2: Excavation with Off-site Disposal at Landfill
- ◆ Alternative 3: On-Site Consolidation and Cap
- ◆ Alternative 4: Ex-Situ Treatment by Composting
- ◆ Alternative 5a: Ex-Situ Treatment by Solidification/Stabilization using Cement
- ◆ Alternative 5b: Ex-Situ Treatment by Solidification/Stabilization using Free Flow<sup>®</sup> Amendment

***Southern Groundwater Plume***

- ◆ Alternative 1: No Action—Monitoring Only
- ◆ Alternative 2: Monitored Natural Attenuation
- ◆ Alternative 3: Air Sparging with Vapor Monitoring
- ◆ Alternative 4: Enhanced Bioremediation using Sulfate
- ◆ Alternative 5: Multiple Technology

### **Northern Groundwater Plume**

- ◆ Alternative 1: No Action—Monitoring Only
- ◆ Alternative 2: Monitored Natural Attenuation
- ◆ Alternative 3: Air Sparging with Vapor Monitoring
- ◆ Alternative 4: Enhanced Bioremediation using Sulfate
- ◆ Alternative 5: Multiple Technology

A comparative analysis of the remedial alternatives considered nine evaluation criteria including:

1. **Overall Protection of Human Health and the Environment:** This criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment.
2. **Compliance with Applicable or Relevant and Appropriate Requirements:** This criterion is used to determine whether the selected alternatives meet the identified ARARs.
3. **Long-Term Effectiveness:** The long-term effectiveness evaluates each alternative against its ability to maintain protection of human health and the environment after implementation considering the magnitude of residual risk (e.g. after source/soil containment and/or treatment are completed) and adequacy/reliability of engineering or institutional controls used for the Site.
4. **Reduction of Toxicity, Mobility, or Volume through Treatment:** This criterion addresses the statutory preference for selecting remedial alternatives that employ a treatment technology.
5. **Short-Term Effectiveness:** This criterion assesses the short-term effects of the alternative during implementation.
6. **Implementability:** This criterion addresses the technical/administrative feasibility of implementing each alternative.
7. **Cost:** This criterion evaluates the overall cost for each alternative including capital costs, annual operation and maintenance, and associated periodic costs. The cost is also evaluated against NPV.
8. **State Acceptance:** This assessment evaluates the technical/administrative concerns the state (or support agency) may have regarding each alternative.
9. **Community Acceptance:** This assessment evaluates the issues/concerns the community may have regarding each alternative.

### **Green Remediation**

Green and sustainable remediation is the practice of balancing environmental, economic, and social indicators so that an acceptable balance exists between the effects of undertaking remediation activities and the benefits that those activities deliver. Conducting remediation to render the land suitable for any purpose no matter how sensitive (unrestricted use) has major green and sustainability flaws and does not typically result in the greatest net environmental benefit. The solution proposed should be the solution that clearly emerges following an assessment of overall benefits, costs and all environmental impacts, value and circumstances of the property, community needs and views, and other relevant issues. In

addition, off-site removal of contaminated soils to a landfill only represents a transfer of contamination from one place to another, even if it does facilitate a redevelopment, and that transfer of contamination has economic, environmental and social costs which may outweigh the benefits arising from treating the contamination on the impacted site.

In April 2008, the EPA issued a Technology Primer addressing the emerging practice of green remediation. In the Primer, green remediation is defined as ‘the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions’. The Primer also states that ‘green remediation strategies offer significant potential for increasing the net benefit of cleanup, saving project costs, and expanding the universe of long-term property use or reuse options without compromising cleanup goals.’ Included in the Primer are a number of Best Management Practices (BMPs) and case studies. The Primer also identifies six core elements of green remediation projects, which are listed below.

- ◆ Energy requirements of the treatment system
- ◆ Air emissions
- ◆ Water requirements and impacts on water resources
- ◆ Land and ecosystem impacts
- ◆ Material consumption and waste generation
- ◆ Long-term stewardship actions

The EPA also issued a draft *Superfund Green Remediation Strategy* in August 2009 (USEPA, 2009b). The Strategy identifies the need for inclusion of BMPs in investigation and remediation activities and goes on to state ‘when developing options for remedial actions that are consistent with remedial action objectives, project managers should consider alternatives that include opportunities for reducing the environmental footprint of remedial design and construction activities.’ In the State of California, the Department of Toxic Substances Control (DTSC) developed a Green Remediation Initiative and issued an *Interim Advisory for Green Remediation* in December 2009 (DTSC, 2009b).

To address green remediation concerns, environmental impacts were analyzed and compared for each of the remediation alternatives for shallow soils and groundwater. The analysis considered the following impacts:

- ◆ Greenhouse Gas (GHG) emissions
- ◆ Air emissions
- ◆ Water usage
- ◆ Electricity usage
- ◆ Material Use Reduction
- ◆ Landfill Space Use

- ◆ Noise
- ◆ Safety

The recommended remedial alternatives for shallow soil and the northern groundwater plume have the **fewest environmental impacts** in terms of green and sustainable remediation. The recommended remedial alternative for the southern groundwater plume has **fewer environmental impacts** than the other engineered remedies.

#### ***Recommended Remedial Alternatives for Shallow Subsurface Soils to 10 ft bgs***

**The recommended alternative is excavation with on-site consolidation and cap.** Based on fate and transport modeling results for soil and site-specific geochemical characterization of lead confirmed by treatability study results, the COCs are relatively immobile. On-site consolidation can adequately treat the COCs (inorganic lead and PAHs) with the added benefit of ‘least overall impact’ to the environment when considering the recent expectation for green and sustainable remediation. The impacted soil will be handled less than other alternatives, thus the added benefit of reduced dust generated during remediation at the Site. Soil excavation based on a risk criterion of  $1 \times 10^{-5}$  is appropriate, as this threshold best aligns with the intended future land use as a commercial/industrial property and reduces the environmental ‘footprint’ of soil remediation activities. Institutional controls will also be an integral part of the remedy. Pipeline removals will occur prior to soil excavation and re-grading activities.

A secondary alternative for consideration is on-site solidification/stabilization with a cement stabilizer. This treatment option is the most frequently implemented technology for lead-impacted soil; however, this option generates nearly 10 times the greenhouse gas emissions and utilizes over 3 million more gallons of water than on-site consolidation within the former main waste pit or other suitable on-site location. In light of the demonstrated lead stability inherent to the native soil at the Site and the fate and transport modeling results for the PAHs, soil treatment with an amendment may provide little value. There is also a potential concern that amendments may liberate naturally occurring arsenic in background soil. The affinity for arsenic adsorbed in soil is pH dependent. Desorption of arsenic from iron oxide surfaces becomes favored as pH values increase substantially above neutrality. Portland cement can increase soil pH to extremely alkaline conditions.

#### ***Recommended Remedial Alternatives for Southern Groundwater Plume***

**The recommended alternative for the southern groundwater plume is the sequential implementation of air sparging (6 years), circulation with existing sulfate-rich groundwater (9 years), and monitored natural attenuation (MNA) (10 years).** The approach takes advantage of the strengths of each technology. First, air sparging will preferentially strip benzene from the LNAPL smear zone, reducing the source to a point where remaining benzene in groundwater is primarily present in the dissolved phase. Then, groundwater circulation will enhance biodegradation of the dissolved phase by mixing naturally occurring sulfate-rich groundwater from the deeper portion of Aquifer I with the shallower plume. Sulfate is significantly more soluble in water and has a much higher biodegradation capacity as an electronic acceptor than oxygen.

An important consideration for conducting the sequential application of these two technologies relates to the transition from an aerobic environment generated during air sparging to anaerobic conditions for the sulfate-reducing environment when implementing the groundwater circulation technology. Air sparging is not likely to deliver sufficient oxygen to create strongly (or even mildly) long-term aerobic conditions in groundwater upon completing air sparging, especially considering the depressed dissolved oxygen concentrations within the southern groundwater plume. It is expected that currently anaerobic conditions will rebound shortly after completing air sparging. This rapid rebound has been documented in published studies. A recent study also supports that re-introduction of sulfate by groundwater circulation should shift the subsurface microbial community to anaerobic character and increase sulfate-reducing bacteria for biodegradation within a fairly short period.

LNAPL trapped in the smear zone is already near the calculated residual saturation, thus recovery via hydraulic methods provides limited (if any) net environmental benefit at this Site. As such, the current LNAPL recovery program will be terminated upon commencing air sparging within the southern groundwater plume. The only true net environmental benefit can be accomplished by changing the LNAPL composition (i.e. benzene content). Thus, once the remaining volatile constituents have been preferentially stripped using air sparging, there will be no net environmental benefit to actively managing any remaining LNAPL; natural source zone depletion will be adequate. Vadose zone monitoring will be conducted during air sparging to evaluate the potential need for soil vapor extraction (SVE). Biodegradation of vapor within the thick vadose zone above the dissolved benzene plumes has been demonstrated and the low mole fraction of benzene remaining in the LNAPL (0.21-0.24%) may not require SVE. Air tight seals will be installed on all monitoring wells in the vicinity of air sparging to prevent short-circuiting of injected air.

A secondary option for consideration is MNA, given that the groundwater plume is well characterized with multiple lines of evidence for natural attenuation. An MNA alternative would minimize infrastructure that may delay redevelopment of the Site. The potential for petroleum constituent vapor migration is very low due to natural degradation in the extensive vadose zone with groundwater at approximately 55 ft bgs, supported by data collected during the vapor study.

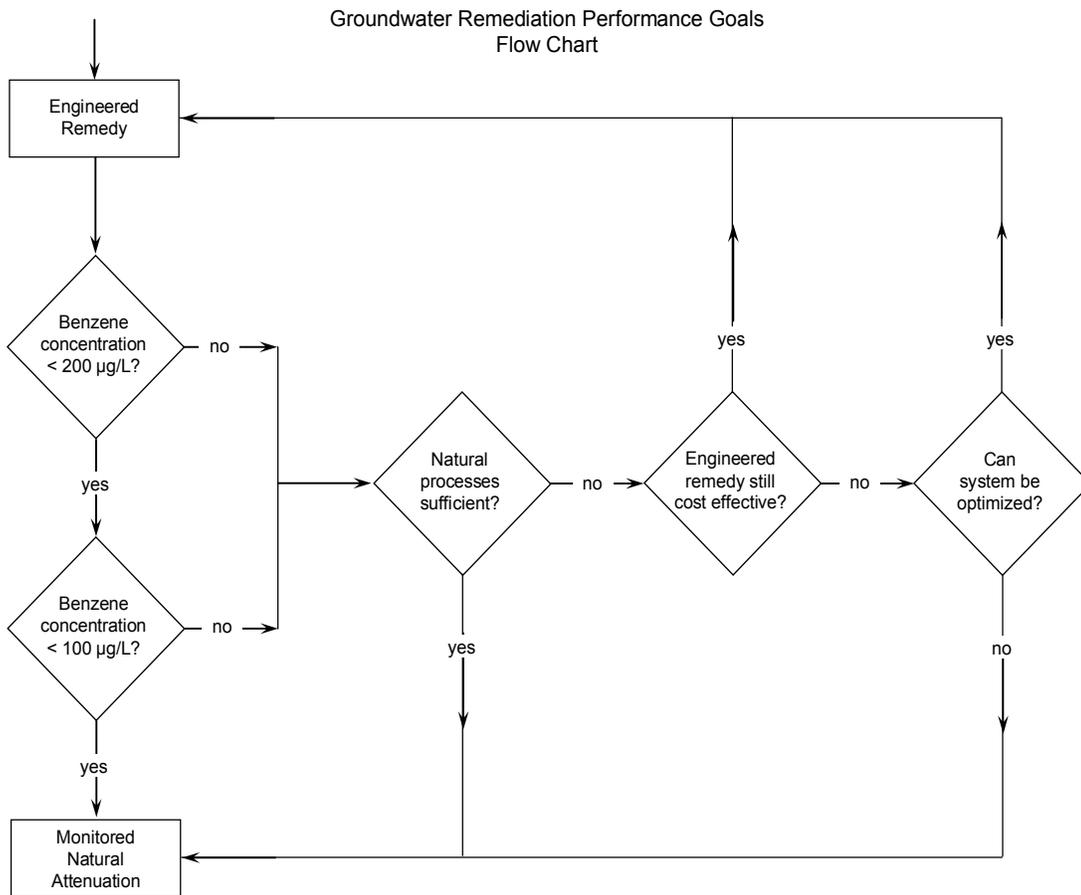
#### ***Recommended Remedial Alternatives for Northern Groundwater Plume***

**The recommended alternative for the northern groundwater plume is MNA.** MNA is preferred since the groundwater plume geometry is well characterized with multiple lines of evidence for natural attenuation. The potential for petroleum constituent vapor migration is very low due to natural degradation in the extensive vadose zone with groundwater at approximately 85 ft bgs, supported by data collected for the vapor study. The cost of implementation is also a consideration since remediation funds would be better focused on the southern groundwater plume, which currently has elevated benzene concentrations extending beyond the property limits of the Site. In addition, the proposed technologies for the southern plume need to be proven successful before considering whether engineered remediation of the northern plume may reduce the timeframe to achieve RAOs or not. An engineered technology (ex. groundwater circulation) may be considered as a contingent remedy in the amended ROD, should MNA progress evaluated during five year reviews not appear to be achieving RAOs within the 50-year reasonable timeframe.

**Optimized Groundwater Monitoring Network and Performance Goals**

An optimized, performance-oriented groundwater monitoring network is proposed regardless of the chosen alternatives. Monitoring wells will be added / reduced to fill data gaps and to eliminate redundant data points or data points that are no longer useful. Performance-oriented monitoring will focus on key indicators to confirm remediation progress and plume stability. The groundwater indicator compounds that will be analyzed by a fixed laboratory are benzene and toluene. The remaining indicator parameters that will be measured using calibrated field instrumentation and a flow-through cell are sulfate, dissolved oxygen, oxygen reduction potential, electrical conductivity, temperature, turbidity, ferrous iron, and pH. The optimized monitoring network and proposed monitoring frequency (sampled semi-annually for 10 years followed by annually in the southern plume, sampled annually in the northern plume), provide adequate data coverage considering historical groundwater concentration trends since 1990. This is especially true when considering the abundant evidence for MNA presented in the RI/FS.

Cleanup standards for groundwater are targeted to reduce the concentration of dissolved benzene to meet the RAO, i.e., the MCL of 1 µg/L. Performance goals are proposed to evaluate remediation progress and to provide the necessary flexibility to manage an engineered remedy before switching to the final remedy of MNA. The performance goals are proposed for the following reasons: 1) the constituents do not pose an imminent threat to human health and the environment under current site conditions, so urgent action is not necessary; 2) groundwater cleanup within heterogeneous units containing abundant fine-grained sediments is often technically challenging; 3) residual LNAPL present beneath the water table (i.e., the smear zone) may persist for many years no matter how aggressive the technology; 4) multiple lines of evidence confirm the effectiveness of natural attenuation; and 5) the remedial approach should attain proposed final cleanup standards for groundwater in a reasonable timeframe. A conceptual process flow for utilizing the performance goals is provided in the following chart.



Maximum benzene concentrations in the northern plume have averaged well below 200 µg/L over the past year and multiple lines of evidence demonstrate that natural processes are sufficient for MNA to achieve the RAO in a reasonable timeframe. Maximum benzene concentrations in the southern plume currently range between 300 and 400 µg/L and natural processes may not be sufficient to achieve the RAO in a reasonable timeframe. The recommended engineered remedy, applied sequentially, may effectively achieve performance goals until natural processes are sufficient for MNA.

**Reasonable Timeframe**

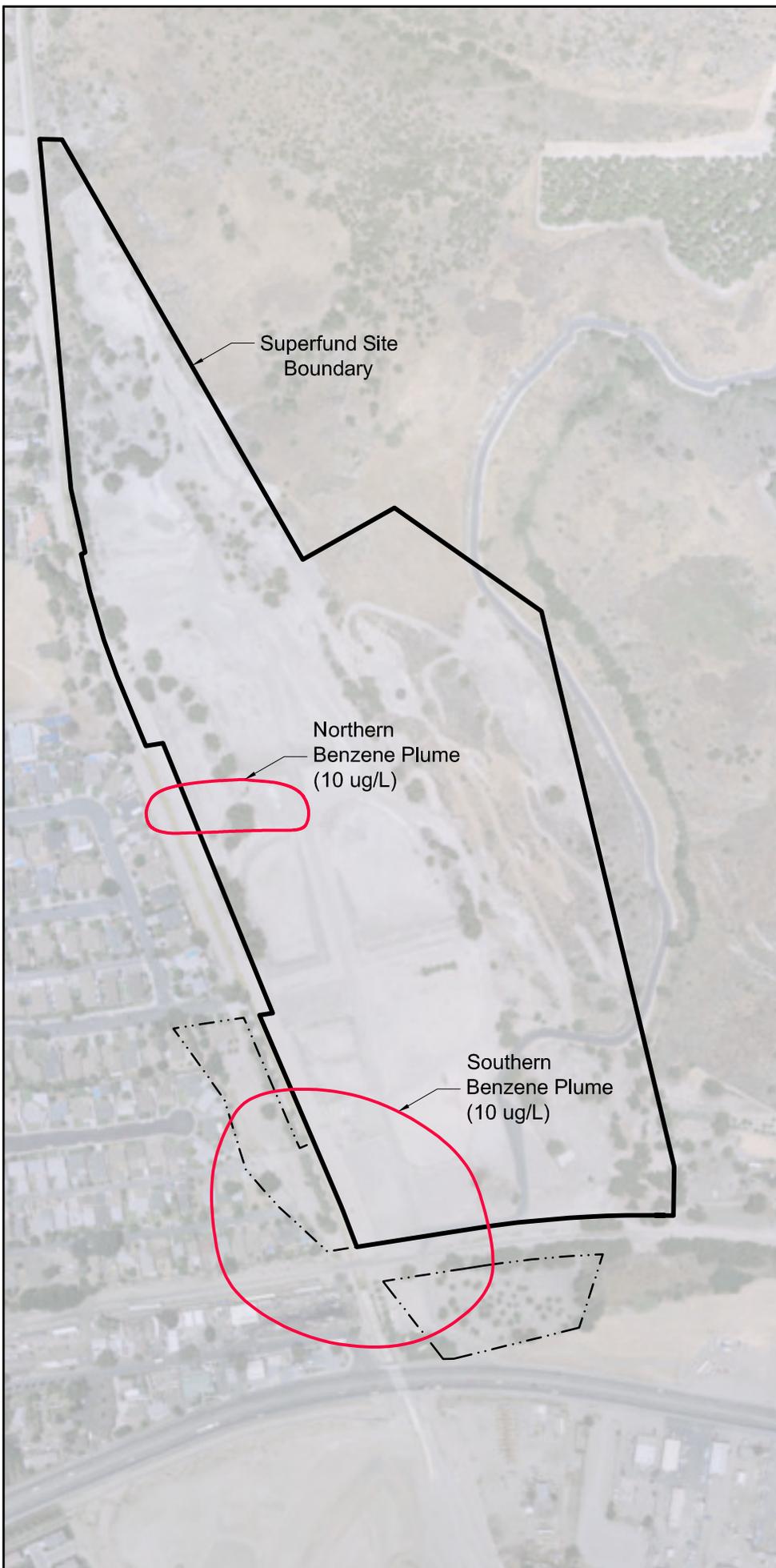
In accordance with EPA’s Office of Solid Waste and Emergency Response (OSWER) Directive, factors to consider in determining whether a groundwater remediation timeframe is appropriate and reasonable include:

- ◆ Need for affected portions of the aquifer for future water supply
- ◆ Subsurface conditions and plume stability
- ◆ Reliability of monitoring and institutional controls over the timeframe
- ◆ Provision by the responsible party over the timeframe



Assumptions have been made in this document about the potential effectiveness of engineered remedies for groundwater. Due to the smear zone and the geologic complexity of the subsurface, effectiveness of the engineered technologies to achieve the groundwater cleanup goal for benzene in less than fifty years is uncertain. Therefore, it is recommended that MNA be an integral part of the final groundwater remedy. Fifty years may likely be a reasonable timeframe that is protective of human health and the environment at this Site. There is no demand in the foreseeable future for the affected Aquifer I at or near the Site. Agricultural water demand is limited at or near the Site and typically is extracted from the deeper, unaffected Aquifer II. As demonstrated by multiple lines of evidence and 15 years of monitoring, the plumes are stable and shrinking. Chevron will maintain adequate provision for long-term reliability of MNA and institutional controls.

The recent investigations and evaluations presented in this RI/FS report provide sufficient information to proceed with decisions on remedial alternatives for the Site. More detailed engineering of selected remedies will be performed during remedial design. During remedial design, soil volumes may be refined with additional lateral delineation as needed to engineer the chosen remedy.



**EXPLANATION**

- - - Property Boundary

**NOTES**

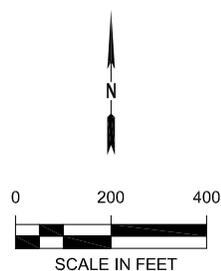
ug/L = Micrograms per Liter

Benzene contours obtained from *Quarterly Groundwater Monitoring Report for First Quarter 2010*, May 15, 2010.

Superfund Site Boundary

Northern Benzene Plume (10 ug/L)

Southern Benzene Plume (10 ug/L)



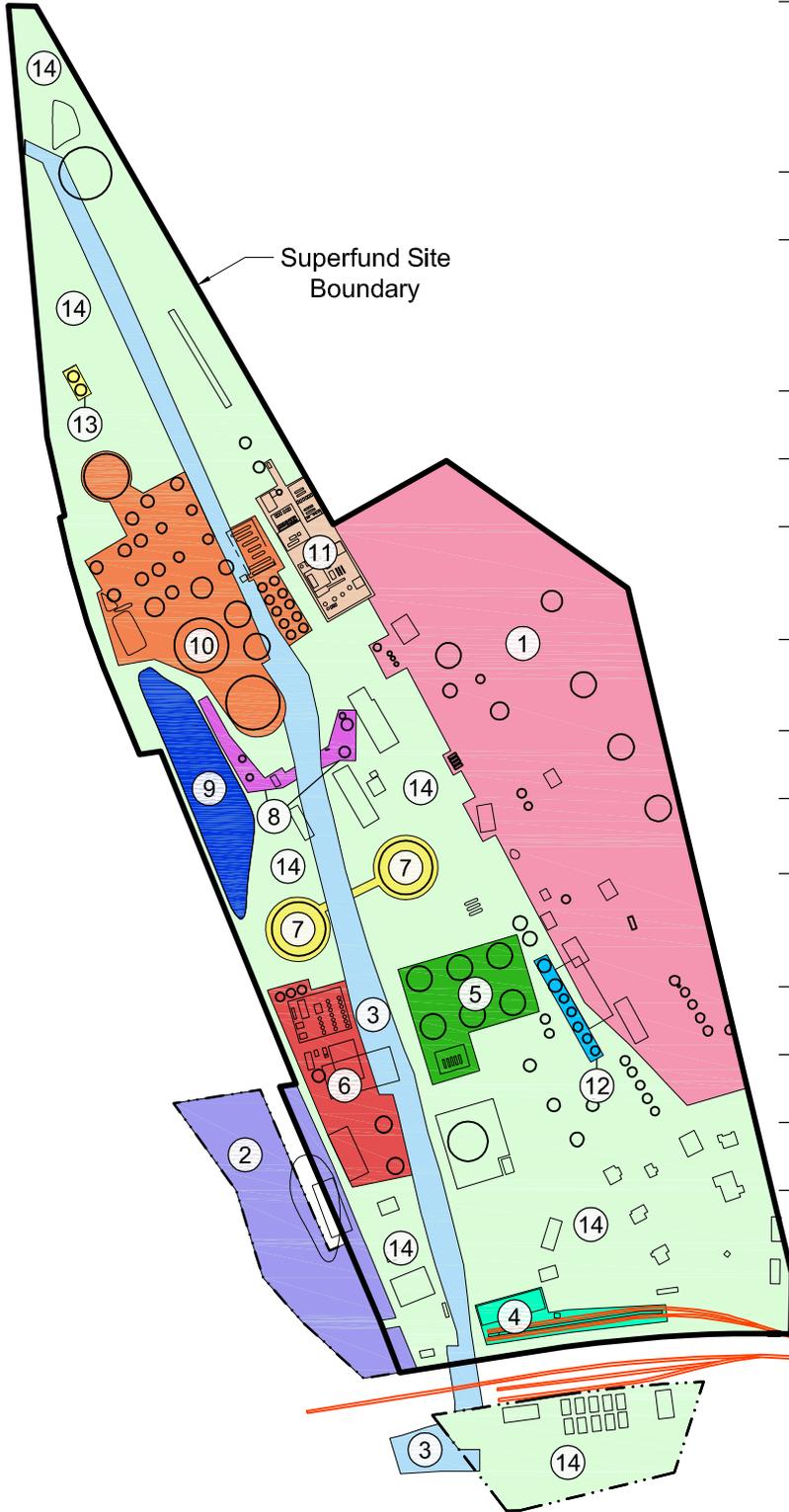
**DISSOLVED BENZENE PLUMES  
(10 ug/L CONTOUR)**

Proj. No.: 29874660	Date: JUNE 2010
Project: CHEVRON PCPL SUPERFUND SITE FILLMORE, CALIFORNIA	Figure: E-1

**EXPLANATION**

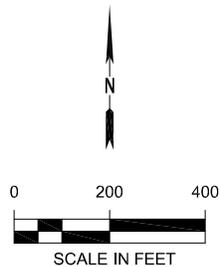
--- Property Boundary

Superfund Site Boundary



AREA OF CONCERN	CHEMICALS OF CONCERN EXCEEDING RISK BASED CRITERIA 10 <sup>-6</sup> Cancer Risk Threshold (Not Applied to Lead*)	CHEMICALS OF CONCERN EXCEEDING RISK BASED CRITERIA 10 <sup>-5</sup> Cancer Risk Threshold (Not Applied to Lead*)
1	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Lead Naphthalene	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Lead
2	None	None
3	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Chrysene Dibenz(a,h)anthracene Lead Naphthalene	Lead
4	Benzo(a)pyrene Indeno(1,2,3-cd)pyrene	None
5	Benzo(a)anthracene	None
6	Benzene Benzo(a)pyrene Ethylbenzene Lead Naphthalene	Benzene Lead
7	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Lead	Lead
8	Benzo(a)pyrene Naphthalene	None
9	Benzo(a)pyrene Lead Naphthalene	Lead
10	Benzo(a)anthracene Benzo(a)pyrene Benzo(k)fluoranthene Lead Naphthalene	Benzo(a)anthracene Benzo(a)pyrene Benzo(k)fluoranthene Lead
11	Lead	Lead
12	None	None
13	Lead	Lead
14	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Naphthalene	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene

\* Lead is a noncancer health hazard and, therefore, unaffected by cancer risk threshold.



<b>URS</b>	
CHEMICALS OF CONCERN IN EACH AREA OF CONCERN	
Proj. No.: 29874660	Date: JUNE 2010
Project: CHEVRON PCPL SUPERFUND SITE FILLMORE, CALIFORNIA	Figure: E-2

## 1.0 INTRODUCTION

This Remedial Investigation / Focused Feasibility Study (RI/FS) report was prepared for the Pacific Coast Pipeline (PCPL) Superfund Site (Site) located in Fillmore, California. URS Corporation (URS) prepared this document under contract to Chevron Environmental Management Company (Chevron). The RI/FS was prepared in general accordance with a document entitled *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* dated October 1988 (USEPA, 1988b), and a *Unilateral Administrative Order (UAO) for Remedial Investigation/Feasibility Study Statement of Work (SOW)* dated September 24, 2009 and amended February 11, 2010 (USEPA, 2009d) (Appendix A). The RI/FS presents several remedial alternatives to address remaining soil and groundwater impacts present at the Site.

In 1992, the EPA issued its remedy decision in a Record of Decision (ROD) for the Site (USEPA, 1992a). The selected remedy for soil (as a preventative measure for groundwater) was Soil Vapor Extraction (SVE). Pump and Treat (P&T) was the selected remedy for groundwater at the Site. The SVE/P&T system operated for several years before reaching asymptotic conditions, and its operation was discontinued with agency concurrence in 2002.

A secondary treatment process was evaluated for groundwater in 2003/2004 by running a pilot test using oxygen release compound (ORC<sup>®</sup>). The pilot test was not successful, but further evaluation of natural attenuation parameters indicate that impacted groundwater is being remediated in-situ by a naturally-occurring sulfate-reducing environment beneath the Site. Monitored Natural Attenuation (MNA) became a preferred logical remedy as stated in the Second Five Year Review (USEPA, 2006b), but needed further evaluation since it was not selected as a contingent remedy in the initial ROD.

A secondary component of past regulatory decisions was the absence of a remedy for shallow soils, which will be needed for potential redevelopment of the Site as a commercial/industrial property. Chevron initiated a three-phased investigation with agency concurrence to address shallow soils within the upper 10 feet below ground surface (ft bgs). The soil results were used in a risk assessment to establish site-specific remediation goals. This, along with an updated groundwater remedy, is the focus of this report for an upcoming revision to the ROD.

### 1.1 PURPOSE OF THE RI/FS

The purpose of this study is to (1) provide sufficient background information to understand the current conditions at the Site and (2) ensure that appropriate remedial alternatives for both shallow soil and groundwater are evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker for appropriate remedy selection for full-scale design.

### 1.2 SITE BACKGROUND

The site background provides a Site description, general history of operations, a chronology of the Site regulatory history, and a summary of previous investigations. A majority of the critical decision documents referenced in this report are provided in electronic format in Appendix B.

The EPA (Region 9) is the regulatory authority administering the Consent Decree (USEPA, 1993a). The Department of Toxic Substances Control (DTSC) is the state agency administering the Consent Decree for the State of California. However, the EPA became the lead agency for the project when the Site was listed on the National Priorities List (NPL).

The Consent Decree lists five chemical constituents with groundwater cleanup goals: benzene, toluene, ethylbenzene, 1,2-dichloroethane (1,2-DCA), and methylene chloride (USEPA, 1993a). The Consent Decree has no regulatory provision for soil characterization, other than for protection of the underlying groundwater from the five listed chemical constituents identified in the EPA ROD (USEPA, 1992a).

### 1.2.1 Site Description

The Site is referred to as the PCPL Superfund Site. The EPA identification number for the Site is CAD980636781. The Site is located along the eastern border of the City of Fillmore in Ventura County, California (Figure 1).

### 1.2.2 Site Operational History

The Site was formerly an oil refinery from circa 1915 until 1950. The earliest known reference indicates that refining operations were conducted as the ‘Ventura Refinery’ in 1917 (ENSR, 1990). Texaco acquired the existing refinery in 1928. The refinery was shutdown in 1950, dismantled by 1951 leaving approximately eight (8) aboveground storage tanks (AST), and converted to a crude oil pumping station by 1952. Pumping station operations discontinued in 2000 and nearly all of the remaining facilities were dismantled and removed by July 2002. The last remaining AST was removed in August 2004.

Former facility features depicted on the figures provided in this report represent a compilation of previous operations, based primarily on two facility drawings dated 1919 and 1933. The second drawing (1933) was last revised in 1947. The drawings contain details of past operations; however, the text on most of the drawings was poor quality due to replication of the drawings over the years. The site operations have been detailed in numerous reports; however, in many cases, the exact history was difficult to evaluate due to the lack of available information in the project records. The available historical facility drawings are provided in Appendix C of the Phase 3 Report (URS, 2009a) (Appendix B).

#### 1.2.2.1 Former Refinery Operations

The petroleum products processed at the refinery were primarily documented within the operating records contained within company annual reports. ENSR (1990) states that a 1923 annual report for Ventura Consolidated Oil Field indicated the refinery had a capacity to process crude oil/blending stock at approximately 4,700 barrels per day (BPD), and that a 1927 annual report for California Petroleum Corporation indicated the refinery had manufacturing facilities capable of producing lubricating oil and paraffin wax. Due to redundant wax manufacturing capabilities at other refining facilities owned by Texaco, it is probable that wax operations ceased upon acquisition of the refinery in 1928. It is unlikely that solvents were used for wax manufacturing since solvent use did not become widespread until the 1940s (ENSR, 1991). A historical review (aerial photographs and site drawings) indicates the wax plant was removed in the early 1930s. A 1947 facility map (ENSR, 1990) shows that the wax plant area was subsequently redeveloped with a gasoline blending tank and piping from the ethyl unloading area.



It appears the refinery was a single topping plant with upgrades for thermal cracking. Facility drawings suggest that the primary products were gasoline, diesel, and fuel oil. The facility also included a steam still, absorber, stabilizer, caustic treater, and polymerization units (ENSR, 1990). The 1947 Texaco map shows a Southern Pacific Railroad (SPRR) spur located in the southern portion of the site with a refueling area for train locomotives and an area to unload tetraethyl lead to a gas blending system. The following list provides a summary of known operating units as well as their approximate capacity. Areas of concern (AOCs), which were developed to facilitate the health risk assessment (AOCs are discussed further in Section 6.2.2) are cross referenced with associated historical units on the table below and depicted on Figure 2.

Summary of Known Operating Units and Approximate Capacity				
Process Unit	AOC	Service	Probable Waste Stream	Capacity (BPD)
Crude Shell Stills 7, 8, 9	11	Crude Processing	Unknown	Unknown
Crude Pipe Still 1	11	Crude Processing	Cleaning Sludge, Wastewater	Unknown
Pressure Pipe Still 1	11	Crude/Thermal Cracking	Cleaning Sludge, Wastewater	4,700
Steam Still	6	Naphtha Treating	Wastewater	1,440
Naphtha Continuous Agitators	6	Naphtha Treating	Acid Sludge	3,100
Polymerization	11	Gasoline Production	Unknown	1,200
Caustic Treater	11	H <sub>2</sub> S Removal	Cleaning Sludge	300
Absorber	6	Naphtha Recovery	Cleaning Sludge	30 MSCFH
Stabilizer	11	Light Ends Removal	Cleaning Sludge	1,680
H <sub>2</sub> S Fractionator	11	Naphtha Treating	Wastewater Containing H <sub>2</sub> S	1,300
Boiler House	8	Utilities	Blowdown, Dissolved Solids	Unknown
Cooling Tower	14	Various	Blowdown, Potential Chromate Concentration	Unknown
Wax Plant	14	Wax Production	Unknown	Unknown
Tanks	Various	Storage of Crude Oil, Naphtha, Blended Gasoline, Wastewater, Diesel, Caustic	Tank Bottoms, Oily Material, Acid Sludge	Various

Source: ENSR (1990 and 1991)

H<sub>2</sub>S = Hydrogen Sulfide

MSCFH = Million Standard Cubic Feet per Hour

AOC: Area of Concern (see Section 6.2.2)

ENSR provided descriptions of each process unit in the *Site Background Summary Report* (ENSR, 1990). The descriptions are summarized as follows:

- ◆ **Hydrogen Sulfide Fractionator** – The purpose of this unit was to treat raw naphtha from the Pressure Pipe Still No. 1 by fractionating out the H<sub>2</sub>S. The resulting products were a stabilized naphtha and gas stream. The gas was routed to a refinery plant fuel system, which was used in heater and boiler operations. Intermittent water drains, which most likely contained H<sub>2</sub>S, were routed to the refinery sewer system.



- ◆ **Crude Pressurization Pipe Still No. 1** – The purpose of this unit was to convert incoming crude oil into a wide range of intermediate refinery streams which were further refined downstream into refinery products. Processing operations at this unit included a flash tower, evaporator tower, bubble tower, accumulators with likely intermittent water draws to the sewer system, a reducing furnace, cracking furnace, condenser box, and a number of heat exchangers. The unit did not contain a desalter.
- ◆ **Continuous Agitators** – The overall objective of this process (known as sweetening) was to remove mercaptans and elemental sulfur from the process streams, which consisted of agitating the oil with a little sulfur and with alkaline sodium plumbite solution. Acid treatment was also utilized to reduce the sulfur present in the straight run stream. Acid sludge was produced from this process. Standard industry practice was to land dispose acid sludge.
- ◆ **Depropanizer** – The purpose of the Depropanizer (also referred to as the catalytic polymer unit) was to convert olefin rich gases from the stabilizer unit into unfinished polymer gasoline. Catalytic polymerization generally utilizes either a solid phosphoric acid catalyst or sulfuric acid as a catalyst. The depropanizer contains a potassium phosphate ( $K_3PO_4$ )  $H_2S$  removal system, charge tank, reflux accumulators that normally have water draws to the sewer, a depropanizer or stabilizer tower, heater and catalyst towers. Heat exchange bundle cleaning sludge is an EPA listed hazardous waste due to potential hexavalent chromium content.
- ◆ **Steam Still** – The steam still was used to further refine acid treated pressure naphtha. Caustic washing was utilized in the steam still to remove sulfur. The steam was routed to a condenser, and condensate was routed to a water separator, and water from the separator was discharged to the sewer system.
- ◆ **Absorption and Stabilizing Unit** – The purpose of the absorption plant, which received gas oil and wet gas from the pressure still, was to recover naphtha. The charge to the stabilizer plant was cracked naphtha distillate from the pressure naphtha dryer. The purpose of the stabilizer was to remove light ends. The only apparent waste was from heat exchange bundle cleaning sludge and periodic water draws.
- ◆ **Caustic Treater** – The purpose of the caustic treater was to remove  $H_2S$  from polymer gasoline, utilizing  $K_3PO_4$ . Equipment on the unit included heat exchangers, settling tanks, absorbers, and a reboiler. The only apparent waste was intermittently generated heat exchange bundle cleaning sludge.
- ◆ **Wax Plant** – This process unit most likely produced lubricating oils and paraffin from paraffin wax distillates by pressing and steaming or sweating wax from wax distillate. Review of a typical process flow diagram (none exists for the Fillmore Refinery), showed no intermittent or continuous waste stream from this operation.

The aboveground storage tank contents (including stained soil removals) summarized by previous consultants are provided as follows:

Tank No.	AOC	Aboveground Storage Tank Contents	Soil Remediation by Excavation
1	7	Leaded Gas, Crude Oil, Water	Stained soil removed to 2 ft bgs Backfilled with clean soil.
2	7	Crude Oil, Water, Paraffin, Solids	Stained soil removed to 2-3 ft bgs Not Backfilled.
3	1	Unknown	---



Tank No.	AOC	Aboveground Storage Tank Contents	Soil Remediation by Excavation
7	14	Crude Oil	---
8	10	Crude Oil, Water, Paraffin, Solids	---
61-71	10	Unknown	---
73-79	10	Unknown	---
101	10	Fuel Oil, Crude Oil, Water	Stained soil removed to 3 ft bgs Backfilled with clean soil.
102	10	Unknown	---
103	10	Fuel Oil, Crude Oil, Water	---
104-105	1	Unknown	---
110-113	14	Unknown	---
152-157	5	Unknown	---
162-166	12	Unknown	---
172-174	6	Unknown	---
175	14	Unknown	---
177-178	14	Unknown	---
201-202	14	Unknown	---
203-204	1	Diesel Oil	---
205-206	1	Stove Oil	---
207	14	Unknown	---
216	1	Unknown	---
351-352	8	Agitators	---
700	8	Unknown	---
1050	8	Crude Oil, Water, Paraffin	---
3321-3322	13	Unknown	---
5028	1	Water Tank	---
7403	6	Leaded Gas, Crude Oil, Water	Stained soil removed to 2 ft bgs Backfilled with clean soil.
7404	6	Leaded Gas, Crude Oil, Water	Stained soil removed to 2 ft bgs Backfilled with clean soil.
35001	14	Leaded Gas	---
Horizontal	10	Unknown	---
Acid Tank	11	Unknown Acid	---
U-01 to U-38	1,10,12	Unknown	---

Note: The tank name/number for 'U-01 to U-38' was generated for this investigation. The name/number was applied to tanks with an unknown (i.e., 'U') designation due to (1) lack of information and/or (2) poor quality text displayed on facility drawings.

The waste pits were used to dispose of refinery materials. Previous investigations have focused on nine waste pits including a main waste pit located in the center portion of the site along the western boundary. The exact composition of refinery materials disposed of at each pit is unknown; however, it is likely the waste products came from process areas within the facility including tank bottoms, filter clays, and sludge. It is thought that no new waste was disposed of in the pits after the refinery was decommissioned/dismantled in 1951 (ENSR, 1990).

URS identified two additional pits during a file review conducted for this phase of the investigation, which are designated as Pit #10 (suspected pit – 2007) and Pit #11 (suspected pit – 2007). It appears the pits may not have been included in previous investigations. The pits are depicted on the facility drawing last revised in 1947.

### 1.2.2.2 Former Pump Station Operations

Texaco Trading and Transportation, Inc. (TTTI) operated a crude oil pumping station at the Site once the former refinery was decommissioned and dismantled in 1951. A majority of the refinery operation structures were removed during the transition; however, the pumping operations used some of the existing tanks and associated conveyance piping. A Texaco facility drawing indicates the pumping operations may have used Tanks 1, 101, 103, 7403, and 7404. The pumping station included a truck loading rack, manifold, scraper trap, and a truck unloading pump. The facility contained several crude oil trunk lines (4-inch to 8-inch diameter) connected to oil fields in Newhall, Sheills Canyon, and Ventura. It appears Tank 2 and the truck unloading pump were inactive as of 1994 (Texaco, 1994).

In 1998, TTTI became Equilon Pipeline LLC (Equilon) as a result of a joint venture between Texaco and Shell. Equilon discontinued pumping station operations in 2000. In 2001, Chevron merged with Texaco, thereby forming ChevronTexaco. Equilon subsequently became a Shell entity. Shell cleaned/degassed/dismantled/removed the last crude oil tank by August 2004, which concluded their responsibilities at the Site. In May 2005, ChevronTexaco was formally renamed as Chevron.

An underground storage tank (UST) with a capacity of approximately 1,000 gallons was formerly located at the Site. The UST was identified during a file review conducted at the County of Ventura, Environmental Health Department (VCDEH) in early March 2007. A URS representative met with Orren Hoover (former employee at the facility) to identify the location of the former UST on March 22, 2007. An application for a permit to abandon the UST was approved on August 6, 1986. A VCDEH abandon tank checklist (File #376) indicates the UST was removed on October 9, 1986. The checklist also indicates ‘no contamination’ was present beneath the UST. The documents obtained during the file review were provided in the Phase 2 Soil Sampling Report (URS, 2008a).

### 1.2.2.3 Current Operations

The remaining infrastructure currently includes subsurface conveyance piping (oil [idled], water, electrical, etc.), several concrete pads, tank dike berms, a deep well that supplies water to a local farmer, a water storage tank, an idle groundwater treatment system, numerous groundwater monitoring wells, and a remedial contractor field office trailer.

## 1.2.3 Regulatory History / Previous Investigations

An annotated chronology of the site regulatory history / previous investigations is provided as follows:

- ◆ **1980** – Investigation requested by the California Regional Water Quality Control Board – Los Angeles Region (LARWQCB).
- ◆ **1983 to 1989** – Voluntary groundwater and soil assessment conducted by Texaco under the Department of Health Services (DHS) and LARWQCB.

- **1986** – Texaco removed 38,000 tons of waste and contaminated soil from the former main waste pit and other small waste disposal areas.
- ◆ **1989** - EPA added Site to NPL and issued an Administrative Order on Consent for a Remedial Investigation / Feasibility Study.
- ◆ **1990 to 1992** – A *Remedial Investigation/Feasibility Study* (RI/FS) was completed (ENSR, 1991/1992). The RI/FS concluded that there were significant levels of total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene and xylenes (BTEX) in groundwater and significant concentrations of TPH in the vadose zone, but very little evidence of BTEX in the vadose zone. The RI/FS concluded that groundwater pump-and-treat coupled with limited SVE in the vadose zone were the appropriate remediation technologies for the Site.
- ◆ **1992** - The *ROD* was issued in March 1992 (USEPA, 1992a). The selected remedy included groundwater pump-and-treat and SVE for those areas that threaten to contaminate groundwater at levels above site cleanup standards. The ROD listed groundwater cleanup levels for benzene, toluene, ethylbenzene, 1,2-DCA, and methylene chloride. Benzene and toluene are the only compounds that currently exceed the groundwater cleanup standards. Because there was little evidence of BTEX in the vadose zone, no soil cleanup standards were mandated.
- ◆ **1992** – A *Preliminary Design Work Plan* (Environmental Solutions, Inc. [ESI], 1992) was submitted and approved by EPA in December 1992.
- ◆ **1993** – The *Consent Decree* was entered in August 1993. The *Phase 1 Design Report* (ESI, 1993) was completed in September 1993. The Phase 1 remedial program included pilot testing for SVE treatment and groundwater extraction and treatment with granular activated carbon and discharge to Pole Creek under a National Pollutant Discharge Elimination System (NPDES) permit. Phase 1 groundwater extraction and treatment began in December 1993.
- ◆ **1994** – Phase 1 vapor extraction began and the *Final Phase 2 Design Report* (E&A, 1994) was submitted and approved.
- ◆ **1995** – The *Final Phase 2 Remedial Action Work Plan* (E&A, 1995a) was submitted and approved. Phase 2 vapor extraction began using thermal oxidation for soil vapor treatment, and the groundwater treatment system (GWTS) operations were upgraded in capacity. The *Operations and Maintenance Plan* and the *Monitoring and Confirmation Sampling Plan* (E&A, 1995b and 1995c) were also submitted and approved.
- ◆ **1996** – An *Interim Remedial Action Plan Report* (E&A, 1996a) was submitted to fulfill the requirements for Construction Complete and Closeout Reporting required by the Consent Decree. System optimization measures were discussed with EPA and documented in a letter (E&A, 1996b).
- ◆ **1997** – Permitting with local agencies was completed and system optimization measures were implemented, including the installation of a new well in an area of higher concentration. The groundwater sampling program was modified as described in an approved technical memorandum (E&A, 1997).
- ◆ **1998** – Monitoring well network upgrades, including abandonment of damaged wells and wells that were no longer useful and installation of new wells, were completed (E&A, 1998a and 1998b).
- ◆ **2000 through 2002** - Texaco applied for renewal of the NPDES permit in March 2000 for discharge of treated water to Pole Creek. LARWQCB indicated that processing for new permits was on hold pending finalization of the California Toxics Rule (CTR) and that the existing permit requirements will remain in effect in the interim. The CTR was finalized in May 2000 in Code of

Federal Regulation (CFR) 40, Part 131. The CTR promulgate numeric criteria for priority pollutants and require the state to issue compliance for new or revised NPDES permit limits. In response, the State Water Resources Control Board (SWRCB) adopted the State Implementation Plan (SWRCB, 2000). As a result of the CTR and the State Implementation Plan, more stringent limits were required for a new permit. Many of the CTR limits were below naturally-occurring background levels. Following negotiations with LARWQCB, ChevronTexaco was given permission to continue operating under the old NPDES permit limits but were required to discontinue discharge under the permit prior to May 2003 (England Geosystem, 2002b).

- ◆ **2001** – EPA completed the *First Five-Year Review Report for Pacific Coast Pipeline Superfund Site* (USEPA, 2001). The report indicated that the treatment systems were operating as designed and the remedial action continued to be protective of human health and the environment.
- ◆ **2001 and 2002** - An early request for authorization to shut off the SVE system was submitted, as shutoff criteria were nearly met (England Geosystem, 2001). In January 2002, the shutoff criteria were met and a technical memorandum detailing the SVE shutoff and monitoring plans was submitted (England Geosystem, 2002a and 2002c). The shutoff was approved on April 11, 2002; and the SVE system operations were discontinued on April 14, 2002. Soil gas concentrations were monitored monthly for eight months following SVE system shutoff. No rebound above the shutoff criteria was observed, and soil vapor monitoring was discontinued in November 2002.
- ◆ **2002 - 2004** – A technical memorandum for GWTS operational modifications and a pilot study for enhanced bioremediation at the PCPL Superfund Site in Fillmore, California was submitted to EPA on October 16, 2002 (England Geosystem, 2002d). On-site conventional groundwater pump-and-treat technology had reached its effective limit at the Site. GWTS operations were discontinued on October 25, 2002 with EPA concurrence. EPA formally approved the modification to the operations of the GWTS at the Site and the pilot testing as proposed in January 2003. The ORC<sup>®</sup> pilot-test, performed in 2003-2004 at the Site, demonstrated that ORC<sup>®</sup> injection was not effective in reducing dissolved-phase benzene concentrations at the Site. The results from the ORC<sup>®</sup> pilot study are described in *Evaluation of the Enhanced Bioattenuation Pilot Study* (England Geosystem, 2005b) (Appendix B). Although the pilot study indicated enhanced bioattenuation was not effective, calculations showed that natural attenuation accounts for a significant amount of destruction of dissolved hydrocarbons in groundwater. Therefore, Chevron continued to evaluate MNA as a groundwater remedial alternative at the Site.
- ◆ **2004** – Regulatory and corporate meetings to discuss forward plans for returning the Site to reuse.
- ◆ **2005** – A work plan for *Phase 1 Soil Sampling* within the former tank areas was submitted (England Geosystem, 2005a) to the EPA, and comments were received from both the EPA and DTSC (USEPA, 2005b). Another work plan was also submitted to EPA and DTSC for review, *Sampling and Analysis Plan for Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolve Phase Benzene Plumes* (URS, 2006a).
- ◆ **2006** – A response to agency comments regarding Phase 1 Soil Sampling was sent by Chevron (Chevron, 2006), and the work plan was subsequently approved by EPA in 2006. Phase 1 soil sampling was conducted by URS and a report was submitted to EPA and DTSC (URS, 2006b). The work plan, *Sampling and Analysis Plan for Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved-Phase Benzene Plumes*, was revised based on comments received from the agencies and subsequently approved by EPA (URS, 2006a). Fieldwork for this investigation began in September 2006 with the collection of soil and preliminary vapor samples.

During the third quarter of 2006, the *Second Five-Year Review Report* was completed (USEPA, 2006b). The review of documents, applicable or relevant and appropriate requirements (ARARs),

risk assumptions, and the results of the site inspection indicate that the remedy is functioning as intended by the ROD to control further migration of the contaminated groundwater.

- ◆ **2007** – A vapor monitoring well installation report, *Continuous Multichannel Tubing (CMT) Well Installation Report* (URS, 2007a), was submitted to EPA and DTSC. Soil vapor samples were collected from the CMT wells in August 2007, as documented in a report titled *Report of Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved-Phase Benzene Plumes*, which was submitted to the EPA and DTSC (URS, 2007c). A work plan for the Phase 2 Soil Investigation was submitted to EPA and DTSC for review. The work plan was revised based on comments received from the agencies and was subsequently approved by EPA (URS, 2007b). Field work for the Phase 2 Soil Investigation was conducted in September and October 2007.
- ◆ **2008** – A report titled *Soil Sampling Report (Phase 2 – Historical Operations)* was submitted to the EPA and DTSC (URS, 2008a). A work plan titled *Work Plan, Phase 3 – Data Gaps for Risk Assessment* was submitted to the EPA and DTSC (URS, 2008b) in April 2008. Chevron responded to comments by the agencies and the work plan was approved in September 2008. The Phase 3 field work commenced in October 2008.
- ◆ **2009** – A report titled *Phase 3 – Shallow Soil Investigation: Data Gap Sampling and Human Health Risk Assessment* was submitted to the EPA and DTSC on May 8, 2009 (URS, 2009a). The EPA provided comments in a letter dated September 15, 2009 (USEPA, 2009c). A response was provided in a letter dated November 20, 2009 (Chevron, 2009b).

EPA issued a Unilateral Administrative Order (UAO) on September 24, 2009 (subsequently amended on February 11, 2010) to acknowledge the voluntary investigations that Chevron had conducted since 2005 with approval from EPA, and to establish a schedule for the focused feasibility study, in progress, for a ROD amendment.

- ◆ **2010** – A report titled *Draft RI/FS* was submitted on November 24, 2009. The EPA and DTSC provided final comments in a letter dated April 27, 2010 (USEPA, 2010).

### 1.2.3.1 Pre-ROD Remedial Activities

From 1983 to 1989 Texaco, under the direction of the California DHS and the Regional Water Quality Control Board, conducted a groundwater and soil assessment. Three groundwater monitoring wells were installed and benzene up to a maximum concentration of 5,800 micrograms per liter ( $\mu\text{g/L}$ ) was detected in groundwater.

In 1986, under the direction of the DHS, Texaco removed 38,000 cubic yards of waste material and contaminated soils from the main waste pit and other disposal areas. This soil removal completed the soil excavation activities that were required at that time. Texaco installed 34 additional groundwater monitoring wells as part of the site investigation. In 1989 the Site was placed on the NPL. Pursuant to an EPA Administrative Order on Consent for Remedial Investigation and Feasibility Study issued in November 1989, Texaco performed some early remedial design activities. These included: 1) preparation of a Preliminary Remedial Design Work Plan; 2) design, implementation, monitoring, and reporting on a pilot study to evaluate the effectiveness of SVE; 3) design of the SVE system; and 4) design of the groundwater extraction and treatment system.

On March 31, 1992, EPA signed the ROD for the Site. The remedial action objectives were to control further migration of the contaminated groundwater, prevent further migration of contamination in soil to

groundwater, and recover and treat contaminated groundwater until the aquifer was restored and groundwater contamination was below cleanup levels. The cleanup levels established in the ROD are the federal and state drinking water standards. EPA selected a remedy that included the following:

- ◆ Construction and operation of a groundwater extraction and treatment system;
- ◆ Discharge of treated groundwater to the aquifer or reuse in a beneficial manner;
- ◆ SVE for those soil areas that threaten to contaminate groundwater;
- ◆ Groundwater monitoring to demonstrate that the extraction system is effectively capturing the contaminant plume; and
- ◆ Maintenance of perimeter fencing until cleanup standards are met.

At the time the ROD was signed, EPA anticipated that the groundwater will be restored to the cleanup standards in 30 years.

### **1.2.3.2 Post-ROD Cleanup (1993 – 2005)**

EPA issued the August 1993 Consent Decree after the ROD was signed. This Consent Decree directed Texaco to install an SVE/P&T system as specified in the ROD. The remedial work was conducted in two phases, a pilot study and the implementation of the pilot study results. The objective of Phase 1 was to provide data necessary for the design of the Phase 2 system while achieving some remediation in the interim.

The Phase 1 GWTS began operating in December 1993. The extracted groundwater was treated with granular activated carbon and discharged to Pole Creek under a NPDES permit. The Phase 1 SVE system operations began in 1994. Several types of soil vapor treatment systems were operated at the Site to evaluate the optimum equipment for Phase 2 operations. Equipment tested at the Site included a regenerative thermal oxidation unit, internal combustion engines (VR Systems), and thermal oxidation units (King Buck/Hasstech and Baker Furnace).

The Phase 2 SVE commenced in May 1995. SVE wells were used in the three target areas evaluated in Phase 1 and the Baker Furnace thermal oxidation unit was selected for the soil vapor treatment. In November 1995, the Phase 2 GWTS began operating. The Phase 2 groundwater system was similar to the Phase 1 system, but it had an increased capacity and several operational modifications to improve performance. The Site achieved construction completion status when the Preliminary Close Out Report was signed on September 27, 1996.

The SVE system reached the shut-off criteria, i.e., benzene less than 100 milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ) (31 parts per million by volume [ppmv]), in January 2002. Soil gas concentrations were monitored monthly for eight months following SVE system shutoff. No rebound above  $100 \text{ mg}/\text{m}^3$  was observed and soil vapor monitoring was discontinued in November 2002. The GWTS operated as designed through October 2002, at which time EPA determined that the ROD cleanup goals could not be achieved by the GWTS. Continued monitoring indicated that the footprint of the groundwater plume remained stable and that concentrations of benzene, the primary contaminant, did not increase. Current



benzene concentrations in groundwater range up to 490 µg/L, a reduction of greater than 90% compare to dissolved benzene concentrations prior to the GWTS and SVE.

Following Tank 101 removal by Shell in August 2004, asphaltic soil material with hydrocarbon odor was found to exist below a portion of the former tank footprint below a layer of clean sand. The material was analyzed and characterized as non-hazardous. Additional material with lead impacts was found in a ring around a portion of the perimeter of the former tank. In July 2005, the material from the perimeter of the former tank was removed from the site and transported under a uniform hazardous waste manifest for disposal. Also in July 2005, the non-hazardous material below the former tank footprint (approximately 240 cubic yards) was removed and transported under non-hazardous waste manifest to a waste treatment facility located in McKittrick, California.

Following removal of the concrete containment pad in the truck rack area by Shell during the first quarter 2005, hydrocarbon stained soils were encountered under the trough area. The stained soil area was approximately 3 feet wide and extended the length of the truck rack pad (55 feet). The stained soil was analyzed and characterized as non-hazardous. The analytical report associated with the waste profiling was included in Appendix D of *Quarterly Status and Groundwater Monitoring Reporting for First Quarter 2005* (England Geosystem, 2005c). In July 2005, the non-hazardous stained soil from the former truck rack area (approximately 42 cubic yards) was removed and transported along with the non-hazardous asphaltic soil material to the waste treatment facility located in McKittrick, California.

### **1.2.3.3 Post-ROD Investigations**

In 2003/2004, an ORC<sup>®</sup> injection pilot test was performed to clean up the remaining benzene in groundwater beneath the Site. ORC<sup>®</sup> injection performed below expectations. Evaluation of the data from the pilot test indicated that the oxygen demand for the saturated zone at this depth was considerably higher than anticipated. Therefore, ORC<sup>®</sup> enhancement is no longer considered as a potential remedial alternative at the Site. For more information about the ORC<sup>®</sup> pilot test, see *Evaluation of the Enhanced Bioattenuation Pilot Study, Pacific Coast Pipeline Superfund Site* (England Geosystem, 2005b) provided in Appendix B.

In 2005, EPA directed Chevron to evaluate the potential for vapor intrusion into residences near two groundwater plumes beneath the Site. Following work plan approval, Chevron conducted the investigation from 2006 to 2007. The evaluation indicated that while vapor (primarily xylene and toluene) from groundwater is migrating up into the deeper soils (40 to 60 ft bgs) located directly above the groundwater plumes; it attenuates rapidly as it rises in the vadose zone and does not pose a risk to nearby residents. The investigation also confirmed that dissolved benzene in groundwater is naturally attenuating.

As the 1992 ROD did not address risk to human health and the environment from exposure to contaminated surface soil, EPA directed Chevron to characterize the Site surface soils in order to evaluate if additional cleanup is required. In 2005 Chevron began a multi-phased shallow soil investigation at the Site in order to assess the potential risk to human health and the environment. Phase 1 focused on the soil under the former storage tanks, Phase 2 included an in-depth review of site historical operations and



shallow soil sampling across the site, and Phase 3 addressed data gaps from the previous investigation phases.

#### **1.2.3.4 Phased Investigation of Shallow Soils**

The phased investigation developed to evaluate shallow (1 to 10 ft bgs) subsurface soil conditions within areas of historical operations is the major focus of this remedial investigation report. Three submittals were prepared and transmitted to EPA (Appendix B):

- ◆ *Soil Sampling Report Phase 1—Former Tank Areas Pacific Coast Pipeline (PCPL) Superfund Site Fillmore, California* (URS, 2006b);
- ◆ *Soil Sampling Report, Phase 2 – Historical Operations, PCPL Superfund Site Fillmore, California* (URS, 2008a); and
- ◆ *Phase 3 Shallow Soil Investigation: Data Gap Sampling and Human Health Risk Assessment* (URS, 2009a).

As noted in each submittal of the phased investigation, a seven-step data quality objective (DQO) process was followed to ensure that appropriate DQOs were defined and met. Each of the three phases were conducted according to EPA-approved work plans. Health and safety during the investigations was guided by the *PCPL Superfund Site Fillmore, California Health and Safety Plan* dated July 21, 2005 [revised October 3, 2006] (URS, 2006c), which is periodically updated to align with site activities and account for updates in state and federal safety requirements. The most recent version of the *Health and Safety Plan* (HASP) is dated October 23, 2009 (URS, 2009c).

While preparations for a feasibility study were underway, a survey of on-site construction materials was completed by URS. The survey was performed to calculate quantities and types of material that could be recycled or need disposal during redevelopment as a commercial/industrial property. The results of this survey are discussed further in Section 4.2.1.9.

### **1.3 REPORT ORGANIZATION**

The EPA provided an RI/FS report format in the UAO SOW (Appendix A). This report was prepared in general accordance with the provided format, but was combined into one document based on past experience to assist with parallel reviews conducted by multiple personnel at EPA/DTSC. As such, the report is organized as follows:

- ◆ Section 2.0 presents site investigation activities since the ROD;
- ◆ Section 3.0 presents descriptions of the Site physical characteristics;
- ◆ Section 4.0 presents the nature and extent of contamination in soil and groundwater;
- ◆ Section 5.0 presents contaminant fate and transport models and discussion;
- ◆ Section 6.0 presents the human health risk assessment for shallow soil;
- ◆ Section 7.0 presents the screening level ecological risk assessment;
- ◆ Section 8.0 presents risk-based concentrations developed for the site;

- ◆ Section 9.0 presents remedial action objectives including ARARs;
- ◆ Section 10.0 presents the screening of remedial technologies;
- ◆ Section 11.0 presents the detailed analysis of remedial alternatives;
- ◆ Section 12.0 presents the comparative analysis of remedial alternatives;
- ◆ Section 13.0 presents a green remediation evaluation of remedial alternatives;
- ◆ Section 14.0 presents the recommended remedial alternatives; and
- ◆ Section 15.0 presents references cited in this report.

The investigation history is fairly complex with numerous past reports including a previous RI/FS. The intent of this document is to summarize and build upon past information and to incorporate the more recent data for an amended ROD. Previous, critical decision documents referenced in this report are listed below and provided in electronic format in Appendix B.

- ◆ *Final Remedial Investigation Report* (ENSR, 1991).
- ◆ *Remedial Investigation/Feasibility Study (RI/FS)* (ENSR, 1992).
- ◆ *Final Phase 2 Design Report, Pacific Coast Pipeline (PCPL) Superfund Site, Fillmore California* (E&A, 1994).
- ◆ *Evaluation of the Enhanced Bioattenuation Pilot Study* (England Geosystem, 2005b).
- ◆ *Report of Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved Phase Benzene Plumes* (URS, 2007c).
- ◆ *Soil Sampling Report Phase 1 – Former Tank Areas* (URS, August 2006b).
- ◆ *Soil Sampling Report Phase 2 – Historical Operations* (URS, April 2008a).
- ◆ *Phase 3 Shallow Soil Investigation – Data Gap Sampling and Human Health Risk Assessment* (URS, May 2009a).
- ◆ *PCPL Fillmore Reuse Assessment* (Chevron, 2010).

## 2.0 SITE INVESTIGATION ACTIVITIES SINCE THE ROD

This section presents a summary of investigation activity conducted since finalizing the ROD (USEPA, 1992a). Pre-ROD investigation activity is not discussed, as requested by the EPA.

- ◆ In 2003/2004, a pilot study was performed to assess an alternative treatment option for groundwater since P&T had reached its effective remedial limit (i.e., asymptotic conditions) within Aquifer I. E&A evaluated the effectiveness of enhanced bioattenuation using ORC®.
- ◆ In 2006/2007, a soil investigation was conducted to characterize subsurface soil vapor conditions and establish natural attenuation characteristics above two dissolved phase benzene plumes located along the western edge of the Site.
- ◆ A three-phased shallow soil investigation was conducted to assess potential impacts from historical operations at the Site. The initial phase commenced in 2006. The final phase concluded in early 2009.

A groundwater monitoring program has been ongoing since the early 1990s. The groundwater monitoring program approved by EPA is currently focused on key indicator wells sampled quarterly or semiannually. The number of monitoring wells sampled each quarter has been optimized over the years to eliminate redundant data points or wells that were no longer useful. An improved, performance-oriented groundwater monitoring network is presented later in this document based on a recent review of historical groundwater concentration trends related to natural attenuation that is evident within groundwater beneath the Site (see Section 11.3.1 and 11.4.1). The pertinent information from groundwater monitoring is discussed briefly throughout this document; however, a more detailed description is provided in the quarterly groundwater reports submitted to EPA (URS, 2010a and 2010b).

The above-listed investigations (including groundwater monitoring) were conducted in accordance with agency approved work plans listed below:

- ◆ *Monitoring and Confirmation Sampling Plan (M&CSP)* (E&A, 1995c);
- ◆ *Revised Technical Memorandum - Recommended Modifications to the Ground Water Sampling Program* (E&A, 1997);
- ◆ *Work Plan for Implementation of Enhanced Bioattenuation Pilot Study* (England Geosystem, 2002e);
- ◆ *Request for Waste Discharge Permit for ORC® Injection* (England Geosystem, 2002f);
- ◆ *General Waste Discharge Requirements (WDR) for ORC® Injection Pilot Test* (Order No. R4-2002-0030) (LARWQCB, 2003a);
- ◆ *Amended Monitoring and Reporting Program* (LARWQCB, 2003b);
- ◆ *Email Documenting Reduction in Monitoring Frequency* (England Geosystem, 2004);
- ◆ *Sampling and Analysis Plan for Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved Phase Benzene Plumes* (URS, 2006a);

- ◆ *Work Plan for Soil Sampling, PCPL Superfund Site, Phase 1 Former Tank Areas* (England Geosystem, Inc., 2005a);
- ◆ *Work Plan for Soil Sampling, Phase 2—Historical Operations* (URS, 2007b); and
- ◆ *Work Plan Phase 3—Data Gaps for Risk Assessment* (URS, 2008b).

The field methods are not discussed in this section since they were already provided in documentation reports submitted to the EPA. The final documentation reports for each investigation are provided for the reader in Appendix B. The investigation results are summarized below.

## 2.1 ENHANCED BIOATTENUATION PILOT STUDY

In 2003/2004, an ORC<sup>®</sup> pilot study was conducted by England Geosystem. The study included an evaluation of three scenarios:

### ***Northern Groundwater Plume: Cut-Off Wall Scenario***

- ◆ ORC<sup>®</sup> slurry injected in a series of boreholes within the northern groundwater plume upgradient of groundwater monitoring wells MW-6S and MW-42S.
- ◆ This option evaluated the effectiveness of a cut-off wall in controlling off-site plume migration in the northern groundwater plume.
- ◆ Twenty-three (23) injection borings (ORC-01 through ORC-23) were installed to approximately 110 ft bgs. The injection spacing was approximately 20 feet. The two rows were oriented in a north-south direction along the eastern bank of Pole Creek (Figure 3).
- ◆ ORC<sup>®</sup> slurry applied to each of the four most northern borings (ORC-01 through ORC-04) was approximately 70 lbs. The slurry applied to each of the remaining borings was approximately 80 lbs.

### ***Southern Groundwater Plume: Source Control Scenario***

- ◆ ORC<sup>®</sup> slurry injected in a series of boreholes within the southern groundwater plume in a grid pattern near MW-39S.
- ◆ This option evaluated the remedial impact in an elevated concentration area with an apparent saturated smeared zone acting as a source of contaminants to the southern groundwater plume.
- ◆ Ten (10) injection borings (ORC-24 through ORC-33) were installed to approximately 85 ft bgs. The injection spacing was approximately 18 feet (Figure 3).
- ◆ ORC<sup>®</sup> slurry applied was approximately 320 lbs in each boring.
- ◆ One groundwater monitoring well (MW-50S) was installed to evaluate conditions down-gradient of the injection area within the southern groundwater plume.

### ***Individual Wells: Bio-fouling / Localized Oxygen Delivery Scenario***

- ◆ Permeable fiber socks containing ORC<sup>®</sup> were installed in groundwater monitoring wells MW-22S and MW-32S.

- ◆ This option evaluated the potential for bio-fouling (iron bacteria production has been encountered in several groundwater monitoring wells at the Site) and to evaluate localized dissolved oxygen (DO) concentrations after sock placement within nearby groundwater monitoring wells.

The ORC<sup>®</sup> pilot study goal was to increase DO in the general vicinity of the injection wells, which would ultimately promote the biological degradation of benzene within Aquifer I. The results of the pilot study did not indicate a positive response since DO concentrations were not detected in nearby groundwater monitoring wells, and benzene concentrations remained relatively stable, fluctuating within the expected historical range for the Site.

The individual well testing results indicated a slight potential for biofouling (presumably iron oxidation) based on the presence of a slimy material on the exterior portion of the product socks. DO concentrations were not detected in the well, nor was it detected in the nearest groundwater monitoring well located at a lateral distance of approximately 15 feet.

## 2.2 NATURAL ATTENUATION ABOVE DISSOLVED-PHASE BENZENE PLUMES

In 2006/2007, a soil investigation was conducted to characterize subsurface soil vapor conditions and establish natural attenuation characteristics above the two dissolved phase benzene plumes located along the western edge of the Site. The sampling area locations were selected so that a transect of vapor monitoring points could be installed approximately perpendicular to the groundwater flow direction and to coincide with the highest dissolved concentrations at the Site. A brief summary is provided as follows:

### ***Drilling Methods***

The drilling methods listed in chronological order of completion included hollow-stem auger, direct push, and rotary sonic drilling.

- ◆ A hollow-stem auger rig was utilized to obtain continuous soil core samples from select boring locations for physical/geochemical testing. The continuous soil core samples were processed for detailed subsurface soil descriptions, physical/geochemical testing, and photographic documentation under ultraviolet light for potential occurrence of light non-aqueous phase liquid (LNAPL).
- ◆ A direct-push rig was utilized during a preliminary vapor sampling investigation conducted perpendicular to the groundwater flow direction to establish a preliminary vapor concentration profile within each investigation area. The preliminary vapor concentration profile was used in conjunction with soil physical/geochemical results to evaluate the final placement of the vapor monitoring points.
- ◆ A rotary-sonic drill rig provided additional continuous cores for soil descriptions as well as installation of CMT sampling systems manufactured by Solinst<sup>®</sup> Canada Ltd. The CMT sampling system allowed the collection of soil vapor from discrete depths within the well.

### ***Southern Sampling Area***

- ◆ Two soil borings (SSA-01 and SSA-02) (Figure 3) were continuously cored to verify subsurface conditions present within the investigation area. Select soil samples were analyzed for physical/geochemical properties at depths commensurate with the vapor monitoring points. The

physical/geochemical data was used to evaluate the final placement of the vapor monitoring points. Photographic documentation was performed under ultraviolet light to evaluate the potential occurrence of LNAPL.

- ◆ Four preliminary vapor sampling locations were advanced at depth intervals of approximately 10 feet (SSA-03, SSA-04, SSA-05, SSA-06) (Figure 3). The vapor samples were submitted for chemical analysis at a fixed laboratory. A preliminary vapor concentration profile was presented to the agency to evaluate the final placement of each vapor monitoring port during installation of the CMT.
- ◆ Four CMT sampling systems were installed with vapor monitoring ports placed at depth intervals of approximately 7 feet (SSA-07, SSA-09, SSA-10, SSA-11) (Figure 3). The depth intervals allowed vapor collection at equal distances between ground surface and groundwater. The bottom sampling port was placed slightly below the water table (55 ft bgs). The depth to groundwater was evaluated from nearby groundwater monitoring wells MW-39S, MW-20S, and MW-50S.

### **Northern Sampling Area**

- ◆ One boring (NSA-01) (Figure 3) was continuously cored to verify subsurface conditions present within the investigation area. Select soil samples were analyzed for physical/geochemical properties at depths commensurate with the vapor monitoring points. The physical/geochemical data was used to evaluate the final placement of the vapor monitoring points. Photographic documentation was performed under ultraviolet light to evaluate the potential occurrence of non-aqueous phase liquid.
- ◆ One preliminary vapor sampling location (NSA-02) was advanced at depth intervals of approximately 20 feet (NSA-02) (Figure 3). The vapor samples were submitted for chemical analysis at a fixed laboratory. A preliminary vapor concentration profile was presented to the agency to evaluate the final placement of each vapor monitoring port during installation of the CMT.
- ◆ One CMT sampling system was installed with vapor monitoring ports placed at depth intervals of approximately 13 feet (NSA-03) (Figure 3). The depth intervals allowed vapor collection at equal distances between ground surface and groundwater. The bottom sampling port was placed slightly below the water table (90 ft bgs). The depth to groundwater was evaluated from nearby groundwater monitoring wells MW-32S and MW-42S.

The investigation included the collection of depth-discrete soil vapor samples from vapor monitoring wells during two seasonal events. The wet season vapor sampling event was conducted in March 2007. The dry season vapor sampling event was conducted in August 2007. Based on the soil vapor sampling results and the natural attenuation and human health risk evaluations, the subsurface vapor-to-indoor air exposure pathway was considered to be insignificant. The conclusions were accepted by EPA.

## **2.3 SHALLOW SOIL INVESTIGATION TO 10 Ft BGS**

The three phases of the shallow soil investigation employed field investigative techniques similar to those used during previous investigations conducted at the Site. A direct push rig was used to obtain soil samples at depths of approximately 1, 5, and 10 ft bgs. A direct push rig was also used to collect soil vapor samples at depths of approximately 5 and 10 ft bgs. The soil/vapor samples were used to establish



risk-based cleanup criteria for potential redevelopment as a commercial/industrial property. A brief summary is provided as follows:

### **Phase 1—Former Tank Areas**

In 2006, twenty-two (22) soil borings were advanced beneath former above-ground petroleum storage tanks during Phase 1. The results were documented in a report entitled *Soil Sampling Report Phase 1—Former Tank Areas* dated September 8, 2006 (URS, 2006b).

### **Phase 2—Historical Operations**

In 2007, two hundred ninety-six (296) soil borings were advanced beneath areas of known historical operations. The results were documented in a report entitled *Soil Sampling Report, Phase 2 – Historical Operations* dated April 15, 2008 (URS, 2008a).

### **Phase 3—Data Gap Sampling**

In 2008/2009, twenty-seven (27) soil/vapor borings were advanced throughout the facility to address data gaps identified during a preliminary risk assessment. The results were documented in a report entitled *Phase 3 – Shallow Soil Investigation: Data Gap Sampling and Human Health Risk Assessment* dated May 8, 2009 (URS, 2009a).

The results of the phased shallow soil investigations are presented in Section 4.2.1 and the boring locations are shown on Figure 3.

## 3.0 PHYSICAL CHARACTERISTICS OF THE SITE

A brief summary of Site physical characteristics is provided in this section from several historical reports as appropriate for the amended ROD. The characteristics discussed include the geography, meteorology, surface hydrology, geology, hydrogeology, beneficial use of water, demography, and ecology. A detailed description is provided in past documentation reports included in Appendix B.

### 3.1 GEOGRAPHY

The land surface elevation changes from north-to-south across the Site. The elevation in the northern portion of the property is approximately 575 feet above mean sea level (ft amsl). The southern portion of the property is approximately 475 ft amsl. The elevation of the hill along the eastern property boundary is approximately 665 ft amsl.

### 3.2 METEOROLOGY

The climate is semi-arid, Mediterranean. The average annual rainfall is approximately 18-inches. The majority of regional precipitation occurs during an approximately four month period in the winter when the daily high temperature is approximately in the mid-60s. The daily high temperature in the summer is approximately in the mid-80s. The prevailing wind direction is estimated to be westerly towards the Pacific Ocean.

### 3.3 SURFACE HYDROLOGY

The Santa Clara River is located approximately 0.5-mile south of the Site. The river flows in a westerly direction towards its terminus at the Pacific Ocean. As expected, peak flows coincide with winter rain events and typically begin to subside around April.

Two perennial streams in the general vicinity of the Site provide water to the Santa Clara River. The first tributary is Sespe Creek. This creek drains the majority of the local mountains to the north and is located west-southwest from the Site at a distance of approximately 1.5 miles.

The second tributary is Pole Creek. This creek runs adjacent to the western border of the Site and drains an area of approximately 7.5 square miles. The lower portion of this creek was channelized with concrete in circa 1973. A debris flow retention basin was recently constructed in 2008, just south of Highway 126.

### 3.4 GEOLOGY

#### 3.4.1 Regional Geology

The Site lies along the northern boundary of the Santa Clara Trough, which contains sedimentary deposits over 40,000 feet thick ranging from Cretaceous to Recent in age (Figure 4). In the Fillmore area, the Santa Clara Trough is bordered by the San Cayetano Fault on the north and the Oakridge Fault on the south. The San Cayetano Fault passes beneath the Site approximately parallel to the eastern site boundary (Figure 4). Fractured bedrock along the fault has resulted in extensive land sliding. This fractured rock

has also provided a conduit for naturally-occurring hydrocarbons to reach the Earth's surface. Crude oil seeps and tar sands are common features in the site vicinity.

The Site lies within a petroleum producing province along the eastern portion of Ventura Basin (Figure 5). Oilfields located within the site vicinity include the Fillmore, Shiells Canyon, and Bardsdale fields. In addition to the oilfields, several surface oil and tar sand accumulations or seeps have been mapped near the Site (Dibblee, 1990). These reportedly occur in the fractured sands and shale of the Monterey Formation north of the site along Pole Creek and in recent landslide debris directly adjacent to the site (Figure 4). It is likely that the observed oil seeps resulted from the migration of hydrocarbons along fractures in the Monterey Formation associated with the San Cayetano Fault. Some of the seep material was previously analyzed and found to contain naturally-occurring benzene.

### 3.4.2 Local Geology

The subsurface interpretations are based on past investigations conducted at the Site. The near-surface geology can be characterized as consisting of laterally discontinuous interlayers of unconsolidated, fine- to coarse-grained detritus deposited in stream channel, alluvial fans, and mass wasting depositional environments associated with nearby landslides. The extreme heterogeneity of the subsurface strata has created a complex hydrogeologic environment as shown in several cross-sections provided in the *Final Phase 2 Design Report* (E&A, 1994). The subsurface conditions within the vadose zone soils were recently confirmed in a report titled *Report of Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved-Phase Benzene Plumes* (URS, 2007c). These reports are provided in Appendix B.

URS generated two additional cross-sections (including the more recent dataset) for this report, parallel to groundwater flow direction, which are generally consistent with past interpretations for the Site. The geologic cross-section lines are shown on Figure 6. The subsurface sediments (including historical groundwater fluctuations) present within the northern groundwater plume area are shown on geologic cross section A-A' (Figure 7). The subsurface sediments (including historical groundwater fluctuations) present within the southern groundwater plume area are shown on geologic cross section B-B' (Figure 8).

## 3.5 HYDROGEOLOGY

### 3.5.1 Regional Hydrogeology

The Site is located within the eastern portion of the Fillmore Groundwater Basin. In the Site area, the alluvial deposits and the underlying San Pedro Formation are the major water-bearing units with groundwater flow directions towards the west following the Santa Clara River. Regionally, long-term groundwater monitoring has been measured in a nearby well owned by Ventura County Watershed Protection District (VCWPD). The maximum recorded groundwater fluctuation within the general vicinity was 50 feet.

### 3.5.2 Local Hydrogeology

The local hydrogeology is categorically divided into three water bearing zones including a Perched Zone, Aquifer I, and Aquifer II. A brief description of each zone (listed according to depth) is provided as follows:

#### **Perched Zone**

- ◆ Fourteen (14) groundwater monitoring wells were initially installed to assess standing water within shallow discontinuous fine-grained sediments designated as the Perched Zone. The only remaining well is MW-10P. The Perched Zone has not been sampled since November 1996.

#### **Aquifer I**

- ◆ Thirty-four (34) groundwater monitoring wells are currently sampled quarterly or semi-annually in Aquifer I. This unconfined to semi-confined zone is the primary focus of groundwater investigations at the Site.

#### **Aquifer II**

- ◆ Six (6) groundwater monitoring wells were initially installed to assess potential impacts within deeper groundwater in Aquifer II. The only remaining well is MW-31D. This zone is not considered to be impacted with shallower petroleum hydrocarbons and has not been sampled since February 1997.

Two distinct groundwater plumes (north and south) are located within Aquifer I (Figure 6). The northern plume groundwater flow direction is generally towards the northwest. The southern plume groundwater flow direction is generally towards the west. The groundwater contours as well as flow directions (First Quarter 2010) are shown on Figure 9. Hydraulic parameters for each plume are summarized as follows:

<b>Designated Plume within Aquifer I</b>	<b>Flow Direction</b>	<b>Depth to Water (ft bgs)</b>	<b>Hydraulic Conductivity (ft/day)</b>	<b>Gradient (Q209)</b>	<b>Seepage Velocity (ft/yr)</b>
Northern Groundwater Plume	northwest	85	13 (P-2)	0.009	142
Southern Groundwater Plume	west	55	14 (EW-04)	0.013	219

Notes:

- 1) Groundwater monitoring data obtained from quarterly groundwater monitoring report for Q1 2010 (URS, 2010b).
  - 2) Aquifer testing data obtained from the Final Phase 2 Design Report (E&A, 1994).
  - 3) The effective porosity used to calculate seepage velocity is 30%.
- ft/day = feet per day  
ft/yr = feet per year

A local groundwater fluctuation trend also exists beneath the Site. Seasonal groundwater fluctuations are estimated to be approximately 20 feet. This is an important consideration when evaluating petroleum hydrocarbon occurrence within Aquifer I, which is discussed further in Section 4.0.



### 3.6 BENEFICIAL USE OF WATER

The LARWQCB developed water quality control plans for basins within their jurisdiction in accordance with the Porter-Cologne Water Quality Control Act (California Water Code, Division 7, Water Quality). In the water quality control plans, beneficial uses of the local water resources are designated and water quality objectives are established to protect or restore these beneficial uses. Beneficial uses of groundwater and surface water of the Site were reviewed in the Water Quality Control Plan for the Los Angeles Region (LARWQCB, 1994).

The Site is located within the Fillmore Hydrologic Subarea of the Sespe Creek Hydrologic Area, associated with the Santa Clara-Calleguas Hydrologic Unit. It is part of the overall Santa Clara River Watershed. The closest surface water body to the site is Pole Creek and, more specifically, the Pole Creek Flood Control Channel. Pole Creek is not mentioned in the regional Water Quality Control Plan (LARWQCB, 1994), but beneficial uses for Sespe Creek and the Santa Clara River are described. Sespe Creek is larger than Pole Creek and is located approximately one-half mile west of the city of Fillmore (Figure 1). It is approximately 1.5 miles from the Site. Similarly to Pole Creek, Sespe Creek flows southerly into the Santa Clara River. Beneficial uses for the Sespe Creek Hydrologic Area were reviewed. For groundwater, beneficial use for the Pole Creek Fan Area, which underlies the city of Fillmore, was reviewed. The Pole Creek Fan Area refers to the area along Pole Creek near the confluence of the Santa Clara River and Sespe Creek (CH2M Hill, 1991).

The existing and potential beneficial water uses for surface waters within the Fillmore Hydrologic Subarea and for groundwater within the Pole Creek Fan Area are presented in the table below:

Beneficial Use	Santa Clara River	Sespe Creek	Groundwater
Municipal and Domestic Supply <sup>1</sup>	Potential	Potential	Existing
Industrial Service Supply	Existing	Existing	Existing
Industrial Process Supply	Existing	Existing	Existing
Agricultural Supply	Existing	Existing	Existing
Groundwater Recharge	Existing	Existing	--
Freshwater Replenishment	Existing	--	--
Water Contact Recreation	Existing	Existing	--
Non-Contact Water Recreation	Existing	Existing	--
Warm Freshwater Habitat	Existing	Existing	--
Cold Freshwater Habitat	--	Existing	--
Wildlife Habitat	Existing	Existing	--
Preservation of Biological Habitats	--	Existing	--
Preservation of Rare/Endangered Species	Existing	Existing	--
Migration of Aquatic Organisms	Existing	Existing	--
Spawning, Reproduction, and/or Early Development	--	Existing	--
Wetland Habitat	Existing	Existing	--

<sup>1</sup> All inland surface and ground waters are assumed to be potentially suitable for municipal use in accordance with State Board Resolution No. 88-63.

Many of the beneficial uses listed above emphasize the importance of maintaining good water quality to protect existing aquatic resources. Although these particular surface water bodies provide habitat critical for sustaining these resources, none of the components of the Fillmore Hydrologic Subarea have been designated as providing critical habitat for the survival of certain listed species (CH2M Hill, 1991).

### **3.6.1.1 Surface Water**

Surface water in the Santa Clara River and Sespe Creek is generally of poor quality during periods of low flow, but water quality improves during the rainy season. Both water bodies are designated as potentially suitable for domestic purposes. Existing uses include industrial and agricultural water supply sources, as well as those associated with maintenance of aquatic ecosystems.

Boron is known to be present at unusually high levels in Sespe Creek, and originates from the Sespe Hot Springs. Chloride and fluoride are also elevated due to the springs. Very high flows in Sespe Creek generate natural erosion resulting in larger amounts of suspended sediments. Most of the watershed falls within the Los Padres National Forest with minimal water quality degradation as a result of development (CH2M Hill, 1991).

### **3.6.1.2 Groundwater**

Groundwater in the Fillmore Basin is suitable for domestic and irrigation uses in some areas, but not all, and the best quality groundwater is found near the mouths of Snow Canyon and Bolder Creek Canyon (CH2M Hill, 1991). Most of the groundwater is considered marginal in quality for these uses. Groundwater is the sole source of the domestic water supply for the city of Fillmore.

As shown in the table above, groundwater in the Pole Creek Fan Area is currently used for municipal, industrial, and agricultural purposes. Groundwater quality in this area ranges from marginal to unsuitable for domestic use, but usable for irrigation of tolerant crops. As previously described, Pole Creek is dry most of the year, and the aquifers beneath the fan area are only minimally recharged by percolation of storm runoff.

## **3.7 DEMOGRAPHY**

The nearby land use designations include primarily agriculture, industrial, and residential. Nearby land use and demographics are presented in more detail in the *PCPL Fillmore Reuse Assessment* (Chevron, 2010) (Appendix B). The neighboring property designations are summarized as follows:

- ◆ North of the Site is primarily open space contained within a relatively steep slope terminating into Pole Creek.
- ◆ East of the Site are rolling hills occupied by an avocado orchard and a large satellite installation. The avocado farm worker lives in a house near the southeastern boundary of the Site.
- ◆ Southeast of the Site is a small parcel zoned for commercial use, located along Highway 126.
- ◆ South of the Site is Highway 126. A small picnic area is located at the entrance to the Site.
- ◆ West of the Site is primarily a residential community with a nearby elementary school.

A rail line currently owned by Ventura County Transportation Commission is located in the southern portion of the Site. A historic train tourist attraction (Fillmore & Western) currently utilizes the rail line and maintains a rail yard adjacent to the southwest corner of the Site. The rail line is also used as a filming location for the entertainment industry.

Fillmore is a relatively small agricultural community with human population of approximately 15,000. The city is committed to slow, well planned growth with a maximum population of 20,000 (City of Fillmore, 2006).

### 3.8 ECOLOGY

The only areas that are not completely graded and devoid of vegetation, and possibly where ecological habitat may exist, are the hillside and the area comprised of former Tanks 7 and 8, on eastern and northern portions of the Site, respectively.

#### **Hillside**

The hillside area of the Site is approximately 11.8 acres and generally very steep, sloping upward to the east. Shrub habitat comprises approximately 85% of the hillside. The vegetation is mostly intact, with a few dirt service roads, and disturbed by the presence of non-native weeds in a few areas. The vegetation consists primarily of Venturan Coastal Sage Scrub (Holland Code 32300). Venturan Coastal Sage Scrub is characterized as low, mostly soft-woody shrubs less than six feet in height, with a mostly closed canopy. This community occurs on dry, often rocky, slopes (Holland, 1986). Species characteristic of this community observed include California sagebrush (*Artemisia californica*), California buckwheat (*Eriogonum fasciculatum*), purple sage (*Salvia leucophylla*), coyote brush (*Baccharis pilularis*), and desert candle (*Yucca whipplei*).

The hillside is approximately 500 to 700 feet away from the Pole Creek Flood Control Channel, a concrete-lined drainage ditch that borders much of the western boundary of the Site. The concrete-lining starts approximately 1700 feet upstream of the Site, where Pole Creek (unlined) becomes the Pole Creek Flood Control Channel. Pole Creek is dry most of the year with a mean daily flow of less than 1 cubic meter per second (CH2M Hill 1991).

#### **Tanks 7 and 8**

The terrain associated with Tanks 7 and 8 (Figure 9) is mostly flat with several manufactured depressions. The approximate size of this area is 7.4 acres. Portions of the area have very little to no vegetation, while other portions contain shrubby native scrub and sparse wooded areas with both native and non-native trees. Ruderal habitat comprises approximately 40% of the groundcover. The ruderal areas are mainly bare, and weeds are chemically-treated on a regular basis with Roundup® to comply with the Fire Department's requirement to minimize brush fire hazards on the property. The few vegetated portions contain non-native annuals, including black mustard and long-beaked filaree.

Shrub habitat comprises approximately 30% of the survey area. The shrub vegetation consists of Venturan Coastal Sage Scrub, described above, but is much less developed and more disturbed than the vegetation observed within the hillside area of the Site. Wooded areas comprise approximately 30% of



the habitat. These areas are patchy, and consist of ornamental, planted trees, including native coast live oak (*Quercus agrifolia*), but are primarily populated by Peruvian pepper tree and eucalyptus.

The tank area ranges from approximately 100 feet away to immediately adjacent to the Pole Creek Flood Control Channel (described above).

## 4.0 NATURE AND EXTENT OF CONTAMINATION

This section includes a review of contaminants present in soil and groundwater at the Site. Historical source areas are identified. Contaminants and the extent of their impacts are summarized. With a focus on impacts in shallow soil to 10 ft bgs, all historical soil results, including results from ‘previous investigations’ and the three-phase shallow soil investigation, were included in this review of the nature and extent of contamination at the Site. The critical decision documents referenced in this report are summarized below and are provided in electronic format in Appendix B. Tables and figures presenting major categories of contaminants are referenced in the section, and tables of the Site historical data are presented in Appendix C.

### 4.1 SOURCES OF CONTAMINANTS

Contaminants found in the historical investigations are typical of petroleum industry operations which were ongoing at the Site since circa 1915. The most recent investigation of shallow soils identified lead impacts within many areas of the Site. Although few VOCs were detected in the recent shallow soil investigation, residual contaminants remain in the saturated zone and continue to be a potential source to groundwater. The key source of groundwater impacts was the main waste pit and assorted smaller pits, especially around the southern portion of the Site. In addition to the groundwater impacts associated with historical operations, groundwater is also impacted by the presence of naturally-occurring hydrocarbons in soils and the underlying strata (see *Final Phase 2 Design Report* [E&A, 1994] in Appendix B).

The ROD identified primary sources of groundwater contamination as a series of nine unlined waste pits that were used to store liquid waste generated during refining operations. The contaminant source from all nine waste pits was removed during soil remediation (excavation) conducted in 1986. Because the pits more or less continuously contained liquid waste while they were in service, they provided a mechanism by which hydrocarbons could migrate into the subsurface. Once operations ceased and the waste within the pits had been removed, the hydraulic head contributing to the vertical migration of hydrocarbon liquids was removed and any further downward migration and lateral spreading was severely curtailed or eliminated.

The majority of groundwater impacts in the former waste areas are the result of groundwater levels that have increased 30 feet since the early 1990s and 50 feet since the 1920s. The saturated zone is impacted predominantly by LNAPL petroleum hydrocarbons trapped in soil pores and sorbed to soils within a smeared zone above and below the water table. These saturated zone impacts are the ongoing source of dissolved phase groundwater contaminants, with two distinct groundwater plumes (a northern and southern plume) identified at the Site. The groundwater conditions within each of these plumes are discussed in further detail later in this section.

LNAPL is occasionally observed in select groundwater monitoring wells in the southern plume. The appearance of LNAPL is generally associated with water table fluctuations. Wells in which LNAPL is periodically observed include EW-1 and EW-4, former extraction wells that operated as part of the SVE/P&T system. In recent years, oily residue (i.e., sheen) has been noted on the gauging probe for a few

other groundwater monitoring wells including MW-8S, MW-9S, MW-17S, and MW-40S. A summary of historical LNAPL removal rates is shown on Table 1.

The majority of soil impacts were addressed as part of the 1986 waste removal actions. Residual soil impacts are present across the Site, predominantly in shallow soils and are likely associated with historical operations, incidental releases, and former waste management practices.

Locations of specific operations and tanks that were suspected as potential sources of subsurface contaminants are listed in Section 1.2.2 and shown on Figure 10 (Site Plan).

## **4.2 CONTAMINANT DISTRIBUTION IN SOIL**

Contaminant distribution in the subsurface soils is differentiated by depth. In the shallow soil, impacts from volatile organic compounds (VOCs) are not commonly seen, and detections of aromatic hydrocarbons (e.g., BTEX) above evaluation criteria are rare. These compounds may have first encountered shallow soil from historical sources but have since either volatilized, biodegraded, or migrated vertically. Hydrocarbons sorbed to deeper soils may now be at residual saturation in the vadose zone or submerged beneath the water table. Contaminants remaining in the shallow soil are PAHs, including benzo(a)pyrene and naphthalene, and metals, specifically inorganic and organic lead.

In the following sections, the analytical results were compared against two industrial screening criteria including Regional Screening Levels (RSLs) established by EPA (USEPA, 2009g) or the California Human Health Screening Levels (CHHSLs) established by Cal/EPA (Cal/EPA, 2009a). The more conservative of the two screening criteria was used as a comparison to determine nature and extent of contamination.

### **4.2.1 Shallow Soils to 10 ft bgs**

This section presents the results of the shallow soil investigation, which occurred in three phases from 2006 to 2009. A summary of all sampling locations (recent Phases 1, 2, and 3, and previous shallow soil results used in the risk assessment) is presented in Table 2. Tables 3, 4, and 5 present sampling plans for the shallow soil investigation phases. Tables 6 through 11 present summary tables of analytical results. Figures 11 through 17 present histograms of constituents of concern in soil and soil vapor. Figures 18 through 20 show locations of results above the industrial RSL or CHSSL at 0 to 10 ft bgs for target constituents naphthalene, benzo(a)pyrene, and inorganic lead. A map in four sections (Figures 21 through 24) presents a summary of soil results used in the human health risk assessment. Data validation reports and laboratory reports, control charts, and calibration data are provided in the Phase 1, 2, and 3 reports (Appendix B). Figure 25 presents a map showing soil vapor analytical results. All historical soil boring locations are shown on Figure 3.

A total of 1,089 soil samples (including 115 replicate soil samples) were collected during the three-phased shallow soil investigation. The soil impacts were generally limited to medium to heavy molecular weight hydrocarbons and inorganics. While VOCs were detected in soils, these were generally at low concentrations with only naphthalene detected in three samples above the industrial RSL. In addition to



petroleum hydrocarbons, elevated levels of organic and inorganic lead were detected in soils at the Site. A brief summary discussion of results by contaminant class follows.

Fourteen (14) AOCs were developed to assist in preparing the health risk evaluation given the size of the property, complexity of past operations, multiple chemical release areas, and geography the Site. The AOCs are discussed further in Section 6.2.2. The soil analytical data (by AOC) are summarized in Tables 6 through 11. The AOCs are shown in Figure 2.

In conjunction with the shallow soil investigation, an assessment of on-site construction debris was performed as well as a shallow soil gas survey, which are also presented in this section.

**4.2.1.1 Volatile Organic Compounds (EPA Method 5035/8260)**

Thirty-two (32) VOCs were detected above laboratory reporting limits in at least one of the soil samples analyzed by EPA Method 5035/8260. Naphthalene was the only VOC with detections above the industrial screening criteria. Naphthalene in three (3) samples exceeded the industrial RSL of 18 milligrams per kilogram (mg/kg). Naphthalene concentrations (as a VOC) are summarized below:

Compound	Range of Detected Concentrations (mg/kg)	Range of Reporting Limits for Non-Detect Samples (mg/kg)	Soil Borings with Detected Concentrations Exceeding Industrial Screening Criteria (ft bgs)
Naphthalene	0.0013 (UT18-URS01 @ 1 ft bgs) to 27 (TK101-WD @ 1 ft bgs)	0.0041 to 0.39	GSP-URS03 (10) P3-URS02 (10) TK101-WD (1)

A VOC analytical data summary is provided in Table 6. A frequency histogram for naphthalene in soil is provided on Figure 11. The naphthalene results (0 to 10 ft bgs) are shown on Figure 18.

**4.2.1.2 Polynuclear Aromatic Hydrocarbons (EPA Method 8270-SIM / EPA Method 8310)**

Twenty-one (21) polynuclear aromatic hydrocarbons (PAHs) were detected above laboratory reporting limits in at least one of the soil samples analyzed by either EPA Method 8310 (Phase 1 soil samples) or EPA Method 8270-SIM (Phase 2 and Phase 3 soil samples). PAH concentrations are summarized below:



Compound	Range of Detected Concentrations (mg/kg)	Range of Reporting Limits for Non-Detect Samples (mg/kg)	Soil Borings with Detected Concentrations Exceeding Industrial Screening Criteria (ft bgs)
Benzo(a)anthracene	0.0022J (TK112-URS01 @ 1ft bgs) to 53 (TK101-WD @ 1 ft bgs)	0.006 to 38	BH-URS02 (1) MPC-URS26 (1) MPC-URS28 (5) P11-URS01 (1) TK101-WD (1) TK2-O2 (1) TK2-F2 (5 and 10) UT18-URS01 (1)
Benzo(a)pyrene	0.0021J (TLR2-URS03 @ 5 ft bgs) to 80 (TK101-WD @ 1 ft bgs)	0.005 to 38	BH-URS02 (1) CLR-URS01-R (5) COU-URS01 (10) HTA-URS05-R (10) MPC-URS26 (1) MPC-URS28 (1 and 5) MWP-URS04 (5) NP-URS04 (5) NP-URS06 (1) P7-URS01 (10) P10-URS01 (1) P11-URS01 (10) P11-URS02 (1) TK101-WD (1) TK162-URS01 (5) TK174-URS01 (5) TK2-F1 (1 and 5) TK2-F2 (1 and 10) TK351-URS01 (1) TK35001-URS02 (10) UT11-URS01 (1 and 5) UT15-URS01 (5) UT18-URS01 (1 and 10) UT22-URS01 (1)
Benzo(b)fluoranthene	0.0023J (TK76-URS01 @ 10 ft bgs) to 52 (BH-URS02 @ 1 ft bgs)	0.006 to 38	BH-URS02 (1) MPC-URS26 (1) MPC-URS28 (5) P11-URS01 (1) UT18-URS01 (1 and 10)
Benzo(k)fluoranthene	0.0030 (NP-URS04 @ 10 ft bgs and TK174-URS01 @ 10 ft bgs) to 25 (TK101-WD @ 1 ft bgs)	0.006 to 38	TK101-WD (1)
Dibenz(a,h)anthracene	0.002J (NP-URS04 @ 10 ft bgs) to 5.8 (BH-URS02 @ 1 ft bgs)	0.006 to 38	BH-URS02 (1) MPC-URS02 (5) MPC-URS04-R (1) UT18-URS01 (1) UPA3-URS02 (5)
Indeno(1,2,3-cd)pyrene	0.002J (BA09-URS01 @ 5 ft bgs and TLR2-URS03 @ 5 ft bgs) to 21,000 (BH-URS02 @ 1 ft bgs)	0.006 to 62	BH-URS02 (1) CLR-URS01 (1) UT18-URS01 (1)
Naphthalene	0.002 (MPC-URS06 @ 5 ft bgs) to 40J (MWP-URS01 @ 10 ft bgs)	0.0060 to 82	GSP-URS01 (5) MPC-URS26 (1) MWP-URS01 (10) P3-URS02 (10) SB-1 (2) SB-3 (2)

The ranges of detections provided above include estimated results (J-flagged), which are concentrations that fall between the method detection limit and the laboratory reporting limit, or are qualified as estimated by the data validation process. The reporting limits for select soil samples collected during Phase 2 exceeded the industrial screening criteria for benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and naphthalene. The laboratory indicated that high reporting limits were due to matrix interference. The problem with elevated reporting limits due to matrix interference is commonly encountered at sites of former petroleum facilities. In an attempt to obtain lower reporting limits during Phase 2, several samples were submitted to a specialty laboratory (TestAmerica in Portland, Oregon) in an attempt to ‘clean up’ the samples using Gel Permeation Chromatography (GPC) separation by EPA Method 3640. This method attempts to reduce matrix interference due to high molecular weight compounds (possibly the heavy end hydrocarbons associated with TPH); however, the separation method was not successful at providing a significant reduction in the laboratory reporting limit. Therefore, gel ‘clean up’ attempts were discontinued.

Benzo(a)pyrene and dibenz(a,h)anthracene have very low screening criteria, and the percentage of non-detect results where laboratory reporting limits exceeded industrial screening criteria was 12.6 % and 8.8%, respectively, which raised some uncertainties as to whether these results truly represented non-detected conditions. One purpose of the Phase 3 sampling was to collect additional samples to reduce uncertainties in site data. As described in the Phase 3 Work Plan, decisions to perform additional sampling were recommended where the reporting limit exceeded the industrial screening criteria.

The Phase 3 sampling results permitted the reduction of data uncertainties by presenting reporting limits less than or equal to the industrial screening criteria established in the Phase 3 Work Plan. However, the screening criteria for benzo(a)pyrene subsequently was reduced from 0.21 mg/kg to 0.13 mg/kg, making the new reporting limits of 0.18 mg/kg or 0.21 mg/kg slightly elevated. Nonetheless, a review of the data set indicated that the 10 re-sample locations with reporting limits of 0.18 mg/kg or 0.21 mg/kg corroborated the previous non-detected results obtained at those locations but at higher reporting limits. Thus, the uncertainty regarding the non-detected PAH results where reporting limits exceeded screening criteria was greatly reduced. For purposes of the screening level risk evaluations, these results were considered to be non-detects. For purposes of the HHRA, the reporting limit was included to derive area-wide average concentrations using calculations in Version 4.0 of ProUCL (Singh et al., 2007).

A PAH summary is provided in Table 7. Frequency histograms for naphthalene and benzo(a)pyrene in shallow soil, incorporating all shallow soil sample results (detections and non-detects) except for background samples, are provided on Figures 12 and 13, respectively. As shown on these figures, 0.63% of naphthalene and 2.99% of benzo(a)pyrene results exceeded the industrial screening criteria. The naphthalene results (0 to 10 ft bgs) are shown on Figure 18. The benzo(a)pyrene results (0 to 10 ft bgs) are shown on Figure 19.

#### **4.2.1.3 Hexavalent Chromium (EPA Method 7199)**

Hexavalent chromium was present at very low detections above laboratory reporting limit in two soil samples analyzed by EPA Method 7199 during Phase 2. Reported concentrations of hexavalent



chromium did not exceed the industrial screening criteria. The range of detected concentrations is summarized below:

Compound	Range of Detected Concentrations (mg/kg)	Range of Reporting Limits for Non-Detect Samples (mg/kg)	Soil Borings with Detected Concentrations Exceeding Industrial Screening Criteria (ft bgs)
Hexavalent Chromium	0.000032J (MWP-URS04 @ 1 ft bgs) to 0.0003 (RW-URS01 @ 5 ft bgs)	0.0002 to 0.0004	Not Exceeded

The detections provided above include an estimated result (J-flagged), which is a concentration that falls between the method detection limit and the laboratory reporting limit, or is qualified as estimated by the data validation process. A hexavalent chromium analytical data summary is provided in Table 8.

**4.2.1.4 Inorganic Lead and Other Metals (EPA Method 6010B)**

Inorganic lead was detected above the laboratory reporting limits in soil samples analyzed by EPA Method 6010B. The range of detected concentrations is summarized below:

Compound	Range of Detected Concentrations (mg/kg)	Range of Reporting Limits for Non-Detect Samples (mg/kg)	Soil Borings with Detected Concentrations Exceeding Industrial Screening Criteria (ft bgs)
Inorganic Lead	0.086J (P3-BH-3-R @ 5 ft bgs) to 34,000 (NP-URS01 @ 1 ft bgs)	0.08 to 8	ASU-URS02 (1) BA02-URS01 (1) FH-URS02 (5 and 10) GSP-URS03 (1) MPC-URS24 (1) MPH-URS01 (1) MWP-URS02 (1) MWP-URS04 (5) N-1 (5) NP-URS01 (1) NP-URS05 (1) P2-URS03 (5) P3-BH-1 (10) P3-BH-3 (5) P6-URS01 (5) P7-BH-2 (5) P7-URS01 (1, 5, and 10) P7-URS02 (1 and 5) RW-URS01 (5) SR-URS01 (1) SSP-URS01 (1) TK1-F1 (1) TK62-URS01 (1) TK66-URS01 (1) TK68-URS01 (1 and 5) TK71-URS01 (1) TK75-URS01 (1) TK79-URS01 (1) TK157-URS02 (1) TK172-URS01 (1) TK174-URS01 (1) TK178-URS01 (1) TK3321-URS01 (5 and 10) TK7404-F1 (10) UT17-URS01 (5) UPA3-URS01 (1, 5, and 10) UPA3-URS02 (10)

The ranges of detections provided above include estimated results (J-flagged), which are concentrations that fall between the method detection limit and the laboratory reporting limit, or are qualified as estimated by the data validation process. An inorganic lead analytical data summary is provided in Table 8. A frequency histogram for inorganic lead in soil is provided on Figure 14. As shown on the histogram, 4.44% of the inorganic lead results exceeded the industrial screening criteria. Inorganic lead results (0 to 10 ft bgs) are shown on Figure 20.

During Phase 1, samples were collected and analyzed for California Assessment Manual (CAM) metals. As shown in Table 8, several metals were detected but only arsenic and lead exceeded the industrial screening criteria. The arsenic detections are consistent with the site background levels study and published regional background levels reported by ENSR in *Final Remedial Investigation Report* (ENSR, 1991). A frequency histogram for arsenic in soil is provided on Figure 15.

#### 4.2.1.5 Organic Lead (HML 939-M)

Organic lead (quantified as total organic lead) was detected above laboratory reporting limits in soil samples analyzed by HML 939-M. The reporting limit for organic lead was 0.025 microgram per kilogram ( $\mu\text{g}/\text{kg}$ ) for all undiluted samples analyzed. The detectable concentrations ranged from 0.0035J mg/kg (UT05-URS01 at 1 ft bgs) to 130 mg/kg (TK68-URS01 at 1 ft bgs). Because there is no RSL for organic lead and tetraethyl lead is one of the more toxic constituents of organic lead, the industrial RSL for tetraethyl lead was used as screening criteria in this document. The organic lead concentrations exceeded the industrial RSL for tetraethyl lead in 126 of the 677 soil samples analyzed. An organic lead analytical data summary is provided in Table 8. A frequency histogram of organic lead in soil is provided on Figure 16.

Subsequent to the Phased Shallow Soil Investigation, additional soil samples were collected from several areas where high concentrations of organic lead were reported. As discussed in Section 6.6, these samples contained no tetraethyl lead and in fact appeared to be inorganic lead adsorbed to soil organic matter.

#### 4.2.1.6 Polychlorinated Biphenyls (EPA Method 8082)

Polychlorinated biphenyls (PCBs) were not detected above laboratory reporting limits in 233 soil samples (206 primary samples and 27 replicate samples) analyzed by EPA Method 8082 during Phase 2. Aroclor 1248 was detected in one sample at a concentration of 0.031J mg/kg (P10-URS02 at 1 ft bgs) (J-flagged as an estimated result). Reporting limits ranged from 0.05 to 1.0 mg/kg. A PCB summary is provided in Table 9.

#### 4.2.1.7 pH (EPA Method 9045C)

Results for pH were reported for 172 soil samples (146 primary samples and 26 replicate samples) analyzed by EPA Method 9045C during Phase 2. The reported pH values average 7.89 and range from 2.89 (P11-URS01 @ 5 ft bgs) to 9.86 (CC-URS01 @ 5 ft bgs). These results are well within the limit criteria ( $\text{pH} \leq 2$  or  $\geq 12.5$ ) established for hazardous waste characteristics (corrosivity) under 40 CFR 261.22. A pH summary is provided in Table 10. Ninety-nine percent (99%) of the samples exhibited  $\text{pH} > 6$  and 69% of the samples ranged from 7.5 to 8.5.

#### 4.2.1.8 Soil Vapor Analytical Results

During Phase 3, 60 soil vapor samples (including 6 duplicate soil vapor samples) were analyzed from 27 borings. The soil vapor analytical results for this investigation are summarized in this section along with a comparison against CHHSLs (Cal/EPA, 2009a). Exceedances of CHHSLs indicate that a site-specific evaluation is warranted.



The laboratory analytical reports for soil vapor samples analyzed during Phase 3 of this investigation are provided in electronic format in a CD-ROM enclosed with this report (Appendix B). Twenty-two (22) VOCs were detected above laboratory reporting limits in at least one of the soil vapor samples analyzed by EPA Method TO-15. Benzene, 1,2-dichloroethane, and naphthalene samples exceeded industrial CHHSLs. VOC concentrations are summarized below:

Compound	Range of Detected Concentrations (ug/m <sup>3</sup> )	Range of Reporting Limits for Non-Detect Samples (ug/m <sup>3</sup> )	Soil Borings with Detected Concentrations Exceeding Industrial Screening Criteria (ft bgs)
1,2-Dichloroethane	0.25J (FSB-4-SV @ 5 ft bgs) to 440 (MWP-URS01-SV @ 10 ft bgs)	1.4 to 5,700	MWP-URS01-SV
Benzene	2.5 (SB-3-SV @ 5 ft bgs) to 8,400 (GSP-URS03-SV @ 10 ft bgs)	590 to 4,800	P7-URS01-SV (5 and 10) GSP-URS01-SV (10) GSP-URS02-SV (5 and 10) GSP-URS03-SV (5 and 10) NP-URS02-SV (10) NP-URS05-SV (5 and 10) P3-BH-2-SV (5 and 10) P3-URS02-SV (10) MWP-URS01-SV (10) TK2-F1-SV (5 and 10) TK2-URS01-SV (5 and 10)
Naphthalene	0.84 (FSB-5-SV @ 5 ft bgs) to 3,100 (P3-BH-2-SV @ 5 ft bgs)	1.4 to 5,700	P7-URS01-SV (5) GSP-URS01-SV (5 and 10) GSP-URS02-SV (5 and 10) GSP-URS03-SV (5 and 10) P3-BH-2-SV (5 and 10) FSB-5-SV (10) TK2-O2-SV (10) TK2-F1-SV (10) TK2-F2-SV (5) TK2-URS01-SV (10) TK2-URS02-SV (5 and 10) TK2-WD-SV (5)

The ranges of detections provided above include estimated results (J-flagged), which are concentrations that fall between the method detection limit and the laboratory reporting limit, or are qualified as estimated by the data validation process. A VOC analytical data summary is provided in Table 11. A frequency histogram for naphthalene in soil vapor is provided on Figure 17. The soil vapor analytical results are shown on Figure 25.

**4.2.1.9 Site Construction Materials**

In evaluating commercial/industrial redevelopment scenarios, it was noted that an abundant amount of construction material (i.e., concrete and bricks) is located throughout the property that could potentially be used as base material during property redevelopment. The Site also contains several earthen berms used as containment dikes for the former aboveground storage tanks that could potentially contain elevated concentrations of lead. A number of other miscellaneous materials (i.e., pipelines, debris piles, floor tiles, etc.) are also present that could potentially contain asbestos, and may require abatement during redevelopment. In light of these issues, URS collected samples of the construction materials (concrete,

bricks, pipe coatings, etc.) and sent them for chemical analysis to TestAmerica Analytical in Irvine, CA. The asbestos analysis was performed by AmeriSci located in Carson, CA. A report titled *Construction Material Sampling* (URS, 2009b) is presented in Appendix D.

The results indicated that the lead content of the tank berms exceeded industrial screening criteria (URS, 2009b – see Table 5). Therefore, the tank berm material was considered in the treatment volume calculations included in the feasibility section of this report (Section 10.0). Asbestos materials were detected above regulatory limits. Samples of asphaltic pipe coating and mastic contained low percentages of asbestos material. Only one sample, from a composite gasket, contained a high percentage of asbestos material (35%). The asbestos-containing material (i.e., mastic, gaskets, debris, etc.) will be removed using a licensed asbestos abatement contractor during pipeline removal. The asbestos will not be reused at the Site. The remaining debris (concrete, bricks, etc.) did not contain elevated constituents of concern and will be reused during property development as a green and sustainable remediation option, which is discussed further in Section 13.0. Based on the proposed cleanup standards (Section 9.4), the tank berms will be included as appropriate in remedial action plans, but may be investigated further prior to preparing the remedial design report.

#### **4.2.2 Contaminant Distribution in Deeper Soil (Previous Investigations)**

This section provides a summary of previous investigations performed at the Site prior to the initiation of the three-phase soil sampling program. The historical soil boring locations are included on Figure 25. The historical soil analytical results detected for VOCs, semivolatile organic compounds (SVOCs), and metals both shallow (0 to 10 ft bgs) and deep (greater than 10 ft bgs), are included in summary tables provided in Appendix C on CD-ROM.

Approximately 89 soil borings were completed (soil sampling generally conducted at 5-foot intervals) at depth intervals between approximately 5 ft bgs to 137.5 ft bgs during previous investigations primarily conducted for the original RI (ENSR, 1991), which was the basis for the ROD. A summary table showing detected results from soil sampling at the Site is provided in Appendix C on CD-ROM.

##### **4.2.2.1 Volatile Organic Compounds**

The ROD indicates that TPH contamination of subsurface soils was found ‘throughout the site’; however, VOCs (primarily BTEX) were found in less than 10% of the subsurface soil samples analyzed. The benzene concentrations ranged from ‘below 11 ppb with a maximum concentration of 38 parts per billion (ppb)’ (USEPA, 1992a).

The distribution of soil contamination beneath the Site was coincident with the historical operation of nine unlined waste pits. In 1986, all of the identified pits were remediated by excavation and disposal of 38,000 tons of contaminated soils. The ROD concluded that:

*The lateral and vertical distribution of VOCs and the range of VOC concentrations detected in sub-surface soils do not indicate the presence of a principal threat in soil. However, the low levels of VOCs (specifically benzene) in the vadose zone or capillary fringe may result in ongoing contamination of ground water.*



Soil vapor extraction and treatment to remove VOCs in the areas that threatened to contaminate groundwater was ongoing at the Site from 1994 to 2002, resulting in the removal of approximately 2,190 pounds of benzene. Soil vapor concentrations in the capillary fringe dropped below the approved shutoff levels and soil vapor extraction and treatment operations were discontinued in 2002. Monitoring for eight consecutive months following treatment system shutoff showed no rebound.

#### 4.2.2.2 Semi-volatile Compounds

As stated in the ROD, the primary SVOCs detected included 2-methylnaphthalene and naphthalene. 2-methylnaphthalene was detected in 34 of the 154 samples with reported results ranging from 10 µg/kg to 160 µg/kg. Naphthalene was detected in 60 samples at concentrations ranging from 10 µg/kg to 160 µg/kg.

#### 4.2.2.3 Metals

The ROD (USEPA, 1992a) concluded ‘metals concentrations presently in subsurface soils were found to be consistent with background levels for the Site and for the region.’ Historically, no additional regulatory requirements were imposed since migration of metals in the soils to groundwater is unlikely.

#### 4.2.2.4 Soil Gas

The soil gas data collected during previous investigations is presented in summary tables of detected results in Appendix C.

### 4.3 CONTAMINANT DISTRIBUTION IN GROUNDWATER

Of the five contaminants of concern identified in the ROD for groundwater (benzene, toluene, ethylbenzene, 1,2-DCE, and methylene chloride), benzene is the primary concern. There are two dissolved benzene plumes (designated as the northern and southern plumes) that are found at the Site. The geometry and distribution of these plumes has been documented in periodic monitoring events that have been performed since 1990. The dissolved benzene plumes are shown on Figure 6. Time series plots of historical results for benzene (through 2008) are included in Appendix E and updated in each groundwater monitoring report. A summary table of historical ROD parameter results is presented in Appendix C.

#### 4.3.1 ROD Cleanup Goals for Groundwater

The ROD cleanup goals for groundwater include five chemicals of concern (COCs) summarized as follows:

ROD Cleanup Goals for Groundwater

Compound	Groundwater Cleanup Level in micrograms per liter (µg/L)
Benzene	1
Toluene	100
Ethylbenzene	680
1,2-Dichloroethane	0.5



Compound	Groundwater Cleanup Level in micrograms per liter ( $\mu\text{g/L}$ )
Methylene Chloride	5

Since 1990, detectable concentrations of ethylbenzene have never exceeded cleanup goals stated in the ROD. As noted in the Second Five Year Review Report (USEPA, 2006b), during the ARARs review for ethylbenzene, a new standard for ethylbenzene has been established. The highest level of ethylbenzene ever detected on site (170  $\mu\text{g/L}$  at well EW-P2) is less than the new standard 300  $\mu\text{g/L}$ ; therefore, the new standard has no effect on the protectiveness of the remedy. Methylene chloride and 1,2-DCA have not been chemicals of significant concern in the groundwater beneath the Site. Low concentrations of both constituents were detected infrequently in groundwater early in the monitoring program (1991). Supplemental investigations have determined that there is no continuous 1,2-DCA plume on site and more recent groundwater monitoring (post-1991) has not detected methylene chloride. While the reporting limits for 1,2-DCA and methylene chloride have exceeded the ROD cleanup goals, there has been no evidence (i.e., no detections above method detection limits) to suggest that there is a problem with either of the two constituents at the Site.

Toluene is significantly less abundant in groundwater beneath the Site than benzene. In the few wells where the toluene concentration exceeds the ROD cleanup goal, benzene concentrations are also above the ROD cleanup goal. Therefore, of the five ROD-identified chemicals of concern, benzene is the current chemical of primary concern in groundwater.

PAHs have been detected in shallow soil, however, fate and transport modeling results described in Section 5.3.4 have indicated that these impacts will not migrate to groundwater under current conditions. Naphthalene is the only PAH that has ever been detected in groundwater and only in monitoring wells within LNAPL source areas. The maximum naphthalene concentration detected in groundwater was 100  $\mu\text{g/L}$  (at MW-39S in 1994). Naphthalene does not have an established maximum contaminant level (MCL). As recommended by EPA in the Second Five Year Review (USEPA, 2006b), a two-year monitoring program (2007 and 2008) was conducted for naphthalene and no groundwater results exceeded a notification level established by the State of California Office of Environmental Health Hazard Assessment (OEHHA) at 17  $\mu\text{g/L}$  (CDPH, 2007). (OEHHA notification levels are typically precursors to MCLs). Therefore, naphthalene is not a chemical of concern in groundwater at the Site.

The sources of groundwater impacts were identified during previous investigations as being associated with the former waste disposal practices during refinery operations that commenced in circa 1915. As such, the ROD constituents have been present in groundwater for multiple decades and have degraded significantly over this time as discussed in Appendix E. As such, an updated constituent list for groundwater should be considered for the amended ROD. The COCs that should be included are benzene and toluene. The remaining constituents should be removed from the groundwater monitoring program based on (1) limited frequency of detections, (2) non-detect analytical results, and/or (3) constituent concentrations have not exceeded cleanup goals established for the Site. Benzene will continue to be the primary constituent of concern in groundwater beneath the Site.

### 4.3.2 Northern Groundwater Plume

The northern dissolved benzene plume has a relatively smaller geometry than the southern plume (Figure 6). The northern plume is approximately 85 ft bgs, providing a more extensive vadose zone than the southern plume, as shown on cross sections presented in Section 3.0. The area of greatest impact (100 µg/L benzene range) in the northern plume has a significantly smaller footprint than the southern plume. LNAPL has not been detected in the northern plume wells since 2003. Recent maximum benzene concentrations in the northern plume have averaged well under 200 µg/L over the past year.

During a study conducted to characterize natural attenuation characteristics above the dissolved-phase benzene plumes (URS, 2007c) (Section 2.2) (Appendix B), continuous cores were collected and analyzed. Petroleum hydrocarbon fluorescence was not present in the continuous soil core collected at the northern plume. Soil vapor results collected for this study indicated that the two most frequently detected compounds (xylene and toluene) are generally consistent with constituents present within the northern dissolved-phase benzene plume. Benzene was not detected above the laboratory reporting limit, which ranged from <5.4 µg/m<sup>3</sup> (13 ft bgs) to <29 µg/m<sup>3</sup> (78 ft bgs). The absence of benzene appears to be related to degradation processes occurring in the vadose zone.

### 4.3.3 Southern Groundwater Plume

Groundwater at the southern plume is approximately 55 ft bgs. The southern plume also has consistent detections of LNAPL in wells EW-1 and EW-4, trapped by fine-grained sediments present at the water table, as shown on cross section B-B' presented in Section 3.0 and on Figure 6. Evidence suggests that LNAPL is sorbed to soils within the smeared zone above and below the current water table elevation. Concentration levels are similar to those in the northern plume, with maximum benzene results typically higher, in the 300-400 µg/L range.

During the natural attenuation study above the benzene plumes (URS, 2007c) (Section 2.2) (Appendix B), continuous cores were collected and analyzed. Moderate petroleum hydrocarbon fluorescence was noted in the continuous core just above the water table, which appears to be associated with residual LNAPL impacts. In the southern sampling area, the two most frequently detected compounds (xylene and toluene) are generally consistent with constituents present within the southern dissolved-phase benzene plume. Benzene was detected above the laboratory reporting limit in six samples (out of 60) at concentrations ranging from 4.4 µg/m<sup>3</sup> (SSA-09 at 15 ft bgs on March 19, 2007) to 65 µg/m<sup>3</sup> (SSA-11 at 36 ft bgs on March 19, 2007). The limited presence of benzene appears to be due to degradation processes occurring in the vadose zone.

A full set of results for the natural attenuation study (URS, 2007c) is presented in Appendix B. A table showing a summary of results from the natural attenuation study is provided below:

Northern Study Area (NSA-03)		Southern Study Area (SSA-11)	
Depth (ft bgs)	Range of Concentrations (ug/m <sup>3</sup> )	Depth (ft bgs)	Range of Concentrations (ug/m <sup>3</sup> )
<b>Benzene</b>			
13	<5.4 (3/2007) to <7.0 (8/2007)	7	<14 (3/2007) to <19 (8/2007)
26	<7.1 (8/2007) to <9.1 (3/2007)	13	<17 (8/2007) to 23 (3/2007)



Northern Study Area (NSA-03)		Southern Study Area (SSA-11)	
38	<5.6 (3/2007) to <7.1 (8/2007)	21	<35 (8/2007) to 51 (3/2007)
53	---	27	<27 (8/2007) to 59 (3/2007)
69	<7.0 (8/2007) to <14 (3/2007)	36	<54 (8/2007) to 65 (3/2007)
78	<7.1 (8/2007) to <29 (3/2007)	43	<930 (8/2007) to <28,000 (3/2007)
<b>Ethylbenzene</b>			
13	5.5 (3/2007) to 6.9 (3/2007)	7	14 (3/2007) to <19 (8/2007)
26	<7.1 (8/2007) to <9.1 (3/2007)	13	16 (3/2007) to <17 (8/2007)
38	<5.6 (3/2007) to <7.1 (8/2007)	21	25 (3/2007) to <35 (8/2007)
53	---	27	<27 (8/2007) to 28 (3/2007)
69	<7.0 (8/2007) to <14 (3/2007)	36	34 (3/2007) to <54 (8/2007)
78	7.4 (8/2007) to <29 (3/2007)	43	<930 (8/2007) to <28,000 (3/2007)
<b>Naphthalene</b>			
13	<5.4 (3/2007) to 17 (3/2007)	7	<14 (3/2007) to <19 (8/2007)
26	<7.1 (8/2007) to <9.1 (3/2007)	13	<13 (3/2007) to <17 (8/2007)
38	<5.6 (3/2007) to <7.1 (8/2007)	21	<14 (3/2007) to <35 (8/2007)
53	---	27	<15 (3/2007) to <27 (8/2007)
69	<7.0 (8/2007) to <14 (3/2007)	36	<19 (3/2007) to <54 (8/2007)
78	<7.1 (8/2007) to <29 (3/2007)	43	<930 (8/2007) to <28,000 (3/2007)

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## 5.0 CONTAMINANT FATE AND TRANSPORT

A detailed description of contaminant fate and transport was primarily discussed in two historical documents for the Site. ENSR provided a description that was incorporated into the existing ROD (ENSR, 1991). E&A expanded on previous interpretations in the *Final Phase 2 Design Report* (E&A, 1994). The historical documents are provided in Appendix B.

The intent of this section is to provide a brief description of past interpretations along with updated information pertinent to the FS. The recent information includes a discussion of the enhanced bioattenuation pilot test results; evaluations of natural attenuation of benzene in groundwater and natural attenuation of benzene in soil vapor; modeling of constituents of potential concern (COPCs) found in shallow soil to groundwater, and modeling performed for residual LNAPL using a LNAPL Dissolution and Transport Screening Tool (LNAST). A site conceptual model is shown in Figure 26.

### 5.1 POTENTIAL SOURCES

ENSR (1991) identified several potential sources at the Site:

- ◆ Main waste pit along with several other smaller disposal pits.
- ◆ Pipelines, aboveground storage tanks, or other refinery equipment or process operations.
- ◆ Naturally-occurring constituents which are augmenting the presence of hydrocarbons.
- ◆ Railroad and commercial property along Highway 126.

The majority of the significant source areas have been removed and currently there are no structures remaining except for historical pipelines that were reportedly drained before decommissioning the Site. This appears to have reduced the potential migration pathway of shallow contaminants to Aquifer I.

### 5.2 CONTAMINANT PERSISTENCE

COPCs currently within shallow soils (up to 10 ft bgs) that have persisted above risk-based thresholds over the years include inorganic lead, organic lead, and several PAHs. Two PAHs (naphthalene and benzo(a)pyrene) have been selected for modeling based on frequency of detection and toxicity. These constituents are generally located in areas that have not been addressed by past remedial actions at the Site.

The COCs currently in groundwater are comprised of dissolved phase petroleum hydrocarbon constituents that are degrading naturally at the Site. The main reason for their persistence is the presence of sorbed LNAPL trapped beneath a fluctuating water table that created a smear zone. A modeling exercise (discussed later in Section 5.3.5) was conducted to describe conceptually the anticipated longevity (i.e., persistence) that can be expected to occur over the next several decades due to saturated-zone-smear LNAPL.

However, multiple lines of evidence for intrinsic biodegradation of dissolved benzene in groundwater beneath the Site have been identified:

- ◆ Time-series plots that demonstrate continued decline in dissolved benzene concentrations.
- ◆ Time-series isopleth maps that demonstrate the dissolved plumes are stable and shrinking.
- ◆ Benzene mass calculations that demonstrate the dissolved plumes are stable and shrinking.
- ◆ Geochemical indicators of biodegradation, specifically sulfate reduction across both dissolved plumes.
- ◆ Stable isotope ratios for carbon ( $^{13}\text{C}/^{12}\text{C}$ ) vs. hydrogen ( $^2\text{H}/^1\text{H}$ ) demonstrate a biodegradation signature.
- ◆ Vertical concentration profiles of soil vapor that demonstrate natural attenuation within the vadose zone above the groundwater plumes such that a subsurface vapor migration exposure pathway is insignificant.
- ◆ Reduction in the mole fraction of benzene in LNAPL in the smear zone.

The supporting data for each line of evidence is provided in Appendix E.

As discussed in Section 10.0, MNA will be an important groundwater remedial option for consideration in the amended ROD. This is particularly important considering the abundance of naturally occurring sulfate within groundwater located beneath the Site. As such, additional information relating to sulfate reduction is discussed in the following paragraphs as requested by EPA/DTSC.

The benzene concentrations in the hundreds of  $\mu\text{g}/\text{L}$  suggest shallow groundwater is largely anaerobic. The presence of LNAPL and dissolved petroleum hydrocarbons have depleted the groundwater of dissolved oxygen and sulfate, and there is also elevated ferrous iron, which are key geochemical indicators of anaerobic conditions in Aquifer I (URS, 2010b). The presence of aerobic conditions are limited to a few wells located outside the zone of impacted groundwater (i.e., dissolved oxygen greater than 1 mg/L). However, data obtained from within the general vicinity of each groundwater plume indicate that anaerobic conditions prevail.

The perception of faster aerobic biodegradation compared to anaerobic biodegradation is based on rates derived from laboratory studies where typically the electron donor (i.e., hydrocarbons) is limited and electron acceptors (i.e., oxygen, nitrate, sulfate etc) are available in abundance. Under these conditions, the thermodynamics of biodegradation controls the relative rates and aerobic oxidation yielding more energy to the bacteria results in the fastest rates, in comparison to sulfate reduction which does not yield as much energy. However, in petroleum-impacted aquifers where electron donors such as hydrocarbons are abundant and electron acceptors generally limited (resulting in anaerobic conditions), the rate of hydrocarbon biodegradation is controlled by the rate of transport of electron acceptors. As a result, in the field, different electron accepting processes can occur simultaneously and at similar rates as shown by McGuire et al. (2002). Sulfate reduction contributes to biodegradation at the Site as groundwater containing elevated sulfate concentration mixes with the dissolved plumes. Also, it is extremely hard to maintain truly aerobic conditions in petroleum-impacted aquifers given the significant oxygen demand

exerted by petroleum hydrocarbons present in residual LNAPL, sorbed and dissolved phases, as well as the other reduced species such as ferrous iron and sulfide minerals. High oxygen demand in the subsurface is the reason that the enhanced bioattenuation pilot study with ORC<sup>®</sup> was unsuccessful (Appendix B). Further description of the transition from aerobic to anaerobic conditions is discussed in Section 14.3.

In respect to petroleum hydrocarbons, sulfate reduction is an important terminal electron accepting process (TEAP). Sulfate is significantly more soluble in water than oxygen. Biodegradation capacity is a measure that a particular TEAP can ‘assimilate’ or degrade the target compounds, based on the electron-accepting capacity of the groundwater and depends primarily on delivery (i.e., contact and mixing of electron acceptor and contaminant) than on increased biodegradation rates. Biodegradation rates can be measured in well-controlled laboratory experiments, which are not limited by the availability of electron acceptors. Biodegradation rates are more difficult to measure in the field than in the lab, and therefore biodegradation capacity may be a more useful way to measure the biodegradation potential at the Site. The remediation time estimates presented later in this document for recirculation of sulfate-rich groundwater will be more dependent on mixing sulfate and benzene than on slow degradation rates.

Wiedemeier et al. (1999) also summarized the biodegradation capacity calculations for 38 sites with petroleum hydrocarbons. The authors found that sulfate reduction contributed to 70% of the expressed biodegradation capacity at these sites. Methanogenesis was the second most important biodegradation mechanism. The relative abundance and solubility of sulfate at many sites account for the important role of sulfate-reducing conditions in constraining petroleum hydrocarbon plumes, which appears to be the primary mechanism at this Site.

### 5.3 CONTAMINANT MIGRATION

The COPCs (primarily inorganic lead, organic lead, and PAHs) within the shallow subsurface soils are not expected to migrate to groundwater within a reasonable timeframe based on modeling recently conducted by URS. The modeling performed during this investigation included (1) SESOIL (2) Analytical Leaching Model, (3) MT3DMS, and (4) SUMMERS Model.

The COCs (primarily benzene) within groundwater may not attenuate naturally to the ROD cleanup goal (drinking water standard) for 50 to 100 years. This is primarily a function of the sorbed and residual LNAPL trapped below the water table and the constraints on attenuation and natural mass losses below the water table (the absence of volatilization). The plume longevity and constraints on natural attenuation were assessed using LNAST. The modeling results are discussed in the following sections.

#### 5.3.1 ROD Constituent Modeling Using SESOIL

SESOIL is an EPA-approved, one dimensional vertical vadose zone transport model developed by Arthur D. Little, Inc. (Little, 1981). England Geosystems (2005a) initially calculated soil screening levels (SSLs) that will be protective of groundwater for constituents listed in the ROD. The SESOIL calculated screening levels by constituent include benzene (230 µg/kg), toluene (35,000 µg/kg), ethylbenzene

(1,370,000  $\mu\text{g}/\text{kg}$ ), 1,2-DCA (65  $\mu\text{g}/\text{kg}$ ), and methylene chloride (675  $\mu\text{g}/\text{kg}$ ). The soil screening level evaluation is presented in Appendix B of the Phase 2 Soil Sampling Report (Appendix B).

The SSLs were exceeded in several samples during the phased investigation conducted by URS. The exceedances are discussed as follows:

- ◆ Reporting limits for methylene chloride and 1,2-DCA exceeded the calculated SSLs in samples collected at Tank #2 (TK2-F1 at 1, 5, and 10 ft bgs / TK2-F2 at 1 and 10 ft bgs / TK2-02 at 1 ft bgs / TK2-WD at 1, 5, and 10 ft bgs) and Tank #101 (TK101-WD at 1 ft bgs). It was not considered necessary to resample these locations since (1) the SSLs were developed to be protective of groundwater, and neither constituent has been detected in groundwater monitoring wells at the Site; and (2) the reporting limits were less than industrial RSLs. Furthermore, if present the potential concentrations are less than criteria considered harmful to human health.
- ◆ Benzene exceeded the calculated SSLs in samples collected at MWP-URS02 (10 ft bgs) and P3-URS02 (10 ft bgs). Based on an overall decreasing benzene concentration trend in nearby monitoring wells (MW-6S for MWP-URS02 and MW-41S for P3-URS02), it does not appear that this potential migration pathway is affecting groundwater concentrations, most likely due to natural attenuation in the vadose zone and sulfate reducing conditions within Aquifer I.

### 5.3.2 Lead Modeling Using SESOIL

SESOIL was also used to calculate the potential impact to groundwater from inorganic lead (Pb) and organic lead (tetraethyl lead and tetramethyl lead) since these constituents were not included in the initial assessment conducted by England Geosystem (2005a). The SESOIL modeling was first performed on lead and organic lead results using maximum concentration data from Phase 1 of the Shallow Soil Investigation. URS used the geographical user interface (GUI) of WHI's UnSat Suite Plus (2004) to develop, run, and process results from SESOIL (Version 2.2.0.3, 2004). The results are presented in Appendix B of the Phase 2 Soil Sampling Report (URS, 2008a) (Appendix B).

In developing the SESOIL model, URS used the same input parameters as England Geosystem except that the chemical properties and initial soil concentration distributions were the maximum concentrations for lead and organic lead. Specifically, the two soil profiles (based on borings of MW-11S and MW-21S), model layer specifications, monthly climatic data, soil property parameters, and groundwater parameters for the mixing zone are the same as used in the England Geosystem SESOIL model (URS, 2008a) (Appendix B).

No reliable modeling results were obtained from the SESOIL model for lead and organic lead. Unlike the five VOCs modeled previously, there is no vapor-phase transport (free-air diffusion) in lead's transport processes; thus, advection associated with water flow is the dominant transport process for lead in the vadose zone. Additionally, SESOIL uses valence along with cation exchange capacity (CEC) to simulate adsorption of metals to soil, usually resulting in very high adsorption (distribution) coefficient, and consequently, very slow migration of metals in the vadose zone. A number of trial runs of modeling lead migration showed that within SESOIL's maximum simulation time of 100 years, lead appears to not migrate at all and the associated groundwater concentration is zero. Similarly, the movement of organic

lead was also modeled to be very low in the vadose zone, and the modeled groundwater concentration at 100 years is zero.

To model the maximum lead concentrations detected during later phases of the shallow soil investigation, which exceeded the Phase 1 maximum results for lead by an order of magnitude, additional lead modeling using the Analytical Leaching Model was performed.

### **5.3.3 Lead Modeling Using Analytical Leaching Model**

An Analytical Leaching Model procedure was used to build upon lead modeling conducted using SESOIL. The maximum lead (inorganic and organic) concentrations were used from the phased investigations (Table 12). The modeling results are described in the following sections.

#### **5.3.3.1 Background**

The Analytical Leaching Model procedure was used for the Site to quantitatively estimate lead and organic lead migration through the vadose zone to the groundwater surface. The Analytical Leaching Model, developed by C.F. Baes and R.D. Sharp (1983), is a conservative calculation for estimating contaminant mobility through vadose zone soil. Model calculations provide a prediction of the travel time for a contaminant in soil to migrate downward through the unsaturated soil column to the groundwater surface. The Analytical Leaching Model also provides calculations for the contaminant concentration in groundwater due to the mixing of the infiltrating contaminant and the flowing groundwater.

Analytical Leaching Model results can be used as a conservative approach to evaluate the impacts on groundwater. The results are conservative because the calculated groundwater concentration is much higher than expected in the field. This is because: 1) It is assumed that the contaminant may dissolve in the percolating water and the dissolved concentration is not limited by its natural solubility, while the solubility is very low for both lead and organic lead; and 2) The dispersion process, which reduces the peak concentration in contaminant migration, is not included in the Analytical Leaching Model calculation.

The estimated travel times of contaminants to the groundwater table are for the arrival of any amount of contaminant and not the time a specific concentration is reached in groundwater. On the other hand, the travel times predicted by the model are typically longer than expected in the field due to the absence of preferential pathways and the dispersion in the calculations.

#### **5.3.3.2 Model Components**

Model components include an estimate of vertical water migration velocity (percolation rate) from average rainfall amounts and average soil moisture (same as used in the previous SESOIL model simulation); estimation and/or calculation of a contaminant retardation factor from adsorption on natural organic material; calculation of the maximum velocity of contaminant migration in the vadose zone; and the calculation of the travel time for a contaminant in soil to migrate to the groundwater table at its maximum calculated migration velocity.

Model parameters include contaminant concentration in soil, contaminant plume length and width, depth to groundwater table, annual rainfall and net groundwater recharge, soil bulk density, soil effective porosity, distribution coefficient  $K_d$  (or fraction of organic carbon  $f_{oc}$  and octanol-water partition coefficient  $K_{oc}$ ), and groundwater zone parameters (saturated hydraulic conductivity, horizontal hydraulic gradient, thickness of mixing zone, and background concentrations in groundwater). To be consistent, all of these parameters were set identical to those used in the previous SESOIL model or Analytical Leaching Model analysis when available. Otherwise, conservative values were used in the calculation.

Since the SESOIL and initial Analytical Leaching Model models were constructed, soil concentrations of lead and inorganic lead, and the lengths and widths of contaminant plumes were updated. Specifically, the maximum lead concentration of 34,000 mg/kg in soil (boring NP-URS01) was used in lead transport analysis, and the length and width of the respective lead plume were estimated based on boring locations of NP-URS01 and its adjacent borings. Similarly, the maximum organic lead concentration of 130 mg/kg in soil (boring TK68-URS01) was used in organic lead transport analysis, and the length and width of the respective organic lead plume were estimated based on boring locations of TK68-URS01 and its adjacent borings.

The calculations were set up in spreadsheets that allow ranges of values to be used in the calculations. Ranges of input values are used because site-specific measurements for soil parameters were not obtained at the Site. The range of values is representative of the type of soil that should be present between surface and groundwater beneath the Site.

### 5.3.3.3 Assumptions and Data Sources

In setting up the model to simulate present and future conditions at the Site, the following assumptions and data sources were used:

- ◆ Net groundwater recharge from rainfall is set to 0.01 foot per year. This value was the higher of estimated values from SESOIL model for borings of MW-11S and MW-21S that use site-specific soil types and climatic conditions.
- ◆ It is assumed that soil layers beneath the Site have an effective porosity 0.25 that is the same as that used in SESOIL model, based on site specific yield tests in the aquifer material (specific yield of 0.22).
- ◆ A conservative assumption is that both of the contaminants may dissolve in the percolating water. It is not limited by its natural solubility; however, it is retarded in its downward velocity by adsorption on natural organic material.
- ◆ The octanol-water partition coefficient  $K_{oc}$  was not used in the calculations for lead because it was not found in the literature. Instead, the average, minimum, and maximum values of the distribution coefficient ( $K_d$ ) were used in the calculations.

### 5.3.3.4 Analytical Leaching Model Results

The Analytical Leaching Model modeling results indicate that for lead, no impact to groundwater in less than 7,647,000 years (for lower end of  $K_d$  value) from contamination at any depth above groundwater, and the maximum groundwater concentration is 12.57  $\mu\text{g/L}$  after lead reaches groundwater table then

mixes with groundwater under current conditions. The  $K_d$  range of values are sufficiently high that migration to the current groundwater surface is unlikely as summarized in Table 13.

Organic lead results differ from inorganic lead results because the values of the retardation factor of organic lead are much lower than those of lead (two orders of magnitude lower). The Analytical Leaching Model results show that the organic lead will not reach groundwater table in less than 78,767 years (for lower end of  $K_d$  value). The maximum groundwater concentration after organic lead reaches groundwater then mixes with groundwater under current conditions is calculated to be approximately 7.77  $\mu\text{g/L}$ . Therefore, the Analytical Leaching Model results indicate that the potential for organic lead impact on groundwater is also unlikely.

As described previously, Analytical Leaching Model analysis results are very conservative in terms of estimated groundwater concentration (i.e., the contaminant concentration is overstated) since the dissolved concentration is not limited by its natural solubility and the dispersion process is not included in the Analytical Leaching Model calculation. Although the estimated travel times are typically longer than expected in the field due to the absence of preferential pathways and dispersion in the calculations, they are still very long. Section 6.6.2 and Appendix H describe additional characterization of lead at the Site conducted in 2010 that confirms its lack of mobility. Section 10.3.1.10 describes the results of a treatability study conducted in November 2009 that also demonstrated that lead in Site soils is not mobile.

The Analytical Leaching Model results provided are based on site-specific information and the previous SESOIL model application (infiltration rate). In making assumptions regarding the input parameters, URS has selected conservative and realistic values that might result in maximum potential concentrations of lead and organic lead in groundwater underneath the Site.

#### 5.3.4 Analysis of PAHs Modeling in the Vadose Zone

Two PAH constituents, naphthalene and benzo(a)pyrene were selected for transport modeling. These analytes were selected based on frequency of detection in shallow soils, RSL exceedance, and high maximum concentrations. The potential impact to groundwater from naphthalene and benzo(a)pyrene in soil and soil gas at the Site was modeled using various transport models. These two constituents were not included in the initial assessment conducted by England Geosystem (2005a), but elevated soil concentrations were detected in TK101-WD and MWP-URS01 (located in the northwest of the main waste pit and north of the main waste pit, respectively) during the Phased Shallow Soil Investigation.

SESOIL model simulation results show that the travel time of benzo(a)pyrene and naphthalene to the groundwater table underneath the site are far beyond SESOIL's maximum simulation time of 100 years, due to very high adsorption of the constituents. Consequently, contaminant transport model MT3DMS (Zheng, 1990; Zheng and Wang, 1999) was used to simulate the chemicals' advection, dispersion, sorption, and degradation processes in the vadose zone, based on the net infiltration rate and moisture content derived from the SESOIL model. The maximum chemical concentration above the groundwater table was derived from the MT3DMS simulation. Finally, the modeled maximum concentration above the water table was taken into the SUMMERS model (Summers, 1980) to calculate the diluted maximum concentration in the groundwater mixing zone.

The chemical properties and initial soil concentration distributions for naphthalene and benzo(a)pyrene are listed in Table 14.

#### 5.3.4.1 SESOIL Modeling

In developing the SESOIL model for naphthalene and benzo(a)pyrene, a new soil profile was used based on the groundwater depth and soil types beneath TK101-WD and MWP-URS01 where the maximum constituent concentrations in soil were detected. Based on the average groundwater depth from 1991 to 2009, a soil profile of 78 feet was conservatively chosen for the SESOIL model. A set of boring logs near TK101-WD and MWP-URS01 (i.e., MW-1S, MW-6S, MW-22S, MW-27S, and MW-49S) were reviewed, and due to its most permeable soils (larger portion of high permeable gravel and sand, and small portion of low permeable silt and clay), the soil column of MW-6S was chosen to be used as the new soil profile in SESOIL model. MW-6S has the following soil types from ground surface to 78 ft bgs: 20 ft sand, 5-ft silt, 15-ft clay, 15-ft sand, 5-ft clay, and 20-ft sand.

Since the SESOIL model allows a maximum of four model layers, the following four SESOIL model layers were selected:

- ◆ Layer 1: 10-ft sand,
- ◆ Layer 2: 15-ft sand (use first 5-ft silt as clay),
- ◆ Layer 3: 20-ft clay (combining 15-ft clay and 5-ft clay), and
- ◆ Layer 4: 33-ft sand

Except for the soil profile, chemical properties, and initial soil concentration distributions, all other model input parameters were set as in the previous SESOIL model (England Geosystem, 2005a). The chemical properties and initial soil concentration distributions are those for naphthalene and benzo(a)pyrene. Specifically, the monthly climatic data, soil property parameters, and groundwater parameters for the mixing zone are the same as those used in the previous SESOIL model (URS, 2008a) (Appendix B). The chemical properties and initial soil concentration distributions for naphthalene and benzo(a)pyrene are listed in Table 14. The concentrations used were maximum concentrations measured during the Phased Shallow Soil Investigation.

No reliable modeling results were obtained from the SESOIL model for naphthalene and benzo(a)pyrene, due to the relatively high retardation factor which leads to very slow migration of the constituents in the vadose zone. A number of trial runs showed that within SESOIL's maximum simulation time of 100 years, naphthalene migrates very slow and benzo(a)pyrene appears not to migrate at all, and the associated groundwater concentrations are zero at the end of 100 year simulation. Both naphthalene and benzo(a)pyrene are almost immobile due to high soil adsorption resulting from a very high octanol-water partition coefficient (1,549 and 954,993 Liters per kilogram [L/kg] for naphthalene and benzo(a)pyrene, respectively).

Because of the above, MT3DMS was developed to simulate the constituent transport in the vadose zone, and the SUMMERS model was chosen to calculate the diluted concentration in the mixing groundwater zone.

#### 5.3.4.2 MT3DMS

MT3DMS is a transport model that can simulate advection, dispersion, and chemical reactions of dissolved constituents. The modeled chemical reactions include equilibrium-controlled linear or non-linear sorption, and first-order irreversible or reversible kinetic reactions.

In the previous modeling of the potential for migration of lead (Section 5.3.3) in the vadose zone, there is no vapor-phase transport (free-air diffusion) in the transport processes, thus the advection associated with water flow is the dominant transport process. In addition, there is no degradation for lead migration. Consequently, the Analytical Leaching Model is an appropriate tool for lead transport in the vadose zone.

Unlike modeling of lead, vapor-phase transport plays an important role in the migration of naphthalene and benzo(a)pyrene in the vadose zone. In addition, degradation also occurs for both naphthalene and benzo(a)pyrene. Consequently, ALM, which does not account for dispersion and degradation, can not be used directly. As a result, the MT3DMS model was chosen to model the naphthalene and benzo(a)pyrene migration in the vadose zone, based on the flow conditions derived from SESOIL model.

A one-dimensional MT3DMS model (vertical, with soil column of 78 feet) was set up. The flow condition used in the MT3DMS model was assumed steady state, with a constant flux of 0.014 ft/yr which is the average modeled groundwater recharge from the SESOIL model.

Due to the very low water velocity and the relatively dry soil condition in the vadose zone, the diffusion in air dominates the constituents' migration. Under this condition, an overall effective diffusion coefficient (both liquid and air phases diffusion) is used in the model simulation. The effective diffusion coefficient is calculated using Millington-Quirk equation:

$$D_{eff} = D_{air} \left( \frac{\theta_{air}^{10/3}}{\theta_{Total}^2} \right) + \frac{D_{water}}{K_H} \left( \frac{\theta_{water}^{10/3}}{\theta_{Total}^2} \right) \quad (1)$$

where:

- $D_{eff}$ : Overall effective diffusion coefficient [ $\text{cm}^2 / \text{sec}$ ]
- $D_{air}$ : Molecular diffusion in air [ $\text{cm}^2 / \text{sec}$ ]
- $D_{water}$ : Molecular diffusion in water [ $\text{cm}^2 / \text{sec}$ ]
- $q_{Total}$ : Total porosity of soil [no unit]
- $q_{water}$ : Volumetric moisture content of soil [no unit]
- $q_{air}$ : Volumetric air content of soil [no unit]
- $K_H$ : Henry's constant [no unit]

The chemical properties ( $D_{air}$ ,  $D_{water}$ , and  $K_H$ ) of naphthalene and benzo(a)pyrene are listed in Table 14. The total porosity and effective porosity are assumed to be 0.30 and 0.25, and the modeled moisture

content is 0.13 (SESOIL model), and the air content is calculated as 0.17. With the above parameters, the over all effective diffusion coefficient was calculated as 0.166 and 0.341 for naphthalene and benzo(a)pyrene, respectively.

The average values of the half lives in the unsaturated zone are listed in the literature as 258 and 1,060 days for naphthalene and benzo(a)pyrene, respectively (GSI, 2009). Considering that the degradation rate also depends on site conditions, a very conservative half life of 10 years was used for naphthalene, and no degradation was considered for benzo(a)pyrene in the MT3DMS model runs.

Other chemical properties (i.e., longitudinal dispersivity, distribution coefficient, effective porosity, and soil bulk density) used in MT3DMS are the same as those used in the previous SESOIL model. The MT3DMS model was run for such a simulation time that the maximum concentration above the water table was reached, and the maximum moisture concentration above the water table was recorded.

The modeled maximum moisture concentrations for naphthalene and benzo(a)pyrene above the water table for baseline simulation and sensitivity runs are shown in Table 15. Since a very long half life was used for naphthalene, and no degradation was modeled for benzo(a)pyrene, the MT3DMS model results are considered very conservative.

### 5.3.4.3 Summers Model

The SUMMERS model was chosen to calculate the groundwater concentrations due to the infiltrating contaminant and flowing groundwater; therefore, certain hydrogeologic and geometric properties of the aquifer and contaminant sources are needed. The hydrogeologic and geometric properties of the aquifer (i.e., horizontal hydraulic conductivity, horizontal hydraulic gradient, and the aquifer thickness) are the same as those used in the previous SESOIL model. Specifically, a horizontal hydraulic conductivity of 9.0 ft/day, a horizontal hydraulic gradient 0.0063, and an aquifer thickness of 50 ft were used in SUMMERS model. The width of contaminant zone was simply the diameter of the modeled contaminant plume, which was conservatively set to 120 feet. In addition, the initial contaminant concentration in the groundwater was assumed to be zero.

When the contaminants reach the water table, they will mix with groundwater over a certain thickness. When the aquifer is sufficiently thick, it may not be realistic to assume that the contaminants will be well mixed with groundwater over the entire thickness of the aquifer. SUMMERS model (USEPA, 1996) provided the following equation to estimate the mixing zone depth.

$$d_m = (0.0112L^2)^{0.5} + d_a \left( 1 - \exp \left[ \frac{-Lr}{K i d_a} \right] \right) \quad (2)$$

where:

- $d_m$ : mixing zone depth [L]
- $L$ : source length parallel to groundwater flow [L]
- $d_a$ : aquifer thickness [L]
- $r$ : recharge (infiltration) rate [L/T]

- $K$ : horizontal hydraulic conductivity of the saturated zone [L/T]; and  
 $i$ : horizontal hydraulic gradient [dimensionless]

The mixing zone depth used in the SUMMERS model should be the lesser of that calculated from the above equation and the actual aquifer thickness. In the case, the aquifer thickness is approximately 50 feet, whereas the calculated mixing zone from above equation is 23.5 feet. Therefore, 23.5 feet of mixing zone depth was used in the SUMMERS model, which is the same as that used in previous SESOIL model.

The contaminant concentration in groundwater in the mixing zone is calculated from the concentration in the infiltration water and the dilution factor which is given by:

$$DF = \frac{rL + K i d_m}{rL} \quad (3)$$

where:

- $DF$ : dilution factor [dimensionless]  
 $r$ : recharge (infiltration) rate [L/T]  
 $L$ : source length parallel to groundwater flow [L]  
 $K$ : horizontal hydraulic conductivity of the saturated zone [L/T]; and  
 $i$ : horizontal hydraulic gradient [dimensionless]; and  
 $d_m$ : mixing zone depth [L]

The groundwater concentration in the mixing zone of the aquifer is calculated by:

$$C_{water} = \frac{C_{moisture}}{DF} \quad (4)$$

where:

- $DF$ : dilution factor [dimensionless]  
 $C_{water}$ : diluted contaminant concentration in groundwater [M/L<sup>3</sup>]  
 $C_{moisture}$ : contaminant concentration in moisture at above water table [M/L<sup>3</sup>]

The contaminant concentration in moisture above the water table is derived from MT3DMS transport model runs.

#### 5.3.4.4 Model Results

SESOIL modeling results provide that the maximum groundwater recharge rate (infiltration rate) is 0.014 ft/yr at the contaminant plume area. The MT3DMS modeling results show that the maximum concentrations in moisture above the water table are 0.02 and 0.26  $\mu\text{g/L}$  for naphthalene and benzo(a)pyrene, respectively for both baseline simulation and sensitivity runs. The SUMMERS modeling results indicate that the maximum groundwater concentrations in the mixing zone are  $6.9 \times 10^{-5}$  and  $9.1 \times 10^{-4}$   $\mu\text{g/L}$  for naphthalene and benzo(a)pyrene, respectively, for both baseline simulation and sensitivity runs. All results are listed in Table 15.

The modeled maximum naphthalene concentration in groundwater is much lower than the OEHHA notification level of 17  $\mu\text{g/L}$ , and the modeled maximum benzo(a)pyrene concentration in groundwater is much lower than its MCL of 0.20  $\mu\text{g/L}$ . Therefore, the model results indicate that the potential for naphthalene and benzo(a)pyrene concentrations in shallow soil to impact groundwater is unlikely.

### 5.3.5 LNAPL Modeling Using LNASt

The LNAPL at the Site is characterized primarily as heavy refined crude/fuel oil with a light product. The LNASt program is primarily an organizational tool used to perform various calculations related to dissolution, volatilization, and solute transport. The software uses standard formulas to calculate (1) the depletion of soluble or volatile components from a multi-component LNAPL source area, followed by (2) the down-gradient movement of a dissolved phase, subject to biodegradation and dispersion. The model was developed jointly by Dr. David Huntley (San Diego State University) and Gary Beckett of (Aqui-Ver, Inc.) for the American Petroleum Institute in 2001.

The model was used to better understand the extent/longevity of dissolved benzene within the southern groundwater plume. The available input parameters using historical data were limited to (1) benzene mole fraction (based on analytical testing of LNAPL samples collected in 2009); (2) lithology profile within the smear zone (based on core sampling and UV photography of the LNAPL smear zone); (3) hydraulic conductivity (based on pump tests conducted at the Site); (4) hydraulic gradient (based on groundwater monitoring data); (5) source area geometry (based on historical investigation data); (6) target concentrations (ROD clean-up levels); (7) product density (physical testing of LNAPL samples); and (8) effective porosity (inferred from soil properties). A two layer model (upper silt unit overlain by a sand unit) was used to simulate conditions within the southern groundwater plume. The LNAPL source depletion in the upper silt unit was calculated with volatilization. The lower sand unit excluded volatilization based on the abundant presence of the upper silt unit and the presence of LNAPL below the water table where volatilization could not occur. The remaining inputs were based on default parameters compiled by the API and Remedial Technologies Forum (a joint Industry/Agency initiative to better understand remediation).

The key model output findings are summarized as follows:

- ◆ LNAPL is already near the calculated residual saturation, thus recovery via hydraulic methods provide limited (if any) net environmental benefit at this Site.
- ◆ The lateral extent of dissolved phase impacts is controlled by the effective solubility of the LNAPL within the saturated zone (sand unit). Removal of mass and/or remediation of impacts within the silt provide no observable changes in plume extent. On the basis of this assessment, the site was characterized as a ‘flux limited’ site where only changes in LNAPL composition (i.e. benzene content) would provide rapid reductions in groundwater concentrations and plume extent.
- ◆ Given the limitations of hydraulic recovery techniques and the modeling results which indicate that changing LNAPL chemistry is critical to changing plume extent and longevity (ITRC, 2009), a range of alternative remedial options were identified. These remedial options were focused on technologies that could facilitate the preferential stripping of volatile constituents (i.e benzene). Soil vapor extraction, multi-phase extraction, and air sparging were identified as potentially

applicable technologies, but only air sparging was considered viable given that the majority of mass is distributed below the water table.

- ◆ Given the current, low benzene mole fraction in the LNAPL (0.21% in EW-04, 0.24% in EW-01), the percent pore volume near residual saturation, and the presence of fine-grained units, air sparging may have limited effect on reducing plume extent and longevity.

The EPA and DTSC, respectively, were informed of these results during meetings held on October 8, 2009 and on October 13, 2009. The modeling results were not published since it was intended to provide a conceptual understanding of product sorbed within the smear zone in Aquifer I. In addition, regression analysis to estimate plume longevity was discussed in concept with EPA. The use of concentration versus time as a tool to estimate cleanup time is based on the assumption that constituent mass is primarily within the dissolved phase, which is not the case for this Site. This type of analysis does not account for constituent depletion within the residual LNAPL. As such, a pilot test will be an integral step in remedial design for any groundwater alternative other than MNA.

## 5.4 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

The potential for COPCs to impact groundwater was evaluated in this section using fate and transport models. Potential sources of groundwater contamination that were evaluated included 1) ROD parameters (benzene, ethylbenzene, toluene, 1,2-DCA, and methylene chloride) in the shallow soil; 2) COPCs found in high frequency and in exceedance of industrial screening criteria (i.e., RSLs/CHHSLs) in the shallow soil, and 3) sorbed LNAPL trapped beneath the water table due to fluctuating water levels that have created a smear zone within both groundwater plumes at the Site. The objective of modeling the COPCs in soil was to predict how long it would take for these constituents to reach groundwater, and if they did migrate to groundwater, would they impact groundwater quality adversely. The LNAPL modeling was performed to conceptually understand plume extent/longevity using constituent concentrations in the southern groundwater plume.

Inputs to the models included site-specific lithologic, hydrologic, geometric, and climatic data, soil characteristics, and chemical properties and concentrations. Where site-specific data were unavailable, conservative values were used. Target COPCs selected for modeling included organic lead, lead, naphthalene, and benzo(a)pyrene. Modeling was performed on maximum detected results.

ROD parameter results from the phased shallow soil investigation were compared to soil screening levels (SSLs) developed using the SESOIL model England Geosystem (2005c). Benzene results at two locations exceeded the SSL (230 µg/kg), and could potentially migrate to groundwater. However, it does not appear that this potential migration pathway is affecting groundwater concentrations based on existing monitoring data near these locations, most likely due to natural attenuation in the vadoze zone and sulfate reducing conditions within Aquifer I.

SESOIL and the Analytical Leaching Model were used to evaluate organic lead and inorganic lead. SESOIL, MT3DMS, and SUMMERS models were used to evaluate naphthalene and benzo(a)pyrene. Maximum results modeled for each of these constituents did not demonstrate a potential to impact



groundwater adversely (i.e., exceed groundwater quality criteria such as MCLs or State notification levels).

The LNASt model provided the following information: LNAPL is near residual saturation, any recovery via hydraulic methods will provide little benefit, and the longevity of the dissolved benzene plume will only be affected by changes in LNAPL composition (i.e., benzene content).

Modeling results provide useful information for addressing these impacts in the shallow soil and groundwater. In situ remedial options for treating lead, naphthalene, and benzo(a)pyrene in shallow soil is feasible and impacts to groundwater are unlikely.

Remedial options for groundwater contaminants should focus on changing LNAPL composition in the smear zone beneath the water table using technologies that can strip volatile constituents (i.e., benzene) such as air sparging. Upon completion of air sparging for the LNAPL objective, naturally occurring sulfate in groundwater could be circulated within the remaining dissolved plume to enhance biodegradation until such a point when the program may be transitioned to long-term MNA.

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## 6.0 HUMAN HEALTH RISK ASSESSMENT

An HHRA was performed to address potential risks to human health from refinery related chemical constituents encountered at the Site. The purpose of this assessment is to evaluate whether or not analytes detected in soil and soil gas are COPCs that present a threat to human health. If particular COPCs pose a significant threat, they become chemicals of concern (COCs) which then warrant further consideration in terms of remediation and/or other site mitigation (e.g., institutional or engineering controls). The Site was evaluated as 14 AOCs to facilitate the human and ecological evaluations, rather than evaluating the entire Site as a whole. The ecological risk evaluation, which was only conducted for AOC 1, is presented in Section 7.0. The HHRA calculations are presented in Appendix F.

The HHRA addresses potential threats to human health under commercial/industrial future land use conditions (based on a thorough land reuse assessment [Chevron, 2010] included in Appendix B), including risks to future construction workers and to future industrial workers. Presently, there is no active use of the Site and, therefore, no anticipated on-site human health risks for current conditions. This baseline HHRA includes evaluation of risk due to inhalation of indoor air vapors from soil gas and risk due to outdoor exposures related to contaminated soil, including ingestion of soil, dermal contact with soil, inhalation of outdoor particulates from soil, and inhalation of outdoor vapors from soil under commercial/industrial and construction worker scenarios. Although residential land use is not anticipated for this Site, a screening-level residential HHRA is provided for comparative purposes and is summarized in Section 6.5.4.1; an evaluation of current offsite residential receptors is provided in Section 6.5.4.2. Part of the Site (e.g., AOC 1) may be used for recreational purposes such as hiking; however, exposures to potential future recreational users will be covered by the evaluation of commercial/industrial workers.

The HHRA relied on environmental site characterization data collected during historical and recent investigations (as presented previously in this document); statistical summaries of the available data are provided in Appendix F-1. The HHRA was prepared according to risk assessment guidelines recommended by the EPA and the California Environmental Protection Agency (Cal/EPA). Relevant provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (Title 40 Code of Federal Regulations [40 CFR] Part 300 et seq.), as amended, are applied. The technical methods used in this HHRA are based on practice guidelines recommended by the EPA (1989, et seq.) and the DTSC (1992 et seq.). Several supplemental guidance documents that reflect current EPA standards of practice also are referenced.

### 6.1 HUMAN HEALTH RISK ASSESSMENT

The HHRA evaluates the potential for adverse human health effects to occur under several exposure scenarios. Two receptor scenarios associated with future land use—commercial/industrial and construction/excavation—were evaluated. The HHRA is presented in five parts:

- ◆ Hazard Identification (Section 6.2)
- ◆ Exposure Assessment (Section 6.3);
- ◆ Toxicity Assessment (Section 6.4);
- ◆ Risk Characterization (Section 6.5); and
- ◆ Uncertainty Assessment (Section 6.6).

The primary HHRA results are presented as part of the Risk Characterization (Section 6.5). Discussion of the results and conclusions of the HHRA are presented in Section 6.7. Detailed calculation worksheets documenting the chemical transport/fate analysis for human exposure evaluation are presented in Appendix F-2, and the quantitative health risk characterizations are presented in Appendices F-3 and F-4.

## 6.2 HAZARD IDENTIFICATION

This section describes the selection of COPCs for the Site, the AOCs, and the data evaluation procedures used as the basis to characterize COPC source term concentrations in environmental media. A conceptual site model illustrating potential pathways between COPC sources and human receptors is also presented in this section. COPCs that present unacceptable health threats based on the results of the risk characterization become COCs, which are summarized in Section 6.7.

### 6.2.1 Constituents of Potential Concern

The identification of COPCs is based on the current and historical site characterizations described previously in this RI/FS. The site investigation data include reported concentrations of metals, PAHs, PCBs, SVOCs and VOCs in soil samples and of VOCs in soil gas samples. Although the ROD (USEPA, 1992a) concluded that Site concentrations of metals were consistent with background levels, metals were included in the HHRA as part of a comprehensive evaluation of available Site data using current risk assessment methodologies and practices. For this HHRA and with EPA concurrence, surface and subsurface soils from 0 to 10 ft bgs were evaluated together as a single stratum. Historical soil data from 0 to 10 ft bgs were retained and combined with more recent data (collected by URS from 2006 through 2008) for evaluation of non-volatile analytes within the same depth range. However, only the recent data (2006 through 2008) were used to evaluate VOCs in soil as representative of more current conditions. Soil gas samples were collected at 5 and 10 ft bgs at locations exhibiting high detections of soil VOCs at any depth, namely naphthalene in soils greater than 10 ft bgs. Soil gas samples were not taken above 5 ft bgs to minimize barometric pumping effects. Soil gas samples were collected in 2009 and were used to evaluate potential future vapor intrusion to indoor air concerns. Appendix F-1 contains the statistical summary tables of analytes detected at the Site by AOC.

As discussed in greater detail in the Section 6.2.2, the Site was evaluated as 14 AOCs (i.e., distinct units for decision-making purposes) to facilitate the risk assessment. There are perhaps hundreds of chemical analytes that could have been evaluated in the various samples that have been collected at the Site. Of all those potential analytes, only some will be detected and identified as COPCs, and, of those COPCs only some will pose a potentially significant threat (i.e., COCs). Consequently, a process was used to evaluate

the data and focus HHRA efforts on chemicals likely to be most influential to health-risk-related concerns at the Site.

### 6.2.1.1 Screening-Level Risk and Hazard Ratios

The COPCs were identified for each AOC based on a comparison of the maximum concentration of each detected analyte to a corresponding agency-derived screening level that constitutes a point-of-departure for health concerns (i.e., a level at or below which health concerns are considered to be inconsequential). At the request of EPA (USEPA, 2008), the screening levels were selected to represent an unrestricted-use ('residential') scenario. The lower of RSLs (RSLs; USEPA, 2009g) or CHHSLs (Cal/EPA, 2009) for exposure to soil under a residential scenario were used. Residential soil gas CHHSLs were selected to screen soil vapor data; soil gas CHHSLs for buildings constructed without engineered fill were used as a health-protective approach. If the maximum detected concentration of an analyte exceeded its corresponding RSL or CHHSL, or if there was no RSL or CHHSL, then that analyte was considered a COPC and retained for further evaluation; if there were no detected concentrations or if the maximum detected concentration was less than the corresponding RSL or CHHSL, then that analyte was not identified as a COPC and was eliminated from further evaluation. These comparisons to RSL or CHHSL values were quantified as 'screening-level risk estimates' or 'screening-level hazard quotients' which represent, respectively, the probability of developing cancer after a long-term exposure in a residential setting to carcinogens in soil or soil gas, or indicate that long-term exposure in a residential setting to noncarcinogens in soil or soil gas might elicit noncancer effects. Residential screening criteria (RSLs and CHHSLs) are health-protective (conservative), given the current and expected commercial/industrial setting of the Site, but these criteria help ensure that potentially important chemicals are not overlooked. Tables 16 through 29 show the results of this screening analysis by AOC.

Based on preliminary review of the screening-level risk estimates and hazard indices, consideration of additional RSL and CHHSL values derived for commercial/industrial exposure settings, and consideration of the full data set for the AOCs, it was apparent that AOCs 1, 6, and 10 have maximum detected concentrations of multiple chemicals at multiple locations which significantly exceed the screening-level and commercial/industrial criteria. For example, the screening-level cumulative risk estimates for residential exposure are greater than  $1 \times 10^{-3}$ ,  $1 \times 10^{-4}$ , and  $1 \times 10^{-3}$  for AOCs 1, 6, and 10, respectively, and the screening-level hazard indices for residential exposure are 20,000, 7,000, and 21,000 for AOCs 1, 6, and 10, respectively. Based on results of the screen, it is likely that quantitative evaluation of these AOCs using commercial/industrial and construction worker scenarios would indicate that mitigation would be required. Therefore, AOCs 1, 6 and 10 were advanced directly to the feasibility study component of this RI/FS and are not quantitatively evaluated any further within this HHRA.

### 6.2.1.2 Evaluation of Background Concentrations

For the remaining 11 AOCs, analytes with maximum concentrations greater than an RSL or CHHSL were then compared to the corresponding maximum background values using soil samples collected specifically outside known operational areas of the Site. A statistical summary table for the background samples is provided in Appendix F (as Table F-1-15). It should be noted that four samples originally collected in suspected background areas are now being regarded as Site samples because of high detected concentrations of COPCs: BA02-URS01 and BA02-URS01-R are now part of the data set for AOC 14;

sample BA02A-URS01 will replace them as background. Results for BA04-URS01 and BA04-URS01R are now part of the AOC 1 data set, and sample BA04A-URS01 will replace them in the background data set.

The background analysis was conducted to ensure that analytes present at naturally occurring concentrations were not evaluated as Site-related chemical threats to human health. Based in part on some of the assumptions embedded within the processes used to derive screening levels, it is possible that screening levels are mathematically derived to be at concentrations lower than naturally occurring concentrations, or below concentrations representative of living in an industrially developed area. Table 30 presents the comparisons of AOC-specific maximum detected concentrations to the background concentrations.

### **Arsenic**

A more in-depth statistical evaluation of arsenic data is discussed in this subsection. The methods described herein were based on the EPA Guidance (USEPA, 1992d) and USGS published literature (Helsel, 2002), and these methods were used as the basis for statistical comparisons between Site and background concentrations of arsenic.

### ***Distributional Tests***

Distributional tests are commonly employed statistical methods for comparing the Site concentration data to background concentration data and, specifically for this text section, arsenic concentrations in surface soil between 0 to 10 ft bgs at Site and background locations. The main purpose of distributional tests was to assess whether a given AOC had higher concentrations of arsenic than the background data set. Because each AOC was matched with the background samples from similar environmental conditions (except for the site influence), a direct comparison of the two distributions (site and background areas) was meaningful. An appropriate method of statistical analysis for this comparison would be a paired test that compares two independent data sets (such as the Wilcoxon Rank Sum test or the Student's *t* test).

An alternative to the two-data-set comparison method would be to compare more than two independent data sets (such as the Kruskal-Wallis test or parametric analysis of variance [ANOVA]). In the multiple-data-set comparison method, one would first assess whether any two data sets (i.e., all Site areas vs. background) are significantly different from each other. If so, one would then compare each Site area to the background area using the common error variance for all areas. An advantage of the simultaneous analysis of multiple data sets was that the sample size for the estimation of error variance would be larger and hence the statistical power of the test (i.e., the ability to discriminate differences) would be higher.

The goal of this comparison was to control the site-wide false positive error rate ( $\alpha$ ) at 5% (i.e., confidence level of 95%). The non-parametric Kruskal-Wallis test was used, with multiple comparisons conducted using Dunnett's Test on rank-transformed data.

### ***Results of Background Comparisons***

A summary of statistical comparison results for arsenic is presented in Table 31. The summary statistics of background data and site data are shown, along with the appropriate test statistics for arsenic

concentrations, and the *p*-values and statistical conclusions associated with overall differences and individual differences. Figure 27 shows the box-and-whisker plots of arsenic concentrations for each individual AOC and the background data set.

As noted in Table 31, the arsenic concentrations in all AOCs were not significantly higher than the background area, and, hence, arsenic concentrations were not considered to pose additional risk beyond that presented by background levels. This comparison result was confirmed by visual inspection of the box-and-whisker plots.

### 6.2.1.3 COPCs for Evaluation in the Quantitative HHRA

Chemicals with a maximum detected concentration that exceeded a corresponding residential RSL or CHHSL, and also exceeded the background concentration, were retained as AOC-specific COPCs and evaluated in this HHRA for commercial/industrial and construction worker scenarios. In addition, any chemical that lacked a residential RSL or CHHSL was also retained for further evaluation in the HHRA. Following is the list of COPCs evaluated in this HHRA, although not all COPCs are present in every AOC:

<b>COPCs considered in the HHRA</b>	
<b>Metals in Soil</b>	Chromium VI, Lead, and Organic Lead.
<b>Polyaromatic Hydrocarbons in Soil</b>	Acenaphthylene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Chrysene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Naphthalene, and Phenanthrene
<b>Semi-Volatile Organic Compounds in Soil</b>	Naphthalene and Phenanthrene
<b>Volatile Organic Compounds in Soil</b>	1,3-Dichlorobenzene, Ethylbenzene, Bromochloromethane, 1,2,3-Trichlorobenzene, 1,2-Dibromo-3-chloropropane, 1,2-Dibromoethane (EDB), Naphthalene, n-Butylbenzene, n-Propylbenzene, p-Isopropyltoluene, sec-Butylbenzene, and tert-Butylbenzene
<b>Volatile Organic Compounds in Soil Gas</b>	1,2-Dichloroethane, 2-Butanone (MEK), 2-Hexanone, 4-Methyl-2-Pentanone (MIBK), Acetone, Benzene, Bromomethane, Carbon disulfide, Chloromethane, Ethylbenzene, Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane), Isopropanol, Naphthalene, Styrene, Trichlorofluoromethane, and Vinyl Acetate

### 6.2.2 Areas of Concern

Given the size of the Site and complexity of past operations, chemical releases, and geography, it was determined that evaluating the Site as individual AOCs would help to focus the health risk evaluations on specific units amenable to discrete risk-management or remedial actions. After the Phase 2 site investigation conducted by URS in 2008, the available data were reviewed in the context of Site history and conditions to define the AOCs. Criteria used to group sample locations into defined AOCs included similarities in:

- ◆ Historical uses (e.g., process, storage, conveyance, etc.);
- ◆ Chemical releases;

- ◆ Geographical proximity;
- ◆ Terrain (e.g., steep slope limiting future development); and
- ◆ Potential future land use (e.g., area on west side of creek).

Using these criteria 14 AOCs were identified for this Site, as shown on Figure 2. The sample locations comprising each area are listed in Table 2. Additional sampling for the Phase 3 site investigation was conducted for each AOC to address the following data gaps:

- ◆ Characterization of organic lead in soil at depth;
- ◆ Confirmation of detections of specific soil constituents in certain locations;
- ◆ Provision of adequate coverage of soil samples in defined areas; and
- ◆ Characterization of soil gas in areas with high naphthalene and/or other VOC concentrations in soil.

After the Phase 3 sampling and review of the Site data, the AOCs were categorized as to the level of effort needed to evaluate potential health risks. While residential screening values were used to identify the AOC-specific list of COPCs, maximum detected concentrations in each AOC were subsequently compared to commercial/industrial RSL and CHHSL values (consistent with the agreed upon future land use for the site) for determining the level of risk assessment that would be needed. The AOC categories were:

1. Those not requiring a full risk assessment because maximum detected concentrations of all chemicals within the AOC are below the commercial/industrial screening criteria.
2. Those not requiring a full risk assessment because maximum detected concentrations of multiple chemicals at multiple locations within the AOC significantly exceed each respective commercial/industrial screening level. Mitigation would clearly be required for these AOCs.
3. Those requiring a complete risk assessment because some chemicals exceed their respective commercial/industrial screening values in limited locations. The risk assessment would help determine what future action would be needed at these AOCs.

No AOCs fell into the first group described above: all 14 AOCs contained samples with maximum detected concentrations of at least one COPC exceeding the commercial/industrial criteria (in addition to already having exceeded the residential screening criteria). As indicated previously, AOCs 1, 6 and 10 fell into the second category because multiple COPCs at multiple locations significantly exceeded residential screening criteria and would be expected to exceed commercial/industrial criteria: the screening-level cumulative risk estimates for residential exposure are greater than  $1 \times 10^{-3}$ ,  $1 \times 10^{-4}$ , and  $1 \times 10^{-3}$  for AOCs 1, 6, and 10, respectively, and the screening-level hazard indices for residential exposure are 20,000, 7,000, and 21,000 for AOCs 1, 6, and 10, respectively. Mitigation would likely be needed at these AOCs and, as stated in Section 6.2.1.1, these AOCs advanced directly to the feasibility study stage of this RI/FS. The remaining AOCs (2, 3, 4, 5, 7, 8, 9, 11, 12, 13 and 14) were considered to be areas in the third group that would be evaluated further by a site-specific risk assessment and are the focus of the remainder of this HHRA.

### 6.2.3 Conceptual Site Model

Although several complete exposure pathways may exist for a particular receptor, not all pathways are comparable in magnitude or significance. The significance of a pathway as a mode of exposure depends on the identity and nature of the COPCs involved and the magnitude of the likely exposure dose. The human health conceptual site model (CSM) diagram (Figure 28) illustrates the COPC sources, release mechanisms, transport pathways, exposure media, and receptors considered in this HHRA. The importance of each of the exposure routes associated with the receptor scenarios for this Site is represented on the CSM diagram by a solid box for potentially complete and significant pathways, by a hatched box for potentially complete but insignificant pathways and by an open box for pathways not applicable for the designated receptor and exposure route. The potentially complete, but insignificant, pathways are evaluated qualitatively in this HHRA.

Receptor scenarios addressed in the HHRA correspond with current and future off-site residents and with future on-site commercial/industrial (e.g., maintenance) workers and future on-site construction/excavation workers. For the purpose of evaluating potential exposure under these conditions, VOCs in soil represent the source for outdoor vapor exposures, and VOCs in soil gas are the source for indoor air. The future exposure scenarios further include the conservative assumption that subsurface soil (0 to 10 ft bgs) is unpaved and available for direct exposure, or for generation of particulates and subsequent inhalation of fugitive dust. These direct exposure conditions potentially could occur in the future if the Site were redeveloped for commercial/industrial use without adherence to a risk management plan specifying engineering and/or institutional controls. Under such uncontrolled conditions, regardless of any existing pavement or other hardscape land cover currently in place, relevant exposure routes of concern for soil include indoor and outdoor vapor inhalation, incidental soil ingestion, dermal contact, and inhalation of outdoor fugitive dust.

Receptor scenarios are further described below.

**Commercial/Industrial Workers** – For the purposes of this HHRA, the ‘commercial/industrial worker’ evaluation includes the outdoor maintenance worker included in the CSM (Figure 29). Commercial/industrial workers occupying the Site in the future potentially could come into direct or indirect contact with surface soils. Thus, the following exposure pathways were quantitatively evaluated for this receptor: incidental ingestion of soil, dermal contact with soil, inhalation of outdoor soil particulate and vapor emissions, and inhalation of indoor vapors emitted from soil gas. Because exposure to full-time workers

**Construction/Excavation Workers** – This receptor scenario addresses workers who may be engaged in earthmoving or subsurface operations in trenches or excavations without strict adherence to the ‘Hazardous Waste Operations and Emergency Response’ (HAZWOPER) standard specified at 29 CFR Part 1910.120. The following exposure pathways are addressed: incidental ingestion of soil, dermal contact with soil, inhalation of outdoor soil particulate and vapor emissions, and inhalation of soil gas vapor emissions in trenches (a partially confined space). Potential chronic health effects for this receptor scenario are evaluated based on intermediate-term exposure (a standard exposure scenario based on a one-year job duration on site).

**Off-site Residents** – This receptor refers to the current residential community to the west of the Site. Because the potentially complete exposure pathways are considered insignificant, the potential health risks are evaluated qualitatively for ingestion and dermal contact with impacted groundwater and outdoor inhalation of fugitive dust particles and vapor from the Site (see Section 6.5.4.2).

#### 6.2.4 Reasonable Maximum Exposure Considerations

Potential exposure under several land use scenarios was quantitatively evaluated using conservative exposure pathway assumptions. Such ‘reasonable maximum exposure’ (RME) receptor scenarios are intended to address the highest expected intensity of exposure based on a combined series of conservative assumptions.

Health risks and hazards associated with environmental exposures are directly related to the duration of exposure. Provided the chemical concentrations in environmental media remain constant, the populations facing longer exposures will receive the highest dose and hence would face the highest estimated health risk. Therefore, it is customary to assess the health risks and hazards based on the populations expected to receive a higher dose. If the health risks estimated for the ‘high dose populations’ are found to be within acceptable levels, then other populations having lower intensity of exposure do not have to be evaluated as their exposures and health risks can be concluded to fall within acceptable levels.

#### 6.2.5 Data Analysis

Data analysis of the analytical testing results was performed in accordance with the most recent risk assessment statistics guidance from EPA: *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA, 2002d). The higher values of duplicate samples were selected for the HHRA statistical calculations. Two key data statistics for each COPC are as follows:

- ◆ **95% Upper Confidence Limit** – The 95th percentile upper confidence limit of the arithmetic mean concentration (95% UCL) was calculated for each detected COPC with EPA ProUCL 4.0 software. As a conservative bounding approach, the source term concentration values produced using this method are likely to be larger than the true geostatistical mean.
- ◆ **Maximum Detected Values** – The maximum detected values were tabulated for each COPC. The maximum serves as a conservative estimate of the source term when the exposure area boundaries are not precisely known (e.g., for indoor inhalation exposures from soil gas) or when the 95% UCL does not apply, such as for limited sample size. The source term concentration values produced using this bounding approach are likely to be considerably larger than the true geostatistical mean for relevant exposure areas.

The use of these statistics by environmental medium and receptor is described in greater detail in Section 6.3.1.

The summary statistics tabulated include minimum and maximum detected concentrations, averages, standard deviations, and the 95% UCL values. Statistical summary tables for soil (0 to 10 ft bgs) and soil gas are presented by AOC in Appendix F-1. Source term concentration assignments for each receptor are described in Section 6.3.1.1.

## 6.3 EXPOSURE ASSESSMENT

The objectives of exposure assessment are to characterize the intensity, frequency, magnitude, and duration of potential human exposures for the subject COPCs and receptor scenarios. The end product of the exposure assessment is an estimate of chemical intake (i.e., a calculated dose) that integrates exposure parameters for the receptors (e.g., contact rates, exposure frequency, and duration) with exposure concentrations for the media of concern. The resulting chemical intakes are used in conjunction with chemical-specific toxicity values to evaluate potential health risks for the receptors. This exposure assessment focuses on COPCs detected in soil and soil gas at the AOCs. The remainder of this section describes the two basic steps used to quantitatively evaluate exposure for each COPC and receptor: (1) quantitative estimation of COPC sources, intermedia transfers, and exposure concentrations; and (2) calculation of intakes or doses.

### 6.3.1 COPC Sources, Transfers, and Exposure Concentrations

The COPCs initially released from a primary source into soil may be redistributed among physical phases and/or environmental media and migrate as liquids and vapors, eventually accumulating in ‘secondary source’ media. The CSM diagram (Figure 28) presents an analysis of chemical sources, release mechanisms, and potential exposure pathways relevant to this HHRA.

#### 6.3.1.1 Source Term Concentrations

The COPC source term concentration (STC) values are used to evaluate both direct contact and cross-media COPC exposures. For direct contact exposure routes, the exposure point occurs directly at the source (e.g., soil). For the incidental ingestion and dermal absorption exposure routes, the soil is considered a (secondary) source medium that may provide opportunity for direct contact unless engineering controls or existing barriers, like pavement or landscape cover, prevent such access. Cross-media exposures may result from the transfer of COPCs from source media (e.g., soil gas) to secondary exposure points, such as indoor air and outdoor air (see Section 6.3.1.2).

To quantitatively evaluate potential COPC exposures for each receptor, representative COPC STCs were assigned as described below using either the maximum detected concentration or the 95% UCL (see Section 6.2.5). Tables 32 and 33 show the STCs for soil and soil gas, respectively. For commercial/industrial workers’ outdoor exposures from soil, the 95% UCL concentration was used, where available, as the STC. If the total number of samples obtained was less than 10, then the maximum detected COPC concentration was used (based on the assumption that fewer than 10 sample observations do not provide a reliable basis for accurate estimation of the 95% UCL). If the total number of samples was greater than 10, then the lower of the 95% UCL or maximum detected concentration was used. Maximum detected concentrations of soil gas (Table 33) were the STCs for modeling potential indoor air exposures (as per DTSC [2004] guidance for future development). Soil gas data were not available for AOCs 2, 4, 5, 11, and 13.

The STCs for construction workers were also based on the 95% UCL COPC concentration in soil, if available, as described for commercial/industrial workers above. The maximum detected soil gas concentration was used as the source-term concentration for vapor exposures in construction-trench air.

### 6.3.1.2 Chemical Fate and Transport

For exposure pathways where chemicals may migrate between environmental media (i.e., for inhalation exposure), mathematical ‘fate and transport’ modeling tools were used to estimate COPC concentrations at the point of human exposure for each pathway. The modeling procedures are described in this section, and Section 6.3.1.3 discusses how the procedures are used to provide exposure point concentrations (EPCs).

Because of the extreme heterogeneity of the subsurface strata (as described in Section 3.4.2), the soil physical properties at the Site were conservatively assumed to be those associated with sandy soil (which is the most transmissive of the media in the fate and transport models). Default soil physical parameters associated with sandy soil type were taken from the DTSC (2009) version of the Johnson Ettinger (J&E; 1991) model of vapor intrusion. Soil physical properties (especially soil bulk density, total soil porosity, and water-filled soil porosity) are influential to subsurface vapor-modeling estimates.

**Outdoor Particulate Emission Modeling** – Potential emissions of COPCs adhered to dust released from soil to outdoor air were estimated using the model described in *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, 2002e). The particulate emission factor (PEF) represents an annual average particulate emission rate based on wind erosion and/or ground disruption during construction/excavation activities. For long-term exposures to commercial/industrial receptors, the emissions part of the PEF equation is based on the ‘unlimited reservoir’ model developed to estimate particulate emissions due to wind erosion (Cowherd et al., 1985). The dispersion part of the PEF equations includes a dispersion coefficient (Q/C) in units of grams per square meter-second per kilogram per cubic meter ( $\text{g}/\text{m}^2\text{-s}$  per  $\text{kg}/\text{m}^3$ ). The Q/C terms applied in the modeling were obtained from EPA (2002c). A default Q/C of  $93.77 \text{ g}/\text{m}^2\text{-s}$  per  $\text{kg}/\text{m}^3$  for commercial/industrial receptors was used. For construction/excavation workers, a default PEF value of  $1.0 \times 10^6 \text{ m}^3/\text{kg}$  was used (DTSC, 2005a). The outdoor air particulate emission equations and calculation worksheets are presented in Appendix F-2.

**Outdoor Vapor Emission Modeling** – Emissions of VOCs from soil to outdoor air were estimated using the model described in Appendix B of *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, 2002e). For each soil VOC determined to be a COPC, an intermedia transfer factor called the volatilization factor (VF) was calculated using the Q/C term described below and certain soil physical properties. The calculated soil-to-outdoor air VFs were used to estimate outdoor EPCs for commercial/industrial workers and for construction workers. Long-term vapor emission calculations based on exposure durations of 25 years were used for commercial/industrial workers (Appendix F-2). For construction workers potential exposure during construction/excavation activities with no exposure controls, the vapor emission calculations were performed based on assumed exposure duration of one year. The Q/C term, which represents air mixing and dispersion of emissions, expressed in units of grams per square meter-second per kilogram per cubic meter [ $\text{g}/\text{m}^2\text{-s}$  per  $\text{kg}/\text{m}^3$ ], is provided by EPA (2002e). These Q/C parameter values were generated using the Industrial Source Complex model. EPA presents these values in an algorithm, with calculation options available for various source area sizes, U.S. cities, and climatic zones. For this HHRA, a default Q/C value of  $68.18 \text{ g}/\text{m}^2\text{-s}$  per  $\text{kg}/\text{m}^3$  was used to model air mixing for the commercial/industrial land use scenario. For construction workers, a variant of the residential volatile emission equation described by EPA (2002e), with a default Q/C value of  $14.31 \text{ g}/\text{m}^2\text{-s}$  per  $\text{kg}/\text{m}^3$ , was used

(equation 5-14 of EPA, 2002e). The modeling results were used to estimate the volatile emissions EPC for chronic health effects assessments of the commercial/industrial worker receptor.

***Indoor Air Vapor Intrusion Modeling*** – The potential for VOCs to migrate from soil gas to indoor air was evaluated based on the approach used in the J&E model. The spreadsheet version of the ‘SG-SCREEN’ model (Version 2.0, last updated February 4, 2009; DTSC, 2009a) was used. For each COPC, the spreadsheet models were used to calculate an intermedia transfer factor called the alpha ( $\alpha$ ) value, which represents the ratio of the indoor air concentration to the subsurface soil gas source term concentration. The model was run using default soil physical property values for sandy soil (see Appendix F-2). Source term concentrations used as inputs for vapor intrusion simulations were developed from the site characterization soil gas data. The results from long-term simulations were used to estimate the indoor volatile emissions EPCs for future commercial (‘inside building’) workers.

***Trench/Enclosed Space Vapor Intrusion Evaluation*** – The potential for subsurface VOCs to migrate into partially enclosed spaces during construction or utility line related activities was evaluated based on modifying an approach published by the Virginia Department of Environmental Quality (VDEQ, 2009). The trench was assumed to be a well-mixed room with soil vapors originating from the trench floor. An emission rate from the bottom of the trench was determined based on the USEPA (2003b) *User’s Guide for Evaluating Subsurface Vapor Intrusion Into Buildings*. The trench was then assumed to be a well-mixed ‘room’ with an air exchange rate of 2/hr based on the trench model parameters used by VDEQ (2009) for trenches where the width of the trench (relative to wind direction) is less than or equal to trench depth. The width and length of the theoretical trench was taken from the VDEQ trench model. For this site a trench depth of 8 ft was assumed, and soil vapors are assumed to originate from 10 ft bgs, however soil vapor samples from 5 ft and 10 ft were used in determining the maximum concentration as a conservative value (VDEQ, 2009).

### **6.3.1.3 Exposure Point Concentrations**

Exposure is defined as the contact of an organism with a chemical or physical agent, that is, a co-occurrence in space and time of the receptor and the COPC. The EPC is the concentration of the agent at the exposure point (location of physical contact) to which a receptor potentially could be exposed. The EPC values used in evaluating potential human health risks should be representative of the exposure area being evaluated and take into account the degree to which COPCs could migrate from source media (e.g., soil) to the actual points of human exposure (e.g., nose, mouth, skin, etc.). As explained previously, the source term concentrations presented in Tables 32 and 33 for soil and soil gas, respectively, were used to evaluate potential human exposures on-site. For potential chemical releases into secondary exposure media, receptors’ EPC values were estimated using chemical transport-fate models, as described in Section 6.3.1.2. The EPC values are summarized in Tables 34 through 38.

### **6.3.1.4 Intake and Dose Estimation for Direct Contact**

Two types of intake dose values were calculated for direct contact exposures (i.e., ingestion and dermal contact). For non-carcinogenic health effects, the applicable measure of intake for chronic toxicants is referred to as the average daily intake (ADI) and for most receptors is a less-than-lifetime exposure. For chemicals that produce carcinogenic effects, intakes are averaged over an entire lifetime and are referred



to as the lifetime average daily intake (LADI). A generalized form of the equation that is used to calculate the (L)ADI for each COPC is given below:

$$(L)ADI = EPC \cdot \frac{RIF \cdot EF \cdot ED}{BW \cdot AT}$$

where:

<i>(L)ADI</i>	=	(Lifetime) Average daily intake (mg/kg-day)
<i>EPC</i>	=	Exposure point concentration (units vary by media)
<i>RIF</i>	=	Route-specific intake factor (mg/day)
<i>EF</i>	=	Exposure frequency (days/year)
<i>ED</i>	=	Exposure duration (years)
<i>BW</i>	=	Body weight (kg)
<i>AT</i>	=	Averaging time (days)

For ingestion, the RIF equals the soil ingestion rate (IR-S). For dermal contact,  $RIF = SA * AF * ABS$  where SA = skin surface area, AF = adherence factor, and ABS = absorption factor (chemical specific). These exposure parameters used to calculate the (lifetime) average daily intake for future commercial/industrial workers and construction/excavation workers under standard RME scenarios are listed in Tables 39 and 40, respectively.

### 6.3.2 Exposure Assessment for Inhalation Pathways

The EPA has recently updated their methods for the evaluation of inhaled chemicals (USEPA, 2009a). Previous methods utilized predictive equations that used inhalation rates and body weights of typical receptors to derive an inhaled dose (mass) of chemical. Current methods recognize that the exposure concentration, the pattern of exposure (e.g., intermittent versus continuous), and the ultimate organ or organ system that is affected by a chemical, all interact to affect the response in an exposed receptor. Consequently, average concentrations (AC) for non-carcinogens or lifetime average concentrations (LAC) for carcinogens are derived using the following equation:

$$(L)AC = EPC \cdot \frac{EF \cdot ED \cdot ET}{AT \cdot CF}$$

where:

<i>(L)AC</i>	=	(Lifetime) Average concentration (ug/m <sup>3</sup> )
<i>EPC</i>	=	Exposure point concentration (mg/m <sup>3</sup> )
<i>EF</i>	=	Exposure frequency (days/year)
<i>ED</i>	=	Exposure duration (years)
<i>ET</i>	=	Exposure time (hours/day)
<i>AT</i>	=	Averaging time (days)
<i>CF</i>	=	Conversion factor (24 hours/day)

The exposure parameters for commercial/industrial workers and construction/excavation workers are listed in Tables 39 and 40, respectively.

## 6.4 TOXICITY ASSESSMENT

The toxicity assessment step in a health risk evaluation characterizes the relationship between the magnitude of exposure to a COPC and the nature and magnitude of adverse health effects that may result from such exposure (i.e., dose-response relationships). Chronic toxicity criteria were selected from Cal/EPA preferred sources, and were used to evaluate risk from both chronic and sub-chronic exposures. The following sources of toxicity values were used, listed in order of preference

1. Cal/EPA Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database (OEHHA, 2010a) and Cal/EPA OEHHA Chronic Reference Exposure Levels (OEHHA, 2010b);
2. EPA Integrated Risk Information System (IRIS) (USEPA, 2010b); and
3. EPA's hierarchy as evidenced in the RSLs (USEPA, 2009g): provisional peer-reviewed reference toxicity values (PPRTVs), the Agency for Toxic Substances and Disease Registry's Minimal Risk Levels, values from EPA's Environmental Criteria and Assessment Office, then other sources (screening values from 'PPRTV Appendix' sources and other specific individual toxicity values).

The toxicity values for the COPCs are listed in Table 41 and summarized below.

### 6.4.1 Carcinogenic Toxicity Assessment

For carcinogenesis, OEHHA and EPA assume a mechanism of action in which a single molecular event can cause changes in cells and lead to cancer. This hypothesized mechanism is referred to as non-threshold, and it assumes that there is no level of exposure that does not pose some finite probability of developing cancer.

Based on the evidence that a chemical is a known or probable human carcinogen, a toxicity value, the slope factor (SF), is developed to quantitatively express the dose-response relationship. SFs are route-specific and are commonly upper-bound estimates of the probability of a carcinogenic response per unit intake of a chemical over a lifetime. The SFs are generally calculated from the 95% UCL on the slope of the dose-response curve. Slope factors for oral exposures are expressed in units of risk per ingestion exposure  $(\text{mg}/\text{kg}\cdot\text{d})^{-1}$ , while slope factors for inhalation exposures are mathematically re-arranged to express the carcinogenic risk as a function of air concentration, that is, as an 'inhalation unit risk' (IUR) expressed in units of  $(\mu\text{g}/\text{m}^3)^{-1}$  (which assumes continuous exposure to COPC-laden air).

### 6.4.2 Noncancer Toxicity Assessment

The toxicity information most often used to evaluate noncarcinogenic, or threshold, effects in risk assessment is the reference dose or concentration. Reference doses are route-specific and can be an ingestion-based oral dose (RfDo) or a dermally-absorbed reference dose (RfDd), expressed as milligrams of chemical per unit of body weight per day (mg/kg-day). An inhalation reference concentration (RfC), expressed as milligram (mg) of COPC per cubic meter of air, is an air concentration and is assumed to be

for continuous exposure. EPA (1989) defines a chronic reference dose or reference concentration as an estimate of a daily exposure level for humans (including sensitive individuals), with uncertainty spanning perhaps an order of magnitude or greater, that is likely to be without an appreciable risk of deleterious effects during a lifetime.

The use of RfDs and RfCs is based on the concept that a range of exposures exist up to a finite value, or threshold, that can be tolerated without producing a toxic effect. RfDs and RfCs are derived with mathematical uncertainty factors (UFs) that generally consist of multiples of 10 to represent areas of uncertainty inherent in the extrapolation from the available data. These UFs account for the following extrapolations: extrapolation of animal data to humans, sensitive individuals in the exposed population, use of a no observed adverse effect level (NOAEL) from subchronic rather than chronic studies, and the use of a lowest observed adverse effect level (LOAEL) rather than a NOAEL to derive the RfD when a NOAEL has not been determined. The decision on inclusion of appropriate UFs is an intrinsic part of the agency-developed processes for publication of toxicity values, i.e., it is not a decision that is part of a site-specific HHRA.

### 6.4.3 Organic Lead

The toxicity value for the COPC organic lead is an RfD specifically derived for tetraethyl lead which, as with RfDs of other COPCs, represents a derived ingestion exposure threshold for the potential onset of adverse noncarcinogenic health effects. Despite that similarity, however, organic lead is unique among the other COPCs because the analytical method used to measure organic lead at the site can include many hundreds of different forms of organic lead, while analytical methods for the other COPCs target specific, individual, molecules for measurement. The potential forms of organic lead include anthropogenic alkylated lead (such as the gasoline additive tetraethyl lead) or lead that is adsorbed to naturally occurring organic acids (such as humic and fulvic acids, which are naturally occurring degradation products of organic matter in the environment). Unfortunately, toxicity criteria are not available for these organic lead species, and the toxicity value for one specific organic lead molecule, i.e., tetraethyl lead, is used to evaluate a potentially highly complex mixture of organic lead compounds in this risk assessment. This introduces considerable uncertainty into the noncancer hazard evaluation of organic lead as a COPC, as further discussed in Section 6.6.2.

### 6.4.4 Inorganic Lead

Inorganic lead toxicity is characterized on the basis of the predicted lead concentration in a receptor's bloodstream, rather than on the basis of an exposure concentration (e.g., an RfC) or an ingested or absorbed dose (e.g., an RfD) like the other COPCs. Formerly, the generally accepted indicator threshold for blood-lead concentration was 10 micrograms lead per deciliter blood ( $\mu\text{g}/\text{dL}$ ); blood-lead concentrations above 10  $\mu\text{g}/\text{dL}$  were considered to contribute to adverse effects in the nervous and blood systems (as the more-sensitive toxicity endpoints). However, more recent scientific literature is tending towards an understanding that adverse effects may occur at lower blood-lead concentrations, and that there may be no blood-lead concentration that is without effect. Current predictive methods for estimating blood-lead concentrations from site-specific data utilize mathematical models that integrate

estimated exposures to lead from multiple sources (for example, in soil, water, and dust) with physiological (metabolic) and behavioral (e.g., activity patterns) characteristics.

The EPA developed the ‘Adult Lead Model’ (ALM) (USEPA, 2003a) to predict blood-lead concentrations in target receptor populations of occupational adults. The ALM estimates the fetal blood-lead concentration associated with occupational exposure of a pregnant woman to lead-contaminated soil and dust. For the EPA, an ‘acceptable level’ is an aggregated exposure concentration (of lead in soil, dust, and water) that results in a predicted 95th-percentile blood-lead concentration that does not exceed 10 µg/dL. The ALM documentation provides several estimates of acceptable concentrations of lead in soil, depending on ethnicity or national region, which range from approximately 800 mg/kg to approximately 1,370 mg/kg. The overall average acceptable concentration of lead in soil (all ethnic groups, all regions) is predicted by the ALM to be approximately 1,200 mg/kg, with the 800 mg/kg soil concentration representing a health-protective (conservative) screening-level concentration, commonly used as a threshold for further analysis. EPA has since updated some of the parameter values used in the ALM (including consideration of data from two large-scale studies of test populations), and revised the ALM computational model (USEPA, 2009h).

OEHHA (2007) reassessed the toxicity of inorganic lead and developed a new toxicity benchmark corresponding to an incremental change of 1 µg/dL in blood-lead concentration resulting from site-related exposures. As a consequence of these changes in the toxicity endpoint and value, OEHHA (Cal/EPA, 2009) has revised the soil CHHSLs for residential and commercial/industrial scenarios. For commercial/industrial scenarios, OEHHA (2009) modified the input parameters of the ALM (USEPA, 2003a) to now estimate the soil concentration associated with a 90<sup>th</sup> percentile estimate for a 1 µg/dL change in blood-lead concentration. Input-value modifications included:

- ◆ A revised geometric mean standard deviation for the blood-lead level in a homogenous population (new value 1.8; formerly 2.1) (see USEPA, 2009h);
- ◆ A baseline blood-lead level set to 0.0 µg/dL (formerly 1.5 µg/dL) because the new endpoint is an *incremental* change of 1 µg/dL in the blood-lead concentration;
- ◆ An exposure frequency set to 250 day per year (formerly 219 days per year) to be consistent with the exposure frequency used to derive other CHHSLs;
- ◆ A new target blood-lead level of 1 µg/dL (formerly 10 µg/dL); and
- ◆ A new threshold set at the 90<sup>th</sup> percentile of the distribution of the blood-lead level versus soil lead relationship (formerly 99<sup>th</sup> percentile).

The revised CHHSL for a commercial/industrial scenario is 320 mg/kg, reduced from the former value of 3500 mg/kg.

Assessments of inorganic lead used the exposure point concentrations of lead in soil at each of the AOCs with OEHHA (2009) and USEPA (2009h) values as inputs to the updated ALM. The AOC-specific result is the predicted probability that the fetal blood-lead concentration would be increased by 1 µg/dL from maternal exposure to lead in soil, for a commercial/industrial exposure scenario. As used by OEHHA

(2009), the threshold for significance was a 10% probability that there would be an incremental change greater than 1 µg/dL in the blood-lead concentration predicted from AOC exposures to lead. The ALM results for a commercial/industrial receptor are presented in Appendix F-4. At present, there is no agency-developed approach for using the ALM to evaluate a construction worker exposure scenario and the potential hazards to this receptor from soil lead cannot be estimated.

## 6.5 RISK CHARACTERIZATION

The risk characterization process integrates the quantitative and qualitative results of the data evaluation, exposure, and toxicity assessments. The purpose of risk characterization is to estimate the likelihood, incidence, and magnitude of the potential human health effects from exposure to the COPCs under study and make judgments about the nature of the health threat to the defined receptor populations. The risk characterization methods and results are presented in the remainder of this section.

### 6.5.1 Risk Characterization Methods

The methods used to characterize potential health risks are specific to carcinogenic and noncancer toxicity. The risk characterization methods applied for each type of chemical toxicity are described below.

#### 6.5.1.1 Cancer Risk

Cancer risks are expressed as the upper-bound, increased likelihood of an individual developing cancer because of exposure to a particular chemical. For example, a cancer risk of  $1 \times 10^{-4}$  refers to an upper-bound increased chance of one in ten thousand individuals exposed, of developing cancer over a lifetime (0.01 percent risk). The following equation is used to estimate the excess cancer risk (a unitless probability):

$$\text{Excess Cancer Risk} = LADI \times CSF \text{ or } LAC \times IUR$$

where:

*LADI* = Lifetime average daily intake (mg/kg-day)

*CSF* = Cancer Slope Factor (mg/kg-day)<sup>-1</sup>

*LAC* = Lifetime average concentration (µg/m<sup>3</sup>)

*IUR* = Inhalation Unit Risk (µg/m<sup>3</sup>)<sup>-1</sup>

Cancer risk estimates for individual chemicals are summed to generate an estimate of cumulative risk (i.e., multiple carcinogenic chemicals, potentially via multiple routes of exposure), and it is this cumulative risk estimate that forms the basis for remedial decision-making. In the NCP, EPA states that: '[f]or known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual between  $10^{-6}$  and  $10^{-4}$ .' Cancer risks less than  $1 \times 10^{-6}$  are generally considered *de minimis*.

### 6.5.1.2 Noncancer Hazard

The potential for noncancer effects resulting from exposure to a particular chemical are expressed as a hazard quotient (*HQ*). An *HQ* is the ratio of the estimated intake (*ADI*) or average concentration (*AC*) of a chemical to the corresponding chemical-specific *RfD* or *RfC*:

$$\text{Hazard Quotient} = \frac{ADI}{RfD} \text{ or } \frac{AC}{RfC}$$

Chemical- and pathway-specific *HQs* may be combined to form a hazard index (*HI*), which is then compared to a typically accepted benchmark level of 1.0. If the *HI* exceeds 1.0, then combined site-specific exposures exceed the *RfDs* and/or *RfCs*, meaning that there is potential for noncancer adverse effects to result from exposure to site *COPCs* under the evaluated receptor scenario(s).

### 6.5.2 Risk Characterization Results for AOCs 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, and 14

The exposure assessment and risk characterization procedures described above were used to estimate cancer risks and noncancer hazard threats to human health from exposure to *COPCs* by commercial/industrial and construction workers. A summary of the chronic health risk assessment results by *AOC* are presented in Table 42; note that *AOCs* 1, 6, and 10 went directly to the feasibility study (see Section 6.5.3) and, therefore, Table 42 only presents results for *AOCs* 2, 3, 4, 5, 7, 8, 9, 11, 12, 13 and 14. Detailed risk assessment calculation worksheets are presented in Appendix F-3 (risk and hazard estimates) and Appendix F-4 (inorganic lead evaluation), and the remainder of this section summarizes the health risk characterization developed for each receptor, by *AOC*.

#### **AOC 02**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the *COPCs*, for soil ingestion, dermal contact, and outdoor inhalation was  $5.6 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 180. The cumulative outdoor cancer risk was *de minimis* but the non-cancer hazard index was above the target of 1. Organic lead was not the only noncarcinogenic *COPC* but it accounted for >99.99% of the hazard index; the hazard index for the other *COPCs* totaled approximately 0.0000007.

Based on the inorganic lead *EPC* in *AOC 02* soil (11 mg/kg), the *OEHHA* (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated *ALM* (*USEPA*, 2009h), there is a <1% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by *OEHHA* (2007) in their derivation of a soil *CHHSL* that is protective of fetuses. Consequently, lead concentrations in soil at *AOC 02* do not pose a significant hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the *COPCs* for soil ingestion, dermal contact and outdoor inhalation was  $5.4 \times 10^{-8}$ . The calculated outdoor cumulative non-cancer hazard index was 470. The cumulative outdoor cancer risk was *de minimis* but the non-cancer hazard index was above the target of 1. Organic lead was not the only

noncarcinogenic COPC but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.000002.

### **AOC 03**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $2.3 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 53. The calculated cumulative cancer risk for indoor exposures from soil gas was  $7.5 \times 10^{-8}$ , and the calculated cumulative indoor non-cancer hazard index was 0.0004. The cumulative cancer risk was *de minimis* for indoor exposures and within the risk management range of  $10^{-6}$  to  $10^{-4}$  for outdoor exposures. The cumulative non-cancer hazard indices for outdoor exposure was above the target of 1, but indoor exposures were below the target. Organic lead was not the only noncarcinogenic COPC but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.0007.

Based on the inorganic lead EPC in AOC 03 soil (212 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a 2% to 6% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 03 do not pose a significant hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $2.3 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 140. The cumulative outdoor cancer risk was *de minimis*, but the non-cancer hazard index was greater than the target of 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.003. The calculated cumulative cancer risk for trench/enclosed space exposure from soil gas was  $2.8 \times 10^{-8}$  which was *de minimis*; and the calculated cumulative trench/enclosed space non-cancer hazard index was 0.003 which does not exceed the target.

### **AOC 04**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $3.4 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 6.4. The cumulative outdoor cancer risk was within the risk management range of  $10^{-6}$  to  $10^{-4}$ , but the non-cancer hazard index was above the target of 1. Organic lead was not the only noncarcinogenic COPC but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.000004.

Based on the inorganic lead EPC in AOC 04 soil (43.7 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a <1% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil



CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 04 do not pose a significant hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $3.3 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 17. The cumulative outdoor cancer risk was *de minimis* but the non-cancer hazard index was above the target of 1. Organic lead was not the only noncarcinogenic COPC but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.000009.

#### **AOC 05**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $2.3 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 0.047. The cumulative outdoor cancer risk was within the risk management range of  $10^{-6}$  to  $10^{-4}$  and the non-cancer hazard index was below the target of 1.

Based on the inorganic lead EPC in AOC 05 soil (93.8 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a <1% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 05 do not pose a significant hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $2.3 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 0.12. The cumulative outdoor cancer risk was *de minimis* and the non-cancer hazard index was below the target of 1.

#### **AOC 07**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $6.5 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 3.7. The cumulative outdoor cancer risk was within the risk management range of  $10^{-6}$  to  $10^{-4}$  and the non-cancer hazard index was slightly above the target of 1. Organic lead was not the only noncarcinogenic COPC but it accounted for >99.8% of the hazard index; the hazard index for the other COPCs totaled approximately 0.004. The calculated cumulative cancer risk for indoor exposures from soil gas was  $1.2 \times 10^{-6}$ , and the calculated cumulative indoor non-cancer hazard index was 0.005. The cumulative indoor cancer risk was *de minimis* and the non-cancer hazard index was below the target. VOCs in soil gas do not present unacceptable vapor inhalation risks via indoor air.

Based on the inorganic lead EPC in AOC 07 soil (415 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a 20% to 26%

probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results exceed the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 07 pose a potential hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $6.6 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 9.7. The calculated cumulative cancer risk for trench/enclosed space exposure from soil gas was  $4.7 \times 10^{-7}$ , and the calculated cumulative trench/enclosed space non-cancer hazard index was 0.05. The cumulative cancer risk for both outdoor exposures and for trench/enclosed space was *de minimis*, the non-cancer hazard index for inhalation of trench/enclosed space air was below the target of 1, but the non-cancer hazard index for outdoor exposure was greater than the target of 1. Organic lead was not the only noncarcinogenic COPC but it accounted for >99.9% of the hazard index; the hazard index for the other COPCs totaled approximately 0.001.

#### AOC 08

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $2.0 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 70. The calculated cumulative cancer risk for indoor exposures from soil gas was  $4.2 \times 10^{-10}$ , and the calculated cumulative indoor non-cancer hazard index was 0.00002. The cumulative cancer risk was *de minimis* for indoor exposures and within the risk management range of  $10^{-6}$  to  $10^{-4}$  for outdoor exposures. The non-cancer hazard index was below the target of 1 for indoor exposures, but was greater than the target for outdoor exposures. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.002.

Based on the inorganic lead EPC in AOC 08 soil (216 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a 3% to 6% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 08 do not pose a significant hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $2.0 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 180. While the cumulative outdoor cancer risk was *de minimis*, the non-cancer hazard index was above the target of 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.003. The EPC for organic lead is due to one detection (sample SR-URS01) of 13 mg/kg at 1 ft bgs. Removal of this concentration would leave residual health risks within acceptable levels for construction workers in this AOC. The calculated cumulative cancer risk for trench/enclosed space exposure from soil gas was  $1.6 \times 10^{-10}$ , and the calculated cumulative



trench/enclosed space non-cancer hazard index was 0.0002. The cumulative cancer risk for trench/enclosed space was *de minimis*, and the non-cancer hazard was below the target.

### **AOC 09**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $6.6 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 15. The calculated cumulative cancer risk for indoor exposures from soil gas was  $3.7 \times 10^{-7}$ , and the calculated cumulative indoor non-cancer hazard index was 0.0004. The cumulative cancer risk was *de minimis* for indoor exposures and was within the risk management range of  $10^{-6}$  to  $10^{-4}$  for outdoor exposures. The cumulative non-cancer hazard index for indoor exposure was below the target of 1, but the hazard index for outdoor exposure was greater than 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.9% of the hazard index; the hazard index for the other COPCs totaled approximately 0.01.

Based on the inorganic lead EPC in AOC 09 soil (1830 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a 91% to 95% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results exceed the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 09 pose a potential hazard to the commercial/industrial worker. Note, however, that the EPC is highly reflective of the statistical influence of two results (a detection of 2500 mg/kg from 5 ft bgs at MWP-URS04 and a detection of 3700 mg/kg from 5 ft bgs at N-1; excluding these two elevated outliers from the other 19 detected concentrations of lead in AOC 09 soil would result in a EPC less than the soil lead CHHSL (320 mg/kg), and would not indicate a potential hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $7.3 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 40. The calculated cumulative cancer risk for trench/enclosed space exposure from soil gas was  $1.6 \times 10^{-7}$ , and the calculated cumulative trench/enclosed space non-cancer hazard index was 0.004. The cumulative cancer risks were *de minimis* for both outdoor and trench/enclosed space exposures, the hazard index for inhalation of trench/enclosed space air was below the target of 1, but the hazard index for outdoor exposure was greater than the target of 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.8% of the hazard index; the hazard index for the other COPCs totaled approximately 0.05.

### **AOC 11**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $1.8 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 14. The cumulative cancer risk was *de minimis* but the non-cancer hazard index was greater than the target of 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.0002.



Based on the inorganic lead EPC in AOC 11 soil (660 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a 48% to 49% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results exceed the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 11 pose a potential hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $6.1 \times 10^{-8}$ . The calculated outdoor cumulative non-cancer hazard index was 36. The cumulative cancer risk was *de minimis* but the non-cancer hazard index was greater than the target of 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.001.

### **AOC 12**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $1.4 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 0.2. The calculated cumulative cancer risk for indoor exposures from soil gas was  $1.7 \times 10^{-10}$ , and the calculated cumulative indoor non-cancer hazard index was 0.00001. The cumulative cancer risk was *de minimis* for indoor exposures and within the risk management range of  $10^{-6}$  and  $10^{-4}$  for outdoor exposures. The cumulative non-cancer hazard indices were both below the target of 1.

Based on the inorganic lead EPC in AOC 12 soil (53.4 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a <1% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 12 do not pose a significant hazard to the commercial/industrial worker.

**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COPCs for soil ingestion, dermal contact and outdoor inhalation was  $1.4 \times 10^{-7}$ . The calculated outdoor cumulative non-cancer hazard index was 0.5. The calculated cumulative cancer risk for trench/enclosed space exposure from soil gas was  $6.3 \times 10^{-11}$ , and the calculated cumulative trench/enclosed space non-cancer hazard index was 0.0001. The cumulative cancer risk for both outdoor and trench/enclosed space exposures were *de minimis* and the cumulative non-cancer hazard indices were below the target of 1.

### **AOC 13**

**Commercial/Industrial Workers:** For outdoor exposures via soil ingestion, dermal contact, and outdoor inhalation, there were no carcinogenic COPCs and, consequently, no cancer risk estimates. The calculated outdoor cumulative non-cancer hazard index was 14. The cumulative cancer risk was *de minimis*, but the non-cancer hazard index was greater than the target of 1. Organic lead was not the only

noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.000004.

Based on the inorganic lead EPC in AOC 13 soil (4300 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a 99% to nearly 100% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results exceed the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 13 pose a potential hazard to the commercial/industrial worker. Note, however, that the lead EPC is the maximum detected concentration (a 95% UCL could not be derived due to an insufficient sample count) from 10 ft bgs at location TK3321-URS01. Consequently, this potential hazard is the result of one location deep within the soil.

**Construction/Excavation Workers:** As with the commercial/industrial worker scenario, there were no carcinogenic COPCs and no cancer risk estimates. For outdoor exposures, the calculated outdoor cumulative non-cancer hazard index was 37. The cumulative outdoor cancer risk was *de minimis* but the non-cancer hazard index was greater than the target of 1. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.000009. As with the commercial/industrial worker results (above), this potential hazard is the result of the concentration at a single subsurface location.

#### **AOC 14**

**Commercial/Industrial Workers:** For outdoor exposures, the calculated cumulative cancer risk level, summed across the COPCs, for soil ingestion, dermal contact, and outdoor inhalation was  $1.5 \times 10^{-5}$ . The calculated outdoor cumulative non-cancer hazard index was 3.3. The cumulative outdoor cancer risk was within the risk management range of  $10^{-6}$  to  $10^{-4}$ , but the cumulative outdoor non-cancer hazard index was slightly greater than the target of 1. The health risk driver was benzo(a)pyrene for outdoor cancer risk due to one detection (sample BH-URS02) of 32 mg/kg at 1 ft bgs. Removal of this concentration would leave residual health risks within acceptable levels for commercial/industrial workers. Organic lead was not the only noncarcinogenic COPC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COPCs totaled approximately 0.0002. The calculated cumulative cancer risk for indoor exposures from soil gas was  $2.0 \times 10^{-7}$ , and the calculated cumulative indoor non-cancer hazard index was 0.0014. The cumulative indoor cancer risk was *de minimis*, and the non-cancer hazard index was below the target.

Based on the inorganic lead EPC in AOC 14 soil (31.3 mg/kg), the OEHHA (2007) toxicity threshold (a 1 µg/dL change in fetal blood lead), and the updated ALM (USEPA, 2009h), there is a <1% probability that fetal blood lead would exceed the toxicity threshold (see Appendix F-4). These results are below the 10% probability threshold for significance, as used by OEHHA (2007) in their derivation of a soil CHHSL that is protective of fetuses. Consequently, lead concentrations in soil at AOC 14 do not pose a significant hazard to the commercial/industrial worker.



**Construction/Excavation Workers:** For outdoor exposures, the calculated cumulative cancer risk, summed across the COCs for soil ingestion, dermal contact and outdoor inhalation was  $1.5 \times 10^{-6}$ . The calculated outdoor cumulative non-cancer hazard index was 8.6. The cumulative cancer risk for outdoor exposures was *de minimis*, but the non-cancer hazard index was greater than the target of 1. Organic lead was not the only noncarcinogenic COC in soil, but it accounted for >99.99% of the hazard index; the hazard index for the other COCs totaled approximately 0.0007. The calculated cumulative cancer risk for trench/enclosed space exposure from soil gas was  $6.8 \times 10^{-8}$ , and the calculated cumulative trench/enclosed space non-cancer hazard index was 0.012. The cumulative cancer risk for trench/enclosed space exposures was *de minimis*, and non-cancer hazard index was below the target.

**6.5.3 Risk Characterization Results for AOCs 1, 6, and 10**

As addressed previously in Section 6.2.1.1, quantitative health risk assessments were not conducted for AOCs 1, 6, and 10 because of multiple COCs significantly exceeding screening criteria at multiple sample locations. The screening-level cumulative cancer risk estimates using residential benchmarks are greater than  $1 \times 10^{-3}$ ,  $1 \times 10^{-4}$ , and  $1 \times 10^{-3}$  for AOCs 1, 6, and 10, respectively, and the screening-level hazard indices are 20,000, 7,000, and 21,000 for AOCs 1, 6, and 10, respectively. The cancer risks are driven by varying combinations of eight carcinogenic PAHs (cPAHs): benzo(a)anthracene, benzo(b)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and naphthalene. The high hazard indices are due to organic lead. In addition, there are lead detections exceeding the CHHSL of 320 mg/kg at multiple locations in these AOCs. Therefore, mitigation will most likely be needed at these AOCs. The following table lists the analytes (i.e., ‘risk drivers’) most influential to the risk and hazard exceedances of target values for each of these AOCs.

AOC	Risk Drivers	
	Soil	Soil Gas
1	lead, organic lead, cPAHs	None
6	lead, organic lead, cPAHs	Benzene, ethylbenzene, naphthalene
10	lead, organic lead, cPAHs	None

**6.5.4 Risk Characterization Results for Unrestricted Use (‘Residential’) Scenarios**

As described previously, the Site is a former petroleum refinery with associated infrastructure that has been non-operational for approximately 60 years. Current conditions at the Site constitute a commercial/industrial land use, which is expected to continue for the foreseeable future. Consequently, unrestricted (‘residential’) land uses are not expected but there are offsite residential land uses to the southeast and west of the Site.

**6.5.4.1 Summary and Conclusions of the Screening-Level HHRA for Hypothetical Residents**

A screening-level residential HHRA addressed potential threats to human health from exposure to refinery-related chemical constituents encountered at the Site, under a hypothetical residential future-land-use condition. A residential land-use evaluation was requested (USEPA, 2009c) to provide additional information in the evaluation of cost differences among cleanup options for the Feasibility Study. The screening-level residential HHRA included evaluation of risk due to inhalation of indoor air

vapors from soil gas and risk due to exposures related to contaminated soil, including incidental ingestion of soil, dermal contact with soil, inhalation of outdoor particulate from soil, and inhalation of outdoor vapors from soil. The screening-level residential HHRA is included as Appendix G, and is summarized in following text.

Every AOC exceeds a  $1 \times 10^{-6}$  cancer risk and every AOC exceeds a HI of 1, the commonly used thresholds for indicating that unrestricted (residential) land use is possible. AOC-specific risk estimates have a diversity of carcinogens that are influential contributors to the risk estimate (i.e., ‘risk drivers’), while the HI estimates are dominated by the contribution from organic lead. There is significant uncertainty associated with the organic lead evaluation, as discussed in Section 6.6.2, so the calculated HI estimates may not represent actual health threats.

#### **6.5.4.2 Off-site Residents**

Several exposure pathways are potentially complete for off-site residents: ingestion and dermal contact with impacted groundwater, outdoor particulate inhalation and vapor inhalation from on-site soils, and indoor inhalation from soil vapors.

Impacted groundwater at the Site is considered available for beneficial use (Section 3.6), but it is not currently being used. As discussed in Section 4.3.1, the cleanup goals for four of the five chemicals of concern included in the ROD are being met. For the fifth chemical, benzene, it has been demonstrated that the two dissolved plumes are stable and shrinking and that natural attenuation is occurring (Section 4.3.2 and 4.3.3). For these reasons, ingestion and dermal contact with impacted groundwater are not considered significant exposure pathways (Figure 29).

With respect to outdoor inhalation of site-related particulates or vapor, the residential community and other developments to the west of the Site are located 100 feet or more from the Site on the other side of Pole Creek. At that distance, the potential threats to receptors from site-related soils could not be differentiated from other contributors to outdoor air quality.

A vapor intrusion study was conducted in 2007 to evaluate potential risks to off-site residential receptors from indoor inhalation of on-site soil vapors (URS, 2007c). Initially, groundwater plumes were known to contain VOCs and were present near the western boundary of the Site, and near the offsite residential area. Based on the presence of contamination in groundwater, soil vapor data were collected over the contaminated groundwater, and the results demonstrated that shallow soil vapor samples (collected at 7 ft bgs, but above the areas of the highest known groundwater concentrations) contained concentrations lower than the residential CHHSLs. In addition, VOCs were observed to be naturally attenuating as they migrate from depth toward the ground surface (URS, 2007c). Therefore, there are no unacceptable vapor intrusion health risks anticipated to offsite residential receptors. Because there are no known groundwater plumes underlying the rest of the Site, the primary reason for the supplemental shallow soil vapor sampling in the Phase 3 site investigation was to fill potential data gaps with respect to onsite soils, not groundwater, as potential vapor sources within each AOC. These soil-gas VOC data form the basis of two ‘vapor intrusion’ pathways included in the on-site, AOC-specific, analyses: inhalation of VOCs in indoor air for commercial/industrial office workers, and inhalation of VOCs in trench/confined space

outdoor air by construction worker receptors. As the previous AOC-specific results indicate, VOC concentrations in soil gas do not result in unacceptable inhalation risks to any potential future onsite receptors, except for commercial workers at AOC 6 due to benzene, ethylbenzene, and naphthalene.

## 6.6 UNCERTAINTY ASSESSMENT

This HHRA has been prepared in a manner consistent with that generally used in professional practice and in accordance with State and Federal guidance at the time it was prepared. The assessment is based on site-specific data, laboratory analytical results, area-specific environmental data, and assumed values and conditions. Although careful professional judgment was used in the selection of exposure assumptions, some argument can be made about the validity of each assumption. The purpose of this section is to provide information concerning the validity of each assumption, including the effect of each assumption on the overall risk, the major data gaps, and the effect of these data gaps on the accuracy or reasonableness of the risk assessment. This text section first addresses a variety of general and Site-specific uncertainties (Section 6.6.1), and then provides a detailed evaluation of specific uncertainties associated with this HHRA's evaluation of organic lead (Section 6.6.2).

### 6.6.1 General and Site-Specific Uncertainties

**Site Data Uncertainties** – Chemical analytical data are subject to uncertainty associated with sampling and analysis. Sample analysis is subject to uncertainty associated with precision, accuracy, and detection of chemicals at low concentrations. In the risk assessment, it was assumed that samples collected were representative of conditions to which various populations may be exposed. However, the collected samples may not be completely representative due to biases in sampling and due to random variability of samples. In general, sampling was biased toward areas of suspected elevated chemical concentrations, which will lead to an overestimation of risk. These errors are typically of low magnitude compared to other sources of uncertainty in the risk assessment.

One purpose of the Phase 3 sampling for data gaps was to take additional soil samples and to sample soil gas to reduce uncertainties in site data.

**Exposure Assessment Uncertainties** – Risk assessments require assumptions in order to assess potential human exposure. This risk assessment includes assumptions about general characteristics and potential patterns of human exposure at the Site. The assumptions made in this assessment were based primarily on EPA and DTSC guidance for indoor and outdoor exposures. Because there are no specific agency-published guidelines for evaluating vapor inhalation exposures to construction workers in trench conditions, the VDEQ methodology for VOCs in groundwater to trench air was modified to use soil gas data as the contaminant source instead of groundwater. While the indoor and outdoor inhalation modeling approaches applied herein are considered reasonable and consistent with guidance, it should be recognized that other exposure assessment approaches may be applied in the future to address potential health risks from vapor intrusion to indoor air and from outdoor exposures. Nonetheless, the approaches are intended to be protective and, therefore, likely overestimate health risks.

**Toxicity Assessment Uncertainties** – In order to evaluate the potential adverse effects associated with exposure to chemicals, the relationship between the dose of each chemical and the probability of an adverse health effect in an exposed population must be determined. This is known as dose-response assessment, some of which is based on data collected from animal studies and theoretical precepts about what might occur in humans. This risk assessment considers both carcinogenic and non-carcinogenic health effects associated with chemical exposures based on dose-response criteria published by various regulatory agencies. Sources of uncertainty related directly to toxicity data include:

- ◆ The use of dose-response data from experiments on homogeneous, sensitive animal populations to predict effects in heterogeneous human populations with a wide range of sensitivities.
- ◆ Extrapolation of data from: (1) high-dose animal studies to low-dose human exposures; (2) acute or subchronic experimental exposure to chronic, long-term exposure; and (3) one exposure route to another (e.g., from ingestion to inhalation or dermal absorption).
- ◆ Use of single-chemical test data that do not account for multiple exposures or synergistic and antagonistic responses.
- ◆ Various authoritative bodies producing toxicity information sometimes generate differing toxicity reference values. In accordance with DTSC health risk assessment protocol, this HHRA employs values published by Cal/EPA OEHHA preferentially to values available from EPA, even when the OEHHA values are less stringent. EPA values are used when OEHHA values are not available.
- ◆ Chronic toxicity values were used to evaluate the subchronic exposures of future construction/excavation workers, which could over-estimate the potential health risks for this receptor. However, the risk drivers for construction workers were inorganic lead (based on the results of the evaluation of commercial/industrial workers exposed to inorganic lead) and organic lead. Inorganic lead is evaluated by predicted blood lead levels rather than by toxic dose, and organic lead does not have a subchronic toxicity value, so the impact of using chronic toxicity values for this receptor would be minimal.

**Risk Characterization Uncertainties** – As there are uncertainties in each step of the risk assessment process, these uncertainties may be magnified in the final risk characterization. To minimize the consequences of uncertainty in the estimation of health risk, conservative assumptions were used in every step of the process (exposure assumptions, toxicity assessment and risk characterization) in an effort to not underestimate potential risks. Because a HHRA contains multiple sources of uncertainty, simplifying assumptions are often made so that health risks can be estimated quantitatively. Since the exact amount of uncertainty cannot be quantified, the HHRA evaluation is intended to overestimate rather than underestimate risk.

### 6.6.2 Uncertainties in the Risk Characterization for Organic Lead

There is a high degree of uncertainty associated with the risk characterization of organic lead because of the non-specific characterization of organic lead measured in the environmental samples (i.e., the exposure component) coupled to the assumption that all of the organic lead reported in the samples is in the specific form of tetraethyl lead and the application of the RfD for tetraethyl lead to the measured result.

***Characterization of Organic Lead in Environmental Samples.*** The analytical method used to determine the soil concentrations of organic lead in samples collected from this site (Method HML-939-M) is not specific to any particular compound. There are potentially hundreds of different forms of organic lead, which can occur in the environment from a variety of sources, including:

- ◆ Gasoline releases into the environment, resulting in contamination with tetraethyl lead;
- ◆ Chemical breakdown of tetraethyl lead to less toxic forms;
- ◆ Combustion products from automobile engines (forms unknown);
- ◆ Biotransformation of inorganic lead to organic forms; or
- ◆ Non-biological complexing of inorganic lead with organic compounds in soil.

While the Site certainly had a historical source of tetraethyl lead, it has likely been 60 years since any new source-related tetraethyl lead was released into the environment (the refinery produced gasoline until about 1950)<sup>1</sup>. Activities at the site predate the addition of tetramethyl lead and other alkylated lead additives to gasoline, which began in 1960 (Rhue et al., 1992). Accordingly, tetraethyl lead is the only suspected alkylated lead additive at the Site. Once released, environmental degradation of tetraethyl lead occurs through a series of abiotic and biotic dealkylation steps (Gallert and Winter, 2004; also see Appendix H). Once lead is dealkylated to inorganic lead, its fate in soil is affected by adsorption at mineral interfaces, the precipitation of sparingly soluble forms, and the formation of organic-metal complexes with soil organic matter. These processes are dependent on a variety of factors including soil pH, soil type, particle size, organic matter content of soil, the presence of iron oxides, and the amount of lead in soil (NSF 1977; Reddy et al. 1995).

California Method HML-939-M was used to measure organic lead in environmental samples collected from the AOCs. This method is performed using a xylene extraction, with the extract processed through a graphite-furnace atomic absorption spectrometer (GFAAS) for determination of total lead (DTSC 2002). It does not specifically measure tetraethyl lead and, in fact, it does not target **any** specific organic lead species. In particular, the xylene extraction does not distinguish between lead complexed with naturally occurring organic materials (such as humic and fulvic acids) and anthropogenic alkylated lead, and further, the graphite furnace does not differentiate between species. As originally employed to measure lead in petroleum sludges, analytical results could be called ‘tetraethyl lead’ because tetraethyl lead was a known alkyl-lead additive in petroleum products; however, application of Method HML-939-M to environmental samples does not provide any definitive indication of the existence of tetraethyl lead in the samples analyzed.

In order to obtain more specific information concerning the presence of organic lead at the Site, 20 soil samples with a wide range of lead content were analyzed for alkylated species by gas chromatography–electron capture detection (GC-ECD). Results of this more specific analytical technique indicated that **no**

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<sup>1</sup> Non-source related tetraethyl lead was still released into the general environment until the phase-out of leaded gasoline beginning in the 1980’s (ATSDR 2007).

**alkylated species of any form were detected in any of the 20 samples** (see Appendix H). For comparison purposes, the 20 soil samples were also tested by URS for organically bound lead, using California Method HML-939-M, with reported results ranging from <0.025 to 5.7 mg/kg Pb. In the absence of alkylated lead at the site, the most likely explanation for the detections of organically bound lead is adsorption to soil organic matter. Lead is strongly adsorbed to humic and fulvic fractions of soil organic matter, with a preferential affinity over other heavy metals (Qin et al. 2006; Saar and Weber 1980).

Based on these data (Appendix H), it is clear that the organic lead results referenced in this document do not contain tetraethyl lead; therefore, the assumption that 100% of the total reported organic lead concentrations is tetraethyl lead significantly over-estimates potential health hazards presented by organic lead at the Site. The noncancer hazard estimates at various AOCs that are greater than the target value of 1 are almost entirely (>99.7%) due to the contribution of organic lead and, consequently, are likely to indicate a potential health threat from **tetraethyl lead that is not actually present**. The hazard index for other noncarcinogenic COCs total to a value no greater than 0.05 at any AOC, far below the target value of 1.

**Bioavailability and Metabolism.** Tetraethyl lead's high toxicity (relative to inorganic lead) is due to its higher bioavailability and its metabolism to triethyl lead, which is more toxic than inorganic lead. The lipid solubility of tetraethyl lead results in rapid absorption across gastrointestinal tract, skin, and lung tissue compared to inorganic lead (which is poorly absorbed). Unmetabolized tetraethyl lead is not toxic. Although a small percentage of tetraethyl lead is metabolized to inorganic lead, the high toxicity of tetraethyl lead is primarily due to its triethyl lead metabolite. Tetraethyl lead in the bloodstream is very rapidly metabolized to triethyl lead in the liver, then triethyl lead is rapidly distributed and absorbed across cell membranes of target tissues due to its lipid solubility. The mode of action of triethyl lead in target tissues (such as neural tissues) is also different than that of inorganic lead. Therefore, the higher toxicity of tetraethyl lead relative to inorganic lead is related to (1) the high bioavailability of tetraethyl lead, (2) metabolism to triethyl lead, (3) rapid transport of triethyl lead across cell membranes, and (4) different mode of action of triethyl lead in target tissues.

The 20 soil samples described previously were also submitted to Dr. John Drexler for *in vitro* bioavailability assays using a method confirmed for lead (Drexler and Brattin 2007; EPA 2004a) and were found to have relative bioavailability ranging from 7% to 128%, with an average of 68%. The results are in keeping with the USEPA (2009i) default relative bioavailability of inorganic lead of 60% used in the IEUBK model rather than the nearly 100% expected for tetraethyl lead.

Organic lead at the site does not appear to be any form of alkyl lead. It appears to be inorganic lead attached to soil organic matter (SOM), and, from the *in vitro* bioavailability testing, it would be expected to behave like inorganic lead in the gastrointestinal tract. The toxicity of this type of organic lead would be expected to be similar to inorganic lead (and dissimilar from tetraethyl lead) because (1) absorption from the GI tract would require cleavage of the SOM, followed by absorption of  $Pb^{2+}$  (soluble inorganic lead) and (2) absorbed  $Pb^{2+}$  would not be converted to triethyl lead, and, therefore, would not result in triethyl lead concentrations in target tissues.



Therefore, organic lead should not be a COC at the site. Inorganic lead should be the only form of lead that is the focus of the risk assessment and cleanup actions. The maximum detected organic lead concentration at the site was 130 mg/kg, which is well below the health-protective threshold of 320 mg/kg for commercial/industrial workers.

**Toxicity Criteria.** EPA does not have a toxicity value for total organic lead. EPA has only an RfD for tetraethyl lead, and this RfD was used for risk characterization at the Site. The RfD for tetraethyl lead was developed in the mid 1980s and was based on a 20-week gavage study conducted in rats in 1964. The RfD is  $1 \times 10^{-7}$  mg/kg-day, which is one of the lowest RfD values in the EPA IRIS database, potentially indicating very high toxicity for this compound. However, the RfD is based on a lowest observable adverse effect level (LOAEL) of  $1.2 \times 10^{-3}$  mg/kg-day divided by an uncertainty factor (UF) of 10,000. Therefore, the RfD value of  $1 \times 10^{-7}$  mg/kg-day is more reflective of the high uncertainty (total UF of 10,000) associated with the RfD, than of the actual toxicity of tetraethyl lead. EPA's agency workgroup review and verification date for the oral RfD for tetraethyl lead was August 5<sup>th</sup>, 1985 and the RfD was placed on EPA's IRIS database in 1987. In 1988, EPA concluded that the RfD had only a low to medium confidence rating. The current IRIS file for tetraethyl lead notes the following: '*A screening-level review conducted by an EPA contractor of the more recent toxicological literature pertinent to the RfD for tetraethyl lead conducted in September of 2002 identified one or more significant new studies.*' Therefore, there is a high degree of uncertainty regarding the validity of the RfD value derived in 1985.

**Potential Range of Tetraethyl Lead Hazards.** As requested by EPA, Table 43 presents tetraethyl lead HQ values for commercial workers and construction workers under four different assumptions of the amount of tetraethyl lead present within the total organic lead result: 100% tetraethyl lead, 50% tetraethyl lead, 5% tetraethyl lead, and 1% tetraethyl lead. Note, too, that these HQ values are based on the IRIS RfD of  $1 \times 10^{-7}$  mg/kg-day. Given that there is no detectable alkyl lead in samples collected from the sites, all of these HQ values are overestimates.

Given the uncertainties described above, any potential remedial actions based on tetraethyl lead should be carefully reviewed due to the following:

1. No alkyl lead of any kind was detected at the site.
2. The uncertainties in the RfD for tetraethyl lead are sufficiently high that extensive remedial efforts based on HQs above 1 appear unwarranted.

## 6.7 SUMMARY AND CONCLUSIONS OF HHRA

The site characterization data evaluated in this HHRA consisted of site-wide soil and soil gas sampling and analysis. Potential threats to human health from COPCs encountered during historical and recent site characterization efforts were evaluated using Cal/EPA and EPA risk assessment protocols for each of 14 AOCs. The primary HHRA findings for the Site are summarized in Table 42.

Quantitative risk assessments were not conducted for AOCs 1, 6, and 10 because screening results indicated that unacceptable health risks were potentially present at levels such that remediation or

mitigation in these AOCs would be needed. Quantitative risk assessments were prepared for AOCs 2, 3, 4, 5, 7, 8, 9, 11, 12, 13 and 14 for future commercial/industrial workers and future construction workers. The following are key findings for these AOCs:

- ◆ Only AOCs 5 and 12 demonstrate noncancer health hazard indices less than the target of 1.0 assuming organic lead is 100% tetraethyl lead; AOCs 2, 3, 4, 7, 8, 9, 11, 13, and 14 have noncancer hazard quotients greater than the target value of 1. However, these values are almost exclusively dependent upon the contribution from organic lead (>99.7% of any hazard index is attributable to the assumption that the organic lead in site soil was 100% tetraethyl lead). Given that there is no indication of the presence of tetraethyl lead (or any other alkyl lead forms) in soil samples, this ‘significant contribution’ is likely just a mathematical construct, not an actual health threat.
- ◆ Carcinogenic risks at the Site are driven by eight carcinogenic PAHs (cPAHs): benzo(a)anthracene, benzo(b)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and naphthalene. The results by AOC are:
  - AOCs 2, 11, 12, and 13 demonstrate carcinogenic risks less than or equal to  $1 \times 10^{-6}$  for both receptors.
  - AOCs 3, 4, 5, 7, 8, 9, and 14 demonstrate carcinogenic risks  $>1 \times 10^{-6}$  for the commercial/industrial worker receptor, but less than or equal to  $1 \times 10^{-6}$  for the construction worker receptor. The risk estimate for AOC 14 is due primarily to one sample (BH-URS02) at 1 ft bgs. Removal of soils associated with this sample location would leave residual health risks within acceptable levels in this AOC.
- ◆ The probabilities that fetal blood-lead concentrations predicted to occur from maternal exposure to lead in soil under a commercial/industrial worker scenario were evaluated using AOC-specific soil concentrations of inorganic lead and OEHHA (2009) and EPA (2009h) methods:
  - The probabilities that AOC concentrations of inorganic lead in soil pose a hazard to a commercial/industrial workers were less than 10% (the probability threshold used by OEHHA to derive the soil-lead CHHSL) for AOCs 2, 3, 4, 5, 8, 12, and 14 (i.e., inorganic lead is not a potential health hazard at these AOCs);
  - The probabilities that AOC concentrations of inorganic lead in soil pose a hazard to a commercial industrial worker were greater than 10% for AOCs, 1, 6, 7, 9, 10, 11, and 13 (i.e., inorganic lead is a potential health hazard at these AOCs).
- ◆ VOCs in soil gas did not pose unacceptable risks for vapor intrusion into indoor air (for commercial/industrial workers) or trench/confined space air (for construction workers) for AOCs 3, 7, 8, 9, 12 and 14. Soil vapor samples were not collected in AOCs 2, 4, 5, 11 and 13 because there was no evidence from previous soil studies of subsurface VOC sources in those areas.
- ◆ AOCs 1, 6, and 10 will require mitigation due to multiple COC detections (not including organic lead) exceeding industrial screening criteria: lead and cPAHs in soil at AOCs 1 and 10; and lead in soil and benzene, ethylbenzene and naphthalene in soil gas at AOC 6 (Section 6.5.3).

Given that the organic lead detections at the Site do not present a real health threat as discussed in the uncertainty assessment (Section 6.6.2), the results of the baseline HHRA indicate that the constituents of concern (COCs) in soil are inorganic lead and cPAHs and those in soil gas are benzene, ethylbenzene, and naphthalene. Figure 29 shows the CSM for the COCs identified at the site. The following table summarizes the COCs present at each AOC and the number of boring locations impacted by each COC.



Constituents of Concern (COCs) for Each AOC (Assuming 10 <sup>-6</sup> Target Cancer Risk)			
AOC	Medium	COCs	No. of Impacted Locations
1	Soil	Lead	7
		cPAHs	6 (1 co-located with lead)
	Soil Gas	None	—
2	Soil	None	—
	Soil Gas	NA	—
3	Soil	Lead*	1
		cPAHs	3
	Soil Gas	None	—
4	Soil	cPAHs	2
	Soil Gas	NA	—
5	Soil	cPAHs	1
	Soil Gas	NA	—
6	Soil	Lead	9
		cPAHs	7 (2 co-located with lead)
	Soil Gas	Benzene	4 (2 co-located with lead)
		Ethylbenzene	5 (2 co-located with lead)
	Naphthalene	2 (1 co-located with lead)	
7	Soil	Lead	1
		cPAHs	3
	Soil Gas	None	—
8	Soil	cPAHs	3
	Soil Gas	None	—
9	Soil	Lead	3
		cPAHs	2 (1 collocated with lead)
	Soil Gas	None	—
10	Soil	Lead	7
		cPAHs	2
	Soil Gas	None	—
11	Soil	Lead	3
	Soil Gas	NA	—
12	Soil	None	—
	Soil Gas	None	—
13	Soil	Lead	1
	Soil Gas	NA	—
14	Soil	cPAHs	3
	Soil Gas	None	—

NA= Not available

\* Though lead is not an unacceptable health concern in this AOC, one hot spot is identified for removal (see Tables 55 and 56).

## 7.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

This section describes the methodology and findings of the screening-level ecological risk assessment (SLERA) conducted for AOC 1. The SLERA is limited to AOC 1 because a facility-wide environmental assessment (CH2M Hill, 1991) concluded that AOC 1 and the area comprised of former Tanks 7 and 8 were the only areas that potentially held habitat for ecological receptors. The Ecological Scoping Assessment (Section 10 of the Phase 3 Report in Appendix B) then concluded that AOC 1 was the only area that was not completely graded and devoid of vegetation, was the only AOC where ecological habitat existed, and was the only area recommended for further ecological evaluation.

### 7.1 OBJECTIVE AND BACKGROUND

The purpose of an ecological risk assessment (ERA) is to provide decision makers with an understanding of the potential risks to the environment posed by current constituent concentrations in the absence of a remedial action. A risk assessment can be used to support a proposal for no further action at a site or to identify areas of concern for ecological receptors to focus risk management decisions.

This SLERA supplements the current focused feasibility study in which human health-related concerns at AOC 1 (and other AOCs) are addressed (Section 6.0). The findings of this SLERA indicate whether or not risk to ecological receptors also warrants consideration in the evaluation of remedial alternatives and, if so, provides information necessary to characterize remedial goals that are protective of the environment.

A phased approach that is consistent with EPA and DTSC guidance for ERAs (USEPA, 1997b, 1998; DTSC, 1996a and b) was used to assess the potential for risk to ecological receptors. The main purpose of the phased framework is to allow for decisions to be made at the end of each phase of the ERA as to whether or not further risk assessment is warranted. The initial Ecological Scoping Assessment was submitted as part of *the Phase 3 – Shallow Soil Investigation, Data Gap Sampling and Human Health Risk Assessment* (URS, 2009a), included as Appendix B of this report. A Scoping Assessment as per DTSC guidance (1996b) is generally equivalent to the Problem Formulation phase of a baseline ERA in the federal guidance (USEPA, 1997b) and is primarily a qualitative analysis of the potential for complete pathways for exposure of ecological organisms to site-related chemicals, and comprises the first step of an ERA.

Based on information gathered during the Scoping Assessment (Section 10 of the Phase 3 Report in Appendix B), a SLERA was deemed necessary for the terrestrial habitat at AOC 1. At the end of the Scoping Assessment, constituents of potential ecological concern (COPECs) were identified for quantitative evaluation in a SLERA. COPECs are comparable to COPCs identified in human health risk assessments. The SLERA is the first quantitative step in the ERA process in which the potential for risk to ecological receptors is assessed, based on ecologically protective ('conservative') assumptions. The findings of this SLERA provide risk managers with information to decide if the site can be recommended for no further action, if further risk assessment would be useful, or if a remedial action should be implemented, with respect to ecological resources. At the end of this SLERA, the COPECs (or COPCs)

initially identified in the Scoping Assessment are either recommended for no further action or are retained as ‘final’ COPECs. Further risk assessment of final COPECs could entail a site-specific, or ‘baseline,’ ERA in which the assumptions made in the SLERA would be refined in order to focus potential future remedial efforts. Constituents of concern (COCs) are typically identified from the roster of final COPECs only after the more rigorous baseline ERA is conducted but, based in part on the results of the HHRA, a baseline ERA was not deemed necessary for this project. Alternatively, ‘final’ COPECs established at the end of the SLERA could be considered COCs in the development of risk-based concentrations for establishing remedial action objectives (Section 8 of this report), thereby forgoing further risk assessment.

The following section summarizes the information collected during the Scoping Assessment.

## 7.2 SUMMARY AND FINDINGS OF SCOPING ASSESSMENT

The Scoping Assessment (Section 10 of the Phase 3 Report in Appendix B) was comprised of the following elements:

- ◆ A reconnaissance-level biological survey;
- ◆ A search of the Department of Fish and Game’s California Natural Diversity Database (CNDDDB) for special status species in the vicinity of the Site;
- ◆ An evaluation of former Site-related activities and associated releases; and
- ◆ A review of available chemical analytical data to identify COPECs.

These elements were evaluated to identify potential ecological receptors and potentially complete exposure pathways to determine the necessity of a SLERA, and focus this next phase of the ERA process. The remainder of this section summarizes the information gathered during the Scoping Assessment and the ultimate findings. The information presented in this section differs from the content of the Scoping Assessment (presented in Section 10 of Appendix B) in that the inhalation pathway was added as a potentially complete and significant exposure pathway to be carried into the SLERA. This exposure scenario was added to address concerns expressed informally by EPA regarding the potential exposure of burrowing mammals at AOC 1 to VOCs originating from subsurface contamination. The discussion of exposure pathways and the findings of the 2009 Scoping Assessment presented below were supplemented with the evaluation of inhalation exposure by fossorial mammals.

### 7.2.1 Environmental Setting

AOC 1 is generally very steep, sloping upward to the east. The approximate size of this study area is 11.8 acres. The vegetation is mostly intact, with a few dirt service roads, and disturbed by the presence of non-native weeds in a few areas. The vegetation consists primarily of Venturan Coastal Sage Scrub, and shrub habitat comprises approximately 85% of the survey area. A small amount (roughly 10%) of patchy wooded area was observed consisting of non-native trees that are indicative of historical disturbance. Ruderal habitat comprises approximately 5% of AOC 1. This portion of AOC 1 is mostly bare with sparse vegetation consisting of non-native annuals.

AOC 1 is approximately 500 to 700 feet away from the Pole Creek Flood Control Channel, a concrete-lined drainage ditch that borders much of the western boundary of the Site. During the time of the biological survey, the concrete lining was in good condition (no cracks observed) and no sediment, water, or vegetation was present. Pole Creek is dry most of the year with a mean daily flow of less than 1 cubic meter per second (CH2M Hill 1991). A more detailed description of Pole Creek and the Flood Control Channel is provided in the Scoping Assessment (Section 10 of the Phase 3 Report in Appendix B).

### 7.2.2 Receptor Identification

The results of the CNDDDB search indicate that three of the 16 special status species observed within the Fillmore 7.5' United States Geologic Survey (USGS) Quadrangle have been noted within a 1-mile radius of the site: pallid bat (*Antrozous pallidus*), hoary bat (*Lasiurus cinereus*), and two-striped garter snake (*Thamnophis hammondi*) (Figure 24 of the Phase 3 Report in Appendix B). No special status species were noted during the one-day biological survey that was performed in February 4, 2009.

No special status birds were reported in the CNDDDB as observed within a 1-mile radius of the site. However, the potential for special status birds reported within the Fillmore Quad to be present at the site was considered because avian species often have significantly larger home ranges than ground-dwelling animals. Although three protected species of birds have been identified within the Fillmore Quad, more attractive habitats nearby would likely result in transient exposure, if any. The Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) and Least Bell's vireo (*Vireo bellii pusillus*) prefer riparian habitats, and the California condor (*Gymnogyps californianus*) requires vast expanses of open grasslands. No riparian habitat is present within the study areas, and the open vegetated areas (mainly at AOC 1) would likely be of limited value to a condor in comparison to the surrounding habitats primarily to the east and north of the Site. Condors were extirpated from the wild in the mid-1980s and reintroduction into the wild in Southern California was initiated in 1992.

The special status species reported by the CNDDDB are either not expected to be present due to inadequate habitat conditions at AOC 1 (mainly the lack of permanent water bodies and roosting environments) or would likely be present on only an intermittent or transitory basis. Although the bats could forage in the vicinity of the site, the duration spent there would likely be short due to the lack of species-suitable habitat, and their main source of food (airborne insects) have little contact with soil-bound contaminants which limits the potential for exposure through food items. Therefore, exposure to bats from Site-related contamination would probably be very low, if at all.

There are very little toxicological data available for assessing risk to reptiles, such as the two-striped garter snake, and it is believed that the risks assessed here, and any actions taken to protect other species, should be protective of reptiles.

Based on the results of the CNDDDB search and information collected during the biological survey, the following ecological receptor groups are potentially present:

- ◆ Terrestrial plants;
- ◆ Soil invertebrates;

- ◆ Herbivores (ground squirrels, voles, doves);
- ◆ Invertivores (e.g., robins, shrews);
- ◆ Omnivores (mice, raccoons, sparrows, lizards); and
- ◆ Top-level predators (e.g., hawks and other raptors, foxes, coyotes).

These receptor groups represent the major types of trophic levels present that could come into contact with contaminated soils at AOC 1. Aquatic biota are not expected to be impacted from soil-bound constituents at AOC 1, and depth to groundwater (approximately 50 ft bgs) precludes exposure by aquatic biota that may reside in nearby surface water bodies, i.e., there is no known discharge of groundwater to surface water in the area.

### 7.2.3 Constituents of Potential Ecological Concern

Organic analytes in soil with a detection frequency greater than 5% were identified as COPECs, and inorganic analytes with a 5% detection frequency in soil and with a maximum detected concentration greater than the Site-specific background level were identified as COPECs (see Section 10.3 in Appendix B). COPECs in soil gas collected from 0 to 6 ft bgs were also identified for the supplemental inhalation pathway (not considered within the original Scoping Report). Data for Site soils were grouped into two exposure depths to accommodate the various ecological receptor groups at AOC 1:

- ◆ 0 to 1 ft bgs (surface soil);
- ◆ 0 to 6 ft bgs (surface and subsurface soil, and soil gas—maximum extent of burrowing animal zone).

For evaluation of the potential exposure of burrowing mammals to soil-related contaminants, DTSC recommends using soil samples collected from 0 to 6 ft bgs to calculate the EPC (DTSC, 1998). This approach is a conservative estimate of exposure depths even for rodents because only a few species are known to burrow this deep or deeper. Most burrowing rodents remain within the first 2 to 3 feet of soil (DTSC, 1998). Most ecological receptors that do not burrow are only likely to come into direct contact with the first few inches of soil, except in areas for which scouring may expose subsurface soils. For these reasons, an evaluation of soil samples collected from 0 to 1 ft bgs (surface soil) was conducted for all non-burrowing terrestrial target receptors, and an evaluation of soil samples collected from 0 to 6 ft bgs (surface and subsurface soil) was conducted for burrowing mammals at a screening level, with recognition of the inherent uncertainties and potential for overestimation of exposure. Soil gas data from 0 to 6 ft bgs was only evaluated for burrowing mammals.

Tables M-1 and M-2 (Appendix M of the Phase 3 Report in Appendix B) present all analytes detected above a 5% detection frequency, and with a maximum concentration above site-specific background levels for metals, in AOC 1 soil collected from 0 to 1 ft bgs and 0 to 6 ft bgs, which include the following:

#### **0 to 1 ft bgs soil (Table M-1)**

- ◆ Lead, 10 PAHs, PCBs (Aroclor 1248) (J-flagged as uncertain), and six VOCs.

**0 to 6 ft bgs soil (Table M-2)**

- ◆ Copper, lead, 12 PAHs, eight VOCs.

**0 to 6 ft bgs soil gas**

- ◆ Eleven VOCs.

Of the COPECs identified at AOC 1, PCBs and some of the PAHs (i.e., the high-molecular-weight PAHs) have the potential to bioaccumulate or biomagnify in the terrestrial food chain. Aroclor 1248 is considered the most bioaccumulative of these COPECs. However, Aroclor 1248 was only detected in one of 20 surface samples (detection frequency of 5%) and in one of 28 surface and subsurface samples (detection frequency of 4%), J-flagged as uncertain, and, therefore, was not considered a COPEC for the 0 to 6-ft bgs exposure depth interval.

Organic lead was also identified as a COPEC in soil at the end of the Scoping Assessment, but has been dropped as a COPEC for this SLERA based on the extensive investigation of the chemical form and properties of organic lead that was performed subsequent to submittal of the Scoping Assessment. The analytical methods and results of the additional testing and evaluation that was conducted for organic lead are described in detail in Section 6.6.2 of the HHRA. In summary, organic lead at the site does not appear to be any form of alkyl lead. It appears to be inorganic lead adsorbed to SOM, and, from the *in vitro* bioavailability testing, it behaves like inorganic lead. The toxicity of this type of organic lead would be expected to be similar to inorganic lead for the reasons described in Section 6.6.2. Therefore, it was determined that organic lead should not be a COPEC at the site. Inorganic lead is the only form of lead that is considered in the remainder of this SLERA.

**7.2.4 Exposure Characterization**

An ecological CSM was developed for AOC 1 to provide a schematic representation of the links between sources, release and transport mechanisms, affected media, exposure routes, and potentially exposed ecological receptors (Figure 30). The CSM depicts the potential ecological exposure pathways at the site and demonstrates the potential for chemicals to bioaccumulate. It was developed based on information collected during the biological survey, results of the CNDDDB search, site history, COPECs (COPCs) present, fate and transport mechanisms, and general literature regarding the bioaccumulation and bioavailability potential of the COPECs. Professional judgment was used to determine the significance of the pathways identified on the CSMs. Only potentially complete and significant exposure pathways are recommended for inclusion in a SLERA.

**7.2.5 Summary and Recommendations**

Soil-related exposure pathways associated with terrestrial receptors at AOC 1 were recommended for quantitative evaluation in a SLERA. Specifically, the following receptor groups were selected for the SLERA: terrestrial plants, soil invertebrates, and terrestrial birds and mammals. The COPECs identified for the 0 to 1 foot and 0 to 6 feet sample depths, which include metals, PCBs, PAHs, and VOCs, comprise the focus of the SLERA. In addition to VOCs in soil, exposure to these compounds in soil gas by burrowing mammals via inhalation was recommended for quantitative evaluation in the SLERA. All

receptor groups are assumed to be exposed to surface soil, and only mammals (burrowers) are assumed to be exposed to surface and subsurface soil, as well as to soil vapors in their burrows.

### 7.3 EXPOSURE ASSESSMENT

The terrestrial receptor groups and their potentially complete and significant exposure pathways (Figure 30) recommended for evaluation in this SLERA are summarized in the previous section.

Assessment endpoints are explicit expressions of the actual environmental component to be protected, and may be perceived as a valued environmental characteristic. If these endpoints are found to be significantly affected they can trigger further action. The assessment endpoints for the terrestrial ecological receptors are:

- ◆ Protection of the terrestrial plant community and soil invertebrate populations that may be exposed to COPECs in surface soil to maintain species diversity, abundance, and nutrient cycling.
- ◆ Protection of resident small birds and mammals, with no unacceptable effects on reproduction or development at a population level due to COPECs in soil and food items (e.g., terrestrial plants, invertebrates, and small mammals).
- ◆ Protection of resident burrowing mammals, with no unacceptable effects on reproduction or development at a population level due to COPECs in soil vapors confined in burrow air.
- ◆ Protection of top-level predatory birds and mammals, with no unacceptable effects on reproduction or development at a population level due to COPECs in soil and food items (e.g., small mammals and birds).

The EPCs calculated for the COPECs in soil identified in the Scoping Assessment (see Section 7.2.3) are described below.

#### 7.3.1 Exposure Point Concentrations

The basic unit of exposure is the EPC, defined as the concentration of a chemical in a specific environmental medium at the point of contact for a receptor. As previously stated, all ecological receptors are assumed to be exposed to soil from 0 to 1 ft bgs, and only burrowing mammals are assumed to also encounter soils and soil vapors from 1 to 6 ft bgs (DTSC's EcoNote No. 1; 1998). Within the community of plants or soil invertebrates living at the Site, some individuals could feasibly be exposed to the maximum concentration throughout their life span due to limited, or lack of, mobility. Therefore, the EPCs for these receptors are represented by the maximum detected concentration for the SLERA (Table 44).

Mobile receptors like birds and mammals generally integrate their exposure over larger spatial areas and depths. Therefore, use of the 95 percent UCL is an appropriate measure of exposure, given the mobility of most wildlife species. EPA's most recent ProUCL software program (Version 4.0) was used to calculate the 95% UCL concentrations for the COPECs in soil. This software reflects the latest EPA guidance (USEPA, 2002d; Singh et al. 2007) for the recommendation of the use of a 95% UCL concentration, based on data distribution, data skewness, and sample size. The 95 percent UCL

represents an upper-bound estimate of the mean concentration of a COPEC in a particular medium. In other words, if many soil samples are collected and the confidence interval generated, the true mean (if the *entire* population could be sampled) would be upper-bounded by the 95% UCL value 95 percent of the time. The lower of the 95% UCL and maximum detected concentration represents the EPCs for birds and mammals, because sometimes the statistical procedures may result in a 95% UCL estimate that is greater than any measured maximum value (due to high data variability, low sample counts, or highly skewed data) (Tables 44 and 45). Table 46 provides the concentrations of VOCs detected in the soil gas sample collected from AOC 1.

### 7.3.2 Data Quality Evaluation

To ensure the data collected from AOC 1 are usable for purposes of ERA, a comparison of analytical method reporting limits (MRLs) to ecological screening benchmarks was performed (Table 47). This comparison was only performed for analytes with a detection frequency less than 100 % (i.e., those with at least one non-detect sample). The data for analytes that have actual measurable detections at every location are less uncertain than those that were not quantifiable in some samples. MRLs that are elevated above ecological screening levels (ESLs) in non-detect samples present an uncertainty in the SLERA. Of the 84 analytes in soil with at least one non-detect sample (70% of which are VOCs), MRLs for ten PAHs and one VOC, methylene chloride, are elevated above one or more ESL. Of the 35 VOC analytes in soil gas with at least one non-detect sample, MRLs for 1,1,2-trichloroethane and vinyl chloride are elevated above one or more ESL. The implications of the uncertainty associated with these elevated MRLs are discussed in the uncertainty section (Section 7.6).

## 7.4 EFFECTS ASSESSMENT

The effects assessment phase involves the identification of chronic toxicity thresholds for exposure to COPECs. For purposes of this SLERA, literature-based ESLs protective of the various receptor groups were selected for comparison to the receptor-specific EPCs discussed in the previous section.

### ***Ecological Screening Levels for Soil***

The following list presents the hierarchy of sources of ESLs for soil that were used for this SLERA:

- ◆ EPA's *Interim Ecological Soil Screening Levels* (EcoSSLs) (USEPA, 2005c);
- ◆ Oregon Department of Environmental Quality's (ODEQ's) *Level II Screening Level Values* (SLVs) (DEQ, 2001);
- ◆ Toxicity reference values (TRVs) in EPA's *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (USEPA, 1999b); and
- ◆ Primary literature documents for PAHs and soil invertebrates (Sverdrup, Nielsen, and Krogh, 2002).

The selected ESLs are concentration-based toxicity thresholds expressed as the mass of contaminant per unit mass of dry weight soil (Tables 44 and 45). The first two sources listed above provide soil ESLs protective of each of the four ecological receptor groups being evaluated. The EPA 1999 document only



provides concentration-based ESLs for plants and soil invertebrates, and the Sverdrup, Nielsen, and Krogh 2002 study was used to derive ESLs for soil invertebrates exposed to individual PAHs.

EPA's EcoSSLs (2007b) are risk-based screening values developed from conservative assumptions and parameters (e.g., no-observable-adverse-effects-levels [NOAELs] for birds and mammals), and these values were designed for application at hazardous waste sites. ODEQ's SLVs (2001) and EPA's TRVs (1999b) were developed using similar methodologies and are also intended for screening purposes. The selected ESLs are intentionally conservative in order to provide adequate confidence that COPECs eliminated during the screening phase do not pose an unacceptable ecological risk (USEPA, 2007a). Screening-level ESLs are often below background concentrations for metals. For lead, the lowest EcoSSL (for birds) identified for surface soils (0 to 1 ft bgs) is below site-specific background concentrations and, therefore, the background value was used as the default value for screening. EPA's EcoSSLs for lead are based on the inorganic form. The EcoSSL for lead that is protective of burrowing mammals exposed to lead below the surface (1 to 6 ft bgs) is above the background concentration and was, therefore, used in the screening comparison.

EPA has EcoSSLs for total high-molecular-weight PAHs (HPAHs) and total low-molecular-weight PAHs, and a slightly different approach was implemented in this SLERA for screening these COPECs at AOC 1 in order to assess risk for individual PAHs. The individual PAHs were screened against ESLs selected from specific toxicity studies reviewed in EPA's EcoSSL document (2007b); the same studies EPA used to generate the EcoSSLs for total HPAHs and total LPAHs. EPA did not develop EcoSSLs for PAHs protective of plants and birds due to insufficient toxicity data (USEPA, 2007b).

For this SLERA, the ESLs for PAHs protective of soil invertebrates were extracted from the Sverdrup, Nielsen, and Krogh 2002 study (Table 2 of the study). There are chemical-specific toxicity values for both LPAHs identified as COPECs in soils at AOC 1, and most of the HPAHs that are COPECs (Table 44). The lowest HPAH ESL was used as a surrogate screening value for the two HPAHs lacking a chemical-specific ESL. The selected soil invertebrate ESLs are EC<sub>10</sub> values based on a 10% reduction in reproductive output by the soil-dwelling springtail, *Folsomia fimetaria*. To address the potential for cumulative effects from exposure to multiple HPAHs or LPAHs, the risk estimates for individual HPAHs were added and risk estimates for individual LPAHs were added (as discussed in the following section).

As EPA's EcoSSL guidance does not provide concentration-based EcoSSLs protective of mammals for individual PAHs, the mammalian ESLs for the individual PAHs were extracted from ODEQ's Level II SLVs. These were calculated by DEQ from NOAELs and screening-level exposure parameters presented in publications by Oak Ridge National Laboratory. Should any exceedances of ESLs occur for mammals, the individual TQs would be added to estimate cumulative risk for HPAHs and LPAHs.

ESLs could not be identified for several COPEC and ecological receptor combinations, and surrogate values were used in these cases for the risk screening. The implication of this approach is discussed in the uncertainty section. Lack of adequate toxicity studies to develop plant and avian ESLs for PAHs is also discussed in the uncertainty section.

### **Ecological Screening Levels for Soil Gas**

Within the last several years, the DTSC and Region 9 EPA have promoted use of the inhalation-based toxicity reference values (TRVs) developed for Edwards Air Force Base (AFB) by Tetra Tech (2004) to evaluate soil gas data for burrowing mammals at sites in CA when VOC contamination of soil or groundwater is a potential concern. High values of uncertainty factors were applied in the development of these TRVs, which are intended for use at a screening level (and not as preliminary cleanup goals). More recently published inhalation TRVs ('ESLs') have been developed by Los Alamos National Laboratory (LANL) (Gallegos et al. 2007) and reflect similar screening-level assumptions.

For purposes of screening EPCs for soil gas in this SLERA, inhalation ESLs from both studies were used (Table 46), but for purposes of screening MRLs to assess data quality the lower of the Edwards AFB and LANL TRVs were selected as the appropriate ESLs (Table 47).

## **7.5 RESULTS OF RISK SCREENING**

The first step of the risk screening for this SLERA involves a simple comparison of EPCs to the appropriate ESLs. Then, toxicity quotients (TQs) were calculated for those COPECs that exceeded an ESL. The equation to calculate TQs is:

$$TQ = EPC/ESL$$

where:

- TQ = Toxicity quotient for a specific chemical and receptor (unitless)
- EPC = Exposure point concentration for chemical in soil (milligram [mg] of chemical per kilogram [kg] soil or mg chemical per cubic meter air)
- ESL = Ecological soil screening level representing a concentration below which adverse effects are not expected (mg chemical per kg soil or mg chemical per cubic meter air)

The TQ provides a mathematically derived index that expresses the relationship between the predicted EPC and a representative concentration below which adverse effects are not expected. If the  $TQ > 1.0$ , that is, exposure is greater than the toxicity-related threshold, there is the potential that adverse effects to the ecological receptor may exist. If the  $TQ < 1.0$ , then exposure is less than the toxicity-related threshold, and adverse effects are not expected. The magnitude of the TQ provides a general indication of the potential for ecological risk if a reasonable level of confidence exists in the estimated EPC and the corresponding ESL. The level of conservatism built into a SLERA typically results in an overestimate of exposure and risk.

Tables 44, 45, and 46 provide the results of the risk-based screening performed for AOC 1 soils from 0 to 1 ft bgs and 0 to 6 ft bgs, respectively, and soil gas at 5 ft bgs (used to represent the 0 to 6-foot exposure depth interval). The following table provides a summary of these results:



Analyte Class	COPEC	Toxicity Quotients			
		Plants	Soil Invertebrates	Birds	Mammals
<b>Soil 0 to 1 ft bgs</b>					
<b>Inorganics</b>	Lead	150	11	105	49
<b>HPAHs</b>	Pyrene	No ESL	1.8	No ESL	<1.0
<b>LPAHs</b>	Phenanthrene	No ESL	1.04	No ESL	<1.0
<b>VOCs</b>	1,2,4-Trimethylbenzene	2.1	<1.0	No ESL	<1.0
<b>Soil 0 to 6 feet bgs</b>					
<b>Inorganics</b>	Lead	Only burrowing mammals evaluated			43
	Copper	for soils collected from 0 to 6 foot bgs			11
<b>Soil Gas 0 to 6 ft bgs</b>					
<b>VOCs</b>	Naphthalene	Only burrowing mammals evaluated			2.0
	Toluene	for soil gas			4.6

The findings of this SLERA indicate that lead is the primary risk-driver in soil at AOC 1, as ESLs are exceeded for all receptor groups at the surface and for burrowing mammals in subsurface soils. Additionally, copper was detected above the ESL in one sample below the surface. As discussed in the previous section, the avian ESL for lead is actually the site-specific background concentration because the risk-based value (USEPA's EcoSSLs 2007b) is below background. Section 9.2.1 of the Phase 3 Report (in Appendix B of this report) provides a description of the background dataset, a subset of which was used for this SLERA (i.e., soil background data from 0 to 6 ft bgs). To mimic the Phase 3 investigation, maximum background concentrations were used in this SLERA.

For soil gas, the ESLs derived from Edwards AFB (Tetra Tech 2004) were exceeded by Site concentrations of naphthalene and toluene. A soil gas ESL for toluene is also available from the LANL study (Gallegos et al. 2007), and the detected concentration of toluene is well below that ESL.

### 7.5.1 Soil – Inorganics

The locations exhibiting lead and copper concentrations above the corresponding ESLs are shown on Figure 31. A total of 20 locations have total lead concentrations above the ESLs (26 mg/kg for 0 to 1 ft bgs samples and 56 mg/kg for 1 to 6 ft bgs samples). Maximum concentrations of lead in surface soil (18,000 mg/kg) and subsurface soil (20,000 mg/kg) were detected in a sample from former waste Pit #7 (P7-URS02). In general, concentrations of lead are higher in subsurface samples (collected at 5 ft bgs).

One location exhibited copper above the mammalian ESL, and this exceedance was in the subsurface sample only (P8-BH-1; 5 ft bgs). It is unlikely that burrowing mammals would be exposed to the copper concentration at this one location over a chronic exposure period, and the concentration is moderately elevated (approximately ten times the ESL). Based on the level of conservatism reflected in the exposure

assumptions for burrowing mammals (i.e., continuous contact), adverse effects to this receptor group from copper in subsurface soils are expected to be negligible and no further assessment is recommended.

### 7.5.2 Soil – Organics

With the exception of two PAHs and one VOC, EPCs of organic COPECs were below the ESLs (Table 44) and, with the exception of the concentrations detected at U-18 and Pit #11, concentrations were relatively low.

For PAHs, the low value TQs for soil invertebrates exposed to pyrene (TQ = 1.8) and phenanthrene (TQ = 1.04), in conjunction with the conservative assumptions used to protect the soil invertebrate community (e.g., use of the maximum concentration as the EPC, poor habitat quality in areas contaminated with PAHs, etc.) are expected to over-predict exposure and risk. No further evaluation of soil invertebrate exposure to PAHs is recommended.

The low value of the plant TQ calculated for the VOC 1,2,4-trimethylbenzene (TQ=2.1) is expected to be an overestimate of risk due to the use of the maximum detected concentration (collected from Pit #11) as the EPC, low detection frequency (8%), and habitat quality at the former waste pit. For these reasons, no further evaluation of plant exposure to PAHs and 1,2,4-trimethylbenzene is recommended.

### 7.5.3 Soil Gas

As shown in Table 46, of the 12 VOCs detected in shallow soil gas, only concentrations of naphthalene and toluene exceed the lowest ESLs, which were developed for Edwards AFB. However, the resulting TQs were fairly low: 2.0 (naphthalene) and 4.65 (toluene). The TQ for toluene is estimated to be lower (3.8) based on the average concentration of toluene measured in the primary and duplicate samples collected from P7-URS01, rather than just the single highest value from those two. The TQs for naphthalene and toluene are not considered high enough to warrant additional evaluation or action given the conservative nature of the ESLs for soil gas, which are intended for use at a screening-level and should be used with recognition of their assumptions and uncertainties (see Section 7.6.2).

Only an Edwards AFB inhalation TRV is available for naphthalene (0.375 mg/m<sup>3</sup>), but both Edwards and LANL soil gas screening levels are available for toluene: Edwards AFB TRV = of 0.0839 mg/m<sup>3</sup> (Tetra Tech 2004) and LANL ESL = of 60 mg/m<sup>3</sup> (Gallegos et al. 2007). A TQ based on the LANL ESL for toluene is well below 1.0. Both the Edwards AFB and LANL screening levels for soil gas represent chronic NOAELs derived from inhalation exposure toxicity data (adjustments to the primary toxicity data were made in both studies to achieve chronic NOAEL equivalents). The Edwards AFB TRV for toluene was established from one rat study with an endpoint based on immune function (increased susceptibility to infection), while the LANL TRV represents the geometric mean of toxicity data from 33 studies with endpoints relating to effects on reproduction, development, survival, and body weight. The LANL-derived value has a more robust underpinning and provides a better point of comparison.

To summarize, no further evaluation of the burrowing mammal inhalation pathway is warranted for the following reasons:

- ◆ Low number of ESL exceedances for soil gas.

- ◆ Low magnitude of TQs estimated for the only two ESL exceedances (naphthalene and toluene).
- ◆ The detected concentration of toluene in soil gas is below the more recent LANL TRV that was developed from a greater number of inhalation toxicity studies on rodents.
- ◆ The ESLs protective of the inhalation pathway were developed from the assumption that mammals would continuously be present in their burrows, which is considered to be a conservative assumption because fossorial mammals likely spend some portion of their time aboveground for foraging.
- ◆ The assumptions inherent in the EPCs do not account for behavior that would minimize exposure to volatiles in burrow air, such as the fact that burrowing mammals build their tunnels to maximize ventilation (Gallegos et al. 2007).

## 7.6 UNCERTAINTY ASSESSMENT

This section discusses the uncertainties associated with the assumptions made in this ERA and the influence of these uncertainties to over- or under-estimate the potential for risk to ecological receptors at AOC 1.

The risk screening process unavoidably involves assumptions and uncertainties that may underestimate or overestimate the potential for adverse effects. However, in general, the process is more likely to overestimate risk. This tendency is intentional, especially for a screening level risk assessment. The sources of uncertainty occur during each phase of the screening process, as summarized below.

### 7.6.1 Uncertainty with Exposure Assessment

Risk is most likely overestimated in the exposure assessment because the selected EPCs are the maximum concentrations or 95% UCLs from the site data. It is unlikely that most receptors would be consistently exposed to the maximum or an upper-bound estimate of the average concentration (i.e., the 95 percent UCL) for long periods. In addition, the calculated 95% UCL was higher than the maximum detected concentration for some COPECs (e.g., copper in 0 to 6 ft bgs soils), in which case the maximum detected concentration was used as the EPCs. This statistical artifact was due to the small sample size and high standard deviation for copper data collected from 0 to 6 ft bgs. Use of a maximum concentration is expected to over-predict exposure, especially for mobile receptors. Use of these EPCs is intentionally conservative but generally follows regulatory guidelines.

MRLs that are elevated above ESLs in non-detect samples present an uncertainty in the SLERA. Table 47 provides a comparison of analytical reporting limits to ESLs for soil and soil gas data from AOC 1. Of the 81 analytes in soil with at least one non-detect sample (70% of which are VOCs), the maximum MRL for methylene chloride is elevated above the ESL for plants, the maximum MRLs for anthracene and fluorene are above the soil invertebrate ESLs, and the maximum MRL for lead is above the ESL for birds (which is actually the site-specific background concentration). No other ESLs were exceeded by the MRLs for non-detected samples.

It is typical for the MRLs for some organic COPECs to be higher than the lowest risk-based screening levels, especially for PAHs, because most ecological screening levels are based strictly on toxicological

data and do not take into account analytical limitations (e.g., interferences in an analytical sample that give rise to elevated detection limits). However, potentially elevated MRLs for some soil samples are expected to have minimal influence on the exposure assessment and risk estimates given that MRLs for the majority of analytes with non-detected analytes (80 of 84 COPECs) are below ESLs.

Of the 35 analytes in soil gas with at least one non-detect sample, MRLs for 1,1,2-trichloroethane and vinyl chloride are elevated above the lowest ESLs, which were developed for Edwards AFB (Tetra Tech 2004). Soil gas ESLs are not available for these VOCs in the LANL study (Gallegos et al. 2007), but one ESL is presented for 1,1,1-trichloroethane at 240 mg/m<sup>3</sup>. The ESL for 1,1,2-trichloroethane provided for Edwards AFB is 0.05675 mg/m<sup>3</sup>, demonstrating an almost 4 orders-of-magnitude range of toxicity thresholds derived for chemically similar compounds to address the inhalation pathway for burrowing mammals. The MRL for 1,1,2-trichloroethane is only slightly above the ESL from Edwards AFB and well below the ESL from the LANL study. No LANL ESL is available for vinyl chloride for comparison purposes, but the Edwards AFB ESL for this compound is the lowest ESL of any VOC. Exceedance of this ESL presents an uncertainty in the ERA; however, as stated above for the soil MRLs, the uncertainty associated with the potentially elevated MRL for this one VOC is expected to have minimal impact on the exposure evaluation of the burrowing mammal population given that 33 of 35 analytes met the conservative soil gas ESLs.

Another source of uncertainty originates from the limited characterization that has been done for soil gas at AOC 1 (i.e., one sample, P7-URS01-SV, collected from 5 ft bgs). However, this sample was collected from the area of AOC 1 that is expected to have some of the highest concentrations of VOCs because it is the only location with concentrations in soil in exceedance of human health RSLs (benzene and naphthalene). Both of these VOCs were detected in P7-URS01-SV, and naphthalene is the only COPEC that slightly exceeded an inhalation ESL (TQ < 2.0). Given the low concentrations of VOCs detected in soil gas from the location with highest VOC concentrations reported in soil, and the estimated low potential for risk to burrowing mammals demonstrated in Section 7.5.3, lack of soil gas data from other locations at AOC 1 is not expected to represent an important data gap for the SLERA.

## 7.6.2 Uncertainty with Effects Assessment

The selected ESLs are conservative threshold doses primarily extracted from regulatory guidance documents. Numerous factors that may reduce the potential for effects are not considered at all or are assumed to operate at minimum levels in the derivation of these screening-level benchmarks (e.g., the assumption of 100 percent bioavailability of the accumulated intake, no consideration of egestion and elimination mechanisms, and no consideration of detoxification or metabolic mechanisms). Therefore, given the inherent conservatism of the exposure estimation process, it is uncertain whether adverse effects would be observed even if site-related concentrations exceed one or more ESLs.

ESLs could not be identified for several COPEC and ecological receptor combinations, and surrogate values were used in these cases for the risk screening. Use of surrogate toxicity values for COPECs lacking chemical-specific data could lead to an over- or under-prediction of effects, but it is less uncertain that the complete absence of quantitative benchmarks. Use of toxicity information for one COPEC to represent the toxicity potential of other COPECs introduces an uncertainty in the SLERA, but surrogates

are generally based on structurally or chemically similar molecules and there is reasonable expectation for some similarity in an organism's response.

A quantitative evaluation of exposure to PAHs by plants and birds could not be performed due to the lack of ESLs. Despite EPA's review of approximately 162 PAH studies on plants and 5,500 PAH studies on birds, there were not enough toxicity data to support development of EcoSSLs for LPAHs or HPAHs (USEPA, 2007b). Some studies indicate that PAHs are rapidly metabolized upon ingestion by birds and, therefore, there is little potential for bioaccumulation. A low potential for exposure through the bioaccumulation pathway, which is typically the most significant pathway for wildlife, would minimize the potential for risk to birds from PAHs.

The ESLs for soil gas are considered conservative screening levels that should be used with recognition of their inherent uncertainties, which likely result in an over-prediction of risk. The inhalation TRVs developed for Edwards AFB, for example, were calculated by adjusting the exposure dose of the original study to presume continuous exposure. Other uncertainty factors were also applied to adjust the TRVs further downward to represent a chronic exposure period and no-adverse-effects level (Tetra Tech 2004). Based on these adjustments, the Edwards AFB TRVs are protective of an *individual* fossorial mammal that would spend continuous time in its burrow without coming to the surface to forage, gather resources, court or breed, etc. The LANL ESLs for soil gas were established with similar assumptions regarding exposure duration. These assumptions are expected to over-estimate exposure and risk associated with the inhalation pathway for burrowing mammals. In addition, many of the Edwards AFB TRVs were derived from one study, while the LANL ESLs are a geometric mean of several studies, which lends more confidence in the LANL ESLs.

### 7.6.3 Uncertainty with Risk Characterization

The risk characterization process incorporates uncertainties that may overestimate risk, especially at the screening level. The exceedance of an ESL by the corresponding EPC does not necessarily mean that there is a threat to the referenced receptor. It means only that the potential for adverse effects may exist, and the likelihood of over-estimating risk may be further explored to gain a better understanding of the confidence placed in the assumptions (exposure and effects) used to calculate risk.

## 7.7 SUMMARY AND CONCLUSIONS

A phased approach was used to assess the potential for risk to ecological receptors that may be present at AOC 1. Based on information gathered during the Scoping Assessment (Section 10 of the Phase 3 Report in Appendix B), a SLERA was warranted for the terrestrial habitat at AOC 1. Soil-related exposure pathways associated with the following terrestrial receptor groups were evaluated in this SLERA: terrestrial plants, soil invertebrates, and terrestrial birds and mammals. The COPECs identified for the 0 to 1 ft and 0 to 6 ft sample depths, which include metals, PCBs, PAHs, and VOCs, comprise the focus of this SLERA. In addition to VOCs in soil, exposure to these COPECs in soil gas by burrowing mammals via inhalation was quantitatively evaluated in this SLERA. All receptor groups were assumed to be exposed to surface soil (0 to 1 ft bgs), but only mammals (burrowers) were assumed to be exposed to the combination of surface and subsurface soil (0 to 6 ft bgs), as well as to soil vapors in their burrows.

The findings of this SLERA indicate that lead is the primary risk driver in soil at AOC 1, with ESLs that are exceeded for all receptor groups at the surface, and for burrowing mammals in subsurface soils. The ecological CSM (Figure 30) presented in Sections 7.2.4 and 7.3 was updated to reflect the findings of this SLERA. A final ecological CSM (Figure 32) was created to identify the ecological receptors and exposure pathways (for lead) that are recommended for risk management. The following exposure pathways are presented as complete and potentially significant on Figure 32:

- ◆ Direct contact (uptake or dermal contact) with surface soil by terrestrial plants and soil invertebrates,
- ◆ Incidental ingestion and food web exposures originating from surface soil by terrestrial birds and mammals, and
- ◆ Incidental ingestion of subsurface soil by burrowing mammals.

Based on the results of the SLERA, no other exposure pathways pose a potential ecological concern and can be eliminated from further evaluation.

Of the 12 VOCs detected in the soil gas sample collected from 5 ft bgs at Pit #7, two were reported at concentrations above the lowest ESL protective of burrowing mammals. Given the low TQs associated with the exceedances of the soil gas ESLs and the highly conservative assumptions factored into the inhalation pathway evaluation, no further assessment of this pathway is recommended. Thus, lead is the only final COPEC identified for the site. Constituents of concern (COCs) for ecological receptors are typically identified from the roster of final COPECs only after the more rigorous baseline ERA is conducted. However, with only one final COPEC, and based in part on the results of the HHRA, a baseline ERA was not deemed necessary for this project. Instead, the single final COPEC, lead in soil, is considered directly for development of a risk-based concentration as a remedial action objective protective of ecological resources (see Section 8.2).

A total of 19 locations have lead concentrations above the ESLs (seven of those locations coincide with lead impacted locations determined in the HHRA). The locations where lead is elevated at the surface are of most concern for ecological receptors, but, in general, lead concentrations are higher in subsurface samples. Although exposure to subsurface soils by burrowing mammals is a viable exposure pathway, most burrowing rodents remain within the first 2 to 3 feet of soil (DTSC, 1998) and would not be exposed to soils at 5 ft bgs, which were included in the SLERA. Ecological receptors that do not burrow are most likely to come into direct contact with only the first few inches of soil.

In summary, existing conditions are not protective of ecological receptors in some parts of AOC 1. If a removal action is implemented at AOC 1 to address lead in soil based on human health concerns, the AOC-wide average concentrations (i.e., 95% UCLs) should also be below the selected ecologically-protective cleanup goals for lead in soil. For surface soil, the selected cleanup goal is the site-specific background level of 26 mg/kg, and for subsurface soil it is the EcoSSL for mammals of 56 mg/kg. The following table summarizes the number of locations at AOC 1 that should be considered during the risk management phase.



<b>Constituents of Ecological Concern (COCs) for AOC 1</b>			
<b>AOC</b>	<b>Medium</b>	<b>Final COPECs</b>	<b>No. of Impacted Locations</b>
1	Soil	Lead	19
	Soil Gas	None	—

## 8.0 RISK-BASED CONCENTRATIONS

The HHRA (Section 6.0) and the SLERA (Section 7.0) indicate that the concentrations of detected analytes in certain AOCs result in risk or hazard estimates that exceed target thresholds designating them COCs for this site (Figure 33). The COCs in soil are lead and cPAHs; the COCs in soil gas are benzene, ethylbenzene, and naphthalene. Consequently, those designated AOCs may require remedial action(s) to eliminate, reduce, or otherwise control the potential for the exposures that cause the exceedances of the risk or hazard targets. The derivation of site-specific, risk-based concentrations (RBCs) for the COCs was an initial step for developing remedial action objectives (Section 9.0) and developing information for the technical feasibility and cost-estimate evaluations that are needed for remedial decision-making within the Superfund program. RBCs are concentrations in environmental media that are derived to be protective of human health or the environment at specified ‘acceptable’ levels (in contrast to the HHRA and SLERA methods, which used specific environmental concentrations to predict the health or environmental threat level. The RBCs derived herein were calculated using the same EPA (1989, 1991, and 2004b) and DTSC (1994, 1996a, and 2004) guidance documents for evaluating health risks as presented in Section 6.0.

### 8.1 APPROACH FOR HUMAN HEALTH RBCS

The HHRA’s risk and hazard estimates are summarized in Sections 6.5.2 and 6.5.3, and detailed in Appendix F. At every AOC with a hazard index which exceeded the target value of 1.0, the exceedance was due to organic lead; however, those conclusions are based (in part) on the use of toxicity data for tetraethyl lead, and soil samples collected from the Site do not contain any alkylated lead (Appendix H). Consequently, those hazard index values do not indicate a noncarcinogenic threat to human health. However, based on the predicted blood-lead results from the ALM model, inorganic lead concentrations in soil are a potentially significant threat to health at some AOCs. For carcinogens, cPAHs were the greatest contributors at every AOC with a cumulative cancer risk estimate greater than a target value of  $1 \times 10^{-6}$ . In soil gas, benzene, ethylbenzene, and naphthalene were the significant contributors to risk exceedances at AOC 6. Therefore, inorganic lead and cPAHs in soil and benzene, ethylbenzene, and naphthalene in soil gas constitute the COCs for the Site as a whole. These COCs are the focus of subsequent analyses of remedial alternatives (Section 9 and thereafter).

Section 8.1 herein describes the initial derivation of human health RBCs for each COC in soil and soil gas. The general approach for determining site-specific RBCs involves assuming unit concentrations as the source term concentration, calculating associated health risks following standard DTSC and EPA protocols, and then scaling those risks by target risk values to generate the RBCs. RBCs were calculated for outdoor exposures for both commercial/industrial and construction workers, indoor air exposure due to vapor intrusion for commercial workers, and trench air exposure due to vapor intrusion for construction workers. For this Site, a range of target cancer risks of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$  and a target noncancer hazard index of 1.0 were used for the combined multiple pathways of exposure to COCs by commercial/industrial and construction worker receptors, shown on Tables 48 through 51. RBCs were calculated for COCs for which cleanup criteria were not otherwise defined. These RBCs for individual chemicals do not address the potential cumulative risks and hazards that might occur at an AOC due to

exposures to multiple chemicals. However, cumulative-exposure RBCs are difficult to calculate *a priori* because chemicals that are influential to the value of an RBC might not be co-located (assuming co-location would lead to overly stringent RBCs) or, conversely, the multiple chemicals might be co-located but be readily mitigated by focusing on a single influential COC, as is the case for the cPAHs. Based on these difficulties, cumulative impacts will be addressed during the remediation phase and documented through a post-remedial risk evaluation.

***Inorganic Lead*** - Inorganic lead toxicity is characterized on the basis of the predicted lead concentration in a receptor's bloodstream, rather than on the basis of an exposure concentration (e.g., an RfC) or an ingested or absorbed dose (e.g., an RfD). Using the EPA (2009d) Adult Blood Lead model, OEHHA (2009) methods, and a target blood lead concentration of an incremental change of 1 µg/dL in worker receptors, the RBC for inorganic lead in soil would be 320 mg/kg (the CHHSL for inorganic lead in soil).

### 8.1.1 Exposure Pathways and Toxicity Criteria

The exposure assessment steps followed EPA (1997a) recommendations to develop 'reasonable maximum exposure' (RME or upper-bound) estimates. The RME dose estimates incorporate several conservative assumptions in order to address variability in key characteristics of receptor populations. The calculated RME dose is intended to be an estimate of the highest exposure that is reasonably expected to occur in a receptor population, and, therefore, probably leads to overestimates of actual health risk for the majority of the population. Typically, RME is defined using a combination of upper-bound and average exposure factor values that reflect intakes between the 90<sup>th</sup> and 98<sup>th</sup> percentile of the range of possible exposures. The exposure factors selected for commercial/industrial workers and for construction workers (Tables 39 and 40, respectively) were used to estimate RME intake levels.

As evaluated in the HHRA (Section 6.0), both outdoor and indoor/trench exposure pathways are potentially complete for commercial/industrial workers and for construction workers. The outdoor exposure pathways include incidental ingestion, dermal contact, inhalation of particulate emissions, and inhalation of airborne vapor emissions from soil. The indoor/trench exposure pathway consists of inhalation of vapor emissions from soil gas.

Consistent with the HHRA (Section 6.0) chronic toxicity criteria were selected from the following sources, listed in order of preference:

- ◆ Cal/EPA OEHHA Toxicity Criteria Database (OEHHA, 2010a);
- ◆ Cal/EPA OEHHA Chronic Reference Exposure Levels (OEHHA, 2010b);
- ◆ EPA Integrated Risk Information System (IRIS) (USEPA, 2010b); and thereafter
- ◆ EPA's hierarchy as evidenced in the RSLs (USEPA, 2009b): provisional peer-reviewed reference toxicity values (PPRTVs), the Agency for Toxic Substances and Disease Registry's Minimal Risk Levels, values from EPA's Environmental Criteria and Assessment Office, then other sources (screening values from 'PPRTV Appendix' sources and other specific individual toxicity values).

Table 41 lists the toxicity criteria used for determining the RBCs for the COCs at this Site.

### 8.1.2 Fate and Transport Modeling

Under certain conditions, soil matrix contaminants can migrate among and between environmental media, from primary or secondary source areas to points where human receptors may be exposed. Potential intermedia transfers of COCs from soil to outdoor air and soil gas to indoor air were evaluated using mathematical contaminant fate and transport models, as described below. Appendix I includes the fate and transport modeling input parameters and intermediary results. See Section 6.3.1.2 for a description of the mathematical fate and transport modeling used to estimate COC concentrations at the point of human exposure for each pathway.

### 8.1.3 Calculating RBCs

RBCs were calculated for both carcinogenic and non-carcinogenic health effects under the commercial/industrial land use scenario. For each COC (in the computations in Appendix I2), the target cancer risk goal was  $1 \times 10^{-6}$  and the target hazard index was 1.0 for both commercial/industrial and construction workers (Tables 48 through 51 adjust the computed value for the range of risk estimates [ $10^{-4}$  to  $10^{-6}$ ]).

Unit concentrations were assumed for source term concentrations and the resulting hypothetical unit health risks calculated using standard risk assessment approaches as described above.

$$\text{RBC} = (\text{STC}_{\text{unit}} / \text{Risk}_{\text{unit}}) \times \text{Target Risk}$$

where:

- RBC = risk-based concentration (cancer-based or noncancer-based)
- $\text{STC}_{\text{unit}}$  = unit source term concentration in soil
- $\text{Risk}_{\text{unit}}$  = cancer risk or hazard index for  $\text{EPC}_{\text{unit}}$
- Target Risk =  $10^{-6}$  for cancer risk or 1.0 for hazard index

Equations used to calculate the average daily intake, the hazard index or cancer risk, and corresponding RBCs for unit concentrations of each COC by receptor, exposure pathway and medium are presented on the calculation tables in Appendix I. The overall RBC values (shown in Tables 48 through 51 for this Site) were specified as the lower (more conservative) of either the cancer-based concentration threshold or the noncancer-based concentration threshold.

## 8.2 APPROACH FOR ECOLOGICAL RBCs

The SLERA, which was only conducted for AOC 1, identified lead (inorganic form) as the only analyte recommended for further investigation. In the absence of a site-specific ERA, lead is considered a COC and the ecological screening benchmark for lead was set at the maximum background concentration of 26 mg/kg in 0- to 1-ft soils. The ecological screening benchmark for lead in 1- to 6- ft bgs soils is 56 mg/kg, which is protective of burrowing mammals. These soil depth intervals were evaluated for ecological receptors in the SLERA to concur with DTSC guidance (1998), even though studies on burrowing mammals in California demonstrate confinement to the upper 2 or 3 feet of soils for most rodents. Both ecological screening benchmarks are lower than the human health RBC of 320 mg/kg for



inorganic lead, which will need to be considered when evaluating mitigation options to be protective of ecological receptors at AOC 1.

Because soil samples collected from the Site specifically for an in-depth lead evaluation were not found to contain any alkylated lead (see Section 6.6.2), organic lead was not considered a final COC for AOC 1 and no screening benchmark was established.

### 8.3 SUMMARY AND CONCLUSIONS

Figure 33 presents the COCs by AOC based on 1) a 10<sup>-6</sup> cancer risk threshold for cPAHs and 2) a 10<sup>-5</sup> cancer risk threshold for cPAHs. No COCs were identified in AOCs 2 and 12; therefore, no actions are necessary for those two AOCs. No COCs were identified at the 10<sup>-5</sup> cancer risk threshold for AOCs 4, 5, and 8; therefore, no actions would be necessary for these three AOCs based on 10<sup>-5</sup> cancer risk threshold.

Lead was a COC in soil at AOCs 1, 3, 6, 7, 9, 10, 11, and 13. The cPAHs were COCs in soil for the 10<sup>-6</sup> cancer risk threshold at AOCs 1, 3, 4, 5, 6, 7, 8, 9, 10, and 14 and for the 10<sup>-5</sup> cancer risk thresholds for AOCs 1, 10, and 14. Additional COCs in AOC 6, based on vapor intrusion of soil gas into indoor air, included benzene for the 10<sup>-5</sup> and 10<sup>-6</sup> cancer risk thresholds and ethylbenzene for the 10<sup>-6</sup> cancer risk threshold.

The table below lists the locations of impacted soil requiring removal and treatment for use in the focused feasibility study.

Summary Table for RBCs Section			
AOC	Medium	Action for 10 <sup>-6</sup>	Action for 10 <sup>-5</sup>
1	Soil	Soil removal at 21* locations at depths up to 12 ft bgs.	Soil removal at 20 locations at depths up to 12 ft bgs.
	Soil Gas	—	—
2	Soil	No action needed.	No action needed.
	Soil Gas		
3	Soil	Soil removal at 4 locations including one lead detection of 2,400 mg/kg at depths up to 7 ft bgs.	Soil removal at 1 location at depths up to 1 ft bgs.
	Soil Gas	—	—
4	Soil	Soil removal at 2 locations at depths to 7 ft bgs.	No action needed.
	Soil Gas	—	
5	Soil	Soil removal at 1 location at depths to 3 ft bgs.	No action needed.
	Soil Gas	—	
6	Soil	Soil removal at 16 locations at depths up to 12 ft bgs.	Soil removal at 9 locations at depths up to 12 ft bgs.
	Soil Gas	Soil removal at 2 additional locations at depths up to 12 ft bgs.	Soil removal at 2 additional locations at depths up to 12 ft bgs.



Summary Table for RBCs Section			
AOC	Medium	Action for 10 <sup>-6</sup>	Action for 10 <sup>-5</sup>
7	Soil	Soil removal at 4 locations at depths up to 12 ft bgs.	Soil removal at 1 location at depths up to 3 ft bgs.
	Soil Gas	—	—
8	Soil	Soil removal at 3 locations at depths up to 7 ft bgs.	No action needed.
	Soil Gas	—	
9	Soil	Soil removal at 4 locations at depths up to 12 ft bgs.	Soil removal at 3 locations at depths up to 7 ft bgs.
	Soil Gas	—	—
10	Soil	Soil removal at 9 locations at depths up to 12 ft bgs.	Soil removal at 8 locations at depths up to 7 ft bgs.
	Soil Gas	—	—
11	Soil	Soil removal at 3 locations at depths up to 7 ft bgs.	Soil removal at 3 locations at depths up to 7 ft bgs.
	Soil Gas	—	—
12	Soil	No action needed.	No action needed.
	Soil Gas		
13	Soil	Soil removal at 1 location at depths up to 12 ft bgs.	Soil removal at 1 locations at depths up to 12 ft bgs.
	Soil Gas	—	—
14	Soil	Soil removal at 3 locations at depths up to 12 ft bgs.	Soil removal at 1 locations at depths up to 12 ft bgs.
	Soil Gas	—	—

\*19 locations for lead and 2 for cPAH locations not co-located with lead. Includes lead locations that exceeded ecological criteria. (Section 8.2).

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## 9.0 REMEDIAL ACTION OBJECTIVES

The follow sections describe site-specific Remedial Action Objectives (RAOs).

### 9.1 CONTAMINANTS OF INTEREST

The analytical data were evaluated during a risk assessment for several contaminants of interest related to potential impacts to human health as well as ecological concerns at the Site. Several compounds were identified as chemicals of concern in soil as part of the HHRA. The COCs are inorganic lead, and cPAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, dibenz(a,h)anthracene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, and naphthalene) in soil, and benzene, ethylbenzene, and naphthalene in soil vapor. Groundwater contaminants of interest are benzene and toluene (see groundwater contaminant discussion in Section 4.3.1).

### 9.2 DETERMINATION OF ARARs

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 121 (d)(2)(A) requires site specific remedial actions meet any federal standards, requirements, criteria, or limitations that are evaluated to be legally ARARs. CERCLA Section 121 (d)(2)(A)(ii) indicates a state may establish stricter requirements than federal guidelines as in the case of California. In addition, local ordinances, unpromulgated criteria, advisories, or guidance that do not meet the definition of ARARs but that may assist in the development of remedial objectives must be listed as ‘to be considered’ (TBC) as noted in the National Contingency Plan (NCP) in Part 300.

ARARs consist of two sets of requirements, those that are applicable and those that are relevant and appropriate. Applicable requirements are those substantive standards that specifically address the situation at a hazardous substance release site. Relevant and appropriate requirements are those laws and/or regulations that address a problem/situation sufficiently similar (i.e., relevant) to the circumstances of the proposed response action, and which are well-suited (i.e., appropriate) to the conditions of the Site (USEPA, 1992b). The determination that a requirement is relevant and appropriate generally involves a comparison of site-specific factors such as the characteristics of a remedial action, hazardous substances present at the site, or physical circumstances of the site, with those addressed in the statutory or regulatory requirement (USEPA, 1988a).

The DTSC (as requested by EPA) provided an initial set of applicable guidelines on August 11, 2009. Chevron responded with suggested revisions on August 25, 2009. DTSC provided clarification on their assumptions in proposing ARARs in an email dated September 10, 2009. The final ARARs were incorporated in a memorandum describing the remedial action objectives submitted on September 15, 2009. The ARARs for groundwater had already been established and revised during the Second Five-Year Review (USEPA, 2006b). The ARARs are provided in Table 52.

### 9.3 IDENTIFICATION OF ARARs

ARARs may be categorized as (1) chemical-specific requirements that define acceptable exposure levels (or water quality standards) leading to the establishment of remediation specific goals, (2) location-specific requirements that set restrictions within certain areas, (3) action-specific requirements for controlling/restricting particular treatment/disposal activity related to managing hazardous wastes. These three categories are described further in the following sections.

#### 9.3.1 Chemical-Specific ARARs

Chemical-specific ARARs are usually health- or risk-based numerical values that establish an acceptable chemical concentration (i.e., cleanup goal) that may remain in the environment at a Site. A more conservative value is often applied when competing values are established in the ARARs (USEPA, 1988b). Chemical-specific ARARs are summarized in Table 52.

#### 9.3.2 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements/limitations on actions taken with respect to hazardous wastes. These requirements are triggered by remedial activity selected to accomplish a remedy. Action-specific ARARs are summarized in Table 52.

#### 9.3.3 Location-Specific ARARs

Location-specific ARARs are restrictions placed on concentrations of hazardous substances (or the conduct of activities) solely because they are in specific locations such as floodplains, wetlands, historic places, and/or sensitive habitats (USEPA, 1988b). Location-specific ARARs were not identified for the Site. This is consistent with past assessments conducted by the EPA.

#### 9.3.4 Potential Guidance and Advisories to be Considered

There are two potential guidance and advisories to be considered for the Site. Potential guidance and advisories to be considered are summarized in Table 52.

### 9.4 PROPOSED PRELIMINARY CLEANUP STANDARDS

Chemical-specific ARARs were used in conjunction with the human health risk assessment to derive preliminary cleanup standards for the Site.

#### 9.4.1 Standards for Soil

The proposed cleanup standards for soil are fairly straight forward since the final remedy includes removing impacted soil to industrial/commercial risk-based cleanup standards (primarily inorganic lead and PAHs) within the upper 10 ft bgs. See Tables 48 through 51 for a complete list of risk-based cleanup criteria for soil. In the case of AOC 1, cleanup standards for lead that are protective of ecological receptors will need to be considered when evaluating mitigation options. The Site cleanup standard for lead in soil for commercial/industrial workers is 320 mg/kg. The Site cleanup standard for lead in AOC 1 that is protective of ecological receptors in surface soil (0- to 1-ft) is 26 mg/kg; the cleanup standard for lead in AOC 1 that is protective of burrowing mammals is 56 mg/kg at depths of 1-ft to 6-ft bgs.



### 9.4.2 Standards for Groundwater

Cleanup standards for groundwater are targeted to reducing the concentration of benzene to meet the RAO, i.e., the MCL of 1 µg/L. As discussed in Section 4.3.1, the ROD constituents have been present in groundwater for multiple decades and have degraded significantly over this time as discussed in Appendix E. As such, an updated constituent list for groundwater should be considered for the amended ROD. The COCs that should be included are benzene and toluene. The remaining constituents should be removed from the groundwater monitoring program based on (1) limited frequency of detections, (2) non-detect analytical results, and/or (3) constituent concentrations have not exceeded cleanup goals established for the Site or State notification levels. Groundwater remedial options, evaluated in Section 10, will target benzene as the primary constituent of concern in groundwater beneath the Site.

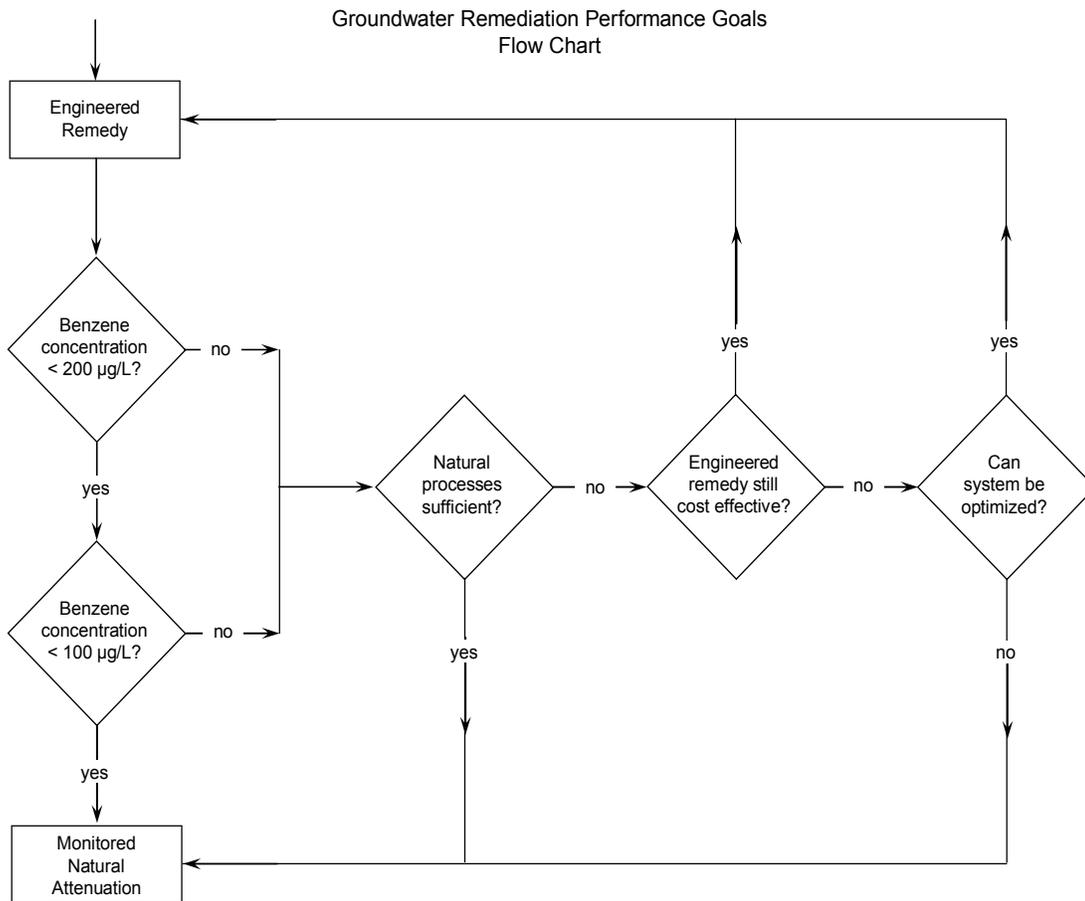
For benzene in groundwater, a performance goal matrix is proposed to evaluate remediation progress and to provide the necessary flexibility to manage an engineered remedy before switching to the final remedy of MNA. The performance goals (which exceed the final cleanup standard) are proposed for the following reasons: 1) the constituents do not pose an imminent threat to human health and the environment under current site conditions, so urgent action is not necessary; 2) groundwater cleanup within heterogeneous units containing abundant fine-grained sediments is often technically challenging; 3) residual LNAPL present beneath the water table (i.e., the smear zone) may persist for many years no matter how aggressive the technology; 4) multiple lines of evidence confirm the effectiveness of natural attenuation; and 5) the remedial approach should attain proposed final cleanup standards for groundwater in a reasonable timeframe. The proposed groundwater remediation performance goals are as follows:

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Constituent	Performance Goal #1 (µg/L)	Performance Goal #2 (µg/L)	Final Cleanup Standard (µg/L)
Benzene	200	100	1

---

LNAST modeling indicates that a reduction in groundwater concentrations to the proposed performance goals may result in sufficient attenuation of off-site impacts to constrain the southern plume and associated management requirements to the Site boundary. A conceptual process flow for utilizing the performance goals is provided in the following chart. Pilot test results will be a critical component of the remedial design.



As suggested in the process flow diagram, a selected remedial alternative (see Section 11.0) may be monitored and periodically evaluated to determine progress. As discussed in Section 5.3.5, and later addressed in Section 11.0, the submerged LNAPL and the nature of the Site geology may require different approaches and timeframes for cleanup of the groundwater plumes to meet the RAOs. For instance, in the northern plume, natural processes are sufficient and MNA appropriate as recent maximum benzene concentrations have averaged well under 200 µg/L over the past year. As proposed in Section 11.0, for the southern plume, more than one engineered remedy could be applied sequentially to most effectively reduce benzene concentrations.

### 9.4.3 Standards for Vapor

Cleanup standards were also established for elevated soil vapor concentrations identified during shallow soil investigations conducted at the Site. The soil vapor sampling was conducted commensurate with elevated soil concentrations identified during the phased investigations (i.e., Phase 1 to Phase 3). The remedy for shallow soil impacts (i.e., excavation) should adequately address the majority of the potential vapor issues related to those constituents derived from past operations at the Site. However, consideration should be given to the presence of naturally-occurring methane most likely migrating along

the San Cayetano Fault. In 1994, vapor samples were collected to investigate the origin of subsurface methane. The isotopic analytical results were presented in the Final Phase 2 Design Report (E&A, 1994). The evaluation of vapor sample results indicated a thermogenic or natural deep earth origin for the methane gas. Vapor mitigation options will be addressed during property redevelopment and may likely include vapor barriers beneath structures as an institutional control, which is discussed further Section 9.6.

## 9.5 REMEDIAL ACTION OBJECTIVES

The RAOs for this project are defined by medium-specific criteria to be protective of human health and the environment at the Site. In accordance with the NCP, the site-specific RAOs were developed to address (1) contaminants of concern, (2) media of concern, (3) potential exposure pathways, and (4) preliminary remediation levels. The basis for the RAOs are risk-based concentrations (RBCs) and ecological screening criteria, and a list of applicable or relevant and appropriate regulations (ARARs) selected for the Site, which was developed using a list of potential remedial action alternatives.

The RAOs are:

### ***Protection of Human Health***

- ◆ Prevent ingestion of groundwater containing constituent concentrations above state/federal maximum contaminant levels (MCLs).
- ◆ Prevent shallow soil-related exposures (i.e., incidental ingestion, direct dermal contact, particulate inhalation and outdoor vapor inhalation of VOCs adhering to soil) to constituent concentrations exceeding a selected commercial/industrial land use designation cancer risk threshold of  $1 \times 10^{-5}$  or  $1 \times 10^{-6}$  and a non-cancer hazard index of 1.
- ◆ Prevent indoor inhalation through vapor intrusion of constituent concentrations exceeding a selected commercial/industrial land use designation cancer risk threshold of  $1 \times 10^{-5}$  or  $1 \times 10^{-6}$  and a non-cancer hazard index of 1.

### ***Protection of the Environment***

- ◆ Restore water quality, at a minimum, to water quality objectives that are protective of beneficial uses within a reasonable timeframe. LNAPL will be removed to the maximum extent practical.
- ◆ Prevent constituent soil concentrations from degrading groundwater in excess of state/federal MCLs.
- ◆ Maintain communities of terrestrial plants and soil invertebrates at AOC 01 by achieving soil concentrations below toxicity threshold levels protective of these receptor groups.
- ◆ Maintain Site conditions suitable for populations of terrestrial birds and mammals at AOC 01 by achieving soil and dietary tissue concentrations below toxicity threshold levels protective of these receptor groups.

## 9.6 INSTITUTIONAL CONTROLS

EPA, the City of Fillmore, and Chevron agree that limiting future development at the site to commercial/industrial uses only (as opposed to residential or similar uses) makes sense, based on both



historical use and reasonably anticipated future uses (Chevron, 2010) (Appendix B). EPA and Chevron consider institutional controls (ICs) to be an essential part of the remedial action.

Table 53 sets forth an in-depth analysis of institutional controls, including:

- ◆ Type of institutional control and the relationship of the control to the remedy;
- ◆ The objective to be obtained by each institutional control;
- ◆ The performance standard associated with each institutional control (e.g., prohibit well drilling to prevent exposure to contaminated groundwater);
- ◆ An institutional control monitoring plan; and
- ◆ The entity responsible for implementing, maintaining, and enforcing each institutional control.

## 10.0 SCREENING OF REMEDIAL TECHNOLOGIES

The screening methods used to evaluate potential remedial options are described in this section.

### 10.1 GENERAL RESPONSE ACTIONS

A general response action (GRA) describes those medium-specific actions that will satisfy the RAOs. The GRAs are typically comprised of a broad category of actions that may include treatment, containment, excavation, extraction, disposal, and institutional actions. The GRAs are summarized on Table 54.

The Site has been broken into three broad categories requiring remedial action. These include shallow soil to 10 ft bgs, southern groundwater plume, and northern groundwater plume. This method allows different remedial technologies to be evaluated, and ultimately selected, based on their relevance to varying RAOs. In addition, since impacted soil is not migrating to (or significantly degrading) groundwater, the remedy evaluation will be separated along medium-specific criteria through the remainder of the feasibility study.

#### 10.1.1 Shallow Soils to 10 ft bgs

The shallow soil impacts were defined based on the results of the HHRA. As requested by EPA, the first step included a detailed analysis of several remedial options compared against a baseline criterion of  $1 \times 10^{-6}$ . Seventy (70) areas were included under this scenario for remedial action with a total treatment volume (estimated for evaluation purpose only) of approximately 8,050 cubic yards. The volume estimates were generated equally based on the anticipated excavation depth as follows:

Exceedence Depth (ft bgs)	Excavation Dimension		
	Depth (feet)	Length (feet)	Width (feet)
1	3	15	15
5	7	20	20
10	12	25	25

In addition, tank berm material throughout the property is expected to be above the risk-based criteria for lead based on limited soil sampling (URS, 2009b). The tank berm material treatment volume is estimated at an additional 11,950 cubic yards. The estimated commercial/industrial removal volumes are summarized in Table 55. The commercial/industrial removal volumes are shown on Figure 34. It's understood the soil volumes presented in this document are estimated for evaluation purpose only, since the development of remedial alternatives should be comparable when similar volumes are used for each technology considered. Sufficient site data exist to select a remedy. The vertical limit of soil remediation is already defined to prevent an exposure pathway to 10 ft bgs. During remedial design, soil volumes may be refined with additional lateral delineation as needed to engineer the chosen remedy.

Upon completing the baseline evaluation at  $1 \times 10^{-6}$ , the EPA requested a separate cost comparison analysis for two of the most promising soil remedial options at a risk criterion of  $1 \times 10^{-5}$ . The second

criterion total treatment volume (including tank berm material) was approximately 16,400 cubic yards (Figure 35) The commercial/industrial removal volumes using the  $1 \times 10^{-5}$  cancer risk threshold are summarized on Table 56. The cost details for both options are discussed further in Section 11.

The EPA also requested considering shallow soil impacts in exceedance of residential criteria for comparing unrestricted use against commercial/industrial use proposed for the Site. The results of a residential screening level risk assessment (Appendix G) are the basis for determining areas to be addressed under a potential residential cleanup scenario. The total treatment volume (estimated for evaluation purpose only) was approximately 150,000 cubic yards. The residential baseline assessment assumed the impacted material will be excavated to the specified depth, and then transported off-site for disposal at an appropriately licensed facility. The estimated residential removal volumes are summarized in Table 58. The residential removal volumes are shown on Figure 36.

### 10.1.2 Southern Groundwater Plume

The southern groundwater plume treatment area is defined based on the historical presence of LNAPL. The vertical thickness of sorbed, residual LNAPL within saturated sediments is estimated to be 10 feet. The lateral limit perpendicular to groundwater flow (i.e., north-south) is approximately 200 feet. The lateral limit parallel to groundwater flow (i.e., east-west) is approximately 250 feet. The target area for pilot testing is within the general vicinity upgradient of extraction well EW-04. The total treatment area is estimated to be 500,000 cubic feet. The estimated groundwater treatment volume (using porosity of 0.30) is approximately 1,122,000 gallons.

LNAPL has been detected during recent groundwater monitoring events in monitoring wells EW-01 (0.84 foot), EW-04 (0.34 foot), and MW-8S (0.01 foot). LNAOST modeling indicates hydraulic recovery methods will provide very little net environmental benefit within a reasonable timeframe since the product is near residual saturation. As such, LNAPL hydraulic recovery methods were not evaluated as viable remediation options for the feasibility study. Furthermore, the model suggested that remedial options focusing on changing the LNAPL composition (i.e. benzene content) within the saturated sand interval may reduce groundwater plume extent and longevity, but effectiveness may be constrained by the presence of fine-grained units.

### 10.1.3 Northern Groundwater Plume

The northern groundwater plume treatment area was also defined based on the historical presence of LNAPL, which is smaller in distribution compared to the southern groundwater plume. The vertical thickness of sorbed, residual LNAPL within saturated sediments is estimated to be 10 feet. The lateral limits (30 feet by 30 feet) are estimated based on the historical occurrence of measurable product in the general vicinity of extraction well EW-P2. The total treatment area is estimated to be 9,000 cubic feet. The estimated groundwater treatment volume (using porosity of 0.30) is approximately 20,200 gallons.

LNAPL has not been detected in the northern plume since 2003. The base assumption that minimal sorbed product is present within the saturated zone seems plausible, given the multiple lines of evidence for a stable and shrinking plume (Appendix E). Thus a less aggressive remedial approach, such as MNA, should be considered for the northern groundwater plume.

## 10.2 SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES

The Federal Remediation Technologies Roundtable (FRTR) document entitled *Remediation Technologies Screening Matrix and Reference Guide (4th Edition)* was used as a baseline for identifying various remedial options considered applicable at the Site (FRTR, 2002). The remedial options were evaluated against three screening criteria that included effectiveness, implementability, and cost. The nine NCP evaluation criteria are used in the detailed analysis section discussed later in the RI/FS.

The effectiveness evaluation focuses on the (1) ability of handling the anticipated volume as well as meeting the project established RAOs, (2) potential impacts the process may have on human health and the environment, and (3) reliability of the process with respect to constituents being addressed at the Site.

Implementability covers both the technical and administrative feasibility of implementing the selected technology. The evaluation commonly includes the ability to obtain necessary permits, availability of treatment/storage/disposal services, and procurement of necessary equipment and/or skilled workers to implement the technology.

Remedial cost estimates prepared during this portion of the evaluation play a limited role in the screening process since the estimates are based on engineering judgment against general criteria among similar technology types as low, medium, or high.

The initial screening process was completed within professional guidelines to represent options generally considered applicable at the Site. The initial screening evaluation results for soils are summarized on Table 58. The initial screening evaluation results for groundwater are summarized on Table 59.

## 10.3 IDENTIFICATION OF POTENTIAL REMEDIAL TECHNOLOGIES

This section provides an overview of the various remedial options evaluated for the Site. A combined technology evaluation (due to similar process options) is provided for groundwater.

### 10.3.1 Soil Remedial Technologies

The soil remedial technologies are discussed in this section.

#### 10.3.1.1 No Action – Monitoring Only

This baseline alternative includes ‘no action’ with respect to subsurface soils beyond implementing control measures already imposed by the current ROD. The main feature of the monitoring only alternative will be to maintain the integrity of the perimeter fencing (including signage) around the Site. The impacted soils will not be addressed by this alternative, which will not achieve the established RAOs. This option was retained for further consideration in the detailed analysis.

#### 10.3.1.2 Institutional Controls

Institutional controls proposed for the Site are described in Section 9.6 and Table 53. Because of the historical methane and other soil gas detections reported during site investigations, construction of future structures on site related to a commercial/industrial land use will require vapor barriers. Costs that may be associated with future land use are not considered in this report.

### 10.3.1.3 Capping (in-situ and ex-situ)

A cap is an engineered, multi-layer cover designed to (1) prevent direct contact with impacted soil and (2) minimize surface water infiltration to prevent leaching to groundwater. The capping option could be implemented at each area exceeding risk-based soil concentrations established by the HHRA. However, this may be cost prohibitive considering the impacted areas are fairly dispersed across the Site. A potential alternative will be the placement of asphalt/concrete material over impacted areas, which will require increased coordination during the planning phase of property redevelopment; however, the performance of this option will require periodic monitoring, inspection, and maintenance. This in-situ capping option was not retained for further analysis since the impacted areas are fairly dispersed across the Site.

However, a cap in conjunction with an excavation scenario (Section 10.3.1.4) could offer protectiveness without conflicting with future redevelopment plans for the Site. This option was retained for further evaluation during the detailed analysis along with the excavation scenario discussed in Section 10.3.1.4.

### 10.3.1.4 Excavation

The excavation option involves selective removal of impacted soil within the upper 10 ft bgs. The RI/FS identified three options for addressing impacted soil once excavated including disposal at a landfill, consolidation within the existing, former main waste pit, and treatment either by composting or by using an amendment for solidification/stabilization. The final disposal for both treatment options is the main waste pit. A protective barrier (i.e., engineered fill and cap) will be placed over the main waste pit to avoid direct contact of construction workers with a fill depth up to 10 feet. A bottom liner would not be required for leachate collection and to limit vertical migration to groundwater based on constituent modeling results discussed in Section 5.0. This option was retained for further evaluation during the detailed analysis.

### 10.3.1.5 Phytoremediation (in-situ and ex-situ)

Phytoremediation is a biological process that utilizes plants to remove, transfer, stabilize, and destroy contaminants present within subsurface soils. The mechanisms of phytoremediation may include enhanced rhizosphere biodegradation, phyto-extraction (also called phyto-accumulation), phyto-degradation, and phyto-stabilization. At this particular Site, the process is only considered applicable to ex-situ applications, where the soil could be consolidated over a large area amenable for plants. The in-situ option will be difficult to implement since the impacted areas are fairly dispersed across the Site. The most appropriate location for this remedial option will be within a treatment cell placed in a setback zone required for a potentially active fault along the eastern portion of the Site.

Phytoremediation is generally considered a long-term option compared to the other technologies. The performance of this option will require irrigation, possibly fertilizer, periodic monitoring, inspection, and maintenance. Some plants, including prairie grasses, have proven effective in remediating PAHs in soils via rhizospheric biodegradation. However, the most prevalent soil contaminant on the Site is lead, which does not biodegrade and requires a different mechanism to remove it from the soil. Plants, identified in the literature as “hypoaccumulators” for lead, i.e., plants that are capable of accumulating high concentrations of lead in their aboveground shoots (and thus suitable for harvesting), are mostly native to

wetter climates than found at the Site. Because lead has poor bioavailability, successful phytoremediation would likely require addition of amendments to increase uptake and subsequent translocation of lead to the aboveground shoots of the plant. The two main amendment techniques used to increase bioavailability of lead in soils and the mobility of lead within the plant tissue are lowering soil pH (which is alkaline on the Site) to slightly acidic, and adding synthetic chelates, which increase solubility of metal cations. This could increase the mobility of the lead (and possibly other metals) in the soil.

Because of the long-term and complex nature of this option, the uncertainty of total success, the possibility of undesirable collateral effects, and the fact that phytoremediation in the case of lead is considered a transfer of contamination, this option was not retained for further consideration in the detailed analysis.

#### **10.3.1.6 Soil Flushing**

In-situ soil flushing involves the extraction of contaminants from the soil using an aqueous solution (often along with a cosolvent) via injection and/or infiltration, which is then captured within the underlying aquifer for subsequent treatment. However, the presence of highly heterogeneous soils makes it difficult to control migration of dissolved constituents and may further degrade water quality in Aquifer I. This option may also be cost prohibitive considering the impacted areas are fairly dispersed across the Site. This option was not retained for further consideration in the detailed analysis.

#### **10.3.1.7 Composting**

Composting is a controlled biological process by which contaminants are converted to innocuous, stabilized byproducts. The excavated soil is typically mixed with a bulking agent and/or organic amendments to enhance the porosity of the mixture for treatment within aerated static piles, in-vessel systems, or within windrows. The windrow method is considered to be the most cost-effective alternative, but may require additional monitoring during processing due to fugitive dust emissions. Maximum degradation efficiency is achieved through maintaining oxygenation (e.g., daily windrow turning), irrigation as necessary, and closely monitoring moisture content and temperature.

Metals are not necessarily remediated by composting. Instead, the bioavailability of metal impacted soil can be reduced by adsorption, which is an electrochemical process where positively- or negatively-charged organic molecules bind with their charge-opposite counterparts in organic matter and/or fine-grained sediments. This option was retained for further consideration in the detailed analysis.

#### **10.3.1.8 Chemical Reduction / Oxidation**

Reduction/oxidation (Redox) reactions chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. Redox reactions involve the transfer of electrons from one compound to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). The oxidizing agents most commonly used for treatment of hazardous contaminants are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. Elevated hydrocarbon concentrations may require a large amount of oxidizing reagent for a complete reaction. In addition, oily soil may limit the effectiveness of the technology, and this method may not be effective for the remediation of lead. This option was not retained for further consideration in the detailed analysis.

### 10.3.1.9 Soil Washing

Soil washing is a water-based process for scrubbing soils to remove contaminants. The process removes contaminants from soils in one of the following two ways:

- ◆ By dissolving or suspending them in the wash solution; or
- ◆ By concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to those techniques used in sand and gravel mining operations).

The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay, silt, and organic soil particles. The silt and clay, in turn, are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the fine (small) clay and silt particles from the coarser sand and gravel soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be further treated or disposed of. Gravity separation is effective for removing high or low specific gravity particles such as heavy metal-containing compounds (lead, radium oxide, etc.).

Complex mixtures of contaminants in the soil (such as a mixture of metals) and heterogeneous contaminant compositions throughout the soil mixture make it difficult to formulate a single suitable washing solution that will consistently and reliably remove all of the different types of contaminants. For these cases, sequential washing, using different wash formulations and/or different soil to wash fluid ratios, may be required.

Soil washing is generally considered a media transfer technology. The contaminated water generated from soil washing is treated with the technology(s) suitable for the contaminants. Based on consultation with a vendor, this process option typically requires a more substantial amount of impacted soil than is present on Site to be economically feasible. This option was not retained for further consideration in the detailed analysis.

### 10.3.1.10 Solidification / Stabilization (in-situ and ex-situ)

Solidification / stabilization are used to reduce the mobility of constituents present within impacted soil (in-situ and/or ex-situ) by both physical/chemical means to essentially encapsulate the contaminants. The most commonly used stabilizer is cement. The preferred option would be to transport excavated soil to the former main waste pit where an inorganic binder (e.g., cement, fly ash, lime, soluble silicates, or sulfur) is added for final solidification / stabilization. This option is consistent with the majority of projects using this technology (USEPA, 2000a). This technology is by far the most popular remedial option for inorganic compounds (such as lead) according to a study conducted by EPA. According to EPA, 23% of Superfund remedial actions involving source control have used solidification/stabilization treatment (USEPA, 2007g). This option was retained for further consideration in the detailed analysis.

An alternate stabilizer was also evaluated using a proprietary phosphate product manufactured by Free Flow Technologies Ltd. located in Machesney Park, Illinois. The application would be similar (excluding

the abundant use of water) to cement solidification / stabilization. Phosphate amendment is typically considered at sites where lead is a COC, as a means of reducing mobility and bioavailability by forming low-solubility lead phosphate minerals. A bench-scale treatability study was conducted in November 2009 with Site soil samples amended with liquid phosphate products (FF-100<sup>®</sup> and FF-200<sup>®</sup>) in concentrations of 0% (no amendment), 1%, 2%, and 3% (Table 60). The soils were subjected to the synthetic precipitation leaching procedure (SPLP). Lead was not mobile in the SPLP, with or without phosphate amendment, demonstrating the lead is already stable at the Site.

There is also a potential that phosphate amendment could liberate naturally occurring arsenic in background soil (Section 6.2.1.2.1). Pentavalent arsenate ( $\text{AsO}_4^{3-}$ ) is the most stable species in well-aerated soils, typical of shallow Site soils. Arsenate and phosphate ( $\text{PO}_4^{2-}$ ) are chemically very similar, with similar ionic radii ( $\text{As} = 0.33 \text{ nm}$ ,  $\text{P} = 0.29 \text{ nm}$ ) (Shannon, 1976). They exhibit the same structure and similar acid dissociation constants (arsenic acid [ $\text{pK}_{\text{a}2} = 6.94$ ] and phosphoric acid [ $\text{pK}_{\text{a}2} = 7.21$ ]) (Stumm and Morgan, 1996). As a result of these similarities, they compete for similar binding sites in soil. Consequently, phosphate addition to soils may facilitate arsenate leaching into soil solution by displacement of arsenate from specific adsorption sites through competitive anion-exchange (Williams et al., 2003). With phosphates and arsenates in direct competition, the addition of phosphates could induce high phosphate/arsenate ratios, overwhelm arsenate adsorption sites, and desorb arsenic. The potential for phosphate-induced leaching of arsenic from lead-contaminated soil has been well documented (Peryea and Kammereck, 1997; Boisson et al., 1999; Kilgour et al., 2008).

The treatability study with FF-200<sup>®</sup> also caused marked increases in soil pH from slightly alkaline ( $7.47 < \text{pH} < 7.75$ ) in native soil to extremely alkaline ( $9.23 < \text{pH} < 11.1$ ) (Table 59). The affinity of arsenate for most minerals is pH dependent. Increasing pH reduces the effectiveness of iron hydroxide and clay adsorption (Manning and Goldberg, 1997). Desorption of arsenate from iron oxide surfaces becomes favored as pH values increase substantially above neutrality (Dzombak and Morel, 1990). Furthermore, Portland cement also increases soil pH.

Portland cement consists mostly of calcium silicates  $(\text{CaO})_3(\text{SiO})_2$  and  $(\text{CaO})_2(\text{SiO})_2$ . When dry cement is hydrated,  $\text{Ca}(\text{OH})_2$  is produced.  $\text{Ca}(\text{OH})_2$  readily dissolves in water to increase pH to about 12.4. Poured concrete is rapidly encased with hydrated calcium silicates and calcium aluminosulfates, limiting intrusion to the curing concrete by surrounding water and impeding leaching. However, amending soil with Portland cement as an additive would produce extensive contact between infiltrating water and  $\text{Ca}(\text{OH})_2$ , thereby leaching hydroxyl and raising soil pH.

Increasing soil pH poses the risk of releasing natural arsenic as previously discussed, but with a Portland cement amendment, arsenic is not the only concern. Long-term conversion of chemicals in Portland cement, such as  $\text{Ca}(\text{OH})_2$  and  $\text{Mg}(\text{OH})_2$ , to more stable carbonates, i.e.,  $\text{CaCO}_3$  and  $\text{MgCO}_3$  respectively, can promote leaching of other metals contained in the Portland cement (Van Gerven, 2005). This is also a concern given the increasing practice of mixing fly ash of unknown quality from various sources in the cement manufacturing process. For instance, hexavalent chromium leachate has been documented from Portland cement amended soils well in excess of the  $50 \mu\text{g}/\text{kg}$  MCL (Kamon, 2001).

In light of the demonstrated lead stability inherent to the native soil at the Site and the fate and transport modeling results for both lead and PAHs (Section 5.0), soil treatment with an amendment may provide little value. Should an amendment be required, another treatability study will be needed to evaluate the potential liberation effects of naturally occurring arsenic at the Site.

### **10.3.2 Groundwater Remedial Technologies**

The groundwater remedial technologies are discussed in this section.

#### **10.3.2.1 No Action – Monitoring Only**

This baseline alternative includes ‘no action’ with respect to subsurface groundwater beyond implementing control measures already imposed by the current ROD. The main feature of the monitoring only alternative will be to maintain the integrity of the perimeter fencing (including signage) around the Site. The impacted groundwater will not be actively addressed by this alternative, which will not achieve the established RAOs. This option was retained for further consideration in the detailed analysis.

#### **10.3.2.2 Institutional Actions**

Institutional controls proposed for the Site are described in Section 9.6 and Table 53.

#### **10.3.2.3 Monitored Natural Attenuation**

The MNA option relies on natural processes to clean up or attenuate pollution in soil and groundwater. Natural attenuation occurs at most impacted sites. However, the right conditions must exist in the subsurface to clean sites adequately. Monitoring and/or testing are performed at regular intervals to make sure natural attenuation is working effectively.

Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials are allowed to reduce contaminant concentrations to acceptable levels. Consideration of this option usually requires modeling and evaluation of contaminant degradation rates and pathways and predicting contaminant concentration at down-gradient receptor points, especially when the plume is still expanding/migrating. The primary objective of site modeling is to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, long term monitoring must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives. This option was retained for further consideration in the detailed analysis.

#### **10.3.2.4 Enhanced Bioremediation with Oxygen Addition**

Bioremediation is a process in which indigenous or inoculated microorganisms (i.e., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or groundwater. Enhanced bioremediation is a process that attempts to accelerate the natural biodegradation process by providing nutrients, electron acceptors, and competent degrading microorganisms, the lack of which may otherwise be limiting the rapid conversion of organics to innocuous end products. Several options for the enhancement of bioremediation are discussed below:

- ◆ **Oxygen Release Compounds** – Oxygen release compounds are typically solids with low water solubility. When hydrated, these compounds release their full amount of oxygen over a period of time (typically 1 year). This process enables aerobic microorganisms to accelerate degradation rates over extended periods of time.
- ◆ **Ozone Injection** – Ozone reacts with water to form hydroxyl radicals or degrades back to oxygen. Due to its high solubility in water, ozone can saturate the water with DO following degradation; thereby enhancing aerobic degradation of contaminants.
- ◆ **Oxygen Injection** – Similar to ozone injection, the addition of oxygen to groundwater increases the oxygen concentration and enhances the rate of biological degradation of organic contaminants by naturally-occurring microorganisms. This process also increases mixing in the saturated zone, which increases the contact between groundwater and the soil.

The addition of oxygen may not be beneficial, as there is an abundant supply of naturally-occurring electron acceptors (e.g., sulfate) available at the Site. In addition, elevated hydrocarbon concentrations may require an impractical quantity of oxidizing reagent for a complete reaction based on the results of the unsuccessful enhanced bioattenuation pilot test using ORC<sup>®</sup> (Appendix B). This option was not retained for further consideration in the detailed analysis.

#### **10.3.2.5 Enhanced Bioremediation – Sulfate-Rich Groundwater Circulation Wells**

Petroleum hydrocarbon constituents have been shown to degrade rapidly under aerobic conditions, but success often is limited by the inability to provide sufficient oxygen to the contaminated zones as a result of the low water solubility of oxygen and because oxygen is depleted due to the presence of other organic compounds. Sulfate can also serve as an effective electron acceptor, is significantly more soluble in water than oxygen, and has a much higher biodegradation capacity than oxygen (Section 5.2). The addition of sulfate to an aquifer results in the anaerobic biodegradation of petroleum hydrocarbons. Chevron is currently funding University of California Davis (UC Davis) to conduct research at Fillmore. This research will deploy molecular biological tools (MBTs) to study sulfate reducing bacteria within the dissolved plumes. If microbiological conditions are favorable, groundwater recirculation to mix sulfate-rich groundwater from outside the plume with benzene-contaminated groundwater can potentially increase the rate of in situ biodegradation. This option was retained for further consideration in the detailed analysis.

#### **10.3.2.6 Air Sparging with Vadose Monitoring**

Air sparging is an in-situ technology in which air is injected into an impacted aquifer. Injected air flows horizontally and vertically in channels through the soil column, creating an underground stripper that removes contaminants by volatilization. This injected air helps to transport the contaminants up into the vadose zone where they are often removed by a complementary technology such as SVE. This technology is designed to operate at relatively high flow rates to maintain increased contact between ground water and soil and strip more groundwater by sparging. Monitoring of the concentrations in the vadose zone is necessary to track the effectiveness of air sparging. The low mole fraction of benzene in the LNAPL, 0.21-0.24% (Section 5.3.5), and the relatively thick vadose zone may not require the use of SVE based on natural attenuation demonstrated in soil vapor above the dissolved benzene plumes (URS, 2007c). This option was retained for further consideration in the detailed analysis.

### 10.3.2.7 Thermal Treatment

Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. The vaporized components rise to the vadose zone where they are removed by soil vapor extraction and then treated. This process may be used to reduce portions of oily waste accumulations and to retard downward and lateral migration of organic contaminants. The method can also be implemented using heating elements placed in subsurface soils at a relatively tight spacing. The surrounding materials will be heated above the constituent boiling point, capturing the resulting vapors typically with SVE. This technology is costly with few successful case studies and would be difficult to implement in the heterogeneous soils present beneath the Site. This option was not retained for further consideration in the detailed analysis.

### 10.3.2.8 In-Well Air Stripping using ART/SVE

The ART technology combines in-situ air sparging, soil vapor extraction, and air stripping, in a single wellhead system. The air sparge component results in mounding of the water table in the vicinity of the well – similar to an inverted cone of depression exhibited with pump and treat technology. This causes a net reduction in static head at the well location and results in water flowing away from the well.

The vapor extraction component applies a vacuum at the wellhead to extract vapor from the subsurface. The negative pressure from the vacuum extraction results in water suction that creates additional water mounding and a lower net gradient. The combined in-well sparging and vacuum extraction act to further enlarge the radius of influence.

The air stripping component consists of a submersible pump placed at the bottom of the well to circulate water to the top of the well for downward discharge through a spray head. The water cascades down the interior of the well providing multiple wetted surfaces for mass transfer. Enhanced stripping via air sparging near the bottom of the well occurs simultaneously with the recirculation of water within the well. ART/SVE may not be beneficial, as there is an abundant supply of naturally-occurring electron acceptors (e.g. sulfate) available at the Site. Hard water conditions and naturally occurring ferrous iron documented at the Site (E&A, 1994) may also cause significant plugging of internal components, rendering this technology impractical. This option was not retained for further consideration in the detailed analysis.

### 10.3.2.9 Groundwater Extraction with Above-Ground Treatment

Groundwater extraction is a technology that uses pumps (typically submersible) to bring groundwater to the surface where it can be treated in a groundwater treatment system. Various treatment systems are discussed below:

- ◆ **Bioreactors** – Contaminants in extracted groundwater are put into contact with microorganisms in attached or suspended growth biological reactors. In attached systems, such as rotating biological contactors and trickling filters, microorganisms are established on an inert support matrix. In suspended systems, such as activated sludge, contaminated groundwater is circulated in an aeration basin.
- ◆ **Air Stripping** – Volatile organics are partitioned from ground water by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.



- ◆ **Granular Activated Carbon** – Groundwater is pumped through a series of canisters or columns containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required.
- ◆ **Advanced Oxidation** – Advanced oxidation including ultraviolet radiation, ozone, and/or hydrogen peroxide oxidants are used to destroy organic contaminants as water flows through a treatment stream.

Advanced oxidation is a destruction process that oxidizes organics by the addition of strong oxidizers and/or irradiation with ultraviolet light. Oxidation of target contaminants is caused by direct reaction with the oxidizers and ultraviolet photolysis. If complete mineralization is achieved, the final products of oxidation are carbon dioxide, water, and salts. The main advantage of advanced oxidation is that it is a destruction process, as opposed to air stripping or carbon adsorption, for which contaminants are extracted and concentrated in a separate phase.

The treated effluent might be addressed via discharge to groundwater, surface water, or a publicly owned treatment works (POTW). The GWTS had previously discharged to Pole Creek under permit with the LARWQCB; however, more stringent NPDES requirements implemented by the State in 2003 make this discharge option unlikely today. The previous groundwater extraction system was taken offline due to reaching asymptotic conditions with concurrence from EPA. Resuming groundwater extraction would likely be ineffective, due to residual LNAPL sorbed within submerged fine-grained units. This option was not retained for further consideration in the detailed analysis.

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## 11.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The remedial alternatives retained from the screening process are discussed in this section. The institutional actions presented in Section 11.1 are considered an integral part of retaining the commercial / industrial land use designation for the Site, and will be implemented with each alternative proposed for the three categories requiring remedial action (i.e., shallow soil to 10 ft bgs, southern groundwater plume, and northern groundwater plume). The cost estimates provided in this section are generally based on a document entitled *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* dated July 2000 (USEPA, 2000b). A companion memorandum, *Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis*, established a discount rate of 7% for calculating the Net Present Value (NPV) (USEPA, 1993b). The selected alternatives are summarized in Table 61. A cost estimate summary for remedial options is provided in Table 62. The cost details are provided in Appendix J.

### 11.1 INSTITUTIONAL CONTROLS

Institutional controls proposed for the Site are described in Section 9.6 and Table 53.

### 11.2 SHALLOW SUBSURFACE SOILS TO 10 FT BGS

The retained process options for shallow subsurface soils (to 10 ft bgs) include no action, institutional action, excavation with off-site disposal at a landfill, excavation with on-site consolidation, excavation with on-site composting, excavation with on-site solidification/stabilization using cement, and excavation with on-site solidification/stabilization using proprietary amendment (i.e., Free Flow). The remedial options (excluding off-site disposal) will take advantage of existing open space within the former main waste pit or another suitable on-site location could be employed. Due to low mobility of the primary constituents, a bottom liner (including associated monitoring) would not be required. Engineered fill material and a cap will be placed over the consolidated material during redevelopment as a commercial/industrial property. Furthermore, the institutional controls that will be implemented eliminate construction worker contact with potentially impacted soils beyond 10 ft bgs. The conceptual plan for these remedial options is shown on Figure 37.

The process of excavating impacted soil is similar for each proposed option except for no action. The remedial option will be implemented using an appropriately sized excavator capable of reaching a minimum depth of approximately 15 ft bgs. Water will be used as a dust suppression media using multiple water trucks while operating heavy equipment. The main constituent for consideration is lead. An air monitoring station will be established to conduct perimeter sampling along the western property line east of Pole Creek. An on-site weather station already exists to document conditions while conducting the soil removals at the Site. A dump truck will be used to transport impacted soil to a central staging area located near an existing on-site scale. For an off-site disposal alternative, the scale may be used to maintain the weight of impacted soil within each truck to legal limits prior to leaving the Site. The scale may need to be relocated at the Site and would require calibration prior to commencing



fieldwork. The trucks will exit the facility onto Highway 126. As such, traffic control would be considered an integral component for safety during the remedial design.

The excavation activity will occur during the summer months in an effort to (1) minimize potential impacts to a nearby elementary school, and (2) adhere to County requirements to limit grading activities to dry season to prevent stormwater pollution concerns. A community action plan will be implemented similar to previously successful engagements conducted in the past for this Site.

Confirmation soil samples (bottom and sidewall) from each excavation will be compared to the site-specific RBCs. An exceeding value will require additional excavation, while a passing value will allow the excavation to be backfilled with clean import soil to maintain risk-based commercial/industrial standards within the upper 10 ft bgs. The remaining details will be engineered in the remedial design.

### **11.2.1 Alternative 1: No Action - Monitoring Only**

This baseline alternative includes ‘no action’ with respect to subsurface soils beyond implementing control measures already imposed by the current ROD. The main feature of the monitoring only alternative will be to maintain the integrity of the perimeter fencing (including signage) around the Site. The impacted soils will not be addressed by this alternative, which will not achieve the established RAOs.

This alternative (although not effective) could be selected as a low cost intermediate step towards minimizing potential exposure by limiting access to the property while evaluating potential redevelopment options as a commercial / industrial property.

### **11.2.2 Alternative 2: Excavation with Off-Site Disposal at Landfill**

The next alternative retained for further consideration is the excavation of impacted soil for off-site disposal as non-hazardous waste at a Waste Management Incorporated (WMI) facility located in Kettleman City, California. The estimated one-way distance to the landfill is approximately 160 miles.

This alternative is relatively straightforward to implement and effective at removing impacted soil to 10 ft bgs. A commercial/industrial risk-based cleanup level of  $1 \times 10^{-6}$  is estimated at approximately \$3,373,500 (NPV is \$3,370,300). An unrestricted (residential) cleanup level of  $1 \times 10^{-6}$  (requested by EPA for comparison purposes) is estimated at approximately \$25,249,000 (NPV is \$25,245,900).

### **11.2.3 Alternative 3: On-Site Consolidation and Cap**

The third alternative assumes excavated soil will be consolidated within the former main waste pit or other suitable on-site location. This is considered a viable option for a number of reasons including (1) limited bioavailability and mobility of lead (Appendix H), (2) COCs will not migrate to groundwater, and (3) there will be no unacceptable risks to commercial/industrial workers since impacted soil will be covered with an engineered cap to prevent infiltration of water and a layer up to 10 feet of clean fill, to be determined during remedial design. The cap will be protected by institutional controls.

This alternative will be relatively straightforward to implement and will be effective at removing impacted soil to 10 ft bgs. The consolidation option using commercial/industrial risk-based cleanup level

of  $1 \times 10^{-6}$  is estimated at approximately \$1,596,825 (NPV is \$1,593,718). As requested by EPA, the comparative cost using commercial/industrial risk-based cleanup level of  $1 \times 10^{-5}$  was estimated at approximately \$1,340,210 (NPV is \$1,337,103). This is a cost differential of approximately \$256,600

#### 11.2.4 Alternative 4: Ex-Situ Treatment by Composting

The fourth alternative retained for consideration assumes excavated soil will be treated using a composted amendment, and then consolidated within the on-site, former main waste pit or other suitable on-site location. The amendment will be mixed with impacted soil using conventional farming equipment within shallow treatment cells which would encompass the entire southern portion of the Site. It's estimated the process may be feasible within several weeks, but multiple treatment cycles could likely extend that timeframe, particularly for PAHs. An evaluation of this process option will require a treatability study during remedial design.

Chevron is currently conducting a composting treatability study at a refinery Superfund site in Lawrenceville, Illinois. The results indicate amendments are successfully addressing lead impacted soil at the Illinois refinery. As discussed in the literature, composting of PAH-contaminated soil with manure can decontaminate the soil but factors such as pH, moisture, and types and quantities of amendment are variables that must be controlled. Not all PAHs are equal, and 4- and 5-ring PAHs can remain recalcitrant for several months. Amendments that treat the lead and PAHs may not be compatible, which could necessitate additional treatment cycles and further extend the schedule. A treatability study using site-specific soils will be required to measure the effectiveness and compatibility of soil amendments and the length of the time necessary for successful treatment. Odor is also a consideration. The composted manure generates odors and the composting process can generate ammonia. Over a period of weeks or months, this could become a concern for the neighboring community, which includes the San Cayetano Elementary School. Extra soil handling and excess water for dust suppression due to strong winds may also be required for this alternative.

Once treated, the soil will be consolidated and compacted on-site. But first, the composted manure will require the addition of a cement stabilizer to provide geotechnical strength for the compaction, similar to that described in Alternative 5a. A cost estimate was prepared using the most conservative composting amendment (i.e., the most expensive) option. The composting option using a commercial/industrial risk-based cleanup level of  $1 \times 10^{-6}$  is estimated at approximately \$3,006,500 (NPV is \$3,003,300).

#### 11.2.5 Alternative 5a: Ex-Situ Treatment by Solidification / Stabilization (using Cement)

The fifth alternative assumes excavated soil will be treated using cement for solidification/stabilization. The amendment will be mixed with impacted soil using heavy equipment within shallow treatment cells inside the former main waste pit. This process option is the most frequently implemented technology for lead impacted soil as discussed in a document entitled *Treatment Technologies for Site Cleanup: Annual Status Report – Twelfth Edition* dated September 2007 (USEPA, 2007g). However, there is a potential that cement used as an amendment to soil could liberate naturally occurring arsenic and other metals used in the cement production process as discussed in Section 10.3.1.10.

This alternative will require additional effort to implement compared to the consolidation option (Alternative 3), but will also be effective at mitigating impacted soil within the upper 10 ft bgs. Solidification/Stabilization using a cement stabilizer under a commercial/industrial risk-based cleanup level of  $1 \times 10^{-6}$  is estimated at approximately \$1,664,600 (NPV is \$1,661,400). As requested by EPA, the comparative cost using commercial/industrial risk-based cleanup level of  $1 \times 10^{-5}$  is estimated at approximately \$1,277,200 (NPV is \$1,274,100). This is a cost differential of approximately \$387,400.

### **11.2.6 Alternative 5b: Ex-Situ Treatment by Solidification / Stabilization (using Free Flow)**

A variation of the fifth alternative assumes excavated soil will be treated using Free Flow (FF-100<sup>®</sup> or FF-200<sup>®</sup>) for solidification/stabilization. The amendment will be mixed with impacted soil using heavy equipment within a shallow treatment cell located inside the former main waste pit. This process option does not require hydration (i.e., a significant potable water resource) like the cement product discussed in Alternative 5a. However, there is a potential that phosphate amendment could liberate naturally occurring arsenic in background soil as discussed in Section 10.3.1.10. Thus, another treatability study will be required during remedial design to evaluate the potential liberation effects of naturally occurring arsenic at the Site. This alternative will also require additional effort to implement compared to the consolidation option (Alternative 3). Solidification/Stabilization using the Free Flow amendment under a commercial/industrial risk-based cleanup level of  $1 \times 10^{-6}$  is estimated at approximately \$1,541,700 (NPV is \$1,538,600).

## **11.3 SOUTHERN GROUNDWATER PLUME**

The retained process options for the southern groundwater plume include no action, monitored natural attenuation, circulation with existing sulfate-rich groundwater, air sparging with vapor monitoring, and a multiple technology alternative using a combination of all three process options.

### **11.3.1 Optimized Groundwater Monitoring Network**

The southern groundwater plume geometry is well characterized and has not changed significantly since 1990. As such, the groundwater monitoring network was reevaluated as part of the feasibility study. An optimized, performance-oriented monitoring network is proposed for the southern groundwater plume. Groundwater monitoring costs include a reduction in long-term monitoring frequency as appropriate by technology as well as the reduction/addition of monitoring wells in the groundwater monitoring network to eliminate redundant data points or data points that are no longer useful and to fill data gaps. Performance-oriented monitoring will focus on key indicators to confirm remediation progress and plume stability. The groundwater indicator compounds that will be analyzed by a fixed laboratory are benzene, and toluene. The remaining indicator parameters that will be measured using calibrated field instrumentation and a flow-through cell are sulfate, dissolved oxygen, oxygen reduction potential, electrical conductivity, temperature, turbidity, ferrous iron, and pH. Other natural attenuation indicator compounds (i.e., nitrate, manganese) are less meaningful at the Site and were previously removed from the monitoring program with concurrence from EPA. The optimized groundwater monitoring network is described in Table 63 and shown on Figure 38. The sampling frequency (including analytes) is provided in the detailed analysis in Appendix I.

### 11.3.2 Alternative 1: No Action - Monitoring Only

This baseline alternative includes ‘no action’ with respect to groundwater beyond implementing control measures already imposed by the current ROD. The main feature of the monitoring only alternative will be to maintain the integrity of the perimeter fencing (including signage) around the Site. The impacted groundwater will not be actively addressed by this alternative, which will not achieve the established RAOs.

### 11.3.3 Alternative 2: Monitored Natural Attenuation

The next alternative retained for further consideration is MNA. As previously discussed, multiple lines of evidence indicate petroleum hydrocarbons are degrading naturally at the Site (Appendix E). It’s anticipated it will take many years to achieve the agency required benzene action limit of 1 µg/L. This is primarily due to the presence of residual LNAPL sorbed onto saturated sediments within the smear zone present in Aquifer I. The southern groundwater plume longevity is estimated to be 100 years. This is based on professional judgment as well as conceptual modeling conducted with LNAST.

This alternative will be relatively straightforward to implement, but will require many years before achieving the RAOs. Fourteen (14) groundwater monitoring wells in the optimized network (Section 11.3.1) will be sampled annually for 100 years. A groundwater monitoring report will be submitted annually to the EPA. The MNA option is estimated at approximately \$2,961,100 (NPV is \$587,900).

### 11.3.4 Alternative 3: Air Sparging with Vapor Monitoring

The third alternative for consideration is air sparging with vapor monitoring within the southern groundwater plume. As noted in Section 5.4, groundwater remediation should focus on changing the LNAPL composition (i.e. benzene content) in the smear zone that sources the dissolved plume. Air sparging may be effective in stripping the remaining benzene. For this evaluation, it is currently assumed that this technology might need to operate for 20 years followed by 10 years of MNA to potentially remediate the southern plume within 30 years. A pilot test will be required to validate this assumption, which would be conducted prior to implementing the full-scale remedial design. A cross-sectional view of the conceptual plan is shown on Figure 39. A plan view of the well network for the conceptual design is shown on Figure 40.

Single-completion air sparging wells (spaced laterally approximately every 30 feet) will be installed below the smear zone (evaluated by continuously coring each boring) to a depth of approximately 80 ft bgs. Single-completion groundwater monitoring wells will be installed to evaluate the treatment system operations including a multiple port well to monitor the vadose zone. Vadose zone monitoring will be conducted to evaluate the potential need for SVE. As discussed in Section 10.3.2.6, the low mole fraction of benzene remaining in the LNAPL (0.21-0.24%) may not require SVE due to demonstrated biodegradation within the thick vadose zone. It is currently understood that petroleum hydrocarbon degradation is occurring locally within the vadose zone as documented in *Report of Natural Attenuation Characteristics and Soil Vapor Characteristics above Dissolved-Phase Benzene Plumes* (URS, 2007c). Air tight seals will be installed on all monitoring wells in the vicinity of air sparging to prevent short-circuiting of injected air. Groundwater elevations will be monitored using dedicated pressure transducers

(along with a site-dedicated barometer) tied into a telemetry system for remote monitoring using a Supervisory Control and Data Acquisition (SCADA) System.

This alternative will require additional effort to implement due to the abundance of fine-grained sediments in the treatment zone. If successful, it may reduce the time required to achieve the RAOs. Fourteen (14) groundwater monitoring wells in the optimized network (Section 11.3.1) will be sampled semi-annually for the first 10 years. An annual sampling program will be implemented for the remaining 20 years. The groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The air sparging with vapor monitoring option is estimated at approximately \$9,091,600 (NPV is \$5,676,400).

### 11.3.5 Alternative 4: Enhanced Bioremediation using Sulfate

The fourth alternative for consideration is enhanced bioremediation using sulfate-rich groundwater from the Site. The UC Davis research described in Section 10.3.2.5 is applying MBTs to confirm whether sulfate mixing has the potential to enhance benzene biodegradation. For this evaluation, it is assumed that this technology might need to operate for 50 years followed by 10 years of MNA to remediate the southern plume within 60 years. The reason for the longer time estimate is that this technology targets the dissolved plume only, whereas air sparging also targets the source (residual LNAPL in the smear zone). A pilot test will be required, which would be conducted prior to implementing the full-scale remedial design. A cross-sectional view of the conceptual plan is shown on Figure 41. A plan view of the well network for the conceptual design is shown on Figure 42.

Sulfate has a much higher biodegradation capacity as an electron acceptor than oxygen (Section 5.2) and is naturally abundant outside the plume limits at concentrations exceeding 1,000 mg/L. Dual-completion groundwater circulation wells (spaced laterally approximately every 30 ft) would be installed to a depth of approximately 120 ft bgs. Triple-completion groundwater monitoring wells would be installed to evaluate the treatment system operations. Groundwater elevations would be monitored using dedicated pressure transducers (along with a site-dedicated barometer) tied into a telemetry system for remote monitoring using a SCADA System.

The sulfate-rich water would be pumped from the deeper screen into the smear zone via the upper screen. A packer would be placed between the two screens to promote a constant head within the upper portion of Aquifer I. It's estimated based on the lithology that the smear zone will accept a minimum pumping rate of approximately 0.25 gallons per minute (GPM). An increased production rate may have a beneficial effect in providing additional electron acceptors to potentially reduce plume longevity, but will be evaluated further during pilot testing.

This alternative will require additional effort to implement and may reduce the time required to achieve the RAOs. Fourteen (14) groundwater monitoring wells in the optimized network (Section 11.3.1) will be sampled semi-annually for the first 10 years. An annual sampling program will be implemented for the remaining 50 years. The groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The enhanced bioremediation option is estimated at approximately \$11,833,600 (NPV is \$4,675,300).

### 11.3.6 Alternative 5: Multiple Technology

The fifth alternative is the sequential implementation of each process option including air sparging (6 years), circulation with existing sulfate-rich groundwater (9 years), and MNA (10 years). The approach takes advantage of the strengths of each technology. First, air sparging will preferentially strip benzene from the LNAPL smear zone, reducing the source to a point where remaining benzene in groundwater is primarily present in the dissolved phase. Then, groundwater circulation will enhance biodegradation of the dissolved phase by mixing naturally occurring sulfate-rich groundwater from the deeper portion of Aquifer I with the shallower plume. Sulfate is significantly more soluble in water and has a much higher biodegradation capacity as an electronic acceptor than oxygen (Section 5.2). A pilot test will be conducted prior to implementing the full-scale remedial design. The multiple technology cross-sectional view of the conceptual plans will be similar to those shown on air sparging with vapor monitoring (Figure 39) and enhanced bioremediation using sulfate (Figure 41).

This alternative will require additional effort to implement, and may reduce the time required to achieve the RAOs. Fourteen (14) groundwater monitoring wells in the optimized network (Section 11.3.1) will be sampled semi-annually for the first 10 years. An annual sampling program will be implemented for the remaining 15 years. The groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The multiple technology option is estimated at approximately \$8,679,900 (NPV is \$6,436,100).

## 11.4 NORTHERN GROUNDWATER PLUME

The retained process options for the northern groundwater plume include monitored natural attenuation, circulation with existing sulfate-rich groundwater, air sparging with vapor monitoring, and a multiple technology alternative using a combination of all three process options.

### 11.4.1 Optimized Groundwater Monitoring Network

The northern groundwater plume geometry is well characterized and has not changed significantly since 1990. As such, the groundwater monitoring network was reevaluated as part of the feasibility study. An optimized, performance-oriented monitoring network is proposed for the northern groundwater plume. Groundwater monitoring costs include a reduction in long-term monitoring frequency as appropriate by technology as well as the reduction/addition of monitoring wells in the groundwater monitoring network. Performance-oriented monitoring will focus on key indicators to confirm remediation progress and plume stability. The groundwater indicator compounds that will be analyzed by a fixed laboratory are benzene, and toluene. The remaining indicator parameters that will be measured using calibrated field instrumentation and a flow-through cell are sulfate, dissolved oxygen, oxygen reduction potential, electrical conductivity, temperature, turbidity, ferrous iron, and pH. Other natural attenuation indicator compounds (i.e., nitrate, manganese) are less meaningful at the Site and were previously removed from the monitoring program with concurrence from EPA. The optimized groundwater monitoring network is described in Table 63 and shown on Figure 38. The sampling frequency (including analytes) is provided in the detailed analysis in Appendix J.

#### 11.4.2 Alternative 1: No Action - Monitoring Only

This baseline alternative includes ‘no action’ with respect to subsurface groundwater beyond implementing control measures already imposed by the current ROD. The main feature of the monitoring only alternative will be to maintain the integrity of the perimeter fencing (including signage) around the Site. The impacted groundwater will not be actively addressed by this alternative, which will not achieve the established RAOs.

#### 11.4.3 Alternative 2: Monitored Natural Attenuation

The next alternative retained for further consideration is MNA. As previously discussed, multiple lines of evidence indicate petroleum hydrocarbons are degrading naturally at the Site (Appendix E). It’s anticipated it will take many years to achieve the agency required benzene action limit of 1 µg/L. This is primarily due to the presence of product sorbed onto saturated sediments within the smear zone. The northern groundwater plume longevity is estimated to be up to 50 years. This is based on professional judgment, linear regression analysis, and conceptual modeling conducted with LNASt.

This alternative will be relatively easy to implement, but will require many years before achieving the RAOs. Seven (7) groundwater monitoring wells in the optimized network (Section 11.4.1) will be sampled annually for 50 years. A groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The MNA option is estimated at approximately \$1,533,500 (NPV is \$598,200).

#### 11.4.4 Alternative 3: Air Sparging with Vapor Monitoring

The third alternative for consideration is air sparging with vapor monitoring. As noted in Section 5.4, groundwater remediation should focus on changing the LNAPL composition (i.e. benzene content) in the smear zone that sources the dissolved plume. Air sparging may be effective in stripping the remaining benzene. For this evaluation, it’s assumed that this technology might need to operate for 15 years followed by 10 years of MNA to potentially remediate the northern plume within 25 years. A pilot test will be required to validate this assumption, which will be conducted prior to implementing the full-scale remedial design. A cross-sectional view of the conceptual plan is shown on Figure 39. A plan view of the well network for the conceptual design is shown on Figure 43.

Single-completion air sparging wells (spaced laterally approximately every 30 ft) will be installed below the smear zone (evaluated by continuously coring each boring) to a depth of approximately 110 ft bgs. Single-completion groundwater monitoring wells will be installed to evaluate the treatment system operations including a multiple port well to monitor the vadose zone. Vadose zone monitoring will be conducted to evaluate the potential need for SVE. As discussed in Section 10.3.2.6, the low mole fraction of benzene remaining in the LNAPL (0.21-0.24%) may not require SVE due to demonstrated biodegradation within the thick vadose zone. It is currently understood that petroleum hydrocarbon degradation is occurring locally within the vadose zone as documented in *Report of Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved-Phase Benzene Plumes* (URS, 2007c). Air tight seals will be installed on all monitoring wells in the vicinity of air sparging to prevent short-circuiting of injected air. Groundwater elevations will be monitored using dedicated pressure transducers

(along with a site-dedicated barometer) tied into a telemetry system for remote monitoring using a SCADA System.

This alternative may be relatively straightforward to implement due to the prevalence of coarse-grained sediments in the treatment zone and may reduce the time required to achieve the RAOs. Seven (7) groundwater monitoring wells in the optimized network (Section 11.4.1) will be sampled semi-annually for the first 10 years. An annual sampling program will be implemented for the remaining 15 years. The groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The air sparging with vapor monitoring option is estimated at approximately \$4,230,100 (NPV is \$2,726,300).

#### **11.4.5 Alternative 4: Enhanced Bioremediation Using Sulfate**

The fourth alternative for consideration is enhanced bioremediation using sulfate-rich groundwater from the Site. The UC Davis research described in Section 10.3.2.5 is applying MBTs to confirm whether sulfate mixing has the potential to enhance benzene biodegradation. For this evaluation, it's assumed that this technology might need to operate for 30 years followed by 10 years of MNA to remediate the northern plume within 40 years. The reason for the longer time estimate is that this technology targets the dissolved plume only, whereas air sparging also targets the source (residual LNAPL in the smear zone). A pilot test will be required, which would be conducted prior to implementing the full-scale remedial design. A cross-sectional view of the conceptual plan is shown on Figure 41. A plan view of the well network for the conceptual design is shown on Figure 44.

Sulfate has a much higher biodegradation capacity as an electron acceptor than oxygen (Section 5.2) and is naturally abundant outside the plume limits at concentrations exceeding 1,000 mg/L. Dual-completion groundwater circulation wells would be installed to a depth of approximately 150 ft bgs. Triple-completion groundwater monitoring wells would be installed to evaluate the treatment system operations. Groundwater elevations would be monitored using dedicated pressure transducers (along with a site-dedicated barometer) tied into a telemetry system for remote monitoring using a SCADA System.

The sulfate-rich water would be pumped from the deeper screen into the smear zone via the upper screen. A packer would be placed between the two screens to promote a constant head within the upper portion of Aquifer I. It's estimated based on the lithology the smear zone will accept a minimum pumping rate of approximately 0.37 GPM. An increased production rate will have a beneficial effect in providing additional electron acceptors to potentially reduce plume longevity, but will be evaluated further during pilot testing.

This alternative will require additional effort to implement and may reduce the time required to achieve the RAOs. Seven (7) groundwater monitoring wells in the optimized network (Section 11.4.1) will be sampled semi-annually for the first 10 years. An annual sampling program will be implemented for the remaining 30 years. A groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The enhanced bioremediation option is estimated at approximately \$5,824,200 (NPV is \$2,773,800).

#### 11.4.6 Alternative 5: Multiple Technology

The fifth alternative is the sequential implementation of each process option including air sparging (4 years), circulation with existing sulfate-rich groundwater (6 years), and MNA (10 years). The approach takes advantage of the strengths of each technology. First, air sparging will preferentially strip benzene from the LNAPL smear zone, reducing the source to a point where remaining benzene in groundwater is primarily present in the dissolved phase. Then, groundwater circulation will enhance biodegradation of the dissolved phase by mixing naturally occurring sulfate-rich groundwater from the deeper portion of Aquifer I with the shallower plume. Sulfate is significantly more soluble in water and has a much higher biodegradation capacity as an electronic acceptor than oxygen (Section 5.2). A pilot test will be conducted prior to implementing the full-scale remedial design. The multiple technology cross-sectional view of the conceptual plans will be similar to those shown on air sparging with vapor monitoring (Figure 39) and enhanced bioremediation using sulfate (Figure 41).

This alternative will require additional effort to implement and may reduce the time required to achieve the RAOs. Seven (7) groundwater monitoring wells in the optimized network (Section 11.4.1) will be sampled semi-annually for the first 10 years. An annual sampling program will be implemented for the remaining 10 years. The groundwater monitoring report will be prepared upon completing each event for submittal to the EPA. The multiple technology option is estimated at approximately \$3,801,300 (NPV is \$2,939,400).

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## 12.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

A comparative analysis of each remedial alternative is provided in this section using nine evaluation criteria summarized as follows:

1. **Overall Protection of Human Health and the Environment:** This criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment.
2. **Compliance with Applicable or Relevant and Appropriate Requirements:** This criterion is used to determine whether the selected alternatives meet the identified ARARs.
3. **Long-Term Effectiveness:** The long-term effectiveness evaluates each alternative against its ability to maintain protection of human health and the environment after implementation considering the magnitude of residual risk (e.g. after source/soil containment and/or treatment are completed) and adequacy/reliability of engineering or institutional controls used for the Site.
4. **Reduction of Toxicity, Mobility, or Volume through Treatment:** This criterion addresses the statutory preference for selecting remedial alternatives that employ a treatment technology.
5. **Short-Term Effectiveness:** This criterion assesses the short-term effects of the alternative during implementation.
6. **Implementability:** This criterion addresses the technical/administrative feasibility of implementing each alternative.
7. **Cost:** This criterion evaluates the overall cost for each alternative including capital costs, annual operation and maintenance, and associated periodic costs. The cost is also evaluated against NPV.
8. **State Acceptance:** This assessment evaluates the technical/administrative concerns the state (or support agency) may have regarding each alternative.
9. **Community Acceptance:** This assessment evaluates the issues/concerns the community may have regarding each alternative.

The comparative analysis was conducted similar to previous sections of this report along medium-specific criteria since they are currently acting independent of each other at this Site. An analysis is provided separately for shallow subsurface soils to 10 ft bgs, the southern groundwater plume, and the northern groundwater plume.

### 12.1 ANALYSES FOR SHALLOW SUBSURFACE SOILS TO 10 FT BGS

The remedial alternatives being addressed for shallow impacts are summarized as follows:

- ◆ Alternative 1: Monitoring Only
- ◆ Alternative 2: Excavation with Off-Site Disposal at Landfill (commercial/industrial scenario only)
- ◆ Alternative 3: On-Site Consolidation and Cap
- ◆ Alternative 4: Ex-Situ Treatment by Composting

- ◆ Alternative 5a: Ex-Situ Treatment by Solidification / Stabilization
- ◆ Alternative 5b: Ex-Situ Treatment using Free Flow Amendment

### **12.1.1 Overall Protection of Human Health and the Environment**

The least amount of protection is represented by Alternative 1. The remaining alternatives provide varying levels of protection that will require institutional controls commensurate with a typical commercial/industrial property. Three alternatives (4, 5a, 5b) would require additional soil handling during implementation, which increases the potential for airborne particulates that would require consideration during air monitoring. Alternative 3 would have the least amount of overall impacts since the soil will be placed directly into the former main waste pit or other suitable location without additional handling required by Alternatives 2, 4, 5a, and 5b.

### **12.1.2 Compliance with Applicable or Relevant and Appropriate Requirements**

It is assumed final cleanup standards proposed in this document will be accepted by the EPA. As such, each alternative would be expected to comply with the ARARs over time except for Alternative 1. The potential liberation of arsenic may be of concern for Alternative 5b.

### **12.1.3 Long-Term Effectiveness**

Long-term effectiveness is not considered adequate for Alternative 1. Alternatives 2 and 3 are considered effective long term because the waste will either be removed from Site (Alternative 2) or effectively removed from contact with commercial/industrial workers and prevented from migrating to groundwater (Alternative 3). The remaining alternatives (4, 5a and 5b) may be less effective long term due to amendments that may react with native soils to release naturally occurring arsenic or other metals found in cement stabilizers as described in section 10.3.1.10. A treatability study will be needed to evaluate this potential for Alternatives 4, 5a and 5b.

### **12.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment**

An active treatment technology is not included in Alternatives 1, 2, and 3. These alternatives assume impacted soil will be left in-place, disposed of at a landfill, and/or consolidated on site in the main waste pit, respectively. An active treatment technology using a composting agent is proposed for Alternative 4. An active treatment technology using a solidification/stabilization agent (cement and a proprietary amendment) is proposed for Alternative 5a and Alternative 5b, respectively. The latter alternatives will not reduce the toxicity or volume of the constituents of concern but reduces their mobility. In light of the fate and transport modeling results for both lead and PAHs (Section 5.0) and the demonstrated lead stability inherent to the native soil at the Site (Section 10.3.1.10), soil treatment with an amendment may provide little value because the COCs are already relatively immobile.

### **12.1.5 Short-Term Effectiveness**

Each alternative (except Alternative 1) would require significant soil handling during implementation, which increases the potential for airborne particulates. This will need to be considered during air monitoring events conducted adjacent to the community along the western border of the Site. In addition,

Alternative 2 would involve more traffic, safety, and noise impacts than the other alternatives due to volume of material trucked off site. Alternatives 4, 5a, and 5b would also require deliveries of significant volumes of soil amendment materials to the site. Alternative 4 would have the greatest short-term impacts, because composted manure generates odors and the composting process can generate ammonia. Over a period of weeks or months, this could become a concern for the neighboring community, which includes the San Cayetano Elementary School. Extra soil handling and excess water for dust suppression due to potentially strong winds may also be required for Alternative 4.

### 12.1.6 Implementability

The services are expected to be readily available for Alternatives 2, 3, 4, 5a, and 5b. The selected alternatives are reliable technologies that have been successfully implemented at other sites. A treatability study is recommended for three alternatives (4, 5a, 5b) to determine the most appropriate amendment and methodology for site-specific soils. Alternative 4 may require a substantial spreading area for multiple treatment cells since composting is typically conducted in a treatment cell thickness of approximately 18 inches, may significantly extend the time required to remediate the soils, and may generate nuisance odors to the neighbors. Alternative 2 will involve greater transportation safety risk and require significant coordination when trucks entering traffic flow along Highway 126. A permit may be required for this alternative from the California Department of Transportation (Caltrans). The haul route may also require adjustment based on local ordinances related to heavy vehicle traffic on nearby streets in Fillmore.

### 12.1.7 Cost

Of the EPA requested detailed cost analysis at  $1 \times 10^{-6}$ , the least expensive option to implement is the no action - monitoring only option evaluated as Alternative 1. The remaining alternatives listed in order of total cost are Alternative 5b - Ex-Situ Treatment by Solidification / Stabilization using Free Flow amendment (\$1,541,700), Alternative 3 - On-Site Consolidation and Cap (\$1,596,800), Alternative 5a - Ex-Situ Treatment by Solidification / Stabilization using cement (\$1,664,600), Alternative 4 - Ex-Situ Treatment by Composting (\$3,006,500), and Alternative 2 - Excavation with Off-Site Disposal at Landfill (\$3,373,500). The NPV costs listed in order are Alternative 5b (\$1,538,600), Alternative 3 (\$1,593,700), Alternative 5a (\$1,661,400), Alternative 4 (\$3,003,300), and Alternative 2 (\$3,370,300). The estimated period of treatment is less than one year, which will be completed during summer months to avoid potential disruptions at nearby San Cayetano Elementary School, however, Alternative 4 may not be feasible to accomplish within one season.

EPA also requested a detailed cost comparison against a risk criterion of  $1 \times 10^{-5}$  as discussed in Section 10.1.1. As such, the two most probable remedial options were selected for this analysis including Alternative 3 - On-Site Consolidation and Cap and Alternative 5a - Ex-Situ Treatment by Solidification / Stabilization using Cement. Alternative 3 total estimated cost was \$954,300 (a decrease of \$256,700). Alternative 5a total estimated cost was \$1,277,200 (a decrease of \$387,400). In selecting the final remedy, the reviewer should consider matching the selected remedial option with the intended future land use option of a commercial/industrial property. In addition, the institutional controls also support this decision (Table 54).

### 12.1.8 State Acceptance

The proposed alternatives have been accepted at many sites managed by EPA Region 9. One possible concern is Alternative 3. This option may not be considered an active treatment technology. However, based on fate and transport modeling results for soil (Section 5.0) and geochemical characterization of lead (Appendix H) confirmed by treatability study results (Section 10.3.1.10), the COCs are relatively immobile. Alternative 3 can adequately address the COCs with the added benefit of ‘least overall impact’ to the environment when considering recent green and sustainable remediation guidance (Section 13.0).

### 12.1.9 Community Acceptance

The community engagement for this project has been ongoing for the past couple of decades. Chevron has met with the community on several occasions to discuss future options for the Site. EPA also interviewed several members of the community in 2009. The community opinion will be considered further once final public hearings are conducted by EPA for the ROD amendment.

## 12.2 ANALYSES FOR SOUTHERN GROUNDWATER PLUME

The remedial alternatives being addressed for the southern groundwater plume are summarized as follows:

- ◆ Alternative 1: Monitoring Only
- ◆ Alternative 2: Monitored Natural Attenuation
- ◆ Alternative 3: Air Sparging with Vapor Monitoring
- ◆ Alternative 4: Enhanced Bioremediation using Sulfate
- ◆ Alternative 5: Multiple Technology

### 12.2.1 Overall Protection of Human Health and the Environment

The least amount of protection is represented by Alternative 1. The remaining alternatives provide a varying level of protection that will require institutional controls commensurate with a typical commercial/industrial property. The primary route of exposure is the potential installation of a water supply well near the western border of the Site. This is considered unlikely since the residential community provides a buffer along the western border, the shallow aquifer is of poor quality, adequate municipal water supply infrastructure already exists on the other side of town near Sespe Creek, and the population is not expected to grow significantly. Also noted in the Second Five year Review (USEPA, 2006b), the City of Fillmore Municipal Code mandates CDWR standards that preclude installation of a water well in proximity to known contamination sources.

A secondary route to exposure is the vapor intrusion pathway that has already been addressed for the southern groundwater plume at an off-site location for homes near the Site (Appendix B). This should be a consideration (i.e., vadose zone monitoring) if selecting remedial options other than Alternative 3 or 5.

### **12.2.2 Compliance with Applicable or Relevant and Appropriate Requirements**

Its assumed final cleanup standards proposed in this document will be accepted by the EPA. As such, each alternative would be expected over time to comply with the ARARs (including Alternative 1).

### **12.2.3 Long-Term Effectiveness**

The proposed alternatives would be effective long-term since the constituents will degrade naturally over a long period of time and institutional controls will be compatible with redevelopment plans as a commercial/industrial property.

### **12.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment**

An active treatment technology is included for Alternatives 3, 4 and 5. It's anticipated they will address constituents at varying timeframes that would be acceptable to EPA. Constituents will also be adequately treated over a longer timeframe by implementing Alternative 2.

### **12.2.5 Short-Term Effectiveness**

The short-term effectiveness is not anticipated to be a concern since each alternative will be conducted in-situ inside the property limits established for the Site. Alternatives 3, 4, and 5 may delay redevelopment due to infrastructure required to implement the technology. The installation activity associated with each alternative will produce short-term noise/traffic impacts to nearby residents. This can be mitigated with an active community action plan.

### **12.2.6 Implementability**

Services are expected to be readily available for all alternatives. The selected alternatives are reliable technologies that have been successfully implemented at other sites. The easiest option to implement since constituents are already degrading naturally is Alternative 2. The other treatment technology options will require a pilot test to verify assumptions made in this document.

### **12.2.7 Cost**

The least expensive option to implement is Alternative 1. The remaining alternatives listed in order of total cost are Alternative 2 (\$2,961,100), Alternative 5 (\$8,679,900), Alternative 3 (\$9,091,600), and Alternative 4 (\$11,833,600). The NPV costs listed in order are Alternative 2 (\$587,900), Alternative 3 (\$5,676,400), Alternative 4 (\$4,675,300), and Alternative 5 (\$6,436,100). The estimated period of treatment for each alternative is provided in Table 62.

### **12.2.8 State Acceptance**

The proposed alternatives have been accepted at many sites managed by EPA Region 9.

### **12.2.9 Community Acceptance**

The community engagement is the same as discussed for the soil remedy. The community opinion will be considered further once the final public hearings have been conducted by EPA for the ROD amendment.

## 12.3 ANALYSES FOR NORTHERN GROUNDWATER PLUME

The remedial alternatives being addressed for the northern groundwater plume are summarized as follows:

- ◆ Alternative 1: Monitoring Only
- ◆ Alternative 2: Monitored Natural Attenuation
- ◆ Alternative 3: Air Sparging with Vapor Monitoring
- ◆ Alternative 4: Enhanced Bioremediation using Sulfate
- ◆ Alternative 5: Multiple Technology

### 12.3.1 Overall Protection of Human Health and the Environment

The least amount of protection is represented by Alternative 1. The remaining alternatives provide an adequate level of protection that will require institutional controls commensurate with a typical commercial/industrial property. The primary route of exposure is the potential installation of a water supply well near the western border of the Site. This is considered unlikely since the residential community provides a buffer along the western border, the shallow aquifer is of poor quality, adequate municipal water supply infrastructure already exists on the other side of town near Sespe Creek, and the population is not expected to grow significantly. Also noted in the Second Five Year Review (USEPA, 2006b), the City of Fillmore Municipal Code mandates CDWR standards that preclude installation of a water well in proximity to known contamination sources.

A secondary route to exposure is the vapor intrusion pathway that has already been addressed for the northern groundwater plume at an off-site location for homes near the Site. This should be a consideration (i.e., vadose zone monitoring) if selecting remedial options other than Alternative 3 or 5.

### 12.3.2 Compliance with Applicable or Relevant and Appropriate Requirements

Its assumed final cleanup standards proposed in this document will be accepted by the EPA. As such, each alternative would be expected over time to comply with the ARARs (including Alternative 1).

### 12.3.3 Long-Term Effectiveness

The proposed alternatives would be effective long-term since the constituents will degrade naturally over a long period of time and institutional controls will be compatible with redevelopment as a commercial/industrial property.

### 12.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

An active treatment technology is included for Alternatives 3, 4 and 5. It's anticipated they will address constituents at varying timeframes that would be acceptable to EPA. Constituents will also be adequately treated over a longer timeframe by implementing Alternative 2.

### **12.3.5 Short-Term Effectiveness**

The short-term effectiveness is not anticipated to be a concern since each alternative will be conducted in-situ inside the property limits established for the Site. Alternatives 3, 4, and 5 may delay redevelopment due to infrastructure required to implement the technology.

### **12.3.6 Implementability**

Services are expected to be readily available for all alternatives. The selected alternatives are reliable technologies that have been successfully implemented at other sites. The easiest option to implement since constituents are already degrading naturally is Alternative 2. The other treatment technology options will require a pilot test to verify assumptions made in this document.

### **12.3.7 Cost**

The least expensive option to implement is Alternative 1. The remaining alternatives listed in order of total cost are Alternative 2 (\$1,533,500), Alternative 3 (\$4,230,100), Alternative 5 (\$3,801,300), and Alternative 4 (\$5,824,200). The NPV costs listed in order are Alternative 2 (\$598,200), Alternative 3 (\$2,726,300), Alternative 4 (\$2,773,800), and Alternative 5 (\$2,939,400). The estimated period of treatment for each alternative is provided in Table 62.

### **12.3.8 State Acceptance**

The proposed alternatives have been accepted at many sites managed by EPA Region 9.

### **12.3.9 Community Acceptance**

The community engagement is the same as discussed for the soil remedy. The community opinion will be considered further once the final public hearings have been conducted by EPA.

## 13.0 GREEN REMEDIATION

Green and sustainable or green remediation is the practice of balancing environmental, economic and social indicators so that an acceptable balance exists between the effects of undertaking remediation activities and the benefits that those activities deliver. Conducting remediation to render the land suitable for any purpose no matter how sensitive (unrestricted use) has major green and sustainability flaws and does not typically result in the greatest net environmental benefit. The solution proposed should be the solution that clearly emerges following an assessment of overall benefits, costs and all environmental impacts, value and circumstances of the property, community needs and views, and other relevant issues.

In addition, off-site removal of contaminated soils to a landfill only represents a transfer of contamination from one place to another, even if it does facilitate a redevelopment, and that transfer of contamination has economic, environmental and social costs which may outweigh the benefits arising from treating the contamination on the impacted site.

### **Agency Guidance**

In April 2008, the EPA issued a Technology Primer addressing the emerging practice of green remediation. In the Primer, green remediation is defined as ‘the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions’ (USEPA, 2008). The Primer also states that ‘green remediation strategies offer significant potential for increasing the net benefit of cleanup, saving project costs, and expanding the universe of long-term property use or reuse options without compromising cleanup goals.’ Included in the Primer are a number of Best Management Practices (BMPs) and case studies. The Primer also identifies six core elements of green remediation projects, which are listed below.

- ◆ Energy requirements of the treatment system
- ◆ Air emissions
- ◆ Water requirements and impacts on water resources
- ◆ Land and ecosystem impacts
- ◆ Material consumption and waste generation
- ◆ Long-term stewardship actions

The EPA has continued to provide guidance and technical information regarding green remediation, including numerous case studies, on a Green Remediation website:

(<http://www.cluin.org/greenremediation/>).

The EPA also issued a draft *Superfund Green Remediation Strategy* in August 2009 (USEPA, 2009b). This draft Strategy was developed by a workgroup, including representatives from EPA Headquarters and every EPA region, formed by the EPA Office of Superfund Remediation and Technology. The Strategy identifies the need for inclusion of BMPs in investigation and remediation activities and goes on to state

‘when developing options for remedial actions that are consistent with remedial action objectives, project managers should consider alternatives that include opportunities for reducing the environmental footprint of remedial design and construction activities.’ The Strategy also includes recommendations for ongoing development of green remediation strategies and incorporation of green remediation into existing programs and policies. The Strategy includes ten key actions that the EPA intends to take to further develop green remediation programs. Extensive comments have been received on the draft Strategy, and the EPA is now using the feedback to further focus the strategic areas and identify appropriate and relevant tools for implementing green remediation practices. EPA anticipates release of an updated *Superfund Green Remediation Strategy* in 2010

Also on the federal level, President Obama issued an Executive Order on October 5, 2009, which establishes a policy that all federal agencies shall increase energy efficiency; measure, report, and reduce greenhouse gas (GHG) emissions; conserve and protect water resources; and eliminate waste, recycle, and prevent pollution. This Executive Order also requires federal agencies to establish targets for reducing GHG emissions, and to establish and report a comprehensive inventory of GHG emissions (among other goals).

In September 2009, EPA Region 9 issued a ‘Greener Cleanup Policy’ which states that ‘EPA Region 9 will strive to integrate sustainability practices into its cleanup actions.’ (USEPA, 2009e). The policy also identifies the following preferred practices, strategies, and technologies to support the implementation of greener cleanups:

- ◆ Reduce air emissions, including GHG emissions, by using clean diesel technology and alternative fuels.
- ◆ Conserve natural resource and energy through efficient energy use and by using renewable energy technologies.
- ◆ Minimize virgin material use and waste generation as well as reuse and recycle existing resources.
- ◆ Minimize toxics in materials and products.
- ◆ Minimize impacts to air quality and water resources by water conservation and efficiency measures.

The Region 9 policy also states that project managers are encouraged to consider the application of life cycle analysis tools, which can help account for the manufacture, use, and transport of materials, products, equipment and wastes associated with all phases of cleanup.

In the State of California, the DTSC has developed a Green Remediation Initiative. This Initiative includes a website with a depository of information, and has also included public presentations, as well as a Green Remediation Symposium held in February 2009:

([http://www.dtsc.ca.gov/OMF/Grn\\_Remediation.cfm](http://www.dtsc.ca.gov/OMF/Grn_Remediation.cfm)).

The website includes DTSC’s *Interim Advisory for Green Remediation* issued December 2009.

Based on the number of initiatives at the national, regional, and state levels, there is growing consideration of the environmental effects and sustainability of remedial actions, including the GHG emissions associated with environmental investigations and remediation activities, water usage, emissions of criteria air pollutants, and waste generation. At this time, these recommended policies and strategies are not legally required at Superfund sites, but are recommended for voluntary implementation.

To address these concerns, URS completed a sustainable remediation analysis of the alternatives for remediating the shallow soils and groundwater. Our analysis included consideration of the following impacts associated with each of the proposed alternatives:

***Environmental impacts:***

- ◆ GHG emissions
- ◆ Emissions of criteria air pollutants
- ◆ Water usage
- ◆ Electricity usage
- ◆ Material use reduction
- ◆ Landfill space use

***Additional impacts:***

- ◆ Noise
- ◆ Safety

Section 13.1 describes the calculation methods used to evaluate each of the impacts included in the green and sustainable remediation analysis, and Section 13.2 provides the results of the analysis.

## **13.1 CALCULATION METHODOLOGY FOR GREEN REMEDIATION ANALYSIS**

### **13.1.1 GHG Emissions**

GHG emissions calculated under this analysis include the emissions from vehicles and equipment that will be used to implement each alternative. URS also calculated the GHG emissions associated with the equipment needed for rough grading of the entire site after the remedial actions are complete. Also, life-cycle GHG emissions from the manufacturing and transportation of cement are considered in the alternatives that utilize cement for stabilization. For the groundwater alternatives, GHG emissions are generated from the drilling equipment needed to implement each remedy, as well as usage of other equipment, and ongoing operations and maintenance activities over the lifetime of the remedy.

URS used the California Climate Action Registry *General Reporting Protocol, Version 3.1* (CCAR, 2009), to calculate GHG emissions from the use of construction equipment, drilling equipment, electricity, and vehicles. Data for the calculations included the following: types of equipment and vehicles, operating hours, horsepower, and the type of fuel used for each piece of equipment or each vehicle. Data were provided by Remedial Construction Services for each soil alternative and by URS for

the groundwater alternatives. Data related to electricity usage was dependent on the days needed to power the on-site crew trailer, and the energy requirements of the electrical pumps needed for some of the alternatives.

The GHG emissions included in this analysis are: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O). Emissions of the other three Kyoto GHGs (sulfur hexafluoride [SF<sub>6</sub>], hydrofluorocarbons, and perfluorocarbons) were considered but were not quantified because no or very low emissions of these gases will be generated by implementation of the soil or groundwater alternatives.

To calculate landfill-related emissions under Soil Alternative 2, URS used the *Mexico Landfill Gas Model, Version 2* (USEPA, 2009f). This model is the most recent model for estimating methane emissions from landfills. To use the model, URS assumed that the soil consists of 90% inorganic and 10% organic matter. URS also assumed that the landfill receiving the soil is currently not collecting methane for flaring or burning, but will do so by 2030.

In addition, URS assumed that the concrete currently at the site will be crushed and re-used on site for grading or for other purposes. Reusing the concrete at the site (a BMP) will help achieve a reduction of GHG emissions by avoiding the manufacturing and transportation of new concrete to the site. Reusing the concrete on site also reduces the amount of virgin material needed to restore the site, thus making this a more sustainable alternative while achieving two green BMPs.

URS calculated the GHG emissions that will be saved by reusing the concrete material on site. To calculate these emissions, URS performed two calculations:

- ◆ GHG emissions when concrete on site is *not* reused. Emissions are generated from manufacturing concrete off site and hauling the manufactured concrete to the site. URS assumed that the existing concrete on the site will be left in place and not removed.
- ◆ GHG emissions when concrete on site *is* reused. Emissions are generated from using a concrete crusher on site.

#### **13.1.1.1 Electricity Usage**

A small amount of electricity will be used for implementation of the soil alternatives to power the on-site crew trailer. In addition, the composting alternative for soil remediation requires the use of an electric pump to bring water from an on-site well to the composting treatment cells.

The groundwater treatment alternatives require the use of electricity drawn from the grid, for the operation of an air compressor (for the air sparging alternatives) and well pumps (for the sulfate circulation alternatives). The multiple technology alternatives assume use of both the air compressor and well pumps.

Electricity GHG emissions for the on-site crew trailer were calculated by estimating daily electricity usage with data from the US Department Of Energy Commercial Buildings Energy Consumption Survey,

2003 Detailed Tables. URS used the kwh/square foot energy usage for office buildings found in Table E4: Commercial Building Energy to complete this estimate.

For the composting alternative, the total amount of water needed from the well was assumed to be 3,700,000 gallons, which is approximately 11 acre feet. Previous testing had shown that an electrical pump needed 406 kwh per acre foot to draw water from the well; this value was used to estimate the electricity needed to operate the pump.

Additional electricity GHG emissions were calculated by gathering data on the specifications of the air compressor and well pump likely to be used in implementing each groundwater alternative. Because the electricity will be provided by Southern California Edison, the emission factor for CO<sub>2</sub> emissions from electricity was taken from the Southern California Edison *2007 Annual Entity Emissions Report* submitted to CCAR (SCE, 2007). (2007 was the most recent year for which this report is available.) Using an emission factor specific to Southern California Edison is a more accurate calculation methodology than use of a generic emission factor available for the California electricity grid region. However, more specific emission factors for CH<sub>4</sub> and N<sub>2</sub>O were not available from the Southern California Edison report, so these factors were taken from the CCAR *General Reporting Protocol*, version 3.1.

### 13.1.2 Emissions of Criteria Air Pollutants

Criteria air pollutants are the pollutants that are currently regulated by the EPA under the National Ambient Air Quality Standards, established under the Clean Air Act. These pollutants are: ozone (O<sub>3</sub>), particulate matter, carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and lead (Pb). None of these pollutants are considered a significant GHG and are not included in the GHG analysis.

Only Soil Alternative 2 will generate significant emissions of criteria air pollutants, through the use of dump trucks to transport excavated soil to the landfill, and to transport clean fill to the site. Equipment and truck usage under the other alternatives are not expected to generate large amounts of criteria air pollutant emissions by comparison. Thus, emissions data for criteria air pollutants are only shown for Soil Alternative 2. Also, only NO<sub>x</sub> emissions are provided, as other types of air emissions calculated were less than 2.5 metric tonnes. Currently, major *stationary* sources of air pollution in Ventura County must obtain an air emissions permit under Title V of the Clean Air Act, including stationary emitters of 25 tons per year or more of NO<sub>x</sub> emissions. Although most of the criteria air pollutants from the remedial alternatives will be due to mobile emissions, and thus will not be subject to Title V rules, the 25 ton emission limit is useful to consider. Specifically, URS used 10% of the 25 ton limit, or 2.5 tons, which is equivalent to approximately 2.3 metric tonnes, as the benchmark for emissions to report in this analysis.

Criteria air pollutant emissions calculations were performed using data gathered for the GHG calculations, including the vehicle miles traveled to transport soil to the landfill, and in the case of returning the site to commercial/industrial use, the vehicle miles traveled to import clean fill. In addition, URS used the Emission FACTors 2007 (EMFAC 2007) model, version 2.3, developed by the State of California Air Resources Board to estimate air emissions under Soil Alternative 2 (CARB, 2006). The EMFAC model provided emission factors for each of the criteria pollutants, in tonnes emissions/mile.

These emission factors were applied to the vehicle miles needed for each type of truck used under Soil Alternative 2 to develop emissions calculations. While the general methodology for calculating criteria air pollutant emissions is similar to the methodology used in the GHG analysis, URS used differing protocols for GHG emissions and criteria air pollutants, since there is not one protocol or methodology that considers both criteria air pollutants and GHG emissions.

### **13.1.3 Water Usage**

Water will be used to complete the following activities:

- ◆ Dust suppression (used in all alternatives except Soil Alternative 1)
- ◆ Compacting soil into the Main waste pit (Soil Alternatives 3, 4, and 5)
- ◆ Treatment of soil in treatment cells (Soil Alternative 4)
- ◆ Solidification of soil (Soil Alternative 5)
- ◆ Mixing with Portland cement to create concrete (Soil Alternatives 4 and 5)

Data were provided by Remedial Construction Services, and included the total number of days that water trucks will be needed for dust suppression, and the total water usage needed for each of the other activities. URS assumed that each water truck used for dust suppression would use 15 loads of water per day, with each load using 5,500 gallons of water.

### **13.1.4 Material Use Reduction**

URS determined the amount of concrete on site that will be crushed and reused on site for grading purposes. This concrete reduces the amount of virgin material needed for grading.

### **13.1.5 Landfill Space Use**

Landfill space is needed for Soil Alternative 2; the amount needed is equivalent to the volume of soil that will be excavated for off site disposal.

### **13.1.6 Noise**

Noise impacts were evaluated by determining the decibels (db) that will be emitted 50 feet from the project site. Decibel levels were taken from the EPA publication, *Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances* (USEPA, 1971).

Noise protection for workers is typically required when db levels are above 85. URS tallied the number of days in which noise levels would be above 85 db for each alternative. These noise levels will affect both the workers and members of the surrounding community.

### **13.1.7 Safety**

Adding vehicles to the roadways increases the chances of traffic fatalities. According to 2006 data from the U.S. Census Bureau, there are 1.3 traffic fatalities for every 100 million vehicle miles driven in

California. Using this statistic and previously collected data on the vehicle miles traveled in each alternative, URS calculated the probability of a traffic-related fatality for each alternative.

## 13.2 RESULTS OF THE GREEN AND SUSTAINABLE REMEDIATION ANALYSIS

Table 64 shows the results of the impacts for each soil alternative. Additional results based on the data collection completed for the analysis of the soil alternatives are provided in Table 65. Tables 64 and 65 also include the impacts from grading the Site. These impacts are shown separately since grading will occur regardless of which alternative is chosen.

Furthermore, Figure 45 shows a graphical summary of the GHG emissions and water usage calculated for each soil alternative. The end of this section also summarizes the GHG emissions reduced by reuse of the concrete on the Site.

A summary of impacts from the groundwater alternatives is shown in Table 66, and additional results based on the data completed for the analysis of the groundwater alternative are provided in Table 67. These tables show the impacts separately for each alternative considered for the northern plume and the southern plume. Figure 46 and 47 shows a graphical summary of the GHG emissions and electricity usage for each alternative for both the northern and southern plumes, respectively.

As noted above, URS calculated the GHG emissions reductions from crushing and reusing the concrete on the site, versus importing new concrete. The GHG emissions will be reduced by 272 metric tonnes of CO<sub>2</sub> equivalents if concrete on site is reused. Most of these savings are from avoiding the manufacturing of new concrete, which is an energy-intensive process. The volume of concrete to be re-used is 2,000 cubic yards.

## 13.3 SUMMARY OF THE GREEN AND SUSTAINABLE REMEDIATION ANALYSIS

### 13.3.1 Soil Alternatives

Green and sustainable remediation impacts for soil are summarized in Tables 64 and 65. Soil Alternative 1 has no environmental impacts. Generally, Soil Alternatives 2 (returning to industrial usage), 3, and 5b have similar levels of environmental impacts. Soil Alternatives 4 and 5a have more impacts due to increased soil handling for treatment; Portland cement is made using an energy-intensive process, and these emissions are included in the consideration of these alternatives. Soil Alternative 2 (return to residential usage) has significantly greater environmental impacts associated with the additional vehicle use needed to remove impacted soil from the Site and transport the soil to a landfill.

The alternative with the fewest GHG emissions is Soil Alternative 1, followed by Soil Alternatives 3, 5b, 2-return to industrial usage, and 4. The alternative with the least amount of water usage is Soil Alternative 1, followed by Soil Alternatives 2-return to industrial usage, 3, 5b, 5a and 4. As noted in Section 10.1.1, EPA requested a comparison for returning the site to unrestricted use applying residential screening levels. Soil Alternative 2-return to residential usage increases all the impacts by up to eightfold.



### 13.3.2 Groundwater Alternatives

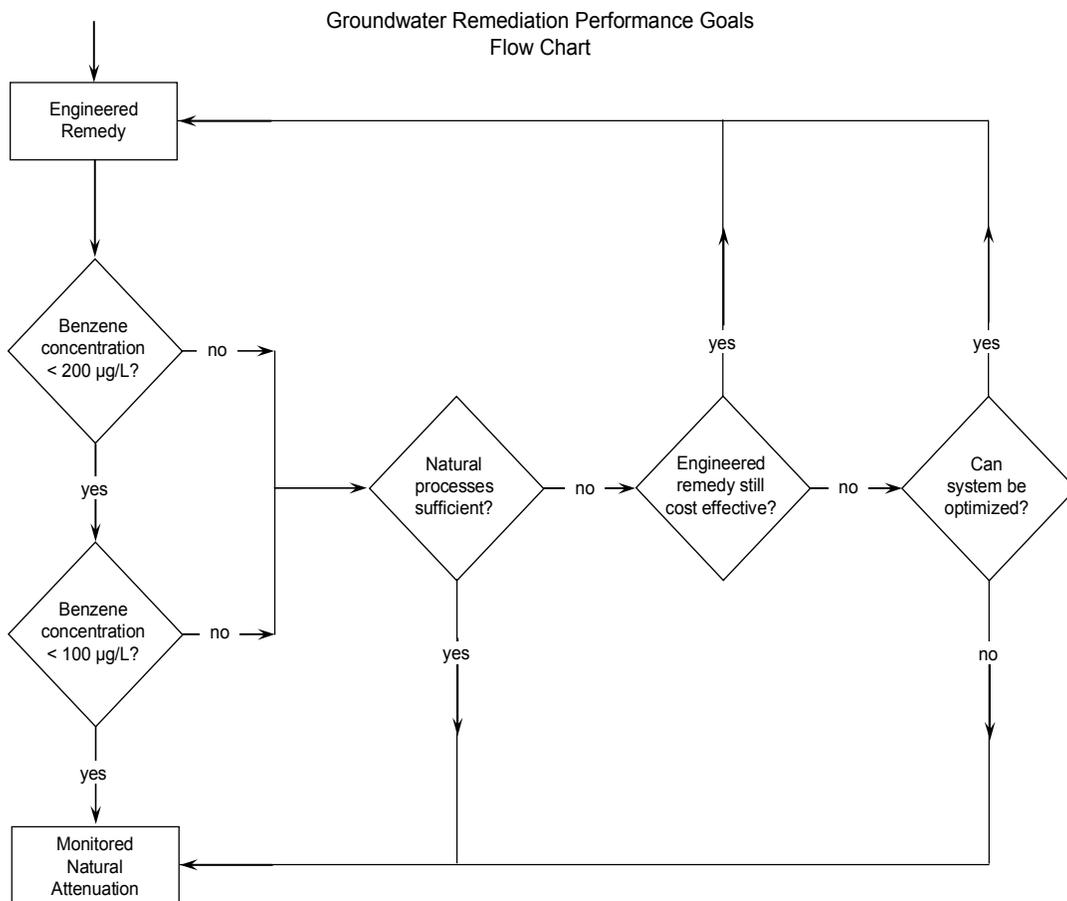
Green and sustainable remediation impacts for groundwater are summarized in Tables 66 and 67. For both the northern and southern plumes, groundwater Alternative 1 has no environmental impacts, and Alternative 2 has minimal environmental impacts. Of the remaining alternatives, Alternative 5 has the least GHG emissions, and Alternatives 3 and 4 have higher and similar levels of GHG emissions. Alternatives 3 and 4 also have higher and similar levels of electricity usage for both the northern and southern plumes.

For Alternatives 3-5, remedies for the northern plume will have fewer impacts than remedies for the southern plume, due to fewer hours of equipment usage and fewer years needed to fully implement each Alternative. Of the engineered remedies, Alternative 5 has fewer environmental impacts. Alternative 4 has high impacts due to the 24-hour use of a well pump to circulate water for 30 years (northern plume) or 50 years (southern plume). Alternative 3 has high impacts due to the 12-hour use of a well pump for 15 years (northern plume) or 20 years (southern plume). Electricity usage is lowest for groundwater Alternative 5.

## 14.0 RECOMMENDED REMEDIAL ALTERNATIVES

The recommended remedial alternatives are provided in this section, as is a description of institutional controls that will be implemented. As part of any selected alternative, important considerations in remedial design may be additional lateral delineation as needed to engineer excavations, a treatability study to engineer site-specific soil amendments if required, and a pilot test to verify assumptions made for groundwater remediation.

A consideration for groundwater is the likelihood that sorbed LNAPL within the smear zone may not decrease as much as anticipated, thus reducing the effectiveness of the selected remedial option for groundwater. As such, it is recommended that MNA be an integral part of the final groundwater remedy in the amended ROD. The proposed groundwater remediation performance goals (Section 9.4.2) are provided in this flow chart:





### 14.1 INSTITUTIONAL CONTROLS

EPA, the City of Fillmore, and Chevron agree that limiting future development to commercial/industrial uses only (as opposed to residential or similar uses) makes sense, based on both historical use and reasonably anticipated future uses at the Site (Chevron, 2010) (Appendix B). EPA and Chevron consider institutional controls (ICs) to be an essential part of the remedial action.

Table 53 sets forth an in-depth analysis of institutional controls, including:

- ◆ Type of institutional control and the relationship of the control to the remedy;
- ◆ The objective to be obtained by each institutional control;
- ◆ The performance standard associated with each institutional control (e.g., prohibit well drilling to prevent exposure to contaminated groundwater);
- ◆ An institutional control monitoring plan; and
- ◆ The entity responsible for implementing, maintaining, and enforcing each institutional control.

The ICs are summarized in Table 53.

### 14.2 SHALLOW SUBSURFACE SOILS TO 10 FT BGS

Six options were evaluated to address impacted soil within the upper 10 ft bgs. Impacts by AOC, COC risk driver, and suggested cleanup threshold and action are summarized below:

Summary of Impacts and Suggested Action			
AOC	Medium	COC Risk Driver	Action for 10 <sup>-5</sup>
1	Soil	Lead, cPAHs	Soil removal at 20 locations at depths up to 12 ft bgs.
	Soil Gas	NA	—
2	Soil	None	No action needed.
	Soil Gas	NA	
3	Soil	Lead*	Soil removal at 1 location at depths up to 1 ft bgs.
	Soil Gas	NA	—
4	Soil	None	No action needed.
	Soil Gas	NA	
5	Soil	None	No action needed.
	Soil Gas	NA	
6	Soil	Lead	Soil removal at 9 locations at depths up to 12 ft bgs.
	Soil Gas	Benzene	Soil removal at 2 additional locations at depths up to 12 ft bgs.
7	Soil	Lead	Soil removal at 1 location at depths up to 3 ft bgs.



Summary of Impacts and Suggested Action			
AOC	Medium	COC Risk Driver	Action for 10 <sup>-5</sup>
	Soil Gas	NA	—
8	Soil	None	No action needed.
	Soil Gas	NA	
9	Soil	Lead	Soil removal at 3 locations at depths up to 7 ft bgs.
	Soil Gas	NA	
10	Soil	Lead, cPAHs	Soil removal at 8 locations at depths up to 7 ft bgs.
	Soil Gas	NA	
11	Soil	Lead	Soil removal at 3 locations at depths up to 7 ft bgs.
	Soil Gas	NA	
12	Soil	None	No action needed.
	Soil Gas	NA	
13	Soil	Lead	Soil removal at 1 location at depths up to 12 ft bgs.
	Soil Gas	NA	
14	Soil	cPAHs	Soil removal at 1 location at depths up to 12 ft bgs.
	Soil Gas	NA	

\*Though lead is not an unacceptable health concern AOC-wide, one hot spot is identified for removal.

The recommended alternative is Alternative 3 (Section 11.2.3), excavation with on-site consolidation and cap within the former main waste pit or other suitable on-site location. This option may not be considered an active treatment technology. However, based on fate and transport modeling results for soil (Section 5.0) and geochemical characterization of lead (Appendix H) confirmed by treatability study results (Section 10.3.1.10), the COCs are relatively immobile. Alternative 3 can adequately address the primary constituents of concern (inorganic lead and PAHs) with the added benefit of ‘least overall impact’ to the environment when considering the recent expectation for green and sustainable remediation (Section 13.0). The impacted soil will be handled less than other alternatives, thus the added benefit of reduced dust generated during remediation at the Site. The total removal volumes based on a risk criterion of  $1 \times 10^{-5}$  is appropriate, as this threshold best aligns with the intended future land use as a commercial/industrial property and reduces the environmental ‘footprint’ of soil remediation activities. The institutional controls will also be an integral part of the justification for risk criterion selection at the Site. Pipeline removals will occur prior to soil excavation and re-grading activities.

A secondary option for consideration is Alternative 5a (Section 11.2.5) on-site solidification/stabilization with a cement stabilizer. This treatment option is the most frequently implemented technology for lead-impacted soil; however, this option generates nearly 10 times the greenhouse gas emissions and utilizes over 3 million more gallons of water than on-site consolidation within the former main waste pit. In light of the demonstrated lead stability inherent to the native soil at the Site and the fate and transport modeling results for the PAHs, soil treatment with an amendment may provide little value. There is also a potential concern that amendments may liberate naturally occurring arsenic in background soil. The affinity for

arsenic adsorbed in soil is pH dependent. Desorption of arsenic from iron oxide surfaces becomes favored as pH values increase substantially above neutrality. Portland cement can increase soil pH to extremely alkaline conditions and liberate arsenic as well as other metals that may be introduced in the manufacture of cement.

Additional delineation is planned to better define the lateral extent of each constituent prior to preparing the remedial design for the Site. Further vertical delineation is not required since past investigations have adequately characterized the subsurface and the shallow soil remedial action will address potential exposure to deeper soil that remains in place as approved by EPA. The limited deeper impacts do not appear to be a threat to groundwater at the Site. Potential soil vapor will be addressed by institutional controls (ex. vapor barriers) due to the presence of naturally occurring methane at the Site.

### 14.3 SOUTHERN GROUNDWATER PLUME

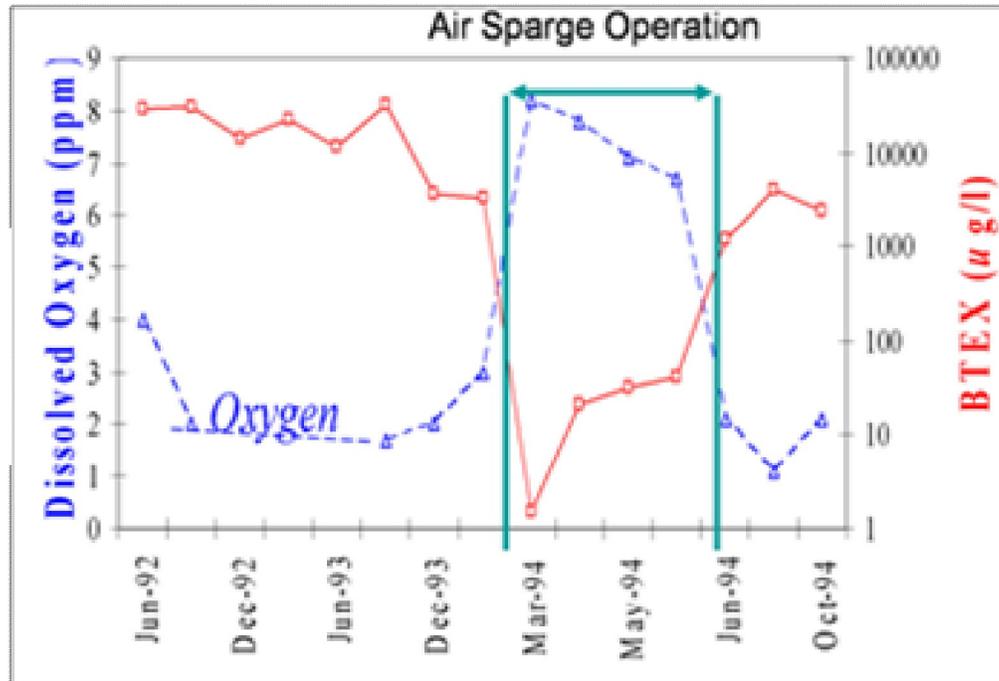
The recommended alternative for the southern groundwater plume is Alternative 5 (Section 11.3.6) the multiple technology option that includes air sparging for up to 6 years, circulation of existing sulfate for up to 9 years, and MNA for 10 years, with an optimized monitoring network as described in Section 11.3.1 (Figure 38). The MNA option may be extended if the groundwater concentrations have not met the remedial goals after 25 years.

As noted in Section 11.3.6, the years of operation are estimated based on the strengths of each selected technology. The air sparging estimate assumes benzene will be preferentially stripped (i.e., volatilized) from the LNAPL smear zone, thus, reducing the source term concentration to a point where the remaining constituents are primarily present in the dissolved phase. The subsequent technology (i.e., groundwater circulation) will enhance biodegradation of the dissolved phase by mixing naturally occurring sulfate-rich groundwater from the deeper portion of Aquifer I with the shallower plume. The success of the second process will be driven primarily by sulfate/constituent ‘contact time’. As discussed in Section 5.2, sulfate is significantly more soluble in water and has a much higher biodegradation capacity as an electronic acceptor than oxygen.

A pilot test will be needed at each stage (air sparging, groundwater circulation) to verify each technology will work at the Site. If successful, the sequential application of these two options in combination (followed by MNA) should achieve the remedial goals in less time than a single technology application as evaluated in this document and the multiple technology alternative has fewer environmental impacts in terms of green and sustainable remediation than the single technology engineered remedies.

One additional important consideration for conducting the sequential application of these two technologies relates to the transition from an aerobic environment generated during air sparging to anaerobic conditions that are required for the sulfate-reducing environment when implementing the groundwater circulation technology. Air sparging is not likely to deliver sufficient oxygen to create strongly (or even mildly) long-term aerobic conditions upon completing air sparging, especially considering the depressed dissolved oxygen concentrations within the southern groundwater plume. It is expected that currently anaerobic conditions will rebound shortly after completing air sparging, which

was the case during a field demonstration project conducted by Sublette et al. (2006). In this case, dissolved oxygen returned to pre-sparge conditions within days as shown below:



Sublette et al. (2006) also used molecular biological tools (MBTs) to evaluate the changes in the subsurface microbial community following introduction of sulfate. The MBT results showed an increase in phospholipid fatty acids (PLFA) that are commonly found in anaerobic bacteria and are major components of sulfate-reducing bacteria (SRB). In addition, real-time polymerase chain reaction (PCR) results supported the PLFA analysis. For example, the PCR results showed a five-order of magnitude increase in concentrations of an anaerobic gene (*bssA*) in a monitoring well where dissolved oxygen was 3 mg/L prior to sulfate injection. These results taken together indicate that sulfate introduction shifted the subsurface microbial community structure to increased anaerobic character and increased proportions of SRB within a fairly short period of time.

A secondary option for consideration is MNA with an optimized groundwater monitoring network (Figure 38), given that the groundwater plume is well characterized with multiple lines of evidence for natural attenuation (Appendix E). An MNA alternative would minimize infrastructure that may delay redevelopment of the Site. The potential for petroleum constituent vapor migration is very low due to natural degradation in the extensive vadose zone with groundwater at approximately 55 ft bgs, supported by data collected for the vapor study (URS, 2007c).

As described in Section 11.3.1, an optimized, performance-oriented groundwater monitoring network (Figure 38) is proposed regardless of which alternative is chosen. The reduction/addition of wells in the groundwater monitoring network to eliminate redundant data points or data points that are no longer useful and to fill data gaps is presented in Table 63, along with the intended purpose for each monitoring

well. Performance-oriented monitoring will focus on key indicators to confirm remediation progress and plume stability. The groundwater indicator compounds that will be analyzed by a fixed laboratory are benzene and toluene. The remaining indicator parameters that will be measured using calibrated field instrumentation and a flow-through cell are sulfate, dissolved oxygen, oxygen reduction potential, electrical conductivity, temperature, turbidity, ferrous iron, and pH. The optimized monitoring network (Figure 38) and proposed monitoring frequency, sampled semi-annually for 10 years followed by annually (Appendix I), provide adequate data coverage considering historical groundwater concentration trends since 1990. This is especially true when considering the abundant evidence for MNA (Appendix E).

LNAPL trapped in the source zone is already near the calculated residual saturation, thus recovery via hydraulic methods provides limited (if any) net environmental benefit at this Site (as discussed in Section 5.3.5). As such, the current LNAPL recovery program will be terminated upon commencing the air sparging pilot study within the southern groundwater plume. The pilot testing results will be evaluated prior to full scale operation since the only true net environmental benefit for free product reduction can be accomplished by changing the composition (i.e. benzene content) of the LNAPL. Thus, once the remaining volatile constituents have been preferentially stripped using air sparging, there will be no net environmental benefit to actively managing any remaining LNAPL, natural source zone depletion will be adequate (USEPA, 2005; ITRC, 2009).

#### 14.4 NORTHERN GROUNDWATER PLUME

The recommended alternative for the northern groundwater plume is Alternative 2 (Section 11.4.3), MNA with an optimized groundwater monitoring network (Figure 38). The natural attenuation mechanisms for this alternative were discussed in Section 5.3.1. MNA is preferred since the groundwater plume geometry is well characterized with multiple lines of evidence for natural attenuation (Appendix E). The potential for petroleum constituent vapor migration is very low due to natural degradation in the extensive vadose zone with groundwater at approximately 85 ft bgs, supported by data collected for the vapor study (URS, 2007c). The cost of implementation is also a consideration since remediation funds would be better focused on the southern groundwater plume, which currently has elevated benzene concentrations extending beyond the property limits of the Site. In addition, the proposed technologies for the southern plume need to be proven successful before considering whether engineered remediation of the northern plume may reduce the timeframe to achieve RAOs or not. An engineered technology (ex. groundwater circulation) may be considered as a contingent remedy in the amended ROD, should MNA progress evaluated during five year review not appear to be achieving RAOs within the 50-year reasonable timeframe (Section 14.5).

As described in Section 11.4.1, an optimized, performance-oriented groundwater monitoring network (Figure 38) is proposed regardless of which alternative is chosen. The reduction/addition of wells in the groundwater monitoring network to eliminate redundant data points or data points that are no longer useful and to fill data gaps is presented in Table 63, along with the intended purpose for each monitoring well. Performance-oriented monitoring will focus on key indicators to confirm remediation progress and plume stability. The groundwater indicator compounds that will be analyzed by a fixed laboratory are

benzene and toluene. The remaining indicator parameters that will be measured using calibrated field instrumentation and a flow-through cell are sulfate, dissolved oxygen, oxygen reduction potential, electrical conductivity, temperature, turbidity, ferrous iron, and pH. The optimized monitoring network (Figure 38) and proposed monitoring frequency, sampled annually (Appendix I), provides adequate data coverage considering historical groundwater concentration trends since 1990. This is especially true when considering the abundant evidence for MNA (Appendix E).

## 14.5 REASONABLE TIMEFRAME

In accordance with EPA's OSWER Directive (USEPA, 1999a), factors to consider in determining whether a groundwater remediation timeframe is appropriate and reasonable include:

- ◆ Need for affected portions of the aquifer for future water supply;
- ◆ Subsurface conditions and plume stability;
- ◆ Reliability of monitoring and institutional controls over the timeframe; and
- ◆ Provision by the responsible party over the timeframe.

Assumptions have been made in this document about the potential effectiveness of engineered remedies for groundwater. Due to the smear zone and the geologic complexity of the subsurface, effectiveness of the engineered technologies to achieve the groundwater cleanup goal for benzene in less than fifty years is uncertain. Therefore, it is recommended that MNA be an integral part of the final groundwater remedy. Fifty years may likely be a reasonable timeframe that is protective of human health and the environment at this Site. There is no demand in the foreseeable future for the affected Aquifer I at or near the Site. Agricultural water demand is limited at or near the Site and typically is extracted from the deeper, unaffected Aquifer II. As demonstrated by multiple lines of evidence (Appendix E) and 15 years of monitoring, the plumes are stable and shrinking. Chevron will maintain adequate provision for long-term reliability of MNA and institutional controls as discussed in Section 9.6.

## 15.0 REFERENCES

- Agency for Toxic Substances and Disease Registry (ATSDR), 2007. *Toxicological Profile for Lead*. August 2007.
- Baes, C.F. and Sharp, R.D., 1983. *Analytical Leaching Model*. 1983.
- Boisson, J, Ruttens, A., Mench, M. and Vangronsveld, J. 1999. Evaluation of hydroxyapatite as a metal immobilizing soil additive for the remediation of polluted soils. Part 1. Influence of hydroxyapatite on metal exchangeability in soil, plant growth and plant metal accumulation. *Environmental Pollution* 104: 225–233.
- California Air Resources Board (CARB), 2006. *EMission FACTors 2007 Model, Version 2.3*. 2006.
- California Climate Action Registry (CCAR), 2009. *General Reporting Protocol, Version 3.1*. 2009.
- California Department of Public Health (CDPH), 2007. *Drinking Water Notification Levels and Response Levels: An Overview*.  
<http://www.cdph.ca.gov/certlic/drinkingwater/pages/default.aspx>. December 14, 2007.
- California Environmental Protection Agency (Cal/EPA), 2005. Use of California Human Health Screening Levels (CHHSLs) in Evaluation of Contaminated Properties. January, 2005.
- \_\_\_\_\_, 2009a. Revised California Soil and Soil Gas Screening Numbers. Office of Environmental Health Hazard Assessment (OEHHA). September 17, 2009.
- \_\_\_\_\_, 2009b. *Toxicity Criteria Database – Cancer Potency Information*. Carcinogen Criteria Group. California Environmental Protection Agency. Online:  
[www.oehha.ca.gov/risk/ChemicalDB/index.asp](http://www.oehha.ca.gov/risk/ChemicalDB/index.asp).
- Chevron Environmental Management Company (Chevron), 2006. *Response letter addressing to agency comments presented in a letter dated November 21, 2005*. January 10, 2006.
- \_\_\_\_\_, 2009a. *Evidence for Natural Attenuation with Institutional Controls for Final Groundwater Remedy*. September 11, 2009.
- \_\_\_\_\_, 2009b. Response to Phase 3 comments, 2009. November 20, 2009.
- \_\_\_\_\_, 2010. *PCPL Fillmore Reuse Assessment*, January 12, 2010.
- CH2M Hill. 1991. *Baseline Risk Assessment, Pacific Coast Pipeline Site, Fillmore, California*, Final. December 1991.
- City of Fillmore, 2006. *Fillmore Vision 2020*, October 2006.
- Cowherd C, Muleski G, Engelhart P and Gillete D, 1985. *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination*. Prepared for EPA Office of Health and Environmental Assessment. EPA/600/8-85/002.



- Department of Toxic Substances Control (DTSC), 1992. *Supplemental Guidance for Human Health Multimedia Risk Assessment of Hazardous Waste Sites and Permitted Facilities*. California Environmental Protection Agency. Office of Scientific Affairs, July (corrected and reprinted, 1996).
- \_\_\_\_\_, 1994. *Preliminary Endangerment Assessment Guidance Manual*, January 1994 (Second Printing, June 1999).
- \_\_\_\_\_, 1996a. *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities: Part B Scoping Assessment*. Sacramento, CA; California Environmental Protection Agency, Department of Toxic Substances Control, Human and Ecological Risk Division. July 4, 1996.
- \_\_\_\_\_, 1996b. *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities: Part A Overview*. Sacramento, CA; California Environmental Protection Agency, Department of Toxic Substances Control, Human and Ecological Risk Division. July 4, 1996.
- \_\_\_\_\_, 1998. EcoNote#1: Depth of soil samples used to set exposure point concentration for burrowing mammals and burrow-dwelling birds in ecological risk assessments. Human and Ecological Risk Division. Ecological Risk Assessment Note Number 1. May 15, 1998.
- \_\_\_\_\_, 2002. HML-939-M. California Department of Toxic Substances Control <http://www.cdph.ca.gov/certlic/labs/Documents/ELAP-HML939-M.pdf>.
- \_\_\_\_\_, 2004. *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air*. California Environmental Protection Agency, December 15, 2004 (revised February 7, 2005).
- \_\_\_\_\_, 2005a. *Recommended DTSC Default Exposure Factors for Use in Risk Assessment at California Military Facilities*. Online: (<http://www.dtsc.ca.gov/AssessingRisk/index.cfm>).
- \_\_\_\_\_, 2005b. *Use of California Human Health Screening Levels (CHHSLs) in Evaluation of Contaminated Properties*. January 2005.
- \_\_\_\_\_, 2009a. SG-SCREEN, EPA Version 2.0; 04/03; last modified by DTSC. February 4, 2009.
- \_\_\_\_\_, 2009b. *Interim Advisory for Green Remediation*. December 2009.
- Dibblee, Thomas W., Jr., 1990. Geologic Map of the Fillmore Quadrangle, Ventura County, CA, 1990.
- Drexler, J.W., Brattin, W., 2007. An *in vitro* procedure for estimation of lead relative bioavailability, with validation. *Human and Ecological Risk Assessment* 13(2): 383-401.
- Dzombak, D., Morel, F. 1990. *Surface Complexation Modeling: Hydrous Ferric Oxide*. New York: Wiley-Interscience.
- England and Associates (E&A), 1994. *Final Phase 2 Design Report, Pacific Coast Pipeline (PCPL) Superfund Site, Fillmore, California*, December 16, 1994.
- \_\_\_\_\_, 1995a. *Final Phase 2 Remedial Action Work Plan*, (This report includes the *Health and Safety Plan* in Appendix A) May 2, 1995.
- \_\_\_\_\_, 1995b. *Operations and Maintenance Plan*, July 31, 1995.



- \_\_\_\_\_, 1995c. *Monitoring and Confirmation Sampling Plan*, September 18, 1995.
- \_\_\_\_\_, 1996a. *Interim Remedial Action Report*, August 30, 1996.
- \_\_\_\_\_, 1996b. *Documentation of Optimization Measures Discussed in the Conference Call of November 13, 1996*, November 22, 1996.
- \_\_\_\_\_, 1997. *Technical Memorandum - Recommended Modifications to the Groundwater Sampling Program*, May 13, 1997.
- \_\_\_\_\_, 1998a. *Revised Technical Memorandum – Well Abandonment and Installation Request*, August 6, 1998.
- \_\_\_\_\_, 1998b. *Monitoring Well Upgrade Completion Notification*, October 1, 1998.
- England Geosystem, Inc., 2001. *Technical Memorandum Request for Authorization to Discontinue Soil Vapor Extraction Operation*, May 21, 2001.
- \_\_\_\_\_, 2002a. *Technical Memorandum SVE Shutoff and Monitoring Plans*, March 28, 2002.
- \_\_\_\_\_, 2002b. *Notice of Intent to Discontinue Use of NPDES Permit*, May 15, 2002.
- \_\_\_\_\_, 2002c. *Response to EPA Letter and Call Associated with SVE Shutoff and Monitoring Plans*, May 24, 2002.
- \_\_\_\_\_, 2002d. *Technical Memorandum Proposal for Groundwater Treatment System Operational Modifications and Pilot Study for Enhanced Bioremediation*, October 16, 2002.
- \_\_\_\_\_, 2002e. *Work Plan for Implementation of Enhanced Bioattenuation Pilot Study*, 2002.
- \_\_\_\_\_, 2002f. *Request for Waste Discharge Permit for ORC® Injection*, 2002.
- \_\_\_\_\_, 2004. *Email documenting reduction in monitoring frequency*, 2004.
- \_\_\_\_\_, 2005a. *Work Plan for Soil Sampling PCPL Superfund Site Phase I—Former Tank Areas*, March 31, 2005.
- \_\_\_\_\_, 2005b. *Evaluation of the Enhanced Bioattenuation Pilot Study*, May 26, 2005.
- \_\_\_\_\_, 2005c. *Quarterly Status and Groundwater Monitoring Reporting for First Quarter 2005*. July 21, 2005.
- ENSR, 1990. *Site Summary Background Report*. March 2, 1990.
- \_\_\_\_\_, 1991. *Final Remedial Investigation Report*. June 1991.
- \_\_\_\_\_, 1992. *Remedial Investigation/Feasibility Study (RI/FS)*. 1992.
- Environmental Solutions, Inc. (ESI), 1992. *Preliminary Design Work Plan*, December 1992.
- \_\_\_\_\_, 1993. *Final (100%) Phase I Design Report, Pacific Coast Pipeline Site*, June 1993.



- Federal Remediation Technologies Roundtable (FRTR), 2002. *Remediation Technologies Screening Matrix and Reference Guide, 4<sup>th</sup> Edition*. 2002.
- Gallegos, P., J. Lutz, J. Markwiese, R. Rytty and R. Mirenda, 2007. *Wildlife Ecological Screening Levels for Inhalation of Volatile Organic Chemicals*. *Env. Tox. and Chem.* 26 (6):1299-1303.
- Gallert, C., Winter, J., 2004. 'Degradation of alkyllead compounds to inorganic lead in contaminated soil.' *Water Research* 38: 4204-4212.
- GSI Chemical Property Database, 2009. <http://www.gsi-net.com/UsefulTools/ChemPropDatabaseHome.asp>
- Helsel, D.R., and Hirsch, R.M. 2002. *Statistical Methods in Water Resources*. U.S. Geological Survey.
- Holland, R.F. 1986. *Preliminary Descriptions of the Terrestrial Natural Communities of California*. State of California, The Resources Agency. 156 p.
- Interstate Technology & Regulatory Council (ITRC), 2009. *Evaluating Natural Source Zone Depletion at Sites with LNAPL*. ITRC, Washington, DC. April 2009.
- Johnson, P.C. and Ettinger, R.A. (J&E), 1991. Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings. *Environmental Science & Technology*, 25(8):1445-1452.
- Kamon, M., 2001. Waste containment and remediation of contaminated sites. In: *Geotechnical engineering: Meeting society's needs*, Vol. 1. Eds. Ho, K., Li, K. Lisse, The Netherlands: Swets and Zeitlinger.
- Kilgour, D., Moseley, R., Barnett, M., Savage, K., Jardine, P. 2008. Potential negative consequences of adding phosphorus-based fertilizers to immobilize lead in soil. *Journal of Environmental Quality* 73: 1733-1740.
- Los Angeles Regional Water Quality Control Board (LARWQCB), 1994. Water Quality Control Plan, Los Angeles Region, Basin Plan for the Coastal Watersheds, Los Angeles and Ventura Counties.
- \_\_\_\_\_, 2003a. *General Waste Discharge Requirements (WDR) for ORC® Injection Pilot Test*. Order No. R4-2002-0030. 2003.
- \_\_\_\_\_, 2003b. *Amended Monitoring and Reporting Program*, 2003.
- Little, A. D., 1981. *SESOIL: Seasonal Soil Compartment Model*, developed for the Environmental Protection Agency (USEPA) Office of Water and the Office of Toxic Substances (OTS).
- Manning, B. and Goldberg, S., 1997. Adsorption and stability of arsenic (III) at the clay mineral water interface.
- McGuire, J. T., Long, D. T., Klug, M. J., Haack, S. K. and Hyndman, D. W. 2002. *Evaluating Behavior of Oxygen, Nitrate and Sulfate During Recharge and Quantifying Reduction Rates in a Contaminated Aquifer*. *Environ. Sci. Technol.* 36, 2693-2700.
- National Cancer Institute, 2008. *Cancer of All Sites*, Surveillance Epidemiology and End Results. Online: <http://seer.cancer.gov/statfacts/html/all.html>.



- NSF, 1977. 'Transport and distribution in a watershed ecosystem.' *Lead in the Environment*, ed. W.R. Boggess. Report No. NSFRA770214, 105-133. Washington, DC: National Science Foundation.
- Office of Environmental Health Hazard Assessment (OEHHA), 2007. Development of Health Criteria for Schools Site Risk Assessment Pursuant to Health and Safety Code Section 901(g): Proposed Child-Specific Benchmark Change in Blood Lead Concentration for School Site Risk Assessment. [http://www.oehha.ca.gov/public\\_info/public/kids/index.html](http://www.oehha.ca.gov/public_info/public/kids/index.html)
- \_\_\_\_\_. 2009. Revised California Human Health Screening Levels for Lead. Integrated Risk Assessment Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. September 2009.
- \_\_\_\_\_. 2010a. *Toxicity Criteria Database – Cancer Potency Information*. Carcinogen Criteria Group. California Environmental Protection Agency. Online: [www.oehha.ca.gov/risk/ChemicalDB/index.asp](http://www.oehha.ca.gov/risk/ChemicalDB/index.asp).
- \_\_\_\_\_. 2010b. *All OEHHA Acute, 8-hour and Chronic Reference Exposure Levels (chRELS) as on December 18, 2008*. Air Toxicology and Epidemiology. California Environmental Protection Agency. Online: <http://oehha.ca.gov/air/allrels.html>
- Oregon Department of Environmental Quality (DEQ), 2001. *Guidance for Ecological Risk Assessment, Final*. Waste Management and Cleanup Division, Cleanup Policy and Program Development Section. Updated version, December 2001.
- Peryea, F. and Kammereck, R. 1997. Phosphate-enhanced movement of arsenic out of lead arsenate-contaminated topsoil and through uncontaminated subsoil. *Water, Air, and Soil Pollution* 93:243–254.
- Qin, F., Wen, B., Shan, X., Xie, Y., Liu, T., Zhang, S., Khan, S. 2006. Mechanisms of competitive adsorption of Pb, Cu, and Cd on peat. *Environmental Pollution* 144: 669-680.
- Reddy, K., Wang, L. and Gloss, S., 1995. 'Solubility and Mobility of Copper, Zinc and Lead in Acidic Environments.' *Journal of Plant and Soil*, 171:53-58.
- Rhue, R.D., Mansell, R.S., Ou, L.T., Cox, R., Tang, S.R., Ouyang, Y. 1992. The fate and behavior of lead alkyls in the environment: A review. *Critical Reviews in Environmental Control* 22: 169-193.
- Saar, R.A., Weber, J.H. 1980. Lead(II) complexation by fulvic acid: how it differs from fulvic acid complexation of copper(II) and cadmium(II). *Geochimica et Cosmochimica Acta* 44: 1381-1384.
- Shannon, R. 1976. Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides. *Acta Crystallographica* A32: 751-767.
- Singh, A., R. Maichle, A.K. Singh, and S.E. Lee, 2007. *ProUCL Version 4.0 User Guide*. Office of Research and Development, U.S. Environmental Protection Agency, Report No. EPA/600/R-07/038.
- Southern California Edison (SCE), 2007. *Annual Entity Emissions Report, 2007*.
- State Water Resources Control Board (SWRCB), 2000. *Policy for the Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California*, March 2, 2000.



- Stumm, W., Morgan, J. 1996. *Aquatic Chemistry*, 3<sup>rd</sup> ed. New York: John Wiley & Sons.
- Sublette, K., A. Peacock, D. White, G. Davis, D. Ogles, D. Cook, R. Kolhatkar, D. Beckmann, and X. Yang. 2006. *Monitoring Subsurface Microbial Ecology in a Sulfate-Amended, Gasoline-Contaminated Aquifer*. *Ground Water Monitoring & Remediation* 26(2), 70-78.
- Summers, K., Gherini, S., and Chem C., 1980. *Methodology to Evaluate the Potential for Ground Water Contamination from Geothermal Fluid Release*, EPA-600/7-80-117, as modified by U.S. EPA Region IV 1980.
- Sverdrup, L.E., T. Nielsen, and P.H. Krogh, 2002. Soil Ecotoxicity of Polycyclic Aromatic Hydrocarbons in Relation to Soil Sorption, Lipophilicity, and Water Solubility. *Environ. Sci. Technol.* Vol. 36, No. 11:2429-2435.
- Tetra Tech, Inc., 2004. *Final Predictive Ecological Risk Assessment (PERA) – Operable Unit (OU) 2, Edwards Air Force Base, CA*. January 2004.
- Texaco Environmental Services (Texaco), 1994. *First Quarter 1994 Quarterly Status Report*. April 20, 1994.
- United States Environmental Protection Agency (USEPA), 1971. *Noise from Construction Equipment and Operations, Building Equipment and Home Appliances*, 1971.
- \_\_\_\_\_, 1988a. *CERCLA – Compliance with Other Laws Manual*. August 1988.
- \_\_\_\_\_, 1988b. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. October 1988.
- \_\_\_\_\_, 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual. Part A. Interim Final*. EPA 540/1-89/002. EPA Office of Emergency and Remedial Response, Washington, D.C.
- \_\_\_\_\_, 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*. Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-0.3.
- \_\_\_\_\_, 1992a. *Record of Decision (ROD) - Pacific Coast Pipeline, Texaco Fillmore Facility*, April 2, 1992.
- \_\_\_\_\_, 1992b. ‘Section XII: Applicable or Relevant and Appropriate Requirements’ from CERCLA/ Superfund Orientation Manual, October 1992.
- \_\_\_\_\_, 1992c. *Estimation of Air Impacts for the Excavation of Contaminated Soil. Air/Superfund National Technical Guidance Series*. Report ASF-24. EPA-450/1-92-004 (NTIS PB92-171925).
- \_\_\_\_\_, 1992d. *Statistical Training Course for Ground-water Monitoring Data Analysis*. Office of Solid Waste and Emergency Response, Washington, DC.
- \_\_\_\_\_, 1993a. *Consent Decree - Pacific Coast Pipeline Site*. February 1993, entered August 1993.
- \_\_\_\_\_, 1993b. Memorandum: ‘Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis.’ 1993.



- \_\_\_\_\_, 1996. *Soil Screening Guidance: User's Guide*, Second Edition, Publication 9355.4-23, Office of Solid Waste and Emergency Response. Washington, D.C., 1996.
- \_\_\_\_\_, 1997a. *Exposure Factors Handbook*. Office of Research and Development. EPA 600/P-95/002Ba. August 1997.
- \_\_\_\_\_, 1997b. *Ecological Risk Assessment Guidance for Superfund: Process for designing and conducting ecological risk assessments*. EPA 540-R-97-006. Interim final. USEPA, Washington, DC.
- \_\_\_\_\_, 1998. *Guidelines for Ecological Risk Assessment*, EPA/630/R-95/002F. Final. Risk Assessment Forum. Washington DC. April 1998.
- \_\_\_\_\_, 1999a. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, OSWER Directive 9200.4-17P, April 21, 1999. <http://www.epa.gov/swerust1/directiv/d9200417.pdf>
- \_\_\_\_\_, 1999b. *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, Peer Review Draft. Office of Solid Waste and Emergency Response. EPA530-D-99-001A. October 1999.
- \_\_\_\_\_, 2000a. *Solidification/Stabilization Use at Superfund Sites*, September 2000.
- \_\_\_\_\_, 2000b. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. July 2000.
- \_\_\_\_\_, 2001. *First Five-Year Review Report for Pacific Coast Pipeline Superfund Site*, September 2001.
- \_\_\_\_\_, 2002a. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*. Washington, D.C.; United States Environmental Protection Agency, Office of Solid Waste and Remedial Response, December 2002.
- \_\_\_\_\_, 2002b. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*. EPA 540/R-96/018. EPA Office of Emergency and Remedial Response. Washington, D.C. December 2002.
- \_\_\_\_\_, 2002c. *Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan*. Office of Environmental Information EPA/240/R-02/005, December 2002.
- \_\_\_\_\_, 2002d. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*. Washington, D.C.; United States Environmental Protection Agency, Office of Solid Waste and Remedial Response, December 2002.
- \_\_\_\_\_, 2002e. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*. EPA 540/R-96/018. EPA Office of Emergency and Remedial Response. Washington, D.C. December 2002.
- \_\_\_\_\_, 2003a. *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil (update to 1996 Final)*. EPA-



- 540-R-03-001. Technical Review Workgroup for Lead, U.S. Environmental Protection Agency, Washington, D.C. January 2003.
- \_\_\_\_\_, 2003b. *User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings*. Office of Emergency and Remedial Response. June 19, 2003.
- \_\_\_\_\_, 2004a. *Test Methods for Evaluating Solid Wastes, Physical/Chemical, (SW-846)*, online, <http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm> Web page updated July 7, 2004. Web page visited September 30, 2004.
- \_\_\_\_\_, 2004b. *Strategy to Ensure Institutional Control Implementation at Superfund Sites*, September 2004.
- \_\_\_\_\_, 2005a. *A Decision-Making Framework for Cleanup of Sites Impacted with Light Non-Aqueous Phase Liquids (LNAPL)*. EPA/542-R-04-011, U.S. EPA OSWER, March 2005.
- \_\_\_\_\_, 2005b. *Agency comment letter regarding Phase 1 Soil Sampling Workplan*. November 21, 2005.
- \_\_\_\_\_, 2005c. *Ecological Soil Screening Levels. Interim Final. OSWER Directive 9285.7-61*. U.S. EPA OSWER. Last updated November 2007. <http://www.epa.gov/ecotox/ecossl/>
- \_\_\_\_\_, 2006. *Second Five Year Review Report for Pacific Coast Pipeline Superfund Site*, September 28, 2006.
- \_\_\_\_\_, 2007a. *Comments on Proposed Scope for Phase 2 Investigation, Pacific Coast Pipe Line Superfund Site*. February 12, 2007.
- \_\_\_\_\_, 2007b. *Comments on Soil Sampling Report, Phase I – Former Tank Areas, Pacific Coast Pipe Line Superfund Site*. February 23, 2007.
- \_\_\_\_\_, 2007c. *Treatment Technologies for Site Cleanup: Annual Status Report – Twelfth Edition*, September 2007.
- \_\_\_\_\_, 2008. *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Soils*, April 2008.
- \_\_\_\_\_, 2009a. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*. Final. EPA-540-R-070-002. Office of Superfund Remediation and Technology Innovation, Environmental Protection Agency, Washington, D.C. January 2009.
- \_\_\_\_\_, 2009b. *Superfund Green Remediation Strategy*. August 2009.
- \_\_\_\_\_, 2009c. *Phase 3 comments letter*. September 15, 2009.
- \_\_\_\_\_, 2009d. *Unilateral Administrative Order (UAO) for Remedial Investigation/Feasibility Study Statement of Work (SOW)*. September 24, 2009.
- \_\_\_\_\_, 2009e. *Greener Cleanup Policy*. September 2009.
- \_\_\_\_\_, 2009f. *Mexico Landfill Gas Model, Version 2*. 2009.



- \_\_\_\_\_, 2009g. Region 9 Regional Screening Levels. Online database (www.epa.gov/region9/superfund/prg/index.html). December 2009.
- \_\_\_\_\_, 2009h. *Adult Lead Exposure Model (ALM)*. U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee. Version date June 21, 2009.
- \_\_\_\_\_, 2009i. *Uptake/Biokinetic Model for Lead, (IEUBK win32 v1.1 build11)*, Software Program Developed by U.S. EPA. June 2009.
- \_\_\_\_\_, 2010. Letter to Chevron Environmental Management Company: *Comments — Draft RI/FS, Pacific Coast Pipeline Superfund Site*. April 27, 2010.
- \_\_\_\_\_, 2010b. Integrated Risk Information System (IRIS). National Center for Environmental Assessment (NCEA). Online database: [www.epa.gov/iris](http://www.epa.gov/iris).
- URS Corporation (URS), 2006a. *Sampling and Analysis Plan for Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolve Phase Benzene Plumes*, August 4, 2006.
- \_\_\_\_\_, 2006b. *Soil Sampling Report Phase 1—Former Tank Areas, Pacific Coast Pipeline (PCPL) Superfund Site Fillmore, California*, Revised September 8, 2006.
- \_\_\_\_\_, 2006c. *PCPL Superfund Site Fillmore, California Health and Safety Plan*, Revised October 3, 2006.
- \_\_\_\_\_, 2007a. *Continuous Multichannel Tubing Well Installation Report PCPL Superfund Site Fillmore, California*, May 11, 2007.
- \_\_\_\_\_, 2007b. *Work Plan for Soil Sampling, Phase 2- Historical Operations, PCPL Superfund Site Fillmore, California*, Revised July 30, 2007.
- \_\_\_\_\_, 2007c. *Report of Natural Attenuation Characteristics and Soil Vapor Characteristics Above Dissolved-Phase Benzene Plumes, PCPL Superfund Site Fillmore, California*, November 13, 2007.
- \_\_\_\_\_, 2008a. *Soil Sampling Report, Phase 2 – Historical Operations, PCPL Superfund Site Fillmore, California*, April 15, 2008.
- \_\_\_\_\_, 2008b. *Work Plan, Phase 3 – Data Gaps for Risk Assessment, PCPL Superfund Site Fillmore, California*, April 15, 2008.
- \_\_\_\_\_, 2009a. *Phase 3—Shallow Soil Investigation: Data Gap Sampling and Human Health Risk Assessment, Pacific Coast Pipeline (PCPL) Superfund Site, Fillmore, California*. May 8, 2009.
- \_\_\_\_\_, 2009b. *Construction Material Sampling*. August 14, 2009.
- \_\_\_\_\_, 2009c. *Health and Safety Plan for Chevron Environmental Management Company, PCPL Superfund Site, Fillmore, California*. October 23, 2009.
- \_\_\_\_\_, 2010a. *Quarterly Monitoring Reporting for Fourth Quarter 2009*. February 15, 2010.
- \_\_\_\_\_, 2010b. *Quarterly Monitoring Reporting for First Quarter 2010*. May 15, 2010.



Van Gerven, T., Cornelis, G., Vandoren, E., Vandecasteele, C., Garrabrants, A., Sanchez, F., Kosson, D. 2005. Effects of progressive carbonation on heavy metal leaching from cement-bound waste. *American Institute of Chemical Engineers Journal* 52:826-837.

Virginia Department of Environmental Quality (VDEQ), 2009. Voluntary Remediation Program Risk Assessment Guidelines. Online document: <http://www.deq.state.va.us/vrprisk/raguide.html>.

Wiedemeier, T.H., H.S. Rifai, C.J. Newell, and J.T. Wilson, 1999. *Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface*. John Wiley & Sons, Inc. New York, NY, 617 pp.

Williams, L., Barnett, M., Kramer, R., Melville, J., 2003. Adsorption and transport of arsenic(V) in experimental subsurface systems. *Journal of Environmental Quality* 32: 841-850.

Zheng, C., 1990. MT3D, A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems. Report to the U.S. Environmental Protection Agency. Robert S. Kerr Environmental Research Laboratory. Ada, OK. 1990.

Zheng, C. and P.P. Wang, 1999. MT3DMS. A Modular Three Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems. Documentation and User's Guide. Contract Report SERDP-99-1. U.S. Army Corps of Engineers. Engineer Research and Development Center, Vicksburg, MS. 1999.



## Tables



## Figures



**Appendix A**

**Unilateral Administrative Order  
September 24, 2009**

## **Appendix B**

### **Historical & Criteria Decision Documents**

#### **(on DVD)**

- Final Remedial Investigation Report (ENSR, 1991).
- Final Feasibility Study Report (ENSR, 1992).
- Final Phase 2 Design Report, Pacific Coast Pipeline (PCPL) Superfund Site, Fillmore California (E&A, 1994).
- Evaluation of the Enhanced Bioattenuation Pilot Study (England Geosystem, 2005).
- Report of Natural Attenuation Characteristics and Soil Vapor Characteristics above Dissolved Phase Benzene Plumes (URS, 2007).
- Soil Sampling Report Phase 1 – Former Tank Areas (URS, August 2006).
- Soil Sampling Report Phase 2 – Historical Operations (URS, April 2008).
- Phase 3 Shallow Soil Investigation – Data Gap Sampling and Human Health Risk Assessment (URS, May 2009).
- PCPL Fillmore Reuse Assessment (Chevron, 2010).



**Appendix C**  
**Summary Tables of Historical Results**  
**(on DVD)**



## Appendix D

### Construction Materials Sampling Report (URS, 2009)



## Appendix E

### Groundwater MNA Multiple Lines of Evidence (Chevron, September 11, 2009)



**Appendix F**  
**Human Health Risk Assessment**  
**(on DVD)**



**Appendix G**  
**Residential Screening Level Risk Assessment**  
**(on DVD)**



**Appendix H**  
**Soil Lead Speciation and Bioavailability**



**Appendix I**  
**Risk-Based Concentrations Calculations**  
**(on DVD)**



## Appendix J

### Detailed Analysis – Cost Details