Casmalia Resources Superfund Site

Final Remedial Investigation Report

Prepared for:

USEPA, Region 9
75 Hawthorne Street
San Francisco, CA 94105

Prepared by:

Casmalia Resources Site Steering Committee

CASMALIA SITE REMEDIATION PROJECT

Corey Bertelsen
Project Manager

January 25, 2011

To: Russell Mechem – EPA
Mark Samolis - EPA

Subject: Final Remedial Investigation Report

The Casmalia Resources Site Steering Committee (CSC) has prepared this Final Remedial Investigation (RI) Report as required by Section 11.6 of the EPA approved Remedial Investigation/ Feasibility Study (RI/FS) Work Plan (CSC, 2004) that summarizes the investigation and remedial activities undertaken for the former Casmalia Hazardous Waste Management Facility (Site). The CSC previously provided EPA a draft final RI Report dated January 30, 2010.

The Final RI Report is organized in the same fashion as the previous draft final report and complies with the requirements of Section 11.6 of the RI/FS Work Plan which meets EPA's guidance documents regarding RI Reports. The RI Report addresses EPA's comments dated June 16, 2010 on the previous draft final report. The CSC and EPA have spent considerable time discussing those comments and agreeing on how we would incorporate them into the revised report. We believe that we have done that consistent with those discussions.

The CSC has distributed copies of the Final RI Report to the distribution list below, which is the same as the draft Final RI Report distribution. The CSC sent complete hard copies of the document to all of those who received hard copies of the draft final report and the remainder of the distribution list is receiving a complete electronic copy (text, tables and figures).

We look forward to your review and approval of the submittal.

Regards,

Corey Bertelsen
Casmalia Project Coordinator

cc: Jim Dragna – Bingham McCutcheon
Glenn Anderson – Chevron
Dave Roberson – Exxon Mobil
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CASMALIA SITE REMEDIATION PROJECT

Corey Bertelsen
Project Manager

April 22, 2011

To: Russell Mechem – EPA
Mark Samolis - EPA

Subject: Final RI Report
Errata /Addendum

The Casmalia Steering Committee (CSC) submitted a Final Remedial Investigation (RI) Report to EPA dated January 25, 2011. In a letter dated March 28, 2011 EPA provided the CSC seven comments on the RI Report and noted that they had identified these minor issues which needed to be corrected before EPA could approve the document.

EPA specifically requested that the CSC prepare and submit errata sheets for the following sheets that were included in the January 25th Final RI Report:

1. Revised Executive Summary (which included the previously agreed to text regarding the TI Evaluation of the RI Report).
2. Revisions to Section 7.3 of the RI Report (including some edits to the text and addition of a new table describing COPCs).
3. Revised Figure 4-54 (with colors that are referred to in the legend turned on).
4. Revised Figure 6-1 and 6-2 (with particle flow paths shown for the PCT and PSCT extraction points).
5. Revised Table D-3 (which includes TDS data)
6. Revised Figure F-29 (which includes potentiometric contours).
7. Copies of the four historical aerial photographs referred to in Appendix V.

As discussed with EPA, we are sending everyone who originally received a hard copy of the January 25, 2011 Final RI Report a set of errata or replacement sheets addressing the above.

We are inserting the errata or replacements sheets into the CD of the Final RI Report and sending a new CD to everyone who originally had received a CD copy of the report.

The CSC looks forward to EPA's approval of the Final RI Report.

regards,

Corey Bertelsen
Casmalia Project Coordinator

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LIST OF ACRONYMS

(the) Site	the former Casmalia Hazardous Waste Management Facility
°C	temperature degree centigrade
°F	temperature degree Fahrenheit
µCi	micro-Curies
µg/dl	micrograms per deciliter
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
µm	micrometer
µmhos/cm	micromhos per centimeter
µmol/g	micromoles per gram
µR/hr	microrems per hour
µV	microvolts
ΣSEM AVS	total SEM minus AVS
ΣSEM	total SEM
0/00	permil or parts per thousand
1×10^{-6}	one in one million
2-D	two-dimensional
3H	tritium
3He	helium-3
95% UCL	95 percent upper confidence limit
ADD	Average Daily Dose
AE	assessment endpoint
Ag	silver
Ag_2S	silver monosulfide
Ah	aryl hydrocarbon
amsl	above mean sea level
APN	Assessor's Parcel Number
ARAR	Applicable or relevant and appropriate requirement
ARCH	air-rotary casing hammer
Area	area defined by the three-mile radius from the boundaries of the Casmalia Site
ASTM	American Society for Testing and Materials
ASTs	Aboveground Storage Tanks
ATL	Air Toxics LTD
atm	atmosphere
ATS	Ameripure Treatment System
ATV	all-terrain vehicle
AUF	Area Use Factor
AVS	acid volatile sulfide
AVS-SEM	Acid Volatile Sulfide-Simultaneously-Extracted Metals
BAF	bioaccumulation factor
Base	Vandenberg Air Force Base
BBL	Blasland, Bouck, and Lee, Inc.

BC Laboratory	BC Analytical Laboratories
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment
BKG	background
BP	before present
BSHS	Biological Species and Habitat Survey
BTA	Burial Trench Area
BTAG	Biological Technical Advisory Group
BTEX	benzene, toluene, ethylbenzene, and xylenes
btoc	below top of casing
C14	Carbon 14 age dating
CA	Caustic/Cyanide and Acid Landfill
$CaCO_3$	calcium carbonate
Cal Prop 65	Safe Drinking Water and Toxic Enforcement Act of 1986
CalEPA	California Environmental Protection Agency
CAM	California Assessment Method
CAS	Chemical Abstract Service
CASRN	Chemical Abstract Services Registry Number
CB	Calibration Blank
CCB	Continuing Calibration Blank
CCR	California Code of Regulations
CCV	Continuing Calibration Verifications
Cd	cadmium
CD	compact disk
CDD	Chlorinated Dioxins
CDF	Chlorinated dibnezofurans
CDFG	California Department of Fish and Game
CdS	Cadmium sulfide
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHHSL	California Human Health Screening Level
cm	centimeter
cm/g	centimeters per gram
cm^3/minute	cubic centimeters per minute
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CNS	Casmalia Neutralization System
COC	chemical of concern
COPC	chemical of potential concern
CPEC	chemical of potential ecological concern
cpm	counts per minute
CPT	cone penetrometer test
CRLF	California red-legged frog
CRWQCB	California Regional Water Quality Control Board

Cs-137	cesium-137
CSC	Casmalia Resources Site Steering Committee
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CTS	California tiger salamander
Cu	copper
CVOCs	chlorinated volatile organic compounds
CVRWQCB	Central Valley Regional Water Quality Control Board
DBCP	1,2 dibromo 3 chloropropane
DCA	dichloroethane
DCB	dichlorobenzene
DCE	dichloroethylene/dichloroethene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEA	diethylamine
DHS	Department of Health Services
DIC	Dissolved Inorganic Carbon
DNAPL	dense non aqueous-phase liquid
DO	dissolved oxygen
DOC	Dissolved Organic Carbon
dpm	disintegrations per minute
DPT	direct-push technology
DQO	data quality objective
DTSC	Department of Toxic Substances Control
DUP	duplicate
DWR	Department of Water Resources
Dynes/cm	dynes per centimeter
EC	electrical conductivity
ECD	electron capture detector
Eco RBC	Ecological risk-based concentration
EDB	Ethylene dibromide
EDD	Electronic Data Deliverable
EE/CA	engineering evaluation/cost analysis
Eh	oxidation reduction potential
EIR	Environmental Impact Report
ELAP	California Environmental Laboratory Accreditation Program
EPA	Environmental Protection Agency
EPC	exposure point concentration
EqP	equilibrium partitioning
EQS	Environmental Quality Standard
ERA	Ecological Risk Assessment
ERG	Environmental Restoration Group
ERI	Environmental Research, Inc.
ERM	Environmental Resources Management
ESB	Equilibrium Partitioning Sediment Benchmark

ESL	Ecological Screening Level
ESRI	Environmental Systems Research Technologies
ET	evapotranspiration
Fe(II)	ferrous iron
Fe(III)	ferric iron
FeOOH	mineral hydrous ferric oxide
FeS	iron monosulfide
FID	Flame Ionization detector
Final Design Report	refers to the Revised Final Pesticides Solvent Landfill Cap Design Report
FMR	field metabolic rate
FOC	fraction organic carbon
FOD	frequency of detection
FPP	Former Ponds and Pads
fps	feet per second
FS	Feasibility Study
FSP	field sampling plan
ft	feet
ft/min	feet per minute
ft/yr	feet per year
g/cc	grams per cubic centimeter
g/cm^3	grams per cubic centimeter
GAC	granular activated carbon
GC	gas chromatograph
GCW	Historical name of Gallery Well
GIS	Geographic Information System
gm/mol	gram-mole or gmole
gpm	gallons per minute
GPS	global positioning system
Gregg	Gregg In Situ, Inc.
GS	Golden State Aerial Surveys
GSCA	Geologic Siting Criteria Assessment
HAR	Hydrogeologic Assessment Report
H_c	Henry's Law constant
HCSM	Hydrogeologic Conceptual Site Model
HDPE	High Density Polyethylene
HEAST	Health Effects Assessment Summary Tables
HH	Human health
HHRA	Human Health Risk Assessment
HH RBC	human health risk-based concentration
HI	Hazard Index
HMW	high molecular weight
HNO_3	nitric acid
HQ	hazard quotient
HSA	Hollow stem auger
HSAA	California Hazardous Substances Account Act

HSCER	Hydrogeologic Site Characterization and Evaluation Report
HSIR	Hydrogeologic Site Investigation Report
HSR	Hydrogeologic Summary Report
HSU	Hydrostratigraphic Unit
HSWA	Hazardous and Solid Waste Amendments
HT	hydrogen (tritium) gas
HTO	tritiated water vapor
Hunt	Hunt & Associates Biological Consultants
HVOCs	halogenated volatile organic compounds
Hz	Hertz
IC	Initial Calibration
ICB	Initial Calibration Blank
ICS	Inference Check Samples
ICV	Initial Calibration Verifications
ID	inside diameter
ILA	Interim Liquids Agreement
Intra	Intrasearch
IPR	Interim Progress Report
IRIS	Integrated Risk Information System
J&E	Johnson and Ettinger Vapor Intrusion Model
JPEG	Joint Photographic Experts Group
K_d	distribution coefficient
K_{deg}	half-life
Kelvin	Degrees kelvin
kg	kilogram(s)
kg/L	kilograms per liter
kHz	kilohertz
K_{oc}	Organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
L	liter(s)
lb	pound
L/kg	liters per kilogram
LADD	Lifetime Average Daily Dose
LCS	Laboratory Control Samples
LDR	Land Disposal Restrictions
LF	landfill
LHSU	Lower Hydrostratigraphic Unit
LMW	low molecular weight
LNAPL	light non aqueous-phase liquid
LOAEL	lowest observed adverse effect level
m^3/day	cubic meters per day
MACTEC	MACTEC Engineering and Consulting, Inc.
MCL	maximum contaminant level
MCPA	2-methyl-4-chlorophenoxy-acetic acid
MCPP	2-(4-Chloro-2-methylphenoxy) propionic acid
MDL	Method Detection Limit

MEK	Methyl ethyl ketone
mg	milligrams
mg/kg bw day	milligrams per kilogram of body weight per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram of body weight per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
MIBK	methyl isobutyl ketone
MIP	Membrane Interface Probe
ml	milliliters
ml/gm	milliliter per gram
ml/min	milliliters per minute
mm Hg	millimeters of Mercury (pressure measurement unit)
mm	millimeters
MMP	Meteorological Monitoring Program
Mn(II)	manganese (II)
Mn(IV)	manganese (IV)
MNA	monitored natural attenuation
MPC	Maximum Permissible Concentration
MS	Matrix Spike
mS/M	milliSiemens per meter
MSD	Matrix Spike Duplicate
msl	mean sea level
MTBE	Methyl tert butyl ether
mV	millivolts
N/A	Not applicable
NA	Not applicable
NaI	sodium iodide
NAPL	non aqueous-phase liquid
NAWQC	National Recommended Water Quality Criteria
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
ND	Not Detected
NDMA	n-nitrosodimethylamine
NE	non-equilibrium
NFESC	Naval Facilities Engineering Service Center
NGVD	National Geodetic Vertical Datum
Ni	nickel
NIST	National Institute of Standards and Technology
NMD	Normal Move Out
NOAEL	no observed adverse effect level
NORCAL	NORCAL Geophysical Consultants, Inc.
NPDES	National Pollution Discharge Elimination System
NT	Not Tested
NTU	Nephelometric Turbidity Unit
OCDD	octachlorodibenzo-p-dioxin

OCDF	octachlorodibenzofuran
OD	outside diameter
OEHHA	Office of Environmental Health Hazard Assessment
ORNL	Oak Ride National laboratory
ORP	oxidation-reduction potential (redox)
OSWER	U.S. Office of Solid Waste and Emergency Response
OVM	organic vapor monitor
PACT	powder-activated carbon treatment
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
pCBSA	Parachlorbenzene sulfonic acid
PCDD	polychlorinated dibenzo p dioxin
PCDF	polychlorinated dibenzofuran
PCE	tetrachloroethylene/tetrachloroethene
PCNB	pentachloronitrobenzene
PCT	Perimeter Control Trench
PE	Performance Evaluation
PEST	Parameter Estimation
pg/g	picograms per gram
pg/L	picograms per liter
pH	unit of measurement for acid/base properties
PHGs	Public Health Goals
PID	photoionization detector
PLSS	Public Land Survey System
POC	Point of Compliance
ppbv	part(s) per billion by volume
ppm	parts per million
ppmv	part(s) per million by volume
PPOs	Poor Purging Organics
ppt	part(s) per trillion
PRG	Preliminary Remediation Goal
P/S	pesticides/solvents
P/S Landfill	Pesticide/Solvent Landfill
PSCT	Perimeter Source Control Trench
psi	pounds per square inch
PTS Laboratories	Petroleum Testing Services Laboratories
PUF	plant uptake factor
PVC	polyvinyl chloride
PW	Pacific Western Aerial Surveys
P_w	pore water pressure
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
Qc	Tip resistance

QED	QED Environmental Systems is a company specializing in water quality remediation/sampling products
R.G.	Registered Geologist
RA	Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RAP	Remedial Action Plan
RATL	Reptile and Amphibian Toxicology Literature
RBCs	risk-based concentrations
RCF	Runoff Containment Facility
RCRA	Resource Conservation and Recovery Act
RDX	nitroamine, an explosive, also known as cyclonite, hexogen, T4, and cyclotrimethylenetrinitramine
REI	relative estimation interval
RfC	reference concentration
RfD	reference dose
RFI	Request For Information form
RGMEW	Routine Groundwater Monitoring Element of Work
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RI/FS Work Plan	Remedial Investigation/Feasibility Study Work Plan
RICH	RI Change Form
RME	Reasonable Maximum Exposure
ROS	Remain On-Site
RPD	relative percent difference
RRF	Relative Response Factors
RSD	Relative Standard Deviation
RWQCB	Regional Water Quality Control Board
SA	semiannual
SAP	Sampling Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SB	Soil boring
SDG	Sample Delivery Group
SEM	simultaneously extracted metals
SFRWQCB	San Francisco Regional Water Quality Control Board
SI	Surface Impoundment
SIC	Silty Clay
SL	Screening Level
SOP	Standard Operating Procedure
SOW	Scope of Work
SQG	Sediment Quality Guideline
SS	Surface soil (0 to 6 inches bgs)
SVL	snout-vent length
SVOC	semi-volatile organic compound
SWAT	Solid Waste Assessment Test
T	Temperature

T&E	Threatened and Endangered
TBA	tert-butyl alcohol
TBC	to be considered
Tc-99	technetium-99
TCA	trichloroethane
TCDD	tetrachlorodibenzo-p-dioxin
TCE	trichloroethylene/trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TCLs	Target Clean-up Levels
TD	Total Depth
TDS	total dissolved solids
TEF	Toxicity Equivalency Factors
TEQ	toxic equivalent
TI	technical impracticability
TIC	Tentatively Identified Compound
TIE	technical impracticability evaluation
TIN	triangulated irregular network
TLVs	Threshold Limit Values
TM	Technical Memorandum
TMB	trimethylbenzene
TOC	total organic carbon
TOX	Total Organic Halogens
TPH	total petroleum hydrocarbons
TPHd	total petroleum hydrocarbons (as diesel)
TRS	Township, Range, and Section
TRV	toxicity reference value
tsf	tons per square foot
TU	tritium unit
UCL	upper confidence limit
UCSB MIB	University of California, Santa Barbara, Map and Image Library
UF	Uncertainty Factor
UHSU	Upper Hydrostatigraphic Unit
UM	University of Miami (Florida)
URF	Inhalation Unit Risk Factors
URS	URS Corporation
USACHHPM	U.S. Army Center for Health Promotion and Preventive Medicine
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USTs	Underground Storage Tanks
UTL	upper tolerance limit
UVIF	ultraviolet induced fluorescence
V_b	bulk volume
VC	vinyl chloride

VOC	volatile organic compound
V_p	Vapor Pressure
WAO	wet air oxidation
WCC	Woodward-Clyde Consultants
WCCB	West Canyon Catch Basin
WDC	Water Development Corporation
WHO	World Health Organization
WMU	Waste Management Unit
Work Plan	June 2004 RI/FS Work Plan
ybp	years before present
Zn	zinc

EXECUTIVE SUMMARY

The Casmalia Resources Site Steering Committee (CSC) is submitting a draft Final Remedial Investigation (RI) Report to EPA. As requested in EPA's October 15, 2008 comments on the draft RI Report that the CSC submitted on April 8, 2008, and as required by Section 11.6 of the EPA approved Remedial Investigation/ Feasibility Study (RI/FS) Work Plan (CSC, 2004), we have prepared this Executive Summary of the draft Final RI Report.

As requested, the Executive Summary includes:

- A discussion of the objectives of the RI sampling
- A brief summary of the schedule and scope of the RI sampling
- A summary of the RI sample results and the CSC's subsequent Human Health Risk Assessment (HHRA) and Ecological Risk Assessments (ERA) that were based on this sampling

The Executive Summary also includes tables listing the HHRA and ERA risk drivers by Study Area of the Site.

The RI Report is a long and complex document. As such the Executive Summary can only briefly discuss the sampling and sample results. We refer the reader to the main text, tables, figures, and Appendices of the RI Report for more details.

The CSC performed the RI in accordance with the objectives and performance standards in the Statement of Work (SOW) of the Casmalia Consent Decree. These are described in Sections 2.9.2 (EE/CA) and 2.10.2 (RI/FS) of the SOW. The EE/CA was to have addressed the Zone 1 (on site) area and the RI/FS was to incorporate the results of the EE/CA and also address the Zone 2 (off site area), in addition to addressing Zone 1 (onsite area). Most of the performance standards in Section 2.9.2 (EE/CA) apply to Section 2.10.2 because the initial EE/CA performed by the CSC addressed only capping of the landfills and not the entire Zone 1 area.

Objectives of the RI Program

The approved RI/FS Work Plan described in detail the various activities the CSC would complete as part of the RI/FS process. Those primary RI/FS tasks included the following, in accordance with the objectives and performance standards of Sections 2.9.2 and 2.10.2 of the SOW:

- A Remedial Investigation (RI) designed to meet the data needs for all RI/FS activities. Sections 2 and 3 of the Work Plan summarized and evaluated the large amount of existing Site-related characterization and remediation data and information which was used to the maximum extent practicable for the RI. Sections 4 and 5 of the Work Plan defined those data needs which were compiled by evaluating existing data and information at the Site and comparing that against the data requirements of the RI/FS process;
- A human health risk assessment (HHRA) to define primary risk-driving chemicals and exposure routes for human receptors. The HHRA results will be used along with the ERA results to identify which Site Study areas may require remediation (see Section 6 of the Work Plan);

- An ecological risk assessment (ERA) to identify and define potential risks to plants and animals at the Site. The results of the ERA will be used to identify Site areas potentially requiring remediation (see Section 7 of the Work Plan);
- Preparing a groundwater flow model to assess overall Site flow patterns, to evaluate the efficacy of current groundwater extraction facilities, and to assess potential future remedies using the groundwater model (see Section 8 of the Work Plan);
- A technical evaluation of the practicability of restoring groundwater to applicable standards, i.e., a Technical Impractability Evaluation (TIE) for the Casmalia Site. If groundwater cannot practicably be restored, as agreed with EPA the CSC will propose a Technical Impracticability (TI) Zone and complete a TIE consistent with United States Environmental Protection Agency (USEPA or EPA) guidance (see Section 9 of the Work Plan) which would be incorporated as part of the final remedy for the Site. As required by the Work Plan, the RI Report includes the preliminary steps of the TIE and proposes a TI zone.
- A Feasibility Study (FS) to identify and screen various candidate technologies that will reduce potential human health and ecological risks at the Site. The CSC will assemble and evaluate various remedial alternatives in concert with the TI evaluation to ensure that groundwater remediation objectives are met. Based on the alternatives evaluation in the FS, the CSC will propose a remedy for the Site (Section 10 of the Work Plan).

The CSC has completed the first five bullet items listed above, including the RI sampling activities, the HHRA, the ERA, and the preliminary TIE. These activities are discussed in the draft Final RI Report the CSC has submitted to the agency.

As we noted above, Section 4 and 5 of the RI/FS Work Plan defined the sampling program objectives for the RI, in part based on the CSC's evaluation of the existing Site-related characterization and remediation data and information available. The reader can find a detailed discussion of the data quality objectives (DQOs) for the RI sampling in the sections of the Work Plan listed below:

- Human Health Risk Assessment (Section 4.1);
- Ecological Risk Assessment (Section 4.2);
- Contaminant Nature, Extent, Fate, and Transport Investigation Data (Section 4.3);
- Groundwater Modeling Data (Section 4.4); and
- Technical Impracticability Evaluation Data (Section 4.5).

These DQOs are discussed by sampling media (soil, sediment, soil vapor, surface water, groundwater).

Summary of RI Sampling

As required by Section 5 of the RI/FS Work Plan, the CSC performed various activities as part of the RI process for the Site. Those primary RI/FS tasks included:

- Collecting Soil and Sediment Samples;
- Collecting Soil Vapor Samples;
- Collecting Surface Water Samples;
- Installing Wells and Collecting Additional RI Groundwater Samples;
- Installing Piezometers and Measure Water Levels;
- Sampling of Existing Wells/Piezometers;

- Assessing Geologic Mapping in RCRA Canyon;
- Performing Gamma Walk-Over Survey in RCRA Canyon;
- Determining the Elevation of the Top and Lateral Limits of Clay Barrier;
- Conducting Light Non-aqueous Phase Liquid (LNAPL) and Residual NAPL Evaluations;
- Conducting Free-Phase Dense Non-aqueouse Phase Liquid (DNAPL) Evaluations; and
- Conduct Lower hydrostratigraphic unit (HSU) DNAPL Evaluation.

The details of the scope of work that each of these tasks required are presented in Sections 4 and 5 of the RI/FS Work Plan and in three subsequent sampling plans that the CSC submitted and EPA approved. The sampling was completed over the course of several years and in several RI sampling programs which are discussed below. The discussion below only summarizes the extent or scope of the various phases of RI sampling and the actual sample or task results for each of these activities can be found in more detail in the appendices listed in Section 1.3 of the RI Report.

RI Sampling Schedule

As we noted above, the RI sampling was completed in three phases. The first phase was proposed in the approved RI/FS Work Plan and completed in the Summer and Fall of 2004. The second or Phase II RI sampling was proposed as follow-up sampling, which was identified after review of the Phase I RI sampling results and was completed in the Fall of 2005 and Spring of 2006. The third or Phase III RI sampling was proposed to provide additional follow-up sampling around an area sampled in the two previous rounds (RISBON-59) and was completed in April 2007. A Tier 2 ecological risk assessment (ERA) sampling event was also completed in spring of 2009 to refine the ERA.

The three phases of RI sampling and the Tier 2 ERA sampling event are discussed below.

Phase I RI Sampling

The CSC began the Phase I RI sampling work on July 19, 2004 and continued the bulk of the various RI activities through the end of November 2004. A few additional samples associated with stormwater runoff were collected in December 2004.

The Phase I sampling program is described in Table 4-4 from the RI/FS Work Plan. That updated table is attached to the RI Report. The specific details of the sampling program (e.g., number of samples for the various activities and media, locations, sample depths) are included in the paragraphs below that discuss the individual sampling activities.

Phase II RI Sampling

The CSC completed the Phase II RI sampling in two periods: the first period occurring in the Fall of 2005 and the second period beginning in July 2006. The Fall 2005 sampling was limited to some soil gas surveys, surface water sampling, and some background soil sampling. The 2006 Phase II RI sampling work began July 17, 2006, and continued through the end of September 2006. Some additional well and piezometer installation work was completed after that date.

The Phase II sampling program is described in Table 4-4.P2 from the Spring 2006 Phase II RI Sampling Plan referenced in the RI Report. The specific details of the sampling program (e.g., number of samples for the various activities and media, locations, sample depths) are included in the paragraphs below that discuss the individual sampling activities.

Phase III RI Sampling

The CSC completed a portion of the Phase III RI sampling in the Spring of 2007. This sampling included some soil boring sampling near previous sampling done at the RISBON-59 location that was completed as follow-up to that earlier sampling. The Phase III RI sampling work began on April 16, 2007, and continued through the first week of May 2007. The CSC also completed some limited confirmation soil vapor sampling on October 12, 2007. This sampling included re-occupying three soil vapor sample locations and resampling them with splits sent to the laboratory originally used to analyze for 1,3 Butadiene using method TO-15 and another laboratory to analyze for the same constituent but using method TO-15 SIM.

The Phase III sampling program is described in Table 4-4.P3 from the Phase III RI Sampling Plan that we referenced in the RI Report. The specific details of the sampling program (e.g., number of samples for the various activities and media, locations, sample depths) are included in the paragraphs below that discuss the individual sampling activities.

Seismic Refraction Follow-Up Surveys

The CSC completed some cone penetrometer test (CPT) surveys and piezometer installation in the pesticide/solvent (P/S) landfill as follow-up to the previous seismic refraction surveys that we completed on the landfill in the Fall of 2007. This follow-up work included the completion of a series of instrumented CPTs and the installation of four piezometers at the locations that USEPA had identified as possible “low spots“ or closed depressions in the clay contact contour under the P/S Landfill.

The Seismic Refraction Follow-Up program is described in the Seismic Refraction Follow-Up Plan referenced in the RI Report. The specific details of the program (e.g., number of CPTs and piezometers, locations, depths) are described in that document.

Tier 2 Ecological Risk Assessment Sampling Event

After completing and reporting the results of the initial Tier 1 (screening) ERA in the draft RI Report, the CSC collected biological samples during Spring 2009 to refine the Tier 1 ERA to a Tier 2 (baseline) ERA. The CSC collected biological tissue samples and co-located media samples in accordance with the *Next Steps for Ecological Risk Assessment* memorandum (ARCADIS, 2008) and accompanying Tier 2 ERA Sampling and Analysis Plan (CSC, 2009). The results of the Tier 2 ERA are presented in this RI Report.

Scope of RI Sampling

The following paragraphs briefly summarize the scope of the various RI sampling or investigative activities.

Background Soil Sampling

As discussed in the RI/FS Work Plan, background concentrations of chemicals in soil were previously evaluated in earlier investigations conducted at the Site (in studies primarily conducted by the owner/operator). Soil borings and test pits were completed in upgradient, off-site areas during these earlier Site investigations to assess the background chemical and geochemical properties of the three stratigraphic units present at the Site. As part of the CSC's Phase I and Phase II RI sampling, the CSC collected new background soil data which was compared with the existing data and used in the risk assessments included in this RI Report.

During the Phase I and Phase II RI sampling, the CSC collected soil samples at various depths and analyzed those samples for a variety of constituents including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), inorganics, polychlorinated biphenyls (PCBs), Dioxin/Furans, and other potential chemicals of potential concern (COPCs). A summary of the background samples, locations, and the analytical suites the soils were sampled for is shown in Table B-1 in Appendix B of the RI Report. Appendix A of the RI Report presents the details of the data collected during RI sampling for background soil, and includes a map that depicts historical and RI background sampling locations (Figure A-1). The appendix also presents the statistics regarding calculated background concentrations for various constituents in the soil at Casmalia.

Soil and Sediment Sampling

As part of Phase I, Phase II, and Phase III RI sampling activities, the CSC collected on- and off-site soil samples and Site pond and off-site drainage sediment samples to further define the nature and extent of Site-related contamination and to evaluate potential health risks to human and ecological receptors. The soil samples were tested both for chemical analysis and for physical properties needed for risk assessment, groundwater modeling, the TI evaluation, and/or the FS.

The soil samples were collected at a combination of random and authoritative locations within the various study areas. Random samples from surface (0 to 6 inches) and shallow (5 feet) depths were collected to evaluate potential human and ecological risks across the Site. In areas of suspected contamination, authoritative samples were collected from surface and subsurface soils.

The CSC also collected bottom sediment samples using continuous core sample collection methods at 0 to 1 feet, 3 feet, and 5 feet, in each of the stormwater ponds and treated liquid impoundments. Like the soil samples, the pond sediment samples were analyzed for a variety of constituents. The sediment samples were also analyzed for grain size and total organic carbon (TOC) for use in the ecological risk assessment.

Appendix B of the RI Report presents the details of the data collected during RI sampling of Site soils and sediments, and includes maps depicting all RI soil and sediment sampling locations (Figures B-1, B-6, and B-21a). A summary of the samples, locations, and analytical suites that the soils were sampled for is shown in Tables B-1 and B-20 of Appendix B.

Soil Vapor Survey

The CSC collected soil vapor data at various locations throughout the Site to evaluate the inhalation exposure pathway for on-site workers and burrowing terrestrial mammals, and for potential off-site human receptors. Because the CSC expected the soil vapor concentrations to be greatest adjacent to the major Site sources, the data collection program targeted collecting data as close to the source areas as practicable and focused on the landfill areas of the Site.

The CSC collected the soil vapor data at depths representing the 0- to 10-foot-depth interval as well as depths of 20 feet (during the Phase II soil vapor sampling). These depths were chosen as a reasonable depth from which to model worker exposures and because 10 feet is the greatest depth where animals are likely to burrow. The soil vapor samples were collected using guidelines from the advisory on active soil gas investigations prepared by the California Environmental Protection Agency – Department of Toxic Substances Control (DTSC) and the Los Angeles Regional Water Quality Control Board (RWQCB) (DTSC and LARWQCB, 2003).

Appendix C of the RI Report presents the details of the data collected during the various phases of RI soil gas surveys, and includes a map depicting all soil vapor sampling locations (Figure C-1).

Following the Phase I soil vapor sampling, the CSC collected six additional soil vapor samples as part of Phase II sampling activities along the northern perimeter of the landfills that were co-located with three previous locations completed during Phase I sampling. After completing that sampling, the CSC completed three more soil vapor samples at step-out locations even further outboard from principal Site sources than the earlier samples.

Finally, to further assess whether the slightly elevated concentrations of COPCs that these step-out soil vapor sample locations continued to show, the CSC reoccupied the last three step-out locations and took additional soil vapor samples, which are reported in the RI Report.

Surface Water Data

As part of Phase I and Phase II RI sampling activities, the CSC collected surface water samples to supplement existing data to evaluate potential exposures to human and ecological receptors to on-site pond water in Zone 1 as well as water that may be present in the drainages within Zone 2. The RI sampling augmented existing information on surface water chemistry that was available from the previous National Pollution Discharge Elimination System (NPDES) Permit application as well as earlier Site studies. The surface water sampling included surface or stormwater runoff sampling from the off-site and on-site drainages, including the C-Drainage, B-Drainage, North Drainage, and the RCRA Canyon drainage, as well as sampling from the on-site treated liquids impoundments and stormwater ponds.

Where possible, the surface water drainage samples were collected at two time intervals: during the initial rainy season (October/November) and during the height of the rainy season (March/April), if possible. Surface water drainage samples were analyzed for full Appendix IX analyses. On-site ponds were sampled and tested in accordance with the ongoing Routine Groundwater Monitoring Element of Work for the Site.

The location identity of surface water samples are listed in Table D-1 and shown on Figure D-1 in Appendix D of the RI Report. Appendix D summarizes the surface water sampling results and the details of the data collected during RI sampling of surface waters.

Well and Piezometer Installation

The CSC installed several new groundwater wells and piezometers to both monitor chemical quality at specific locations on the Site and to augment the groundwater level information previously collected during Routine Groundwater Monitoring completed at the Site.

The location and identity of the new wells and piezometers are listed in Table E-1 and shown on Figure E-1 in Appendix E of the RI Report.

Appendix G of the RI Report summarizes the analytical results from the new chemical quality wells or additional wells for the RI/FS Work Plan, and includes a map depicting upper HSU and lower HSU chemical water quality monitoring locations (Figure G-1). Appendix G discusses the RI chemical quality sampling and puts these results into context with the groundwater sampling results collected as part of the Routine Groundwater Monitoring Element of Work at the Site.

Groundwater Level Data

As part of the RI process noted above, the CSC measured and reported groundwater levels from both existing wells and piezometers and from new wells and piezometers that were constructed for the RI/FS. Appendix F of the RI Report presents the details of the groundwater level data that were collected as specified in the RI/FS Work Plan, and includes maps depicting RGMEW water level monitoring locations (Figures F-1 and F-2).

RCRA Canyon Outcrop Assessment

As part of the Work Plan and the RI Report, the CSC summarized the geologic data that had been collected during previous investigations at the Site. To complement that previous work, the CSC reviewed the existing geologic information reported on the bedrock outcrop area in RCRA Canyon (which had originally been obtained and reported as a part of the Hydrogeologic Site Investigation Report - HSIR) and confirmed and field-verified that data by completing a RCRA Canyon Outcrop Assessment.

Appendix H attached of the RI Report presents the results of the RCRA Canyon Outcrop Assessment or survey, and includes a map depicting the area evaluated (Figure H-2).

Gamma Walk-over Survey

As described in Section 4.7.4 of the RI/FS Work Plan, as part of the Phase I RI activities the CSC assessed the presence of low-level radioactivity that would normally be associated with former oil-field waste spreading areas in RCRA Canyon. To establish background gamma readings, the CSC first conducted a walk-over gamma survey in off-site areas that were not impacted by the Site's activities (where background soil samples were collected). The CSC completed the walk-over gamma surveys using a sodium iodide (NaI) detector.

Appendix I of the RI Report presents the results of the gamma survey that was completed, and includes a map depicting the transects completed (Figure I-1). As described in more detail in the appendix, the CSC completed the background survey of the RCRA Canyon and compared those results with two off-site baseline survey lines that we had first performed. Comparison of the background transects to the RCRA Canyon transects indicated there were no “hot spots” in the RCRA Canyon Oil Spreading areas.

Clay Barrier Investigation

The CSC completed a drilling program to establish the depth and location of the P/S Landfill Clay Barrier during Phase I RI activities. As follow-up to the Phase I RI work, the CSC also conducted additional sampling of the clay in the barrier and performed permeability testing of the barrier materials during Phase II RI activities. The proposed drilling and sampling program was designed to identify the location of the black adobe clay barrier (both lateral and vertical barrier limits) and to confirm the permeability of the barrier as constructed.

Appendix J of the RI Report presents the details of the Phase I RI clay barrier investigations that the CSC completed, and includes a map depicting drilling and sampling locations, and the interpreted position of the clay barrier (Figure J-3). As described in more detail in the appendix, the CSC identified the top and extent of the clay barrier located at the southern boundary of the P/S Landfill.

CPT Signature/Lithology Correlations

During previous investigations, the CSC had used CPTs to evaluate the depth of the native claystone underlying waste and/or alluvium materials. At that time, the CSC reviewed tip resistance data or responses from previous on-site CPT activities with the EPA and generally agreed that an increase in tip resistance (Qc) to 200 tons per square foot (tsf) (over a several foot increment) and positive pore pressure (P_w) represented reaching the contact between the base of the waste and the top of the native claystone.

In order to confirm the CPT methodology, the CSC completed a program to evaluate CPT signatures and assess their effectiveness in identifying the upper HSU/lower HSU contact during the Phase I RI activities. The investigations included pushing 18 CPTs collocated with existing boreholes with existing good quality lithologic data on HSU contact depths.

Appendix K of the RI Report presents the results of the CPT signature/lithology correlation work completed as specified in the RI/FS Work Plan, and includes a map depicting the locations used in this comparison (Figure K-1).

Geophysical Surveys

The CSC proposed a number of geophysical survey alternatives in the RI/FS Work Plan to investigate the depth of the clay contact beneath the P/S Landfill. The issue is whether a closed depression or a “low spot” exists under the P/S Landfill where DNAPL might accumulate, rather than flow along the contact to the toe of the landfill where it would be collected and removed by the existing Gallery Well. The “low spot” issue has been a discussion point between the CSC and the USEPA since 2000, when the USEPA first expressed its concerns that such a depression, which had been previously reported by other agencies, might exist.

The CSC conducted a number of geophysics assessments to evaluate the depth and configuration of the clay contact, including:

- A Pilot Study of Seismic Reflection, Micro-Gravity, and Seismic Refraction;
- A Phase I Seismic Refraction Production Survey; andA Phase II Seismic Refraction Production Survey.

The Pilot Study results are presented in the RI/FS Work Plan and discussed in a separate Geophysical Experimental Plan that was submitted to the USEPA in 2004 (which is included as Appendix L, Attachment L-3 of the RI Report).

Following the pilot studies, the CSC performed a Site-wide Phase I Seismic Refraction Production Survey to investigate areas beyond the P/S Landfill for other potential low spots in the clay contact. The Phase I survey covered the Burial Trench Area, Central Drainage Area, and selected areas south of the Perimeter Source Control Trench (PSCT).

The Phase I Production Survey findings were first presented to the USEPA in February 2005 as Appendix L of the Interim Progress Report (IPR). The Phase I Seismic Refraction Production Survey details are also included in Appendix L of the RI Report.

On the basis of the two previous surveys, the CSC completed a Phase II Seismic Refraction Production Survey on the P/S Landfill as part of Phase II RI activities. The Phase II refraction work comprised a grid of 14 seismic lines centered on the bottom section of the P/S Landfill. Its purpose was to expand the data coverage provided by the two Pilot Study refraction lines so that a 3-dimensional picture of the clay contact surface could be generated.

After collecting the Phase II data, the CSC prepared tomographic models showing velocity layering in the subsurface along each of the seismic lines. These models were provided to the USEPA, along with the raw refraction data, in earlier submittals so the USEPA could perform its own independent modeling and analysis.

EPA and CSC differ on their interpretations of the tomographic models. As agreed with the agency, rather than debate the merits of either set of models, the CSC completed a series of instrumented CPTs at key points beneath the P/S Landfill and installed four piezometers at those locations where EPA suspected potential low spots or depressions.

The results of the CPT/piezometer follow-up work are reported in Appendix G of the RI Report.

Tier 2 Ecological Risk Assessment Sampling Event

For the Tier 2 ERA sampling event, the CSC collected biological tissue samples and co-located media samples during Spring 2009 in accordance with the *Next Steps for Ecological Risk Assessment* memorandum (ARCADIS, 2008) and accompanying Tier 2 ERA Sampling and Analysis Plan (CSC, 2009). The *Next Steps for Ecological Risk Assessment* memorandum (ARCADIS, 2008) provides the rationale and outlines the additional data collection to further evaluate pathways, receptors, and chemicals of interest (COIs) driving risk at the Site in order to refine risk estimates and make the ERA more Site-specific and less general. The Tier 2 ERA Sampling and Analysis Plan (CSC, 2009) details the field and laboratory methods to collect these data. The Tier 2 ERA sampling event included the collection and laboratory analysis of the following samples:

- Tissue samples – Plants, soil invertebrates, small mammals and aquatic invertebrates
- Co-located media samples – Soil and sediment

The completed Tier 2 ERA tissue sampling program is summarized in Table 3-10 of the RI Report. The Tier 2 ERA results are discussed in Section 9 and Appendix U of the RI report.

RI Results

Section 11 of the RI Report provides the findings and conclusions of the investigations and studies for the various media completed as part of the RI outlined above. Those discussions provide summaries of the information presented in earlier sections of the RI Report which are also detailed in the various appendices to the RI Report.

We have summarized that text and our conclusions regarding the nature and extent of contamination detected in the various environmental media below.

Soils

The sampling results from the various phases of RI soil sampling discussed earlier in this RI Report indicate that the majority of the study areas of the Site have some level of soil contamination attributable to former Site operations or facilities. The soil impacts are primarily associated with former disposal areas or previous Site facilities. The soils impacts are typically inorganic and/or organic contaminants and have been documented in the following study areas:

- Administration Building Area;
- Capped Landfills Area;
- RCRA Canyon Area;
- West Canyon Spray Area;
- Burial Trench Area;
- Central Drainage Area;
- Liquids Treatment Area;
- Maintenance Shed Area;
- Roadways Area; and
- Remaining On-site Area, including the Former Ponds and Pads Subarea.

The RI sampling program indicated there are no soil impacts of significance in off-site soils directly adjoining the Site. While high concentrations of organic constituents were detected in a sample from one location from within the Capped Landfills Area, this sample was collected from depths in excess of 70 feet below ground surface, lying within waste and beneath the engineered cap of P/S landfill.

The locations where constituents were found to exceed Site-specific Human Health and/or Ecological risk-bases concentrations in soil (HH RBCs and Eco RBCs, respectively) are much more widely distributed across a larger number of study areas for inorganic constituents than for organic constituents. Inorganic constituents found to exceed Eco RBCs in surface and shallow soil at the Site are limited to barium, chromium, copper, and zinc. No inorganics were found to exceed their respective HH RBCs. Barium and copper are widely present in excess of their respective Eco RBCs in surface and to a lesser extent shallow subsurface soils in both the RCRA Canyon Area and the West Canyon Spray Area. Such exceedances for chromium and zinc are less frequent and widespread. Other study areas found to have one or more of these inorganic constituents in exceedance of their respective Eco RBCs include the Burial Trench Area, Liquids Treatment Area, Central Drainage Area, Maintenance Shed Area, Roadways Area, and Remaining On-Site Area (including Former Ponds and Pads Sub Area). Significantly, however, in comparison to those in the RCRA Canyon Area and the West Canyon Spray Area, Eco RBC exceedances in these other study areas are typically more localized, occurring in only one to several discrete sampling locations, or clusters of sampling locations.

The number and distribution of surface and/or shallow soil sampling locations with organic constituents in excess of Site-specific RBCs is much more limited that that for inorganics. RBC exceedances for organics were limited to portions of six study areas, including the Burial Trench Area, Liquids Treatment Area, Central Drainage Area, Maintenance Shed Area, Roadways Area, and Remaining On-Site Area (including Former Ponds and Pads Sub Area). In strong contrast to inorgcanics, no organic constituents were encountered in excess of their respective HH RBCs or Eco RBCs in either the RCRA Canyon Area or the West Canyon Spray Area. Organic constituents found to exceed RBCs include total DDT, dioxin toxicity equivalent (TEQ) (Mammalian), MCPP, total PCB congeners, and trichloroethylene, tetrachloroethylene (PCE). Each of these organic constituents were found to exceed their respective Eco RBC in one or more locations within the above-listed study areas, whereas HH RBCs exceedances were limited to dioxin TEQ, MCPP, and PCE in only discrete single sample locations within the Central Drainage Area, Liquids Treatment Area, Maintenance Shed Area, and the Remaining On-Site Area (including Former Ponds and Pads Sub-area). With the exception of total DDT which has a more broad and scattered distribution of exceedances, the majority of organics RBC exceedances occur within the central portion of the Site in proximity to the toe of the P/S Landfill or former waste management units within the Central Drainage area and Former Ponds and Pads Subarea proximal to the PSCT. In general, organics RBC exceedances occur in isolated single or several clustered sampling locations.

With a few noted exceptions, the depth and lateral extent of soil impacts in excess of RBCs has been adequately defined across the Site. Elevated inorganic constituents are mostly restricted to surface or shallow to medium depth soils (i.e., 0 to 10 feet below ground surface [bgs]), and typically demonstrate diminishing concentrations with increased depth. Exceptions to this general condition include high barium concentrations to depths of at least 24 feet bgs in the northern portion of the RCRA Canyon Area, localized occurrences of other elevated inorganics at depths of at least 20 feet bgs in several borings completed in the Maintenance Shed Area

and the Administration Building Area, and inorganics impacts in excess of 10 feet bgs in portions of the Central Drainage Area. Elevated concentrations of inorganic and organic constituents are also present in medium to deep soil in the vicinity of location RISBON-59, where soil impacts are locally found to extend to depths of at least 30 feet bgs (inorganics) and 55 feet bgs (organics). Elevated inorganics concentrations were also locally encountered at depths of at least 49 feet bgs along the southeastern margin of the Site, along NTU Road south of the RCF Pond.

High concentrations of organic constituents, principally VOC, polycyclic aromatic hydrocarbons (PAHs) and/or PCBs, also locally present to the maximum depths explored in several borings completed in proximity to former waste management facilities within the Central Drainage Area, the Former Ponds and Pads Sub-area and the Burial Trench Area. High organics concentrations are present to depths of at least 20 feet bgs near former Ponds A and B just south of the PSCT, to depths of at least 5 feet bgs in a cluster of shallow borings completed north of the western end of the RCF Pond, to depths of at least 5 feet bgs in a cluster several shallow soil borings just south of PSCT-1, and to depths of at least 48 feet bgs in the area between the toe of the P/S Landfill south to the PSCT. High VOC concentrations extending to depths of greater than 40 feet bgs in the Liquids Treatment Area are attributable to collection of these soil samples below the local water table, and likely reflect influences of contaminated groundwater present in the area.

Maximum VOC concentrations were encountered in a boring completed within the approximate limits of former Pond B, followed by several deep borings completed in the Burial Trench Area. The maximum depth of soil impacts on Site was encountered in the Burial Trench Area where former deep waste disposal operations have resulted in elevated inorganics concentrations in soil at depths of up to 44.75 feet bgs, and elevated organics concentrations at depths of up to 77.5 feet bgs.

It should be noted that while there may be a few individual samples in a Study Area that exceed a RBC, the Study Area as a whole may not pose a significant risk due to the use of the 95-percent upper confidence limit (95UCL) concentration in the ERA and HHRA. Moreover, it is important to note that elevated constituent concentrations encountered at depths in excess of 10 feet bgs are not pertinent to human health or ecological risks, as there are no complete exposure pathways to potential receptors.

The lateral extent of soil impacts in these above-listed areas is adequately defined by soil samples from surrounding borings that do not indicate significant contaminant concentrations. While the maximum depth of soil impacts has not been demonstrated in all these locations, with few exceptions, field observations and analytical results for the majority of borings completed across the Site indicate that soil impacts typically diminish with increased depth beneath the surface. Moreover, in those locations where sufficiently deep data area available, these data typically indicate that soil impacts do not persist appreciably below the contact between the upper weathered claystone and the underlying lower unweathered claystone.

The CSC has reviewed the soil data collected during the RI and considers this data sufficient to characterize the nature, and the extent, of impacts to this media. As described in this report, the review of available inorganics data for background locations, as well as for off-site and on-site areas, indicate that there are more than sufficient numbers of samples (i.e., high power) and adequate spatial distribution of samples to perform the necessary additional statistical

evaluations (e.g., calculate UCLs) that factor into the human health and ecological risk assessments to be conducted as part of the RI. Lithologic conditions across the Site have been adequately defined, and in conjunction with soil physical property data and the chemical data developed to date, provide the information needed to evaluate fate and transport of the contaminants present in the various study areas, and provide sufficient data with which to complete the forthcoming Feasibility Study.

Results of surface soil samples collected in the Off-site Area indicate these materials have not been significantly affected by historical Site operations or existing on-site conditions. Soil conditions in the Off-site Area have been adequately characterized, and no additional data are necessary.

Sediments

While inorganic constituents were present in sediment samples collected from the various on-site ponds and off-site drainages, none were identified to be risk-driving chemicals, thus no RBCs were established for inorganics in sediment. Only one organic constituent – MCPP – was detected in on-site sediments at concentrations in excess of its Eco RBC. No HH RBCs were exceeded for any on-site or off-site sediment samples tested. MCPP is present above its Eco RBC in surface to shallow sediments (i.e., 0 to 5 feet bgs) in the following on-site ponds:

- RCF Pond;
- Pond A-5; and
- Pond 18.

Organics RBC exceedances for on-site sediments are limited to single, isolated sample locations in the above-listed ponds. No organic constituents were detected above their respective RBCs in the A-Series Pond, Pond 13, nor in sediment samples collected from within off-site drainages.

While inorganic constituents, and to a lesser extent organic constituents, were locally detected in some off-site drainage sediment samples, none were reported at levels in excess of established RBCs. Moreover, the positions of these off-site sediment samples in locations situated either upstream or distal from the Site, indicate these occurrences are likely not Site-related.

The depth of chemical impacts in excess of Site-specific RBCs has been adequately defined in all on-site and off-site sediment sampling locations. Sediment data collected during the RI are considered sufficient to characterize the nature and extent of impacts to this media, and no further sediment data are judged to be necessary. Sediment conditions within across the Site and in off-site areas have been adequately defined, and in conjunction with sediment physical property data and the chemical data developed to date, provide the information needed to evaluate fate and transport of the contaminants present in sediment, and provide sufficient data with which to complete the Feasibility Study.

Soil Vapor

VOC concentrations above sample quantitation limits were reported at all soil vapor sample locations, including both on-site and off-site step-out locations. A total of 43 individual VOCs were detected at the various sampling locations around the perimeter of the landfills, the Burial

Trench Area, and Central Drainage Area, including chlorinated and aromatic hydrocarbons, acetone, methyl ethyl ketone and Freon gases. With only few exceptions, those VOCs detected in off-site step-out locations were also reported to be present in on-site sampling locations. Chemicals detected in soil vapor that demonstrate some of the highest prevalence and reported concentrations, or that may contribute to human health or ecological risk, include acetone, methyl ethyl ketone, Freon 113, benzene, 1,3-butadiene, and tetrachloroehtylene. Maximum concentrations of these chemicals were encountered along the eastern and northeastern limits of the Capped Landfills Area (acetone and 1,3-butadiene), south of the PSCT below the Maintenance Shed Area (1,3-butadiene and benzene), the western limit of the Central Drainage Area and eastern margin of the Burial Trench Area (Freon 113), the southern and western Central Drainage Area (tetrachloroethylene), as well as west of the Burial Trench Area, the northwestern limit of the Capped Landfills Area, and two locations along the PSCT south of the Central Drainage Area and Burial Trench Area (methyl ethyl ketone).

The locations of the samples with elevated concentrations on Site are consistent with previously identified source areas at the Site, including the existing capped landfills, Burial Trench Area, former Pond R where waste was not removed, and the PSCT which has historically contained free product.

The presence of detectable levels of these chemicals in soil vapor at the Site does not pose unacceptable risks to on-site human receptors. Soil vapor concentrations in adjacent off-site locations could result in marginally elevated risks to hypothetical off-site residents via the vapor intrusion pathway, however this exposure is unlikely due to restrictions in residential development that will be put in place. Soil vapor conditions are not considered to cause adverse effects on on-site or off-site ecological receptors.

The soil vapor sampling conducted at several different times at the same off-site locations does not indicate any obvious temporal trends, and no general concentration trend with respect to depth was observed. The CSC has begun a long-term soil vapor monitoring program at three off-site locations to continue to track the slightly elevated chemical concentrations discussed above. That soil vapor sampling will continue to look for temporal trends and to confirm the concentrations do not pose unacceptable risk.

Surface Water

A total of 16 out of 27 inorganic constituents tested were reported in benchmark sampling locations in the North Drainage and upper C-Drainage at dissolved concentrations in excess of one or more screening levels. With few exceptions, for a given sampling period reported values for these constituents in benchmark locations indicate concentrations in the North Drainage are typically elevated relative to those in upper C-Drainage. Noted differences in dissolved inorganics concentrations between these two benchmark locations are likely attributable to soil and hydrologic conditions unique to the North Drainage, and are affected by seasonal factors relating to rainfall and stormwater runoff. Detections of organic compounds in the benchmark locations were mainly limited to several SVOCs and dioxins reported at levels slightly in excess screening levels.

Available data generally indicate that surface water samples collected in the North Drainage contain a larger variety of constituents at overall higher concentrations than comparable samples collected from other off-site and on-site drainages. The notable exceptions to this

general condition include the presence of arsenic, molybdenum, nickel, selenium and N-Nitrosodipropylamine at maximum reported concentrations within surface water from the RCRA Canyon drainage, and the unique presence of acetone and acetonitrile in the RCRA canyon drainage relative to all other surface-water sampling locations.

Surface water within the on-site ponds contains relatively low levels of organic compounds, though some VOCs, SVOCs, and PAHs are commonly detected at elevated concentrations. Concentrations of chlorinated VOCs are generally low to non-detect. Of the inorganic analytes, arsenic, nickel, chromium and selenium are commonly detected at elevated concentrations. Of the ponds sampled, Pond 13 has the highest concentrations of dissolved metals. Total dissolved solids (TDS) concentrations within the ponds have historically been higher than those observed in the off-site drainages and RCRA Canyon, due to the concentration of salts within the ponds that occurs as the water within them evaporates. With few exceptions, inorganic constituents in surface water within on-site ponds are reported to be elevated relative to those present in on-site of off-site drainages. TDS concentrations in on-site ponds are uniformly and consistently higher that corresponding concentrations reported for on-site and off-site drainages. In general, concentrations of inorganic constituents in the on-site ponds have gradually increased over time since the 1997/1998 El Nino winter, with annual fluctuations corresponding to seasonal conditions.

Groundwater and Nonaqueous Phase Liquids

The distribution of groundwater contamination is predominantly located within Zone 1 boundary with little to no contamination in Zone 2. Groundwater contamination consists of nonaqueous phase liquids (NAPLs) and dissolved-phase organic and inorganic contamination. NAPLs at the Site consist of both light nonaqueous phase liquids (LNAPLs) and dense nonaqueous phase liquids (DNAPLs). Both types are present within Zone 1 as a mobile (free) phase and immobile (residual) phase. LNAPLs are lighter than water and float on the water table while DNAPLs are heavier than water and are found over 100 feet below the water table in the Central Drainage area. Constituents identified in LNAPL, DNAPL, and dissolved-phase contamination in groundwater include metals, VOCs, SVOCs, pesticides, herbicides, PCBs, and dioxins. The distribution of NAPL and dissolved-phase contaminants in groundwater is controlled by the physical characteristics of the groundwater flow system, contaminant source areas, contaminant properties, ongoing liquids extraction from several extraction facilities.

Groundwater Flow

Groundwater flow primarily occurs in the Upper Hydrostratigraphic Unit (HSU), a layer of weathered claystone that overlies the Lower HSU, a block of lower permeability unweathered claystone that occurs to a depth of more than 1,000 feet. Localized, moderately permeable alluvium occurs along current and former drainage bottoms, and is considered part of the Upper HSU when saturated. Flow in the Lower HSU occurs through interconnected fractures. The interconnectivity of these fractures is uncertain on a site-wide scale. On a local scale, the presence of both dissolved-phase VOCs and DNAPL more than 100 feet below the top of the Lower HSU demonstrates that fractures are interconnected on a local scale. Detailed unweathered claystone core logging, borehole video logging, and borehole geophysics show that the unweathered claystone is variably fractured, with fracture density generally decreasing with depth. However, the degree of Lower HSU fracture interconnectivity and the ability of the fracture network to transmit groundwater (and contaminants) cannot be definitively quantified

because of the inherent variability the fractures between boreholes. The decrease of fracture density with depth and limited fracture connectivity suggest that fractures terminate at depth and act as areas of dead-zone storage.

From the North Ridge, groundwater within the Upper HSU flows southward across the primary source areas (five landfills, burial trench area, and former waste ponds and pads) towards the Perimeter Source Control Trench (PSCT) where contaminated liquids (groundwater) are extracted, treated onsite using granular activated carbon (GAC), and discharged to Pond 18. Contaminated liquids (groundwater, LNAPL, and DNAPL) are extracted from the Gallery Well at the southern toe of the P/S Landfill and from Sump 9B between the P/S Landfill and the PSCT. The Gallery Well and Sump 9B liquids are sent offsite for disposal.

Groundwater within the Upper HSU in the RCRA Canyon and groundwater south of the PSCT flows southward toward the five ponds that occur at the south part of RCRA Canyon and between the PSCT and three Perimeter Control Trenches (PCTs). When the ponds are relatively full they may act as a source of groundwater recharge and when relatively empty they may act as a source of groundwater discharge. The ponds are currently relatively empty. Groundwater extraction at the A-, B-, and C-Drainage PCTs controls groundwater from moving offsite into these drainages. Surface water from the A-Series Pond and Runoff Control Facility (RCF) are significant recharge sources to the PCTs. Extracted groundwater from the PCTs is discharged to the A-Series Pond and RCF.

Vertical downward hydraulic gradients and some groundwater flow occurs from the Upper HSU into the lower permeability Lower HSU in the upland areas. Onsite, these downward gradients occur under the North Ridge and extend southward toward the PSCT. The vertical groundwater gradients are more neutral between the PSCT and PCTs. Localized upward hydraulic gradients occur along certain portions of the PSCT and PCTs in response to liquids extraction at these facilities. Localized upward gradients also occur in the Central Drainage Area between the Gallery Well and the PSCT. Neutral to upward gradients are present in the RCRA Canyon and at the offsite drainages. The upward gradients in combination with liquid extraction and containment features (PSCT and PCTs) act to restrict contamination to onsite.

Groundwater Contamination

In the Upper HSU, the levels of contamination are separated by the North Ridge groundwater flow divide between Zone 1 and Zone 2, liquids extraction at the PSCT within Zone 1 and by liquids extraction at the PCTs between Zone 1 and Zone 2. The Zone 1 area north of the PSCT contains the majority of the dissolved phased contamination and all of the known NAPL contamination. There is a potential for DNAPL to occur outside of this area due to DNAPL migration from the P/S Landfill or Central Drainage Area source(s) areas through Lower HSU fractures. However, potential fracture pathway likely have steep angle, and no DNAPL has been observed to daylight at surface fractures or seeps.

Dissolved-phase contaminants that originate in the northern uphill portions of the Site, migrate southward with groundwater, primarily through the Upper HSU and toward the PSCT. Contaminants from the P/S Landfill, Metals Landfill, Caustics/Cyanide Landfill and Acids Landfill converge downhill towards the Central Drainage Area and into the PSCT in the PSCT-1 area. Contaminants from the PCB Landfill and Burial Trench Area flow south into the PSCT in the PSCT-4 area. In the perimeter areas, within Upper HSU groundwater, VOCs are sporadically

detected at low concentrations along the North Ridge and slightly into the North Drainage and the A-, B- and C- drainage areas. Following operational closure of the facility, VOC movement within the Upper HSU is consistent with groundwater flow patterns.

The P/S Landfill and Central Drainage Area are the only areas of the Site where both free-phase (mobile) DNAPL and LNAPL in the Upper HSU were observed during drilling, gauged in routine liquid level monitoring, and implied based on dissolved chemistry. The Central Drainage Area is the only area of the Site within the Lower HSU where DNAPL was gauged in routine liquid level sampling and implied based on dissolved chemistry. There is also a significant area of contamination located in the Burial Trench Area that extends from its upgradient reach at the southern toe portion of the PCB Landfill, and flows downgradient into the PSCT. The Burial Trench Area was investigated for the presence of DNAPL and LNAPL, and although dissolved VOC concentrations are relatively high in this area, no wells or piezometers were observed to contain NAPL during liquids level monitoring.

Significant volumes of free-phase LNAPL and DNAPL occur within the P/S Landfill. Approximately 3,000 to 4,000 gallons of DNAPL and minor volumes of LNAPL have historically been extracted and continue to be extracted from the Gallery Well within the P/S Landfill. The rate of DNAPL extraction has been relatively stable for over 10-years, indicating that a significant volume of free phase DNAPL occurs in the landfill. DNAPL thicknesses ranging from approximately 5 to 14 feet in piezometers within the southern end of the P/S Landfill indicate that there may be greater than 100,000 gallons of free-phase DNAPL in the landfill.

Several feet of DNAPL are currently present in two Lower HSU piezometers located approximately 500 feet south of the P/S Landfill and 150 feet north of PSCT-1. This DNAPL potentially migrated from one of two potential Upper HSU source areas through Lower HSU fractures to arrive at this location and depth. One potential DNAPL source is the large volume of known free phase DNAPL within the P/S Landfill. The other potential DNAPL source is the area of former Pads 9A and 9B located between the P/S landfill and PSCT-1, although no free phase DNAPL is known to exist in this area. The vertical extent of free phase DNAPL in the Lower HSU is not known with certainty. However, of the 408 boreholes that explored the Lower HSU, fracture connectivity between boreholes is difficult to demonstrate. The one exception that has allowed NAPL movement likely occurred in the Central Drainage area as evidenced by the orientation of the fractures to neighboring boreholes (as measured in borehole RI-SB-2) and presence on NAPL in the Sump 9B, RI-SB-2 and RGPZ-7C/D boreholes.

Historical trends of VOCs at nearby wells indicate that the PSCT, in combination with natural attenuation mechanisms, appears to contain and capture the VOC contamination north of the PSCT; over time VOC trends in wells south of the PSCT appear to be declining.

Upper HSU VOC contamination in groundwater south of the PSCT is the highest south of PSCT-1 and PSCT-4, and is typically one to two orders of magnitude lower in concentration than the concentrations observed in the Burial Trench Area and the Central Drainage Area. The VOC contamination may be residual contamination that existed in-place prior to the PSCT being installed. The VOC contamination sharply declines north of the current Ponds, and is generally not detected south of the five open ponds.

The majority of the samples collected from the Lower HSU did not contain VOC concentrations in excess of the cleanup levels. However, areas of VOC presence in the Lower HSU primarily

include: The Central Drainage Area; the Burial Trench Area; the southern edge of the Acids Landfill; along the PSCT; along the North Ridge; and northeast of the Caustic/Cyanide Landfill. The Central Drainage Area contains the greatest amount of VOC contamination in the Lower HSU, and this contamination appears directly related to overlying Upper HSU VOC contamination present between the P/S Landfill and PSCT. The greatest number of VOC cleanup level exceedances in the Central Drainage Area Lower HSU was detected in piezometer RGPZ-6D, which may be related to the Lower HSU DNAPL detected in nearby RGPZ-7C and RGPZ-7D. . The Lower HSU location with the second greatest number of VOC exceedances is piezometer RIPZ-16, located in the Burial Trench Area. The remainder of Lower HSU wells with infrequent to few VOC exceedances occur along the PSCT, along the North Ridge, and northeast of the Caustic/Cyanide Landfill.

Dissolved concentrations of arsenic and other metals are elevated within the Zone 1 boundary but are generally not elevated in Zone 2. Similar to VOCs, the higher concentrations of metals in the Upper HSU are located north of the PSCT. Elevated levels also occur south of the PSCT. Unlike the general absence of these VOCs in the ponds and PCTs, however, TDS (salts) and metals are significantly elevated within surface water in the five onsite ponds, groundwater extracted at the PCTs, and other groundwater monitored at other monitoring wells in the vicinity of the ponds and PCTs. Pond surface water is a recharge source to the PCTs. The concentrations of the salt and metals in the ponds that have been increasing due to evaporation since the 1997/98 El Nino winter are causing similar increases in metals and salts in the PCTs and area monitoring wells.

Metals concentrations in the Lower HSU are generally lower than in the Upper HSU; the highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the border of Zone 1 and Zone 2. The metal concentrations in the Lower HSU do not appear to coincide with the potentially elevated Upper HSU concentrations.

Risk Assessments

Section 11 of the RI Report also provides the findings and conclusions of HHRA and the ERA. Those results are discussed in more detail in Appendix T (HHRA) and Appendix U (ERA) of the RI Report.

We have summarized that text and our conclusions regarding the HHRA and the ERA in the paragraphs that follow.

Human Health Risks

The COPCs evaluated in the HHRA include inorganics, PCBs, dioxins, herbicides/pesticides, PAHs, SVOCs, and VOCs. The HHRA considered potential exposure scenarios that included inhalation of indoor air and outdoor air vapors, inhalation of particulates, dermal contact with surface water, and exposure via direct contact to soils and sediment.

The results of the HHRA indicate that the following COPCs are primary risk drivers:

- On-site Soils:
    - MCPP;

  - Tetrachloroethylene; and
  - Trichloroethylene.

- Surface Water (On-site Ponds):
  - Arsenic.

For on-site soils, only the Former Ponds and Pads sub-area (FPP) and Liquid Treatment Study Areas exhibited elevated risk estimates for commercial/industrial worker exposures. PCE in shallow soil was the primary risk driver for the FPP Study Area, and MCPP was the primary risk driver for both surface and shallow soils at the Liquids Treatment Study Area. Both of these chemicals are present at elevated concentrations in localized areas within these Study Areas.

For the hypothetical off-site resident, only the Burial Trench, Central Drainage, and FPP Study Areas exhibited elevated risk estimates from potential exposures from the transport of on-site soil contamination via windborne vapors. The primary risk drivers were tetrachloroethylene and trichloroethylene which are both present at elevated concentrations in localized areas within the Study Areas. It should be noted that as discussed in the Uncertainty Section of the HHRA, the hypothetical off-site resident evaluation is overly conservative, as the calculations assume the resident is located adjacent to the Study Area being evaluated. For hypothetical off-site residential exposures to off-site soil, sediment and soil vapor, only the vapor intrusion pathway resulted in a marginally elevated risk estimate. The primary risk driver for this pathway was 1,3-butadiene.

For off-site soils/sediments cancer risk and noncancer hazard estimates for recreational and rancher exposures were below a cancer risk level of 1×10^{-6} and a noncancer hazard of 1.

Potential cumulative cancer risk and noncancer hazard estimates exceeded target health levels because of a few locations within a few Study Areas at the Site. The sample locations that contributed the majority to the risk estimates were RISBON-37, RISBON-41 and RISBON-63 in the FPP Study Area just south of the PSCT, RISBLT-02 in the Liquids Treatment Study Area, RISBCD-07 in the Central Drainage Study Area and RISSBC-05 in the Burial Trench Study Area. These results indicate that Site cleanup, engineering controls and/or institutional controls should mitigate potential risks associated with these localized areas.

Arsenic concentrations detected in several on-site surface-water impoundments, including the A-Series Pond, Pond 13 and the RCF, are estimated to pose a potentially unacceptable risk to on-site commercial/industrial workers. The potential exposure pathways for on-site and off-site surface drainage waters is considered incomplete, therefore no unacceptable risks are anticipated.

<u>Ecological Risks</u>

Tier 1 ERA

Overall, the results of the Tier 1 ERA identified that risks to terrestrial birds at the Site are driven mainly by:

- Barium in the RCRA Canyon Area and the Former Ponds and Pads Area;
- Cadmium in the RCRA Canyon Area and West Canyon Spray Area (WCSA);
- Chromium in the RCRA Canyon Area, Roadway Area, and WCSA;

- Copper in the RCRA Canyon Area, and WCSA;
- Lead in the RCRA Canyon Area, Roadway Area, and WCSA;
- Zinc in the RCRA Canyon Area and WCSA;
- Aroclor 1260 in the Roadway Area; and
- Total PCBs in the Former Ponds and Pads Areas.

We have attached Tables ES-1 through ES-3 to this Executive Summary that identify ecological risk drivers by area.

Based on the results of the Tier 1 ERA, the invertivorous bird (based on the invertivorous meadowlark) was predicted to be the most sensitive terrestrial bird to potential adverse effects from exposure to these chemicals in soil 0 to 0.5 feet bgs, except for the herbivorous bird (based on the herbivorous meadowlark) from barium. Further evaluation was warranted for these risk drivers in the exposure areas listed above, for which no presumptive remedies are planned.

Tier 1 risks to terrestrial mammals at the Site are driven mainly by:

- Barium in the RCRA Canyon Area;
- Cadmium in the RCRA Canyon Area and WCSA;
- Chromium in the RCRA Canyon Area, Roadway Areas, and WCSA;
- Copper in the RCRA Canyon Area, Roadway Areas, and WCSA;
- Zinc in the Roadway Area, RCRA Canyon Area and WCSA;
- Aroclor 1260 in the Roadway Areas; and
- Total PCBs in the Former Ponds and Pads Areas.

Based on the Tier 1 ERA, the invertivorous mammal (based on the shrew) was predicted to be the most sensitive terrestrial mammal to potential adverse effects from exposure to metals in soil 0 to 5 feet bgs. The carnivorous mammal (based on the skunk) was predicted to be the most sensitive terrestrial mammal to potential adverse effects from exposure to organics in soil 0 to 5 feet bgs. Potential adverse risk to deep burrowing mammals (0 to 10 feet bgs) via inhalation of burrow air or by ingestion of soil is expected to be unlikely from exposure to chemicals at the Site. Further evaluation was warranted for these risk drivers in the exposure areas listed above, for which no presumptive remedies are planned.

Tier 1 risks to terrestrial ecological communities (plants and soil invertebrates) at the Site are driven mainly by:

- Barium in the RCRA Canyon Area the Former Ponds and Pads Area;
- Chromium in the RCRA Canyon Area, Roadway Area, and WCSA;
- Copper in the RCRA Canyon Area, Roadway Area, and WCSA; and
- Zinc in the RCRA Canyon Area and WCSA.

Tier 1 risks to aquatic wildlife at the Site are driven mainly by:

- Chromium, manganese selenium, and vanadium in A-Series Pond;
- Barium and selenium in Pond A-5;
- Selenium in Pond 18; and
- Barium in RCF Pond.

Based on the Tier 1 ERA, the invertivorous bird (based on the killdeer) was predicted to be the most sensitive aquatic bird to potential adverse effects from exposure to these chemicals in surface sediment. However, all of these risk drivers are based on the maximum detected concentrations and may be overestimating potential risk to aquatic wildlife. Additionally, the diet for the aquatic wildlife was based on a mixture of sediment invertebrates and aquatic invertebrates, assuming 50% of each, and this general assumption could potentially introduce uncertainty to the risk estimates.

Tier 1 risks to sediment-dwelling invertebrates at the Site are mainly by:

- Cadmium in the A-Series Pond, Pond 18, and Pond A-5;
- Nickel in A-Series Pond, Pond 13, Pond 18, and Pond A-5;
- Selenium in A-Series Pond, Pond 18, and Pond A-5;
- MCPP in RCF Pond, Pond 18, and Pond A-5;
- Acetone in RCF Pond; and
- 1,1-Dichloroethane in Pond A-5 and RCF Pond.

Based on the Tier 1 ERA, potential risk to aquatic life, aquatic plants, and amphibians are mainly from metals in the on-site ponds. Risks to amphibians for the RCRA Canyon runoff were estimated based on a conservative scenario. This scenario evaluated the potential risk to aquatic receptors under the hypothetical scenario that water pools in RCRA Canyon, which based on Site observations, does not occur under current Site conditions. Additional evaluations of RCRA Canyon runoff and the potential for pooling once a remedy is in place for A-Series Pond will be evaluated in the FS. The seeps are currently dry and onsite facilities (e.g., Sump 9B and Road Sump) are in place to control these seeps. Therefore, onsite seeps are not expected to be sources of exposure to amphibians, aquatic life, or aquatic plants.

Risks to aquatic life in surface water from the RCRA Canyon runoff are from:

- Arsenic, barium, cadmium, selenium, vanadium, benzo(b)fluoranthene, and ethylene glycol.

Risks to amphibians in surface water from the RCRA Canyon runoff are from:

- Arsenic, barium, beryllium, cadmium, chromium, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

Risks to aquatic plants in surface water from the RCRA Canyon runoff are from:

- Arsenic, cadmium, nickel, and selenium.

All of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the Site and will be backfilled/graded to prevent accumulation of water, they will be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all on-site ponds will be further detailed as part of the FS process. Therefore, none of the chemicals in the ponds with HQs greater than 1 were identified for further evaluation.

Tier 2 ERA

As discussed in Appendix U of this report, after completing and reporting the Tier 1 ERA in the draft RI Report, the CSC completed a Tier 2 ERA to further evaluate pathways, receptors, and chemicals of interest (COIs) requiring further evaluation (risk drivers), which included additional studies and evaluations designed to make the ecological risk assessment more Site-specific and less generic.

The Tier 2 ERA included the following additional data collection and further evaluation efforts to further refine the ecological risks at the Site :

- Tissue sampling (plants, soil invertebrates, and/or small mammals); and
- Refinement of ecological benchmarks, including developing tissue toxicity reference values (TRVs) to use as additional weight-of-evidence in the risk characterization. Bioavailability tests were also recommended.

The results of the Tier 2 assessment are discussed in detail in Section 9 and Appendix U of this RI Report. As those sections note, we have been able to further evaluate the areas of the Site that showed unacceptable risks narrowed the areas of concern as well as the COPCs.

A Tier 2 assessment was conducted to further evaluate pathways, receptors, and risk drivers or COIs based on the results of the Tier 1 assessment. The Tier 2 assessment was conducted by building on the results of the Tier 1 assessment and incorporating Site-specific tissue and bioaccumulation data. The objectives of Tier 2 were to provide valuable information for refining risks, reduce the overall uncertainty in the risk estimates by incorporating Site-specific information into exposure estimates, and to provide additional lines of evidence to provide a clearer understanding of the environmental benefit of reducing concentrations at the Site.

The Tier 2 ERA focused on the COIs, receptors, and exposure areas for which there is no presumptive remedy planned or contemplated. The Tier 1 ERA predicted that invertivorous bird and mammal populations were the most sensitive terrestrial wildlife, and their risks were driven by exposure to chemicals in surface soil. The aquatic invertivorous bird (based on the killdeer) was generally predicted to be the most sensitive aquatic bird, exposed to chemicals in surface sediment. The risks to aquatic birds are similar with those for terrestrial birds when the Tier 1 ERA was conducted assuming the ponds would be drained. The pathway that generally contributed most to the risk estimate for all wildlife was food ingestion.

As discussed above, presumptive remedies will be in place as part of the USEPA-approved closure plan for the Site for the treated liquid impoundments (Pond 18 and Pond A-5). Also, as part of the USEPA-approved closure plan for the Site, a potential remedy for the stormwater ponds or impoundments (A-Series Pond, RCF Pond, and Pond 13), Central Drainage Area, Liquid Treatment Area, Burial Trench, and Maintenance Shed areas are also likely to be implemented and will be further detailed as part of the Feasibility Study process. Therefore, the Tier 2 ERA focused on the remaining exposure areas and COIs, which included:

- Administration Building Area;
- RCRA Canyon;
- West Canyon Spray Area;

- Roadway Areas;
- Remaining On-site Areas; and
- Former pond and pad areas south of the PSCT.

Overall, the results of the Tier 2 ERA identified that risks to terrestrial birds at the Site are driven mainly by:

- Barium, chromium, copper, and zinc in the RCRA Canyon Area; and
- Chromium, copper, and zinc in the WCSA.

The invertivorous bird (based on the invertivorous meadowlark) is predicted to be the most sensitive terrestrial bird to potential adverse effects from exposure to these chemicals in soil 0 to 0.5 feet bgs except for the herbivorous bird (based on the herbivorous meadowlark) from barium.

For terrestrial mammals, a comparison of site-specific tissue data to tissue-based TRVs developed for kidney and liver tissue indicates that cadmium, chromium, copper, lead, and zinc are not expected to accumulate in target tissues at levels that would result in potential adverse risks. Tier 2 risks to terrestrial mammals at the Site are driven mainly by:

- Barium in the RCRA Canyon Area.

The invertivorous mammal (based on the shrew) is predicted to be the most sensitive terrestrial mammal to potential adverse effects from exposure to metals in soil 0 to 5 feet bgs.

The results of the spatial analysis indicate that for all receptors, potential risk from barium is the most wide-spread in the RCRA Canyon Area and sample-specific risks for the other receptors are co-located in RCRA Canyon and tend to be located on the west side of RCRA Canyon. In the WCSA, sample-specific risks are generally located in the central portion of WCSA and are co-located among receptors. Barium is the only COI in the Former Ponds and Pads Areas and the potential for cumulative risk to soil invertebrates beyond those identified for barium are likely minimal.

Preliminary Technical Impracticability Evaluation

As part of the Feasibility Study, the CSC plans to evaluate and consider proposing a Technical Impracticability (TI) waiver zone for groundwater restoration as provided in Section 2.9.2.2(K) of the Casmalia Consent Decree. This section of the Consent Decree provides the following performance standard:

> *Perform an analysis, substantiated by data and other evaluation information, consistent with 300.430(f)(ii)(C) of the NCP and the Guidance for Evaluating the Technical Impracticability for Groundwater Restoration. EPA Directive 9234.2-25, of the technical impracticability of restoring the groundwater in the Zone 1 area.*

EPA has not approved any TI waiver for the Casmalia site. EPA will review and consider the CSC's planned TI waiver zone evaluation for groundwater restoration based on information provided in the RI Report, the FS Report, and any other information deemed necessary by EPA. EPA will make an evaluation of whether a TI waiver is appropriate for the Casmalia site only

after all necessary information has been provided and reviewed.

As part of the RI, the CSC performed a Preliminary Technical Impracticability Evaluation (TIE) to evaluate whether groundwater restoration at the Casmalia Site is potentially attainable from an engineering perspective as discussed in EPA's *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration, Interim Final*, USEPA OSWER Directive 9234.2-25 (September 1993). According to this guidance, there are a number of factors that can inhibit groundwater restoration which include hydrogeologic factors and contaminant-related factors, such as the presence of low permeability fractured groundwater bearing zones and DNAPLs. These and other factors at the Casmalia sited may make restoring impacted groundwater to drinking water quality not achievable given limitations of available remediation technologies.

The Statement of Work for the Casmalia Consent Decree provides that the CSC will complete the TIE in two steps. The CSC completed this first as part of the Preliminary TIE presented in this RI Report. This Preliminary TIE provides the first three (of six) components of a complete TI evaluation. The first three steps are to:

- Identify potential specific ARARs or media cleanup standards for which a TI determination is sought
- Identify the potential spatial area over which the TI decision will apply
- Develop and present a conceptual model that describes the geology, hydrogeology, groundwater contaminant sources, transport, and fate

In addition to defining these components, an objective of the first step was to evaluate whether the CSC has gathered the data needed during the RI to support a TI determination. The CSC concluded that sufficient historical data existed or new data were collected during the RI to evaluate the types of conditions that may ultimately require a TI waiver for the site.

The CSC will complete the second and final step of the TIE in concert with the FS, such that appropriate alternate remedial strategies (such as source control and containment) can be developed, in the event that groundwater restoration is not considered to be technically practicable. The FS will provide the second three (of six) components of a TIE, which will complete the CSC's overall TI evaluation. The second three steps are to:

- Evaluate the restoration potential of the Site, including data and analyses that support any assertion that attainment of ARARs or media cleanup standards is technically impracticable from an engineering perspective
- Estimate the cost of the existing and alternate remedy options, including construction, operation, and maintenance cost
- Develop and provide any additional information or analyses that the EPA deems necessary for the TI evaluation

Pairing the TI evaluation with the FS ensures that a consistent technology performance and cost basis is being used to make remedial decisions for the site. As noted above, the groundwork for certain aspects of the TI evaluation (such as defining site hydrogeologic characteristics, the nature and extent of dissolved-phase groundwater contaminants, and the distribution and fate and transport of NAPL in the subsurface) are established in this RI Report.

1.0 INTRODUCTION

The Casmalia Resources Site Steering Committee (CSC) has prepared this Final Remedial Investigation (RI) Report as required by Section 11.6 of the Remedial Investigation/Feasibility Study (RI/FS) Work Plan (CSC, 2004) that summarized the investigation and remedial planning activities to be undertaken for the Casmalia Resources Superfund Site (Site). The Site has been previously referenced by many different names, including, among others, the Casmalia Hazardous Waste Management Facility, Casmalia Site Remediation Project, Casmalia Superfund Site, and Casmalia Site. Our best efforts have been made to unify Site nomenclature used throughout this document to reflect the Casmalia Resources Superfund Site.

This Final RI Report addresses the comments that EPA provided us in a letter dated October 15, 2008 on our draft RI Report that was submitted in April, 2008, as well as several additional communications throughout 2009 and 2010 on our Draft Final RI Report that was submitted in January 2010.

1.1 Objectives of the RI Program

The revised RI/FS Work Plan (Work Plan) described in detail the various activities the CSC would complete as part of the RI/FS process. Those primary RI/FS tasks included:

- A Remedial Investigation designed to meet the data needs for all RI/FS activities (Sections 4 and 5 of the Work Plan);
- A human health risk assessment (HHRA) to define primary risk-driving chemicals and exposure routes for human receptors. The HHRA results will be used to identify which Site areas may require remediation (Section 6 of the Work Plan);
- An ecological risk assessment (ERA) to identify potential risks to plants and animals at the Site. The results of the ERA will be used to identify Site areas potentially requiring remediation (Section 7 of the Work Plan);
- Groundwater modeling to assess overall Site flow patterns, to evaluate the efficacy of current groundwater extraction facilities, and to assess potential future remedies using the groundwater model (Section 8 of the Work Plan);
- A technical evaluation of the practicability of restoring groundwater to applicable standards, i.e., a Technical Impracticability Evaluation (TIE) for the Casmalia Site. If groundwater cannot practicably be restored, the CSC will propose a Technical Impracticability (TI) Zone and complete a TIE consistent with United States Environmental Protection Agency (USEPA or EPA) guidance (Section 9 of the Work Plan). If a TI zone is approved by the agency, the USEPA will grant a TI waiver as part of the final remedy for the Site; and
- A Feasibility Study to identify and screen various candidate technologies that will reduce potential human health and ecological risks at the Site. The CSC will assemble and evaluate various remedial alternatives in concert with the TI evaluation to ensure that groundwater remediation objectives are met. Based on the alternatives evaluation in the FS, the CSC will propose a remedy for the Site (Section 10 of the Work Plan).

The CSC has completed the RI activities (bullet item one above) and has produced this RI Report to summarize the sampling results from that sampling. As required by the RI/FS Work Plan, the RI Report also provides the USEPA the results of the HHRA, provides the USEPA the preliminary

results of the ERA (including the Tier 2 ERA which we completed subsequent to submitting the draft RI Report), and documents the first three elements of our TIE for the Site.

To evaluate the completeness of the RI program, the CSC has compared the data collected during the RI sampling against the established RI program objectives that were discussed in detail in Section 4 of the RI/FS Work Plan. The RI data that was collected was compared, where possible, to each of the various data quality objective (DQO) sets discussed in Section 4 of the RI/FS Work Plan that included:

- Human Health Risk Assessment (Section 4.1);
- Ecological Risk Assessment (Section 4.2);
- Contaminant Nature, Extent, Fate, and Transport Investigation Data (Section 4.3);
- Groundwater Modeling Data (Section 4.4); and
- Technical Impracticability Evaluation Data (Section 4.5).

The discussion of the DQO sets is provided by RI program (i.e., sampling media) and is included in sections of the RI Report that discuss each of these specific sampling tasks.

The CSC has concluded this RI Report with a discussion of any data limitations and recommendations for any additional RI sampling work or additional risk assessment analysis in Section 11.0.

1.2 Content of the RI Report

Section 11.6 of the RI/FS Work Plan specifically states: "*As requested by USEPA, the schedule is broken into three parts: the RI, TI Evaluation and the FS.*" As outlined in the RI/FS Work Plan, the CSC is required to prepare and submit a RI Report to the USEPA after completing the RI investigations. The content of the RI Report is presented in various sections of the RI/FS Work Plan and is discussed in more detail in the paragraphs that follow.

In general, the RI/FS Work Plan required that the RI Report include:

1. A summary of monitored natural attenuation (MNA) data (specifically including well specific charts displaying field parameters – pH, redox potential [Eh], electrical conductivity [EC], temperature [T], and dissolved oxygen [DO]) and electron receptors (nitrate, sulfate, ferrous iron, manganese) to assess the variability of these constituents);
2. Any new data or information or updates of toxicity benchmarks including an updated numerical list of preliminary applicable standards;
3. A summary of the available groundwater data such that it is clear which contaminants exceed the applicable cleanup standards;
4. The first three elements of the TI Evaluation (in draft form):

    A. Specific applicable or relevant and appropriate requirements (ARARs) or media cleanup standards for which a TI determination is sought;
    B. The spatial area over which the TI decision will apply – the TI zone by areal extent and depth using a horizontal coordinate system and map to define the areal extent of the zone and depth by hydrostratigraphic unit; and
    C. A conceptual model that describes Site geology, hydrogeology, groundwater contamination sources, transport and fate (including the nature and extent of dissolved-phase groundwater contaminants, and the distribution and fate and transport of non-aqueous phase liquid [NAPL] in the subsurface).

5. The results of the RI work including field investigations, risk assessments, and groundwater modeling.

The RI/FS Work Plan also stated that…

The RI Report would have the following main headings:

- *Introduction*
- *Media and Study Area Investigations*
- *Physical Characteristics of Site and Study Areas*
- *Nature and Extent of Contamination (including soil vapor, soil, sediment, surface water, groundwater, and NAPL)*
- *Contaminant Fate and Transport (including preliminary model results)*
- *Human Health Risk Assessment*
- *Ecological Risk Assessment*
- *Conceptual TI Zone*
- *Summary and Conclusions*

This RI Report is organized to comply with the requirements of Section 11.6 of the RI/FS Work Plan, to meet the USEPA's guidance documents regarding RI Reports, and to provide the USEPA with a summary of all of the RI data collected.

As previously agreed to with USEPA, certain information that was originally planned for inclusion in the Interim Progress Report (IPR) was not included in the IPR document and was, with the USEPA's approval, deferred until the RI Report. The information that was not included in the IPR was specific tasks that could not be addressed until a calibrated groundwater model was completed.

As such, Appendix F of the RI Report includes the interpretations and updated figures (originally intended for the IPR) listed below:

- Water Table Contour Map (2008) – Appendix F, Figure F-13;
- Potentiometric Surface Contour Map, Upper hyrdostratigraphic unit (HSU) (2008) – Appendix F, Figure F-14;
- Potentiometric Surface Contour Map, Lower HSU (2008) – Appendix F, Figure F-15;
- Potentiometric Differences Between Upper and Lower HSUs (2008) – Appendix F, Figure F-16; and
- Sitewide Cross Sections A-A' through F-F' – Appendix F, Figures F-23 through F-28.

Similarly, the following RI tasks have been performed as part of the groundwater flow model calibration process and are also included in Appendix F of this RI Report:

- Task 5.5 – Site Water Budget – Appendix F, Attachment F-2; and
- Task 5.6 – Summarize Groundwater Flow Information – Appendix F (general).

1.3 RI Report Organization

The RI Report follows the format for a RI Report as discussed in the USEPA guidance on RI Report organization and content and of course the same format we had used to submit the draft RI Report. The RI Report includes the same series of appendices that were originally included in the IPR that discuss the results of RI sampling (updated to now include Phase I, Phase II, and Phase III RI sampling, including follow-up soil vapor sampling). The organization of the RI Report is shown in the Table of Contents and includes the following:

- **Section 1** of the RI Report introduces the report and lists the content, organization, and purpose of the document;
- **Section 2** of the RI Report provides a summary of the Site background information that is presented in more detail in Section 2 and Section 3 of the Final RI/FS Work Plan;
- **Section 3** of the RI Report presents a summary of media and study area investigations completed for the RI program and introduces the appendices, which provide an overall summary of the RI sampling and relevant tasks. This section provides includes a brief summary of the RI Activities including the scope of Phase I, Phase II, and Phase III RI work and a discussion of the RI change process introduced to handle any deviations from the approved RI/FS Work Plan. The section includes a summary of those changes;
- **Section 4** of the RI Report discusses the physical characteristics of the Site and study areas;
- **Section 5** of the RI Report discusses the nature and extent of contamination as characterized by the RI sampling by media. Section 5 of the RI Report provides a summary of the NAPL at the site;
- **Section 6** of the RI Report summarizes the contaminant fate and transport for each media as we currently understand it;
- **Section 7** of the RI Report summarizes how the CSC analyzed and evaluated RI data to calculate the critical inputs to the two risk assessments reported in the report;
- **Section 8** of the RI Report presents the preliminary Human Health Risk Assessment for the Site;
- **Section 9** of the RI Report presents the preliminary Ecological Risk Assessment for the Site;
- **Section 10** of the RI Report provides the first three elements of the TI Evaluation, including the proposed TI Zone for the Casmalia site; and
- **Section 11** provides Summary and Conclusions.

The appendices to this RI Report include:

- Appendix A – Background Soil;
- Appendix B – Soil and Sediment Sample Summary;
- Appendix C – Soil Vapor Investigation;
- Appendix D – Surface Water Data;
- Appendix E – Well and Piezometer Installation;
- Appendix F – Groundwater Flow;
- Appendix G – Groundwater Chemistry;
- Appendix H – RCRA Canyon Outcrop Assessment;
- Appendix I – Gamma Walk-over Survey;
- Appendix J – Clay Barrier Investigation;
- Appendix K – CPT Signature Comparison;

- Appendix L – Geophysical Surveys;
- Appendix M – UVIF/MIP NAPL Investigations;
- Appendix N – Offsite Well Survey;
- Appendix O – Monitored Natural Attenuation Evaluation;
- Appendix P – Biological Species and Habitat Survey Report;
- Appendix Q – RI Change Forms and Request for Information Forms;
- Appendix R – Data Validation and Data Management;
- Appendix S – RI Daily Activity Reports;
- Appendix T – Baseline Human Health Risk Assessment;
- Appendix U – Ecological Risk Assessment;
- Appendix V – Aerial Photograph Review (identical to Appendix J of the Final RI/FS Work Plan);
- Appendix W – Historical Topography Review (identical to Appendix L of the Final RI/FS Work Plan);
- Appendix X – Chemicals of Potential Concern (COPCs) and Exposure Point Concentration (EPC) Supporting Tables; and,
- Appendix Y – Follow-up Work Plans – Phase II and Phase III Remedial Investigation.

We have referenced the following investigation planning documents for basic information regarding that RI follow-up sampling:

- Final Geophysical Survey Plan – Phase II RI/FS Work Plan Supplement (CSC, 2005a);
- Revision 4 – Fall, 2005 Phase II RI Sampling Plan (Soil Vapor, Surface Drainage Water, and Background Soil) (CSC, 2005b);
- Fall Phase II RI GW Sampling (table only) (CSC, 2005c);
- Final Spring 2006 Phase II Sampling Plan (CSC, 2006a);
- Revised Final Phase III RI Sampling Plan (CSC, 2007c);
- Final Plan for RI Follow-up to the P/S Landfill Seismic Refraction Survey (CSC, 2007b);
- Follow-Up Soil Vapor Sampling Plan (CSC, 2007a);
- Final Work Plan RIPZ-13 DNAPL Test Program (CSC, 2009b); and,
- Sampling and Analysis Plan [Tier 2 Ecological Risk Assessment] (CSC, 2009a).

An additional scope element not specifically addressed in the above-referenced planning documents included the completion of Hydropunch© groundwater grab samples collected south of the perimeter source control trench (PSCT), as recommended in the USEPA-approved NAPL Memorandum, dated March 31, 2006 (CSC, 2006b).

1.4 References

Casmalia Resources Site Steering Committee (CSC), 2009a. *Sampling and Analysis Plan* [Tier 2 Ecological Risk Assessment]. March.

Casmalia Resources Site Steering Committee (CSC), 2009b. *Final Work Plan RIPZ-13 DNAPL Test Program*. February.

Casmalia Resources Site Steering Committee (CSC), 2007a. *RI Sampling Plan for Follow-Up Soil Vapor Sampling Plan*. July.

Casmalia Resources Site Steering Committee (CSC), 2007b. *Final Plan for RI Follow-up to the P/S Landfill Seismic Refraction Survey*. June.

Casmalia Resources Site Steering Committee (CSC), 2007c. *Revised Final Phase III Sampling for Follow-up Sampling RISBON-59 Soil Sampling*. March.

Casmalia Resources Site Steering Committee (CSC), 2006a. *Final Spring 2006 Phase II Sampling Plan for Soil Sampling, Soil Gas Surveys, Clay Barrier Sampling, Geologic Boring, and Well and Piezometer Installation*. May.

Casmalia Resources Site Steering Committee (CSC), 2006b. *Lower HSU DNAPL Evaluation*. March.

Casmalia Resources Site Steering Committee (CSC), 2005c *Table A.1- Fall Phase II RI GW Sampling*. November.

Casmalia Resources Site Steering Committee (CSC), 2005b. *Revision 4 – Fall 2005 Phase II RI Sampling Plan – Soil Vapor, Surface Drainage Water, and Background Soil*. November.

Casmalia Resources Site Steering Committee (CSC), 2005a *Final Geophysical Survey Plan – Phase II RI/FS Work Plan Supplement*. September.

Casmalia Resources Site Steering Committee (CSC), 2004. *RI/FS Work Plan*. June.

2.0 SITE BACKGROUND

This section presents a brief summary of the Site development and land-use history, as well as the previous investigations and closure activities undertaken at the Site. Information presented herein is summarized from Section 2 of the June 2004 RI/FS Work Plan (Work Plan). The reader is referred to this source document for a more detailed treatment of these issues. The descriptions presented in this section have been updated with the most recent information available, including data developed during the Remedial Investigation.

2.1 Site Description

The Site is an inactive Class I hazardous waste management facility located in the northwestern corner of Santa Barbara County, California. The Site, which was owned and operated by Casmalia Resources, began accepting wastes in the early 1970s. Site operations were ceased by 1991. Former waste management operations at the Site were conducted within an approximate 252-acre area. Former waste management features included landfills, storage and evaporation ponds, evaporation pads, oil field waste spreading areas, treatment units, and disposal wells and trenches.

The Site lies approximately 4 miles from the Pacific Ocean, approximately 10 miles southwest of the city of Santa Maria, and approximately 16 miles north-northwest of the city of Lompoc. The nearest population center is the unincorporated community of Casmalia, located approximately 1.2 miles south-southeast of the Site. The Site is accessed via NTU Road off of Black Road, approximately 1 mile north of Casmalia (Figure 2-1). An aerial photograph of the site and surrounding area in included as Figure 2-2.

The Consent Decree (USEPA, 1997) has separated the Site and surrounding areas into two distinct segments, including Zone 1 (the approximate 252-acre former waste disposal area) and Zone 2 (surrounding lands) (Figure 2-1). These zones are defined in Sections 1.2.20 and 1.2.21 of the SOW as follows:

> ***"Zone 1*** *– Zone 1, shall mean the area within the Casmalia Hazardous Waste Management Facility boundary depicted generally on the map in this SOW. This definition is for the convenience of identifying geographic areas of the site for purposes of the SOW, and should not be construed as determining the site boundary or the applicability of the permit exemption at Section 121(e) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and 300.5 of the National Contingency Plan (NCP).*
>
> ***"Zone 2*** *– Zone 2, shall mean the area that encompasses the extent of site-related contamination or potential contamination outside of the Casmalia Hazardous Waste Management Facility boundary depicted generally on the map in this SOW. This definition is for the convenience of identifying geographic areas of the site for purposes of the SOW, and should not be construed as determining the site boundary or the applicability of the permit exemption at Section 121(e) of CERCLA and 300.5 of the NCP."*

For the purposes of this RI Report, the Site area is defined as the approximate 252 acres encompassed within Zone 1, as defined above. Throughout the remainder of this report, those areas lying outside the limits of Zone 1 are referred to as being "off-site."

The physical features of the site, including site boundaries, topography, climate, hydrology, geology/hydrogeology, land use, demography, and wildlife habitats, are described in Section 4.0. Section 4.0 has also been updated with the most recent information available, including data developed during the Remedial Investigation.

2.2 Site History and Use

The Site is a former hazardous waste management facility that Casmalia Resources began operating in 1972 in accordance with California Regional Water Quality Control Board (CRWQCB) Waste Discharge Permit No. 72-28. The original CRWQCB waste discharge permit allowed a 61-acre hazardous waste disposal facility including 15 surface impoundments and one landfill area. The waste discharge permit was amended twice, once in 1976 to allow for a 118-acre expansion of the facility to the east and north (Permit No. 75-73), and again in 1980 (Permit No. 80-43) expanding the facility approximately 73 acres toward the west, bringing the facility to its present size of 252 acres (McClelland Consultants, 1989). The current and historical site layouts are shown on Figure 2-3 and Figure 2-4, respectively. A historical timeline of site development and related milestone events are presented in Figure 2-5.

Casmalia Resources ceased accepting off-site liquid wastes in July 1987 and stopped accepting off-site solid waste in November 1989. Casmalia Resources completed pond closure activities in the period from 1989 to 1991 while they awaited approval to modify the Site waste treatment and disposal methods and facilities. After being denied the necessary operating permits to continue waste disposal activities, Casmalia Resources suspended all site activities in 1991, with the exception of extracting liquids from the perimeter control trenches (PCTs). During the 1991 timeframe, Casmalia Resources also developed groundwater monitoring work plans and landfill closure and post-closure plans. From 1992 through 1996, the USEPA maintained the Site. The CSC took over site activities in 1996, and has been responsible for various site investigation and closure projects from that time through the present. Detailed information related to the permits obtained and orders issued by the agencies during site operations is presented in Table 2-1, Permit History Information.

Casmalia Resources accepted the full range of listed and characteristic RCRA wastes as specified in Subparts C and D of 40 Code of Federal Regulations (CFR) 261 (A.T. Kearney/SAIC, 1987). Wastes received at the Site included (in part): petroleum wastes, acids, bases, organic chemical solvents, petroleum solvents, paint sludge, pesticides, infectious wastes, septic tank pumpings, and sewage sludge. Section 3.0 of the April 1988 RCRA Part B permit application (Woodward Clyde Consultants, 1988b) includes a complete list of wastes accepted at the facility by landfill and treatment units. Waste disposal units at the Site included:

- 6 landfills;
- 43 surface impoundments;
- 15 evaporation pads;
- 2 non-hazardous waste spreading areas;
- 6 oil field waste spreading areas;
- 11 shallow injection wells;
- 7 disposal trenches; and

- 1 drum burial unit.

Note that although contaminated liquids were eventually transferred to most site ponds, only a few of the site ponds directly received off-site wastes. The Site also had five waste treatment units: an acid/alkaline neutralization facility, a hydrogen peroxide treatment unit, oil recovery and treatment tanks, a wet air oxidation unit, and a temporary pilot-scale powder-activated carbon treatment (PACT) unit.

Surface impoundments (used for evaporation and treatment of liquid wastes or for storing stormwater), and disposal pads (used to evaporate liquid wastes and site stormwater runoff) primarily occupied the southern and central portions of the Site, whereas the six landfill disposal areas were positioned along the northern and northeastern margins of the Site. A few of the surface impoundments and evaporation pads were also present in some areas of the northern portion of the Site between the major landfill cells (Figure 2-4). The variety of former and existing waste management units at the Site are more fully described in the following sections.

2.2.1 Site Operational Information

Numerous prior studies have been completed at the Site and surrounding area since operations began, including those conducted in support of facility siting and design, regulatory permitting and compliance, waste characterization, and soil and groundwater investigations. The information presented in this section has been compiled and summarized primarily from technical reports previously prepared by others, and these reference documents are listed in Section 2.2 of the Work Plan. The reader is referred to these original source documents for a more detailed treatment of the topics summarized herein.

Parties sending wastes to the Casmalia Site were required to prescreen or profile their wastes before shipping waste to the Site. As part of their waste confirmation program, Casmalia Resources randomly tested approximately 10 to 20 percent of the incoming wastes. The waste pre-screening and confirmation testing programs employed at the Site are more fully described in the Final Environmental Impact Report for the facility (McClelland, 1989).

Casmalia Resources personnel directed haulers with drummed wastes to the drum handling facility south of the Pesticides/Solvents Landfill. Drummed wastes were placed on the loading dock where Casmalia Resources personnel compared the drum labels with the manifests and collected samples of any wastes that were visually inconsistent with the waste profile. Casmalia Resources then transported drummed wastes to the various landfills for final disposal.

Haulers with bulk solid or liquid wastes were directed to a specific landfill, pond, or treatment system, depending on the waste characteristics. Casmalia Resources generally segregated incoming waste by primary type, and the wastes were handled in specific locations of the Site based on whether they were acidic, caustic, oily, solvent-based, etc.

Before leaving the Site, empty trucks washed out their tanks and/or bins at the wash-out facilities located at Ponds D and 16.

2.2.2 Site History Review

In preparing the Work Plan, the CSC reviewed available historical documents and aerial photographs, selected site topographic maps, and interviewed agency personnel. The CSC

also met with former site operations personnel who worked on the Site from the mid and late 1970s through the present to collect additional historical and anecdotal information that may be relevant to remedial planning. Key historical documents reviewed in preparation of the Work Plan included the *RCRA Facility Assessment* (A.T. Kearney/SAIC, 1987), *Environmental Impact Report (EIR) for the Casmalia Resources Class I Hazardous Waste Disposal Site Modernization Plan* (McClelland Consultants, 1989), and the *RCRA Part B Permit Application* (Woodward Clyde Consultants, 1988b).

2.2.2.1 Aerial Photograph Review

In preparing the Work Plan, the CSC conducted a review of available historical aerial photographs of the Site for the time period 1956 through 2002. A complete listing of the photographs examined and the detailed findings of this review are presented in Appendix J of the Work Plan; the salient findings of this review are summarized below. Select photographs depicting the sequential development and closure of the Site are presented in Figure 2-10.

The Site was used for agricultural purposes prior to 1970. The initial site development was first apparent on the 1974 aerial photograph with several oil-field-related surface impoundments situated in the center of the site. Grading and continued surface impoundment expansion is noted in the 1979 and 1980 photographs. Some of the injection wells and disposal trenches were observed in the 1979 and 1980 photos. Waste disposal in the landfills was also noted in these photographs, as were the oil recovery tanks associated with the oil field waste ponds in the center of the site.

By 1983, the A-series ponds had been developed and the RCRA Canyon Area development was evident. Also by this time, the spreading and sludge drying areas appeared to be active. A spray evaporation area in the southwestern portion of RCRA Canyon also was noted only in this photograph (and not in the 1982 or 1984 photographs). Some of the evaporation pads between the landfills also appeared to be active in the 1983 photograph. The building that was initially used for the Zimpro wet air oxidation system and the four associated tanks are shown on the 1983 photograph.

In the 1985/1986 time period, spreading in the RCRA Canyon Area was notably active and a new pond was evident in the Burial Trench Area. Surface impoundment operations and waste disposal in the landfills continued.

By 1988, the surface impoundments were observed to be empty and the site appeared drastically different as a result of the large amount of excavation and grading undertaken for pond closure. Filling in the landfills and using the pads between the landfills continued. The new Administration Building was observed in the 1988 photograph.

In the 2002 photograph, the stormwater ponds and treated liquids impoundments are observed and the Pesticides/Solvents and Heavy Metals/Sludges Landfills are capped; grading in the Caustics/Cyanides Landfill in preparation for capping is evident. By 2003, the Caustics/Cyanides and Acids Landfills are capped.

2.2.2.2 Topographic Map Review

In preparing the Work Plan, the CSC collected selected historical topographic maps of the Site for the time period to help define former surface drainage features, ponds and pads, liquids

treatment facilities, site roads, and site support facilities. Maps from the time period 1956 through 1998 were reviewed, with those from the years 1956 (pre-development), 1982 and 1987 (operational period) providing the most relevant information for documenting historical site features. Relevant historical site features were identified and digitized onto base maps of the site, and used to help plan the remedial investigation and sampling activities. Comparison of site topography between 1987 and 1998 demonstrates the nature and magnitude of cut and fill earthwork that was conducted across the Site during earlier impoundment closure activities. The 1998 site topography is essentially the current topography, with the exception of grades in the capped landfill areas and a portion of the north ridge area. A complete listing of the maps examined, scanned copies of the individual maps, and a discussion of the findings of this review are presented in Appendix L of the Work Plan.

2.2.2.3 Agency Personnel Interviews

In preparing the Work Plan, the CSC met with agency personnel who had involvement in prior site investigations, possessed personal knowledge of historical site operations and facilities, and/or were involved in emergency response actions during the 1992 to 1996 timeframe. Individuals interviewed included select staff from the RWQCB, Department of Toxic Substances Control (DTSC) and EPA. These agency personnel interviews were used to gather additional relevant information regarding pond closure activities, and truth information gleaned from the aerial photograph and topographic map review. Results of these interviews are documented in Appendix M of the Work Plan.

2.2.3 Facilities

2.2.3.1 Waste Management Units

Casmalia Resources operated several waste management units at the Site including:

- 5 existing landfills, including the PCBs, Pesticides/Solvents (P/S), Heavy Metals, Caustics/Cyanides and Acids Landfills;
- Former RCRA Landfill;
- Former surface impoundments, including 43 liquid storage ponds and 15 evaporation pads;
- 2 non-hazardous waste spreading areas known as Sludges 1 and 2;
- 6 oil-field waste spreading areas;
- Burial Cells Unit (or Burial Trench Area), including 11 shallow disposal wells and 7 disposal trenches; and
- Former drum burial unit.

The locations of the waste management units and treatment facilities are illustrated on Figure 2-4, Historical Site Layout. As part of the review of historical documents and photographs, the CSC prepared a summary table indicating the observed status of each waste management unit and treatment facility at the site. Table 2-2 chronicles the development status of each unit from 1973 through 2002, and indicates whether a particular area was being excavated (or developed), whether there is waste present in the disposal units during those years, and notes the years in which remediation or closure activities are evident. The CSC also notes areas where grading takes place and whether a particular area appears vegetated during that year's photo. The information gleaned from the photo review was used to ground-truth some of the

written records of site operations presented in the sections below. The nature of these various waste management units is generally described below.

Note that although some site closure activities were performed at the Site, the sections below concentrate primarily on activities relevant to the operational years. The closure activities and response actions conducted at the Site are later summarized in Section 2.2.5.

2.2.3.1.1 Existing Inactive Landfills

Each landfill was constructed within individual natural canyons incised into native soils and claystone bedrock of the Todos Santos Member of the Sisquoc Formation. The landfills were constructed prior to promulgation of the prescriptive regulatory requirements of Section 40 of the Code of Federal Regulations (CFR), Part 264 of the Hazardous and Solid Waste Amendments (HSWA) to RCRA. Therefore, man-made liners and leachate collection systems were not installed beneath the landfills. As described below, the landfills were generally started at the south end of a canyon and native materials were excavated to bedrock (i.e., the unweathered claystone) to form the base of the landfills. Wastes were then placed at the base of the landfills and excavated native materials were placed over the wastes as cover.

In accordance with the closure plans prepared for the inactive landfills, Casmalia Resources constructed clay buttresses at the toes of the landfills, as necessary, to improve stability. The buttresses soil materials were taken from the former Pond 11, and former Pads 10B, 10C, 10F, and 10G, and Sludges 1 areas after those areas had been closed. With the exception of the PCB Landfill, Casmalia Resources also graded the landfills in accordance with the closure plans then prepared for each landfill. To achieve the desired grades, Casmalia Resources placed approximately 20 to 60 feet of stabilized soils excavated as part of the pond and pad closure activities. Wastes immediately below the surface of the Caustics/Cyanides Landfill were encountered while the CSC capped that landfill in 2001, indicating that wastes may have been placed in the stabilized soil layer during Casmalia Resources' closure period. Casmalia Resources placed a minimal thickness of cover soil over the PCB Landfill because this landfill was never filled to capacity.

The CSC improved the P/S Landfill buttress in 1998 and constructed a RCRA cap over that landfill during the 1999 construction season. Corrective action activities for the P/S Landfill were completed by the CSC in 2001. The CSC constructed the portion of the Engineering Evaluation/Cost Analysis (EE/CA) Area RCRA cap over the Heavy Metals Landfill and the interstitial areas on either side of that landfill during the 2001 construction season. The CSC capped the remainder of the EE/CA Area (including the Caustics/Cyanides and Acids Landfills along with the interstitial areas) during the 2002 construction season. The CSC constructed a buttress for the Caustics/Cyanides Landfill as part of the EE/CA Area capping project.

<u>PCB Landfill</u>

The PCB Landfill is located in the northern area of the Site between the Former RCRA Landfill and the Pesticides/Solvents Landfill. A portion of the area was first operated as a trench fill but Casmalia Resources changed filling techniques to an area fill method (A.T. Kearney / SAIC, 1987). The PCB Landfill was used for the disposal of non-liquid PCB-contaminated materials, such as drained electrical transformers, soil, rags, and other debris (Section 3.5.2.2, Page 3-22, McClelland Consultants, 1989). A total estimated 390,400 cubic yards of waste and soil cover at a ratio of 2.7:1 waste to soil cover were deposited in the PCB Landfill. The PCB Landfill

operated under a TSCA permit issued by USEPA in November 1978, and permits to expand this landfill were issued by USEPA in 1979 and again in 1980. The original size of PCB landfill was 5.46 acres but only 2.83 acres were useable due to terrain. An additional 14.08 acres approved for use by USEPA in 1981, bringing the total acreage of the landfill up to 20.54 acres, however Casmalia Resources never used the additional fill area (A.T. Kearney / SAIC, 1987). Waste disposal operations at the PCB Landfill were discontinued in April of 1986 (Section 3.5.2.2, Page 3-22, McClelland Consultants, 1989). As further discussed in Section 2.2.3.2, a compacted clay barrier was installed below the toe area of the PCB Landfill in 1980 to limit lateral subsurface fluid migration from the disposal cell. Soil cuttings generated during remedial investigation activities were placed into the PCB landfill for disposal.

Pesticides/Solvents Landfill

The Pesticides/Solvents Landfill (also historically referred to as the Solvent/Pesticide Landfill) is located in the north-central portion of the Site between the PCB Landfill and the Heavy Metals Landfill. The P/S Landfill began receiving waste during September 1979. Wastes were placed in an approximate 10.6-acre portion of the now capped 13.5-acre landfill area. The P/S Landfill was developed in an existing canyon and fill placement began at the toe of the landfill and wastes were place to the north as filling operations continued. The landfill was developed by cut-and-fill methods with excavations extending into the unweathered gray claystone. As additional lifts of waste were introduced, more excavation was performed at the head of the existing canyon, with removed native materials being used as daily and interim cover. Casmalia Resources also used oil field drilling muds as daily cover when available.

Solid and liquid wastes placed into the P/S Landfill included organic solvents, paint, pesticides, asbestos, and infectious waste (Section 3.4.1.1, Page 3-6, McClelland Consultants, 1989). A full list of waste by USEPA waste code that was placed in the landfill is found in Table 3-5 (i) of the site Part B permit application of 1988 (Woodward-Clyde Consultants, 1988b). By January of 1989, an estimated 899,000 cubic yards of waste, 527,990 cubic yards of daily soil cover, and 91,460 cubic yards of pond closure soils (for a total of 1,518,450 cubic yards of waste and soil cover) were deposited in the landfill. The P/S Landfill also includes the oil field waste Spreading Area S-4.

Based on a 1998 topographic map, an unknown volume of additional waste and soil waste was placed in the landfill after January of 1989 (Figure 3-2 of Foster Wheeler / GeoSyntec, 1999). Waste disposal activities in the currently capped P/S Landfill are believed to have ceased when former surface impoundment closure activities were discontinued in late 1990. As further discussed in Section 2.2.3.2, a compacted clay environmental barrier and fluid collection and extraction gallery were installed below the toe area of the P/S Landfill in 1980 to limit fluid migration from the disposal cell below.

Heavy Metals Landfill

The Heavy Metals Landfill (also historically referred to as the Heavy Metals/Sludges Landfill) is located in the northeastern portion of the Site between the P/S Landfill and the Caustics/Cyanides Landfill. Wastes were placed in an approximate 5.4-acre area of the currently capped 10.3-acre Heavy Metals Landfill. The Heavy Metals Landfill started receiving waste during November 1979. Construction of the Heavy Metals Landfill commenced with an approximate 20-foot-deep excavation just below the juncture of two small canyons. As lifts of waste were added, the working face was extended up the small canyons with some

subexcavation preceding waste placement. The natural ridge between the two canyons was eventually removed during this process and utilized as interim cover material.

Materials placed in the Heavy Metals Landfill included solidified bulk or containerized wastes containing heavy metals, sludges, empty plastic and metal drums, drilling fluids, and oil field wastes (Section 3.4.1.2, Page 3-6, McClelland Consultants, 1989). The Heavy Metals Landfill also included dried drilling mud and unspecified oil-field waste from Spreading Area S-3. A full list of waste by USEPA waste code that was placed in the landfill is found in Table 3-5 (h) of the site Part B permit application of 1988 (Woodward Clyde Consultants, 1988b). By January 1989, an estimated 230,090 cubic yards of waste, 135,130 cubic yards of daily soil cover, and 233,870 cubic yards of pond closure soils (for a total 599,090 cubic yards of waste and soil cover) were deposited in the Heavy Metals Landfill. Comparison of cross-sectional maps of the landfill for March 1989 and January 1998 identify that an unknown volume of additional waste and soil waste was placed in the landfill after January of 1989 (Figures B3 and B4 of Foster Wheeler / GeoSyntec, 1999). Waste disposal activities in the landfill are believed to have ceased when former surface impoundment closure activities were discontinued in late 1990. In March 1988, liquids were encountered at the Heavy Metals Landfill toe during a landfill drilling program conducted to assess the presence of liquids in the landfills.

Caustics/Cyanides Landfill

The Caustics/Cyanides Landfill is located in the northeast corner of the Site between the Heavy Metals Landfill and the Acids Landfill. Wastes were placed in an approximate 4.5-acre area of the currently capped 7-acre landfill. The landfill started receiving waste during July 1979. This landfill was initiated with only minimal excavation at the southwest end of a small canyon. As lifts were added, the working area was expanded up the canyon toward the northeast. The disposal unit was later expanded toward the east as the canyon side and a small ridge were excavated and used as interim cover.

Waste materials placed into the Caustics/Cyanides Landfill included solidified bulk and containerized wastes containing caustics, cyanides, and sulfides. The Caustics/Cyanides Landfill also includes dried drilling mud and unspecified oil field waste from Spreading Area S-2. A full list of waste by USEPA waste code that was placed in the landfill is found in Table 3-5 (g) of the site Part B permit application of 1988 (Woodward Clyde Consultants, 1988b). Dried drilling muds and oil-field wastes were also disposed of in this landfill (Section 3.4.1.3, Page 3-6, McClelland Consultants, 1989). By January 1989, an estimated 273,940 cubic yards of waste, 160,880 cubic yard of daily soil cover, and 318,850 cubic yards of pond closure soils (for a total 753,670 cubic yards of waste and soil cover) had been deposited in the landfill. Comparison of cross-sectional maps of the landfill of March 1989 and January 1998 identify that an unknown volume of additional waste and soil waste was placed in the landfill after January of 1989 (Figure B5 of Foster Wheeler / GeoSyntec, 1999). Waste disposal activities in the landfill are believed to have ceased when former surface impoundment closure activities were discontinued in late 1990. In March 1988, liquids were encountered at the Caustics/Cyanides Landfill toe during a landfill drilling program conducted to assess the presence of liquids in the landfills. The Caustics/Cyanides Landfill includes a clay buttress constructed to stabilize waste and control fluid migration.

Acids Landfill

The 5.4-acre Acids Landfill is located along the eastern site boundary south of the Caustics/Cyanides Landfill. The landfill started receiving waste during July 1979. The Acids Landfill was initiated at the west end of a small canyon as a narrow excavation less than 20 feet deep just east of the haul road. As lifts were added, more material was excavated from the base and sides of the small canyon.

Waste materials placed into this landfill included solidified or bulk containerized acidic wastes. A full list of waste by USEPA waste code that was placed in the landfill is found in Table 3-5 (f) of the site Part B permit application of 1988 (Woodward Clyde Consultants, 1988b). By January 1989, an estimated 35,930 cubic yards of acid solid waste, 51,270 cubic yards of daily soil cover, and 138,570 cubic yards of pond closure soils (for a total of 225,770 cubic yards of acid solid waste and soil cover) were deposited in the landfill. Comparison of cross-sectional maps of the landfill of March 1989 and January 1998 identify that an unknown volume of additional waste and soil waste was placed in the landfill after January of 1989 (Figure B6 of Foster Wheeler / GeoSyntec, 1999). Waste disposal activities in the currently capped landfill are believed to have ceased when former surface impoundment closure activities were discontinued in late 1990. In March 1988, no liquids were encountered at the landfill toe during a drilling program conducted to assess the presence of liquids in the landfills.

2.2.3.1.2 Burial Trenches and Shallow Disposal Wells

Waste disposal at the Site began in the early 1970s with disposal in seven trenches directly south of the PCB Landfill and directly west of the P/S Landfill. Waste disposal in that area (referred to as the Burial Cells Unit, or Burial Trench Area) also included disposal in shallow wells in the mid to late 1970s and early 1980s. Although records do not go back far enough to indicate the dates of use and type of waste placed in Trench 1, Trenches 2 through 7 operated from August 1974 to October 1979 (A.T. Kearney / SAIC, 1987). The disposal trenches were constructed by excavating a series of cells 15 to 40 feet square and approximately 15 feet deep. Cells were constructed in seven rows and assigned numerical designations, with the individual cells in a given row being assigned an alphabetical designation.

Wastes deposited into the trenches consisted of a wide variety of bulk and containerized liquids and sludges, with the exception of Trench 6, which accepted only PCB wastes. Wastes disposed in the remaining trenches included acid and alkaline sludges, paint sludges, waste paints, waste solvents, oil, metal hydroxides, asbestos, empty pesticide containers, pesticides, iron sponge, DEA, plating sludges, naphtha, ink, and epoxide polymers and filter cake (A.T. Kearney / SAIC, 1987).

PCB-contaminated materials were deposited into Trench 6, exclusively, and were later removed and placed in the PCB Landfill. The eastern portion of Trench 7 (cells 7A, 7B, and 7C) was later incorporated into the P/S Landfill.

The volume of wastes placed in the Burial Cells Unit is estimated to have exceeded 3,000 tons and is reported to be as large as 40,000 tons. Approximately 16,700 cubic yards of waste materials originally placed in the Burial Cells Unit were excavated to allow for the construction of Pond 23 and were placed into an approximate 1-acre area of the Former RCRA Landfill. Identical detailed lists of waste types and approximate volumes discharged into the trenches are found in the RCRA Facility Assessment (A.T. Kearney / SAIC, 1987) and in site's RCRA Part B

permit of 1988 (see Appendix B of Section 21 - Woodward Clyde Consultants, 1998b). References variably indicate that waste materials present in portions of Trenches 2 and 3, or Trenches 2, 4, and possibly 5, were removed and redeposited in the Former RCRA Landfill (Section 3.5.3, Page 3-25, McClelland Consultants, 1989 and Section 2.2.5.3, Page 2-12, Woodward-Clyde Consultants, 1988b).

The available records indicate that the trenches were used as follows:

Trench 2: August 1974 to May 1978
Trench 3: August 1974 to March 1978
Trench 4: May 1977 to October 1979
Trench 5: June 1978 to January 1979
Trench 6: November 1978 until it was incorporated into the PCB Landfill
Trench 7: January 1979 to August 1979

Between December 1977 and September 1982, shallow disposal wells were drilled and operated in the area within the Burial Cells Unit**.** A total of 11 wells were drilled directly adjacent to the trenches within the Burial Cells Unit and were used for the purpose of liquid waste disposal. Available information indicates two of these wells (wells 10 and 11) lie between Trenches 4 and 5, and the remaining 9 wells lie between Trenches 3 and 4.

The available records indicate that wastes were injected into the wells during the following timeframes:

Well 1: January 31, 1978 to May 4, 1978
Well 2: December 19, 1977 to April 17, 1978
Well 3: April 18, 1978 to February 20, 1980
Well 4: April 13, 1978 to August 3, 1978
Well 5: December 28, 1978 to May 3, 1979
Well 6: April 12, 1979 to January 10, 1980
Well 7: May 4, 1979 to February 8, 1980
Well 8: September 22, 1980 to March 15, 1982
Well 9: Never placed in service
Well 10: July 15, 1980 to September 28, 1982
Well 11: March 9, 1982 to September 28, 1982

Wastes discharged into the wells included unspecified solvents, pesticides, acids, and miscellaneous waste materials (A.T. Kearney / SAIC, 1987). Identical detailed lists of waste types and volumes discharged into each well are found in the previously referenced document and in the site's RCRA Part B permit of 1988 (see Appendix C of Section 21 - Woodward Clyde Consultants, 1998b). The shallow disposal wells consisted of approximate 4-foot diameter borings extending to depths of between 30 to 40 feet. The wells were not cased and Well 9 caved in during installation and was never placed in service. The wells were capped with hexagonal reinforced steel well heads that were one foot high and eight feet in diameter. Each well head was equipped with a vent pipe, a quick disconnect coupling, an inspection hatch and a visual float liquid level indicator to prevent overfilling. The wells were drilled adjacent to the disposal trenches with the intent that the trenches would absorb the liquid wastes. Although waste disposal in the wells was limited due to the low permeability of the strata, more than 1.3 million pounds of material were reported to have been discharged to these wells. The facility experimented with the use of dynamite in one well (unknown which one) to fracture the

surrounding strata, and enhance its permeability. This experiment was reportedly unsuccessful and was not repeated with other wells.

2.2.3.1.3 Former RCRA Landfill and RCRA Canyon

The Former RCRA Landfill is located in a natural canyon (currently referred to as RCRA Canyon, and historically sometimes as West Canyon) on the northwest side of the Site. This area was at one time intended to be lined in preparation to receive RCRA-regulated waste from the McColl Superfund site; however, this never occurred. In late 1983 to early 1984, a small area within the uppermost portion of RCRA Canyon received an estimated 16,700 cubic yards of wastes removed from a portion of the Burial Cells Unit during development of Pond 23. Wastes that were deposited into the Former RCRA Landfill at that time included, but were not limited to, solvents, pesticides, PCBs, oily wastes, and metals. Casmalia Resources constructed Pond 23 to provide localized stormwater capacity after the site underwent a couple of extremely rainy seasons. The RCRA Landfill Closure Plan (Woodward-Clyde Consultants, 1991b) estimates the volume of these deposited wastes to be approximately 16,700 cubic yards. As part of the RCRA Landfill preparations, Casmalia Resources constructed a low permeability compacted clay barrier south of the West Canyon Catch Basin (WCCB – also known as Pond 43), located at the southern terminus of RCRA Canyon. The barrier was keyed into the unweathered claystone. When it became apparent that McColl wastes would not be delivered to the Site, Casmalia Resources excavated the RCRA Canyon wastes, the low-permeability barrier and the WCCB. This excavation reportedly took place during the pond closure period from 1988 through 1990.

RCRA Canyon was also the location of the oil field waste Spreading Areas S-5 and S-6. The north and west slopes of RCRA Canyon received oil field wastes (primarily drilling mud), winery wastes, and spray irrigation of leachate and surface stormwater runoff collected from other portions of the Site (Section 3.5.2.1, Page 3-22, McClelland Consultants, 1989). These liquids may have contained a variety of organic and inorganic constituents. Trucks discharged loads along the northern and western perimeter canyon road and the liquids wastes were allowed to gravity flow down the sideslopes. Casmalia Resources constructed terraces in the canyon sidewalls so the wastes could dry and be turned by dozers working the benches. As noted in the aerial photograph review, liquids accumulated in localized areas of the spreading terraces. Dried wastes were reported to have been periodically removed and used as daily cover in the landfills. Some of the wastes on the sideslopes are still evident, and it is not clear how much of the wastes was moved for daily cover.

2.2.3.1.4 Former Surface Impoundments

Casmalia Resources utilized a total of 43 ponds and 15 evaporation pads to accommodate incoming wastes and to manage on-site stormwater and landfill leachates. General pond information, including the year built, construction notes, surface area and operational capacity is presented in Table 2-3, General Pond Information. The combined surface area of the ponds and pads is approximately 51 to 62 acres, and the operational capacity was in the 196 to 205 million gallon range. Note that two of the site's 43 ponds identified were converted to pads and, as such, are "double counted."

Also presented in Table 2-3 are deposition notations, classes, and surface impoundment (SI) unit designations. The "deposition" notation was used to identify which ponds were direct deposit ponds as opposed to first through fourth generation transfer ponds. Note that only 12 of

the site's ponds directly received off-site wastes (Ponds 14, 15, 18, A-5, A, B, C, D, E, J, P, and T). The "class" designation originated as part of pond closure planning to indicate which ponds had hazardous, nonhazardous and marginally hazardous sludges that had to be solidified prior to being placed in the site landfills. Finally, the "SI unit" designation was the numbering system used to refer to either a single pond, or to a group of ponds that were operated as a unit, accepting transfers from one another. There were 10 SI groupings; the remaining ponds were numbered with only their pond designation. Transfer of liquids to and from ponds in other SI units also occurred as part of site operations. Note that the original SI units as defined in the 1985 RCRA Part B permit application (Woodward-Clyde Consultants, 1985) did not specifically include pads; the pads listed below, however, are within the boundaries of the SI units as outlined in the 1985 RCRA Part B permit.

The 10 SI units included:

- SI-1 (Ponds A-1 through A-4, and A-6; Pad 1A is within the bounds of SI-1 but was never used for waste management);
- SI-2 (Pond A-5);
- SI-3 (Pond 1, and Ponds 15, 17, and 18; this SI unit also encompasses Pad 18 [known as Pad 3A in 1983] and the spray area to the north of Pad 18);
- SI-4 (Pond 2, and Ponds E, J, and L; this SI unit includes the area occupied by Pad 4A);
- SI-5 (Ponds 3, 4, and 9);
- SI-6 (Pond 13);
- SI-7 (Ponds 5, 8, and 10; Pad 7A is within the limits of this SI unit);
- SI-8 (Ponds 11, 12, and 20; Pads 8A, 8B, and 8C are within the bounds of SI-8 although Pads 8B and 8C were reportedly not used for waste management);
- SI-9 (Pond 6; Pads 9A and 9B are also within the limits of SI-9); and
- SI-10 (Ponds 19 and 22; Pads 10A, 10B, 10C, 10E, 10F, and 10G are encompassed by this SI unit's bounds).

As described in the 1985 Part B Permit Application (Woodward-Clyde Consultants, 1985), the remaining ponds were historically referred to as single pond surface impoundments, with the SI unit designation being the same as the pond name (these include: SI Units / Ponds 14, 16, 23, A, B, C, D, M, P, R, S, T and V). The information presented in the historic 1985 RCRA permit application is used as an information source in Table 2-3 to illustrate differences in reported pond usage, size and operational capacity in the available documents. The 1988 RCRA permit application (Woodward Clyde Consultants, 1988b) does not present the pond usage, size and operational capacity information.

The limits of the SI units are indicated on Figure 2-6 along with color shadings indicating the ponds' primary use. As shown in Table 2-4, the notations for the primary pond usages varied among historic documents. The pond usage most fitting considering the ponds' overall operational history is shown on Figure 2-6. Cross hatching is used to indicate ponds that were: direct discharge ponds; those that received wastewaster from the Stringfellow site; and those ponds that received treatment system effluent. Figure 2-6 information is duplicated on Figure 2-7 along with arrows indicating which ponds overflowed or contributed to other ponds. The CSC tabulated the pond designations and pond influent and effluent information (McClelland Consultants, 1989, and A.T. Kearney / SAIC, 1987) along with transfer records for the year 1985 to 1986 that were summarized by others (Canonie, 1989) as presented in Table 2-4. The pond transfer arrows shown on Figure 2-7 are an amalgamation of the influent, effluent and pond transfer information presented in Table 2-4. Note also that the documented pond transfer

information is for only the 1985 and 1986 time period; additional pond transfer activities likely occurred although there is no single source documenting pond transfer activities. It is important to note that the SI unit designations did not govern pond transfer activities and that hazardous liquids likely entered each of the ponds at some point during site operations.

Surface impoundment construction began in 1972, and new impoundments were added or enlarged through 1985. These facilities were used for the receipt, treatment, storage, and evaporative disposal of acid and alkaline wastes, oil field wastes, industrial wastewater, and site stormwater runoff. In addition to the hazardous waste ponds and pads, two waste ponds (Sludges 1 and 2) were used for disposal of non-hazardous wastes such as sewage sludge.

Historically, liquid wastes received at the facility were deposited directly into surface impoundments for treatment or evaporative disposal. Spray evaporation disposal techniques were also used to speed the rate of evaporation. The use of spray evaporation was discontinued in 1985 (Section 3.5.1, Page 3-9, McClelland Consultants, 1989). Liquids disposal to the ponds ceased by 1988, and surface impoundment closure activities were completed from 1988 to 1991. A summary of the pond closure information is presented in Table 2-5. Because of Casmalia Resources' funding constraints during pond closure, closure reports were not prepared for all ponds and pads, although all ponds and pads underwent the same closure process under agency review. Table 2-6 presents a summary of the chemicals detected in the pond and pad sludges prior to closure. Data presented in Table 2-6 were collected to profile pond and pad sludges prior to removal to ensure proper on-site placement. The sludge data in Table 2-6 are independent of the later soil sampling data used to document soil removal activities conducted during subsequent phases of the impoundment closure program. Section 2.2.5.1 provides additional details regarding the different phases of the pond closure process.

A general description of the former surface impoundments at the site is presented below. Detailed information regarding pond transfers is not reiterated below because that information is presented in Table 2-4 and on Figure 2-7. Detailed descriptions of the physical character, nature of contained wastes, and interrelations among the various surface impoundments are presented in the HAR (Canonie Environmental, 1987), RCRA Facility Assessment (A.T. Kearney / SAIC, 1987), Final Environmental Impact Report (EIR) (Table 3.5-1, Page 3-13, McClelland Consultants, 1989), the Preliminary Pond and Pad Characterization document (Environmental Solutions, 1987) and the surface impoundment Closure Certification Reports (Canonie Environmental, 1998b; Brierley and Lyman, 1990a-f, 1991a-l).

2.2.3.1.5 Former Ponds

The surface impoundments that were used at the Site can generally be separated into four categories based on their primary use. The groupings presented below are consistent with those presented in the Final EIR (McClelland Consultants, 1989). Note that the RCRA Facility Assessment (A.T. Kearney / SAIC, 1987) used similar categories for discussion although in some cases single ponds were discussed separate from the larger grouping used in the EIR. Primary differences in the groupings are discussed in the section to follow. The general pond categories include:

- Stormwater runoff control/evaporation ponds;
- Acid/alkaline ponds;
- Oil field waste ponds; and
- Washout ponds.

Stormwater Runoff Control/Evaporation Ponds

The majority of ponds at the Site were used for rainfall and stormwater runoff management to comply with the CRWQCB waste discharge requirement that no liquid be discharged from the site. The ponds used for rainfall and stormwater management and to control pond overflow included Ponds 1, 2, 5, 6, 8, 10, 11, 12, 13, 19, 20, 21 (converted to Pad 10E), 22, 23, A-1, A-2, A-3, A-4, A-5, A-6, and Pond 43 (also known as the WCCB) at the southern end of RCRA Canyon. An unnamed pond in the northeastern portion of RCRA Canyon (which managed seasonal flow from the slope) also was identified as a stormwater pond (A.T. Kearney / SAIC, 1987).

Note that the listing above includes Ponds 6, 19 and 23 which were discussed separately in the RCRA Facility Assessment. Ponds 6 and 19 were unique in that they received landfill runoff and were used for leachate control. Pond 23 was constructed in the Burial Trench Area to provide ocalized runoff control. Although it was originally intended for use as an alternate alkaline pond, it is not clear whether the pond was used for that purpose.

Only a few of the above-listed ponds were specifically designated to directly receive landfill runoff or leachate (Ponds 6 and 19) or bulk liquid waste material (Ponds 23 and A-5). However, because all of the above-listed ponds collected surface runoff from the site, they likely received hazardous constituents, and in June 1987, the RWQCB determined that all surface impoundments were to be treated as containing hazardous materials.

The ponds relied upon the underlying materials to provide vertical containment of the liquids in the ponds with the exception of Pond 22, which was the only pond in this category that had a compacted clay liner. All of the ponds had compacted earthen berms to limit lateral migration of fluids and Casmalia Resources installed a system of overflow pipes that was intended to prevent any given pond from overflowing. Overflow pipe leaks and other breaches were noted during the site's operation. Pond 13, at the southernmost site boundary, was maintained as an emergency overflow pond. In February 1978, Casmalia Resources discharged site liquids down the B-Drainage during a storm that could not be managed on site.

Acid and Alkaline Ponds

Ponds 14 and P directly received both acid and alkaline wastes, and were used for the neutralization treatment of acid and alkaline wastes. Ponds E and J were used for the direct receipt of acid and alkaline liquid wastes. Ponds 15, 17, and 18 were interconnected and used for the storage of acidic and alkaline wastes. Ponds 15, 17, and 18 were plumbed with Pond E such that Pond E could receive overflow from those ponds (A.T. Kearney / SAIC, 1987).

Although Pond 14 was designated as an alkaline pond and Pond P was designated for acidic wastes, alkaline or acidic wastes were stored in either of the ponds depending on operational considerations. Both ponds have compacted clay liners and the ponds were used to hold acid or alkaline wastes for on-site treatment, or to neutralize alkaline or acidic wastewaters and precipitate heavy metals in the ponds themselves. Liquids were discharged to the ponds via PVC pipes in a paved unloading area north of the ponds (A.T. Kearney / SAIC, 1987). The approximate location of the unloading area is shown on Figures 2-6 and 2-7. Note that the unloading areas may have changed over time as observed in historical aerial photographs. At

the time of closure, heavy metal sludges in the ponds were taken to the Heavy Metals Landfill for disposal.

Ponds E and J were sometimes used in lieu of Ponds 14 and P for the storage and treatment of acid and alkaline wastes. Liquid effluent form the Zimpro WAO and the CNS were also routed to Pond E. Ponds E and J also had compacted clay liners.

Ponds 15, 17, and 18 were originally developed to receive wastes from the Stringfellow Acid Pits site. These ponds were used in conjunction with the experimental PACT unit in 1984 to pretreat acidic wastewaters containing metals and to receive effluent from the unit. All three earthen ponds were located in the southwest portion of the facility and were used for storage of acidic wastes. Pond 15 was used for pH adjustment and precipitation of metals; Ponds 17 and 18 were used for overflow and storage. From Pond 15, liquids were pumped to the storage tanks feeding the PACT unit. These ponds were once plumbed with Pond E and used for overflow from acidic and alkaline waste storage in that pond. Pond 18 also received diverted runoff from the PCB Landfill and received effluent from Ponds P and 14 (A.T. Kearney / SAIC, 1987).

Although Pond R is not typically referred to as an acid pond, Pond R received acidic and caustic wastes in 1978 (A.T. Kearney / SAIC, 1987), including hydrocetic acid, formic acid, abronium hydroxide, hydrazine, and unspecific caustics. Pond R otherwise received runoff from the P/S Landfill, and runoff and steam cleaning effluent (before the decontamination tank was installed) from the Maintenance Shed Area.

Oil Field Waste Ponds

Ponds A, B, C, M, S, T, and V received bulk oil field wastes consisting of crude oil, brines, water, and refinery sludges. Ponds A, B, and C directly received oil field wastes and were the oldest ponds at the site. These ponds may also have received solvents (A.T. Kearney / SAIC, 1987). Ponds M, S, T, and V received settled and overflow liquids from Ponds A, B, and C. Additionally, Pond T received petroleum refinery sludges, restaurant kitchen grease, and digested sewage sludge. Ponds B and C were routinely discharged to Pond M by excavating a trench between the ponds and allowing the oil to flow to Pond M. Pond A discharged to Pond S in a similar manner.

Ponds 3, 4, and 9 were grouped in the EIR with the oil field waste ponds because they received overflow from oil field waste Ponds M and V. These three ponds were grouped separate from the oil field waste ponds in the RCRA Facility Assessment as oil field waste “overflow ponds.” Based on the operational information available, it appears that these ponds received both oil field waste overflow and liquids from other runoff control ponds. On Figure 2-6, these ponds are indicated as “runoff, evaporation and storage ponds” rather than “oil field waste ponds.” The oil field waste ponds designation was used only for those ponds that primarily contained oil field wastes. Ponds 4 and 9 also were capped with oil to control odor emissions in 1985. Liquids in the Ponds 3 and 9 were subsequently treated with hydrogen peroxide and Ponds 3 and 4 had mechanical aeration systems to control sulfurous odors resulting from anaerobic decomposition of the wastes.

Washout Ponds

Ponds D and 16 were used for direct disposal of washout wastewater from oil field waste trucks. Overflow from Pond D was directed to Pond L, which primarily contained washout sludges. These ponds were shallow and thus the size of the ponds appears to change over the years. The washout ponds were operated as evaporation units. Historical records indicate that trucks that used the washout racks were those that had disposed wastes in Ponds A, B, and C (A.T. Kearney / SAIC, 1987).

2.2.3.1.6 Former Non-RCRA Sludge Areas

Sludge Areas 1 and 2 were located along the eastern side of the site and were used to spread dry, non-RCRA wastes such as sewage sludge and restaurant grease-trap sludges. Sludges were discharged from vacuum trucks, then periodically disced to promote aeration and drying. These areas were periodically cleaned out and the dried materials were used for cover landfill material.

2.2.3.1.7 Former Evaporation Pads

A total of 15 evaporation pads were distributed through the Site, including Pads 1A, 4A, 7A, 8A, 8B, 8C, 9A, 9B, 10A, 10B, 10C, 10E, 10F, 10G, and Pad 18. Note that Pads 1A, 8B, and 8C were never permitted or used for waste management due to their proximity to the site boundaries. Nine of the remaining 12 pads were designated as being used for landfill runoff or leachate control (Pad 9A, 9B, 10A, 10B, 10C, 10E, 10F, 10G, and Pad 18); these pads are grouped with the “landfill runoff / leachate control” ponds on Figure 2-6. Pads 4A, 7A, and 8A were simply designated as evaporation pads (and are thus grouped with the “runoff, evaporation and storage” ponds on Figure 2-6); these pads generally received liquids from adjacent ponds (see Table 2-4). The relatively flat pads were designed to increase evaporation by spreading liquids or saturated solids at shallow depths across large surface areas. The pads were constructed of fill removed from other surface impoundments at the site and from fill in the vicinity of the pad. Pad 10E was constructed on top of Pond 21 and no material was removed from that location before Pond 21 was converted to Pad 10E. Although Table 2-3 indicates that the pads were all constructed in approximately 1985, there is evidence (based on the aerial photograph review) of activity on some of the pad locations prior to that time.

As indicated in Section 2.2.5.5, the CSC capped Pads 10C, 10E, 10F, and 10G, and a portion of Pads 10A and 10B as part of the EE/CA Area cap.

2.2.3.1.8 Oil Field Waste Spreading Areas

Six areas at the site were used for the spreading and drying of oil field wastes and drilling mud. The initial Spreading Area (S-1) was located in the areas of Pads 9A and 9B; disposal in this area likely began in 1981 (A.T. Kearney / SAIC, 1987). The other areas (designated S-2 through S-6) were located primarily adjacent to access roads along the northern and western site boundaries, and varied from approximately 1.0 to 2.6 acres in area (Figure 2-4). The spreading areas were road embankments over which oil field wastes (and other wastes in the cases of S-5 and S-6) were sprayed from a truck driving along the road. Although the spreading areas were not engineered units, an effort was made to terrace the embankments so that liquids did not run down the embankment and erode the road. The beginning and the end of the spreading areas were marked with posts so that spreading occurred over a defined area of the

facility. The oil field and other wastes were allowed to dry, and the dried materials were subsequently excavated and used as cover materials for some of the landfills.

Based on the cuts made during pond closure activities, the spreading area materials in Pads 9A and 9B, and Pond 6 were likely excavated at that time (see Appendix W for more information regarding cut and fill resulting from pond closure activities). The spreading areas along the eastern and northern perimeter roads (S-2, S-3, and S-4) are currently under the capped landfills and associated perimeter roads. Residuals and erosion features associated with Spreading Areas 5 and 6 (located in RCRA Canyon) are currently visible.

2.2.3.1.9 Former Drum Burial Unit

According to Casmalia Resources personnel, disposal of drums occurred on an experimental basis in the area of former Pond 19 (Figure 2-4). Drums containing a small quantity of acidic waste were placed in this area between approximately December 1979 and June 1980, prior to construction and operation of the Acids Landfill. Drums in this area were subsequently covered during the construction of the base of Pond 19. These materials were reportedly removed during closure activities for Pond 19.

2.2.3.2 Subsurface Barriers and Extraction Facilities

Subsurface compacted clay barrier walls were installed downgradient of the P/S and PCB landfills in 1980. The P/S barrier includes an extraction point called the Gallery Well. A subsurface barrier also was installed at the base of RCRA Canyon in 1984 and a barrier near Pond 20 was constructed in 1981/1982. As part of early site operations, subsurface clay barriers with extraction facilities also were installed in the B and C Drainages in 1972/1973 and 1982, respectively (Penfield & Smith, 1973; Penfield & Smith, 1982; Woodward Clyde Consultants, 1988). A relatively shallow liquid extraction point, Sump 9B, was constructed in response to evidence of contamination observed during the closure of the former Pad 9B waste pad in 1988 (Harding ESE, 2001g). An additional shallow liquid extraction point, the Road Sump, was installed downgradient of Sump 9B in 1998 to intercept groundwater recharge potentially migrating downgradient from Sump 9B.

Perimeter collection and extraction facilities, including three collection trenches and five extraction wells, were installed at the facility from February to April, 1989 in accordance with the Site's previous Remedial Action Plan (Canonie, 1988; Brierly & Lyman, 1989c,1990h). These features, located along the A, B, and C Drainages, were originally called plume capture and control trenches but are commonly referred to today as the perimeter control trenches (PCTs). Also in accordance with the Site's previous Remedial Action Plan (Canonie, 1988), the extraction trench (or perimeter source control trench - PSCT) was installed downgradient of the landfills in November 1990 (Brierly & Lyman, 1989a; Woodward-Clyde Consultants, 1991).

These various barriers and extraction facilities are further described in the following sections.

2.2.3.2.1 PCB Landfill Clay Barrier

An environmental barrier was constructed along the southwest corner of the PCB Landfill during December 1980 (Woodward Clyde Consultants, 1988a). This barrier was constructed of compacted clay within a trench excavated to approximately 14 feet beneath the ground surface and installed a minimum of four feet into unweathered claystone bedrock (Pacific Materials

Laboratory, 1980). The clay barrier was designed to be a minimum of 10 feet wide and reportedly includes a 6-mil polyethylene sheet lining on its downstream face. No leachate collection system was installed as part of this landfill barrier.

2.2.3.2.2 P/S Landfill Clay Barrier and Gallery Well

Casmalia Resources constructed a clay barrier and extraction point at the toe of the P/S Landfill in 1980. The clay barrier wall is reportedly approximately 200 feet long, 12 feet thick, and up to 50 feet deep (Woodward Clyde Consultants, 1988a). It is believed that the barrier wall extends a minimum of 4 feet into the unweathered claystone formation (Pacific Materials Laboratory, 1981a). The location, alignment, top elevation, and physical properties of this feature were confirmed by an exploratory drilling and sampling program conducted as part of the Remedial Investigation. Details of the P/S Landfill clay barrier investigation are presented in Appendix J of this report. The location of the P/S clay barrier as confirmed during the RI is also depicted in Figures 2-3 and 2-4.

Clay Barrier Construction

The adobe clay barrier was constructed by excavating an east-west ditch along the southern edge of the P/S Landfill. This ditch was approximately 10 feet wide at the bottom to as much as 30 feet wide at the top of the ditch due to sloughing of the soils. The ditch was approximately 200 feet long running along the southern edge of the P/S Landfill and about 30 feet deep. The ditch was dug down approximately 5 feet beneath the blue-gray clay contact (i.e., keyed into the contact) using heavy equipment and was located to be as close to the waste face as possible. According to on-site personnel who participated in the construction of the clay barrier, there were exposed drums at the top of the ditch during construction due to soil sloughing. An access ditch of approximately the same dimensions as the clay barrier ditch was constructed to “T” into the east-west ditch to allow equipment and trucks containing adobe clay access into the east-west ditch. Clay materials and other soils were delivered to the center of the east-west ditch by dump trucks and spread laterally by equipment to fill the ditch, keeping a generally horizontal (i.e., level) surface. The clay barrier was eventually built up to a height of approximately 50 feet and is nominally 8 to 12 feet wide and 200 feet long.

Gallery Well Construction

Casmalia Resources also installed an extraction point directly upgradient of the clay barrier at that time to reduce the liquid levels in the P/S Landfill (Caldwell, *et. al*, 1982). The extraction point, now known as the Gallery Well, was historically known as SP-1 and GCW. The CSC continues to extract liquids from the Gallery Well.

The Gallery Well reportedly extends 5 feet into the unweathered claystone. The base of the Gallery Well is seated in an approximate 4-foot-diameter collection basin filled with gravel. The Gallery Well consists of a 10-inch-diameter polyvinyl chloride (PVC) casing that extends approximately 84 feet from the existing ground surface. The lower 40 feet of casing is perforated to allow liquids to flow into the Gallery Well.

2.2.3.2.3 RCRA Landfill Clay Barrier

An environmental barrier was constructed downgradient of the RCRA Landfill during June to August 1984. This barrier was constructed at the southern end of Pond 43 (or the WCCB), which is located at the southern end of RCRA Canyon. The barrier was constructed of compacted clay within a trench excavated to approximately 30 feet beneath the ground surface,

and was installed a minimum of four feet into unweathered claystone bedrock. The clay barrier is equipped with a leachate collection well, without sump pump, on the upgradient side of the barrier dam approximately at the mid point (Attachment 21-1, Woodward Clyde Consultants, 1988).

2.2.3.2.4 Former Pond 20 Clay Barrier

Pond 20 served as a runoff control pond and was utilized in the evaporation system. It was constructed by the operator's personnel in mid-to-late 1981 and contained a clay core barrier dam located at the pond's southeast corner (Woodward Clyde Consultants, 1988). The clay core is reported to be 15 feet wide and was constructed of compacted material installed a minimum of 5 feet into the unweathered claystone (Pacific Materials Laboratory, 1981b, c). This barrier was sometimes referred to as the A-Drainage clay barrier although it was located more specifically near the limits of former Pond 20.

2.2.3.2.5 Sump 9B

Sump 9B is a gravel-filled collection trench and associated extraction point installed directly downgradient of the P/S Landfill clay barrier and upgradient of the PSCT. Sump 9B is located approximately 200 feet downgradient (south) of the Gallery Well and was constructed during closure of former Pad 9B in response to the observation of contamination below the groundwater table in this location. This feature consists of a circular sump approximately 27 feet deep and 12 feet wide. Extending approximately 100 to 150 feet westward from the sump is a shallow (estimated 8 to 12 feet deep) trench. The sump and trench are filled with gravel to approximately 6 feet below grade and covered with compacted fill material. The trench was not completed into the unweathered claystone. Drilling activities associated with the installation of the Sump 9B companion well in July 2001, confirmed that the sump was excavated and installed down to the unweathered claystone (Harding ESE, 2001e). An extraction point (Well 9B) was installed at the deepest portion of the sump (Harding ESE, 2001g).

As part of USEPA taking over the site in August 1992, the liquids were treated on-site in the Contaminated Liquids Treatment Area and discharged to Pond A-5. Since 1996, as part of the CSC's Interim Liquids Collection/Treatment/Disposal Element of Work, the Sump 9B extracts have either been treated on site or sent off site for disposal or treatment. Currently, fluids removed from the sump are taken off-site for disposal. Extracted volumes from the Sump 9B during the periods of October 1997 – September 1998 and October 1998 – September 1999 were respectively 0.96 million and 0.79 million gallons. Extracted volumes through June of the 1999/2000 time period is 0.62 million gallons.

2.2.3.2.6 Perimeter Source Control Trench

The PSCT is a continuous, approximate 2,650-foot-long and nominally 3-foot-wide gravel-filled collection trench covered with compacted fill material (Brierly & Lyman, 1989a). The PSCT was installed in 1990, on a roughly northwest-to-southeast alignment, across most of the central portion of the site, and is situated in a downgradient position relative to the five inactive landfill areas and the Burial Cells Unit. The PSCT, while crossing most of the central portion of the site, does not extend west of the Casmalia Neutralization System and into the West Canyon Spray Area/RCRA Canyon Area. The PSCT extends to depths of between approximately 13 and 65 feet, depending on the depth at which unweathered claystone bedrock was encountered during construction. The PSCT is designed to intercept subsurface liquids migrating from north

to south across the site. The major components of the PCST include a filter fabric against the native alluvial or fill soils; a permeable gravel backfill; random backfill above the gravel; a low permeability cap to minimize water infiltration; and four collection sumps and associated extraction points. The gravel backfill extends approximately 10 feet above the highest level of groundwater seepage observed during excavation (Drawing D1046-007-2 through D1046-007-7, Brierley & Lyman, 1989a).

The four collection sumps were constructed by excavating pits into unweathered claystone bedrock. Liquids collected in the PSCT flow along the bottom of the trench toward the center of each sump, away from engineered flow divides, which isolate the individual sumps. When liquid levels exceed the level of the flow divides, liquids flow along the base of the trench to the lowest point in the system located at extraction point PSCT-1. Currently, all four sumps have pumps installed and liquids are extracted to maintain liquid action levels mandated by USEPA. Sumps PSCT-1 and PSCT-4 produce the most significant volumes. Annual extraction volumes for PSCT-1 and PSCT-4 are summarized in Table 2-8. Liquids extracted from sumps are currently treated in the granulated activated carbon treatment system and discharged into Pond 18.

2.2.3.2.7 A-Drainage Perimeter Control Trench

A gravel-filled PCT and associated groundwater extraction points (PCT 1-A and extraction points RAP 1A, 2A, and 3A) were installed in 1989 to collect and pump groundwater at the southeast corner of the facility (Brierly & Lyman, 1990h). This PCT was constructed as an additional means for intercepting groundwater flow toward the A-Drainage area. Annual extraction volumes for RAP-1A, -2A, and -3A are summarized in Table 2-8. Extracted liquids are discharged into the RCF Pond.

2.2.3.2.8 B-Drainage Clay Barrier and Perimeter Control Trench

A subsurface clay barrier was installed in 1973 directly downgradient from Pond 13 between the two low hills flanking the head of the B-Drainage (Penfield & Smith, 1973; Woodward Clyde Consultants, 1988). This clay barrier was constructed to restrict groundwater flow in the B-Drainage area. The barrier is reported to be 8 feet wide and approximately 50 feet deep, extending about 4 feet into unweathered claystone. The barrier is equipped with a 1-foot-wide gravel drainage gallery and associated extraction point (extraction point B-5) on its downgradient side to assist in groundwater collection and removal.

A gravel-filled perimeter control trench and associated extraction point (PCT-B and extraction RAP-1B) was installed downgradient from the B-Drainage clay barrier in 1989 (Brierly & Lyman, 1990h). This PCT provides an additional means for intercepting groundwater flow in the B-Drainage area. Annual extraction volumes for RAP-1B are summarized in Table 2-8. Extracted liquids are discharged into the RCF Pond.

2.2.3.2.9 C-Drainage Clay Barrier and Perimeter Control Trench

A subsurface clay-core barrier was constructed between 1981 and 1982 at the southwest corner of the facility, directly down slope (south) of the five A-series ponds formerly located in this area (Loomis, 1982; Penfield & Smith, 1982; Woodward Clyde Consultants, 1988). This structure is over 1,000 feet long and was installed to intercept groundwater migrating southwesterly from the facility in the C-Drainage toward Casmalia Creek. The clay core is approximately 8 feet thick and a maximum of 75 feet deep, extending a minimum of 4 feet into unweathered

claystone bedrock. The clay barrier is equipped with an approximately 1-foot-wide gravel drainage curtain on its upgradient face to assist in the collection of groundwater, which is removed by pumping at extraction point C-5.

A gravel-filled perimeter control trench (PCT-C) was installed in 1989 as a northern extension to the pre-existing clay barrier (Brierly & Lyman, 1990h). This PCT provides additional control of groundwater that may otherwise migrate down the C-Drainage toward Casmalia Creek. Groundwater collected in PCT-C is removed from extraction point RAP-1C. Annual extraction volumes for RAP-1C and C-5 are summarized in Table 2-8. Extracted liquids are discharged into the A-Series Pond.

2.2.3.2.10 Road Sump

The Road Sump is a subsurface collection and containment sump with an extraction pump designed to intercept and capture groundwater recharge potentially migrating downgradient from Sump 9B into an above ground concrete culvert adjacent to the Sump 9B Road. The Road Sump is approximately 10 feet in length and 3 feet wide and completely filled with gabion rock (ICF Kaiser, 1998c). The sump extends 1 foot down into the clay layer to a total depth of approximately 5.5 below ground surface. The Road Sump was constructed and installed with an 8-inch PVC well in November 1998. A well head and extraction pump was later installed in January 1999. Currently, groundwater level in the road sump is measured twice a day to maintain a compliance action level greater or equal to 6 feet below top of casing (ftbtoc).

2.2.3.3 Former Liquid Waste Treatment Systems

Historical site treatment units and systems included the following:

- Casmalia Neutralization System (CNS) used to treat acidic and alkaline liquids;
- Hydrogen peroxide treatment system to control odors near Pond 3;
- Oil recovery and treatment system tanks operated north of Pond M;
- Zimpro wet air oxidation (WAO) unit used to oxidize organic liquids; and
- Zimpro PACT unit, which was a temporary pilot-scale treatment system.

2.2.3.3.1 Casmalia Neutralization System

The Casmalia Neutralization System was operated at the Site between 1986 and 1989 for the purpose of neutralizing and treating acid, alkaline, and heavy metal wastewater streams delivered to the facility. The initial operation trials were completed on acidic and corrosive waste streams containing hexavalent chromium. The facility was a covered, open-air structure on a concrete slab with a surrounding 2-foot high concrete containment structure. The concrete slab and containment were coated with a corrosion resistant coating and the slab contained three sumps, which were pumped out as needed.

The CNS consisted of six 10,600-gallon wastewater storage tanks, a 10,600-gallon lime storage tank, two 500-gallon feed tanks, three reactor vessels, a 4,880-gallon effluent diversion tank, a 4,880-gallon reducing agent storage tank, and two 20,000-gallon effluent storage tanks. Three of the 10,600-gallon storage tanks were used to accept acid wastewater and three were used to accept alkaline wastewater delivered from trucks from the unloading area. The facility also housed a centrifuge to concentrate and remove solids. Solids were place in roll-off bins and

then transported to the Heavy Metals Landfill for disposal. Liquids from the centrifuge were conveyed to Pond E.

As further discussed in Section 2.2.5.3, the CSC decommissioned and dismantled the CNS in 1997.

2.2.3.3.2 Hydrogen Peroxide Treatment System

The hydrogen peroxide treatment system was located north of Pond 3. This unit was installed and started operation in August 1985 to treat odor problems resulting from the generation of sulfurous gases from Ponds M, 4, and 9. The system included an oil separator tank and two polypropylene treated water storage tanks, as well as two stainless steel hydrogen peroxide feedstock tanks. Liquid was first passed through the oil separator tank, which utilized excelsior for filter material. Liquid then entered PVC pipes where hydrogen peroxide was injected, and flowed to two tanks located at the north bank of Pond 3. The treated water was retained in the tanks for approximately one hour; it then flowed to Pond 3 or was pumped to Pond 10. Both Ponds 3 and 10 were aerated to remove any remaining sulfides.

The oil separation tank was a horizontal steel tank of approximately 5,000-gallon capacity. The treated water tanks each had approximately 8,000-gallon capacity; they were set directly on the ground surface.

2.2.3.3.3 Oil Recovery and Treatment System

The waste oil treatment facility was located between Ponds B and M and became active in the early 1970s. The system consisted of one horizontal 240-barrel (bbl) oil storage/treatment tank, one vertical 200-bbl storage/treatment tank, and one vertical 1,000-bbl oil storage/treatment tank west of Pond S and south of Pond B. The horizontal tank was located on the dike of Pond B, topographically about 30 feet above the vertical tanks, which were at the base of the Pond B dike. All three tanks were steel, closed-roof construction and were set on the ground with no secondary containment.

Originally, the horizontal tank was used for the first phase separation and then oil was sent to the 200-bbl vertical tank for heat treatment. From there it was pumped to and stored in the 1,000-bbl tank for use in dust control and sale as spec oil.

2.2.3.3.4 Zimpro Wet Air Oxidation System

A Zimpro Wet Air Oxidation (WAO) unit was operated at the Site between March 1983 and April 1987. The unit was located within the existing groundwater treatment area (Figure 2-4). The WAO unit was designed to oxidize liquid wastes at high temperatures in order to produce carbon dioxide, water, and other oxidized products. Treated wastes included cyanide/sulfide and organic wastes. Resulting vapors were directed to a WAO vapor treatment system for scrubbing. The unit was ordered closed by the County Santa Barbara in 1987, due to excessive air emissions (Section 3.5.6, Page 3-26, McClelland Consultants, 1989).

The WAO unit was inside a roofed structure, on concrete with diking around it. Four 15,000-gallon waste storage tanks were located west of the unit on concrete pads in a gravel area surrounded by an earthen berm. The other two 15,000-gallon tanks were located north of the building on concrete pads in a gravel area on top of the embankment immediately north of the

WAO unit. These two tanks were later moved adjacent to the four tanks east of the WAO unit and a concrete containment area was constructed (creating what was later referred to as the "six-pack tanks".)

2.2.3.3.5 Zimpro Powder-Activated Carbon Unit

The powered activated carbon treatment (PACT) unit was a temporary pilot-scale treatment unit brought to the site to specifically to treat wastes from Stringfellow Acid Pits. The system was operated by Zimpro under a joint venture arrangement with Casmalia Resources. The system was located near the WAO treatment building and operated from June 1984 through December 1894. All components of the system were removed from the site at that time.

The design flow for the unit was 5,000 gpd and the process was operated 24 hours per day. The PACT equipment consisted of two 21,000-gallon influent storage tanks, one 2,450-gallon aeration tank, one 3,000-gallon clarifier, and one 500-gallon sludge storage tank, as well as other conventional activated sludge equipment (e.g., blowers and pumps). Process solids from the unit went to the Solvent/Pesticides Landfill, and liquids were disposed of in Pond E.

2.2.4 Existing Surface Impoundments

Past CRWQCB Waste Discharge Requirements dictated zero discharge from the Site, and since 1987, all stormwater runoff and treated groundwater was contained within the site boundary. In November 1999, a National Pollution Discharge Elimination System (NPDES) permit for the Site was adopted by the CRWQCB (Permit No. CA0049972, Order No. 99-034) allowing periodic discharge of treated surface waters if certain on-site conditions were met. A General NPDES permit was also adopted by the CRWQCB for the Site in 2003 (Permit No. CA 0049972, Order No. R3-2004-0124), which allowed periodic off-site discharge of clean stormwater runoff draining from capped areas of the site, including the P/S Landfill cap and the EE/CA cap areas.

There currently exist six unlined surface impoundments within the site boundary to store all surface runoff water and treated liquids. These facilities are briefly described below.

2.2.4.1 <u>Stormwater Runoff Collection Ponds</u>

A total of four surface water runoff collection ponds are currently present at the Site. Three of these ponds are located along the south-central and southwestern site boundary, and are identified as the Runoff Containment Facility (or RCF Pond), Pond 13, and the A-Series Pond (Figure 2-3). The RCF Pond lies in the area once occupied by portions of former Ponds 2, 3, 4, 8, 9, 10, and 11. The A-Series pond lies in the area once occupied by portions of former Ponds A-1, A-2, A-3, A-4, and A-6. Pond 13 is the most southerly (downgradient) of the original stormwater runoff containment ponds and is still utilized for its original purpose of runoff control.

The remaining surface water runoff collection pond comprises a small unlined collection basin constructed during 2003 by the CSC in a portion of the Central Drainage Area (Figure 2-3). Clean stormwater runoff from the P/S Landfill cap and EE/CA cap is directed via drainage swales into this basin, and a pipeline from the basin allows impounded stormwater to be drained directly into the RCF Pond or the upper reaches of the B-Drainage for off-site discharge, bypassing uncapped areas of the site. This pipeline is equipped with valves and flowmeters to control the location and rate of discharge. Discharges from this pond are permitted under the

General NPDES permit. Test discharges from this basin were conducted during the 2005-2006 rain year.

2.2.4.2 Treated Liquids Impoundments

Two treated liquid impoundments are currently present at the Site. These ponds are located on the southwestern portion of the site, and are identified as Pond A-5 and Pond 18 (Figure 2-3). The locations of these two holding ponds largely correspond with those of former ponds of the same designation. Treated liquids extracted from Sump 9B and the Gallery Well were once discharged to Pond A-5, although Pond A-5 does not currently receive any liquids. Pond 18 currently receives treated effluent from the PSCT granulated activated, carbon-treatment system.

2.2.5 Closure Activities and Response Actions, and Ongoing Monitoring

Previous closure activities/response actions completed by Casmalia Resources during site operations included closure of the former ponds and pads and removal of two fuel tanks at the site. Additional response actions include CNS decommissioning completed by the CSC and ongoing capture and treatment of liquids from the various active extraction points within the site, including PSCT-1, PSCT-2, and PSCT-4, the Gallery Well, Sump 9B, and the extraction points associated with the several clay barriers, collection galleries, and PCTs installed along the downgradient site margins. Liquids management activities at the Site were initiated by Casmalia Resources and were continued by USEPA during the emergency response period until the CSC began work at the Site. Finally, the CSC constructed RCRA-equivalent caps over four of the five existing site landfills.

2.2.5.1 Surface Impoundment Closure Activities

Closure of existing surface impoundments was implemented in accordance with CAO No. 89-60, issued by the CRWQCB. The overall objective of closure operations was to remove hazardous constituents once present in the former surface impoundments to background or other cleanup levels approved by the CRWQCB. The proposed removal activities and confirmatory sampling and analysis procedures associated with impoundment closure are described in the Existing Surface Impoundment Closure and Post-Closure Plan (Canonie Environmental, 1989b).

Surface impoundment closure was undertaken in three stages: removal, bottom sludge removal, and contaminated subgrade removal. Removed fluids were either evaporated or solidified for disposal into on-site landfill areas. Bottom sludges were similarly solidified and disposed of. Contaminated subgrade materials encountered during closure activities were relocated to on-site landfill areas for disposal.

The excavation of subgrade materials continued until laboratory testing of confirmatory soil samples indicated that pre-approved analyte-specific background concentrations or Toxicity Characteristic Leaching Procedure (TCLP)-based (TCLP-based) Target Cleanup Levels (TCLs) had been achieved, or until further excavation became impracticable.

Procedures in the Existing Surface Impoundments Closure and Post-Closure Plan (Canonie, 1989a) called for a minimum of four randomly located samples to be collected from the floor of all 58 former ponds/pads and chemically analyzed to document subgrade conditions. Chemical

analyses were conducted for all initial confirmation sampling locations, and included the following:

- Volatile organic compounds (VOCs) – USEPA Method 8240;
- Semi-volatile organic compounds (SVOCs) – USEPA Method 8270;
- Organochlorine pesticides and PCBs – USEPA Method 8080;
- Chlorinated herbicides – USEPA Method 8150;
- California Assessment Method (CAM) metals – California Title 22;
- Chromium VI – USEPA Methods 7195, 7196, 7197, or 7198;
- Hydrogen cyanide – USEPA SW-846 Section 7.3.3.2;
- Hydrogen sulfide – USEPA SW-846 Section 7.3.4.2;
- Organic lead – CAM metals, California Title 22;
- pH – USEPA Method 9045; and
- Conductivity – USEPA Method 9050.

Testing for chromium VI and organic lead were conducted only if samples were found to have total chromium or total inorganic lead concentrations in excess of approved background-based TCLs.

After initial closure verification testing was completed to the satisfaction of investigators, all pond/pad excavations were examined by representatives of the CRWQCB and the Department of Health Services, the predecessor agency to the Department of Toxic Substances Control. As described in the available Closure Certification Reports, agency representatives required the collection of multiple additional verification samples for further analytical testing from each former impoundment area.

In addition to sampling and testing former surface impoundment subgrade materials, approximately 84 samples were randomly collected for similar chemical testing from areas where impoundment fluid transfer pipelines and culverts had been removed. These samples were also compared to TCLs to confirm acceptable closure along former pipeline and culvert alignments. Agency-required verification sampling was performed in excavation sidewall areas, beneath entry and exit pipelines and culverts, as well as throughout the floor areas of impoundment excavation areas. It is estimated that in excess of 780 soil samples, or 11 to 12 samples per acre of impoundment area, were collected and chemically analyzed during the impoundment closure process to document closure conditions.

Target cleanup levels were not met in all closure samples, and Casmalia Resources submitted closure reports for only 16 ponds and 3 pads as follows:

- Pond 4 (Canonie Environmental, 1989b);
- Ponds 1, 3, 5, 6 (eastern 2/3), 8, 10, 11, 12, 15, 17, 20, A-1, A-2, A-3, and A-4 (Brierley and Lyman, 1991a, 1991b, 1990b, 1991c, 1990c, 1990d, 1991d through 1991l, respectively); and
- Pads 8A, 8B, and 8C (Brierley and Lyman, 1990b, c, and d, respectively).

Casmalia Resources was negotiating with the agencies to secure the RCRA permits needed to keep the Site in operation during the pond closure period. When it became apparent that the Site would not remain in operation, Casmalia Resources stopped preparing closure certification reports although the closure work was completed (including removing and stabilizing sludges, excavating subgrade soils, and collecting confirmation and verification samples). According to

the RWQCB, the data generated from many of the ponds was not transmitted to the agencies even though the agencies participated in the pond closure walkthroughs at the Site. None of the surface impoundment certification reports were formally approved by the RWQCB.

Of the 19 closure reports reviewed, chemical testing results indicate that some of the impoundment areas had inorganic constituents at concentrations slightly in excess of TCLs at the time of closure. Ponds with concentrations exceeding TCLs included Ponds 1 (selenium), 4 (barium), 10 (barium, copper, and lead), 17 (nickel), and Pads 8A (barium) and 8C (nickel). Additional excavation was reportedly performed at Ponds 10 and 17; concern regarding undermining the adjacent NTU roadway was cited as the reason not to proceed with further excavation at Pond 1. Reported barium concentrations at Pond 10 were 3.0 parts per million (ppm) over the TCL of 140 ppm for this compound. Because initial samples collected at the base of Pad 8C prior to excavation were found to have acceptable concentrations, no further excavation was performed. The closure report for Pond A-1 indicated that diesel fuel contamination (from a nearby fuel pump) was left in place and that further excavation was not completed due to the proximity of NTU Road.

Contamination may have been left in place in other ponds where closure reports are not available. To assess the closure status of the ponds without closure reports, the CSC relies on available correspondence during the period October 1989 and February 1991 between site investigators, Casmalia Resources staff, and the CRWQCB. Based on the available information, it appears that minor organic contamination may have been left in the southeastern corner of Pond 2 and that contamination in the northeast corner of Pond 13 was present at the time of pond closure. Additionally, oil seeps were observed in Ponds B, C, and J and it is not clear what resolution, if any, was made regarding these areas. Casmalia Resources personnel speculated that oil noted in these areas was naturally occurring.

Closure conditions and recommendations for the majority of former surface impoundments were presented to the CRWQCB in a letter from the investigators overseeing the closure activities (Brierley & Lyman, 1990a). Closure conditions as described in this letter were based on analytical results for random confirmatory sampling, agency-required verification sampling, and the findings of field inspections by agency personnel. Closure conditions were also based on the assumption that the impoundment areas would be subsequently covered as part of a landfill closure or become the subsurface of a new lined RCRA Landfill. The 1990 closure recommendations made for each former pond and pad fell into one of three categories, as follows:

- Recommended for closure: applied to all former surface impoundment areas where constituent concentrations were found to be below approved TCLs, or in limited cases where TCLs were only slightly exceeded, or where logistical considerations precluded further excavation;
- Closure process incomplete: applied to former surface impoundments where iterative soil excavation, sampling, and analytical testing activities were still underway when closure activities at the Site ceased. Available information regarding conditions within individual impoundments under this classification indicate that constituent concentrations in excess of TCLs may have been left in place locally; and
- Recommended for closure as a landfill: applied to former impoundments where excavation of contaminated soils to TCLs was judged to be impracticable.

Based on available information, it appears that 40 out of the 58 former surface impoundments, or approximately 70% of the total number, were *recommended for closure*. Four entire impoundments (Pad 9A, Pad 9B, Pond R, and Pond 23) and limited portions of two others (the western one-third of Pond 6 and the southern berm area of Pond 19) were *recommended for closure as landfills*. Impoundments recommended for closure as landfills are restricted to the area lying north of the PSCT. They either overlie or are in close proximity to known existing contamination sources, including the Burial Cells Unit and the toe area of the P/S Landfill. The closure status of former surface impoundments as categorized above is shown on Figure 2-8. The CSC compared topographic maps for years 1987 to 1998 to quantify excavations made during pond closure activities described above. An oblique view of the site, depicting cut and fill between these years, is shown on Figure 2-9.

2.2.5.2 Fuel Tank Removals

Casmalia Resources removed two fuel tanks from the Site. One was an underground diesel fuel tank associated with the Zimpro WAO system and located outside in the southeast corner of the current Operations Building (which formerly housed the WAO equipment). The approximate 500-gallon tank was reportedly removed when the WAO system was dismantled in the late 1980s. Casmalia Resources personnel reported that the tank removal was conducted under Santa Barbara County Fire Department regulations and oversight. Although Casmalia Resources submitted a closure report for this tank removal, the CSC has not been able to locate the associated documentation.

The second tank Casmalia Resources removed from the Site was an aboveground tank located in the transportation yard south of the A-Series Pond. The tank was on a concrete containment structure with curbing on the south side of NTU Road, and the pump and fuel dispenser were located north on the south side of NTU Road adjacent to Pond A-1. The tank was removed from the Site in the late 1980s and no closure documentation was generated. As described in the section above, diesel fuel contamination was noted during pond closure activities in the subsurface soils south of Pond A-1.

2.2.5.3 CNS Dismantling

The CSC dismantled and decontaminated the tanks, process equipment, and piping associated with the CNS facility in November 1997. These activities included emptying residual sludges from the tanks and draining other tanks, valves, and piping. After the tanks, equipment, and piping were removed, the CSC cleaned and pressure washed the remaining concrete containment structure and collected wipe samples from the concrete. The results of the wipe samples indicated low concentrations of metals. Results of investigations conducted in support of ths decommissioning and dismantling process are presented in the Final CNS Demolition Report (ICF Kaiser, 1998d).

2.2.5.4 Subsurface Site Liquids Management

There are several extraction features at the Site including the following: Gallery Well, Sump 9B, PSCT, the PCTs, and the Road Sump. Liquids have been extracted from these features since they were each installed, although the method for treating and/or disposing of these liquids has changed over time.

All of the extracted liquids from the Gallery Well and Sump 9B were sent off-site for disposal until 1995, when the USEPA built and operated a pilot biological/powdered activated carbon treatment (biological/PACT) system for these liquids. The pilot treatment unit treated a portion of the Gallery Well and Sump 9B liquids; the remainder of these liquids was disposed of off-site. The treated effluent from the biological/PACT system was sent to Pond A-5. The CSC dismantled the system in 1998 and began shipping all Gallery Well and Sump 9B liquids off-site for disposal. In 2000, the CSC built and operated the synthetic resin Ameripure Treatment System (ATS) to treat liquids from the Sump 9B and PSCT extraction facilities. The granulated activated carbon canisters continued to be used as polishing units for the system effluent prior to discharge in Pond 18. The ATS was designed to treat a commingled stream of PSCT and Sump 9B liquids at a ratio not to exceed 90% PSCT and 10% Sump 9B. The remaining volume extracted from Sump 9B and all of the Gallery Well extracted liquids continued to be shipped off-site for treatment and disposal. Operation of the ATS treatment system was discontinued in 2003. Currently all extracted liquids from the Sump 9B and Gallery Well facilities are shipped off-site for treatment and disposal. PSCT liquids continued to be treated through the granulated activated carbon adsorption system. PSCT liquids have been treated using the granulated activated carbon adsorption system, and its effluent was sent to Pond 18 since the system was installed by the USEPA in 1993.

Groundwater extraction has been ongoing since 1980 when the owner/operator constructed the Gallery Well and began operating it as a groundwater collection facility. The owner/operator subsequently constructed additional groundwater collection facilities consisting of PCT-A, PCT-B, and PCT-C in 1989 and the PSCT in 1990. Operation and documentation responsibilities for the groundwater collection facilities were transferred from the owner/operator to the USEPA in 1992. Responsibility for operation and maintenance of these facilities was transferred to the CSC after the USEPA ceased emergency response operations at the Site in 1996. Table 2-7 summarizes the historical sequence of contaminated liquids control facility construction, extraction, treatment, and/or disposal, and Table 2-8 summarizes liquid extraction volumes from these features

The groundwater collection facilities are operated to maintain water levels at or below specific criteria elevations. Criteria water level elevations are described by water level depths measured from a datum such as top of casing of the collection facility and have been historically referred to as “action levels.” Tables 2-9 through 2-12 describe the historical chronology of contaminated liquids control facility action levels for the Gallery Well, Sump 9B, PSCT, and PCTs, respectively. Daily liquid level measurements document compliance with the specific action levels established for each pertinent extraction point. Compliance with the established action levels is summarized by the CSC in quarterly operations reports to the USEPA.

2.2.5.4.1 Gallery Well and Other Extraction Feature Action Levels

The Gallery Well was originally approximately 50-feet deep; however, the well casing has been extended twice to accommodate changes to the surrounding surface grade. Approximately 30 feet of casing were added 1981/1982 when the landfill was again expanded, and more recently, an additional 4 feet of casing were added in 1999 when the CSC placed additional fill on the P/S Landfill buttress as part of the P/S Landfill cap construction.

The CSC has been extracting liquids from the Gallery Well since they took over operations at the Site in 1996. In accordance with the Consent Decree (USEPA, 1997), the initial action level that the CSC maintained was 30 feet below top of casing (BTOC). When the Gallery Well casing was

extended 4 feet in 1999, the CSC maintained a measured liquid action-level equivalent to 34 feet BTOC, as was agreed to by the USEPA. Following discussions with the USEPA in 2000, the action level for the Gallery Well was subsequently lowered in a series of step changes beginning in October 2000. Between October 2000 and July 2001, the CSC lowered the liquid level in the Gallery Well in a series of steps to the current action level of 63 feet BTOC.

At that same time, the CSC also lowered action levels in several other extraction features. The action level in Sump 9B was lowered from a Consent Decree level of 6 feet BTOC to 15 feet BTOC. The action level in PSCT-1 was lowered from a Consent Decree level of 22 feet BTOC to 45 feet BTOC. The action level in PSCT-4 was lowered from 43 feet BTOC to 51 feet BTOC. At that time, the CSC also began pumping liquids from PSCT-2 and PSCT-3, setting action levels of 52 and 55 feet BTOC, respectively.

2.2.5.5 Landfill Closure Activities

While the majority of landfill areas remain intact, wastes once deposited in the former RCRA Landfill and the former Drum Burial Area were removed and redeposited in one of the existing inactive landfill areas. With the exception of the PCB Landfill, the inactive site landfills have been capped.
Landfill closure activities have included the following actions:

- Removal of wastes from former RCRA Landfill sometime between April 1989 and early 1990;
- Removal of wastes from the former Drum Burial Area between approximately December 1979 and 1980;
- Capping of the P/S Landfill in 1999; and
- Capping of the Heavy Metals Landfill, Caustic/Cyanides Landfill, Acids Landfill, and interstitials areas between these landfills (EE/CA Area Cap) during 2001-2002.

2.2.5.5.1 Site Spills and Seeps

Since the CSC began work at the Site in 1996, there have been some notable groundwater seeps and liquid spills resulting from extracted liquid pipeline breaks. These have included:

- A contaminated seep known as the “9B Road Seep” that was located immediately west of the road traveling from PSCT1 to Sump 9B approximately 35 feet north of PSCT1. There have been no surface liquids in this seep location for the last six years, however, when the seep did exist, elevated contaminant concentrations were noted;
- A seep on the southern face of the Pond A-5 dike. That particular seep is greatly diminished since the water level in Pond A-5 has been lowered. That seep has been sampled a number of times during the last nine years, and the water quality is similar to or better than the Pond A-5 liquids (which have all been below MCLs);
- A seep in the southeastern dike of Pond 18. Although Pond 18 is on the western side of the road to the treatment area, the seep is on the eastern side of the road. That seep also has been periodically sampled over the past nine years, and the results do not indicate significant contamination. The seep could be Pond 18 liquids or uncontaminated perched water;
- An April 22, 2001, Gallery Well break;
- An October 14, 2001, PSCT pipeline break; and

- An April 11, 2005, approximate 85-gallon spill of RIPZ-8 purge water from mobile polytank container.

In addition to the more significant leaks noted above, the CSC recorded a number of minor line leaks and subsequent liquid releases from 1996 to 2002 along the Sump 9B, Gallery Well, and PSCT conveyance pipeline corridors. These minor releases were generally areas where the glued PVC pipe joints developed a drip and the cleanup was limited to removal of a small amount of soil. In these cases, the impacted soil was over-excavated and any observed areas of contaminated soil were removed and disposed of. The PVC extracted liquid pipelines for the Sump 9B, Gallery Well, and PSCT wells were replaced with welded HDPE pipe in 2000, 2001, and 2002 respectively. There have been no reported leaks or spills from any of the pipelines since the PVC pipe was replaced.

The CSC performs daily pipeline inspections and notes any leaks or other conditions requiring maintenance on inspection forms. Leak repairs and non-routine activities (such as sampling seeps) are noted in the project log book maintained at the Site. The USEPA on-site personnel have access to the daily log book and inspection forms.

2.2.6 Groundwater and Surface Water Monitoring

Site groundwater and surface water quality has been monitored since 1992; the monitoring consisted of measuring water levels and collecting water quality samples for laboratory analysis. The CSC initiated a routine monitoring program pursuant to the Consent Decree SOW in 1997. The monitoring is part of the Routine Groundwater Monitoring Element of Work (RGMEW).

The RGMEW monitoring has been conducted on an approximately semiannual basis. The semiannual monitoring frequency was implemented to evaluate seasonal effects on water level and water quality data.

Prior to 1992, the most comprehensive studies that included groundwater level and quality information were the Hydrogeologic Site Characterization and Evaluation Report (HSCER), (Woodward-Clyde Consultants, 1988a) and the Hydrogeologic Site Investigation Report (HSIR) (Woodward-Clyde Consultants and Canonie Environmental, 1989).

The location of current groundwater monitoring wells and piezometers is shown on Figure E-1 in Appendix E.

2.2.6.1 Groundwater Level Monitoring

Water level monitoring data have been collected and reported as part of water quality monitoring activities conducted at the Site. Prior to 1992, the water quality monitoring activities included:

- Hydrogeologic Assessment Report (HAR) (Canonie Environmental, 1987). Approximately 75 wells and piezometers were installed prior to 1987. The report presented an initial evaluation of the Site groundwater flow system;
- Hydrogeologic Site Characterization and Evaluation Report (HSCER), (Woodward-Clyde Consultants, 1988a). Approximately 90 additional wells or piezometers were installed across the Site. Water levels were collected in 1987 at approximately 150 wells and

piezometers. Water level data was used to create water level elevation maps and analyze the horizontal and vertical groundwater flow system;
- Groundwater Level Assessment Report, (Woodward-Clyde Consultants, 1988c). A round of groundwater level measurement similar to those collected during the HSCER were collected and presented in a supplementary report; and
- Hydrogeologic Site Investigation Report (HSIR), (Woodward-Clyde Consultants and Canonie Environmental, 1989). Water levels were collected in March 1989 at approximately 124 wells and piezometers. The number of available wells was reduced due to well destruction associated with pond closure and site modernization activities. Data were used to create water level elevation maps and to analyze the horizontal and vertical groundwater flow system.

Beginning in 1997, semiannual sampling events have been conducted and the CSC issues Semiannual Monitoring Reports as part of the RGMEW. The semiannual monitoring and reporting activities include quarterly water level monitoring rounds, continuous water level monitoring from selected wells, and water level monitoring from liquid control features.

Since 1997, semiannual groundwater level measurements have been conducted by the CSC in parallel with groundwater quality monitoring events. The dates of these semiannual monitoring events are identified in the following section.

2.2.6.2 Groundwater Quality Monitoring

Water quality monitoring data has been collected and reported as part of water quality monitoring activities conducted at the Site. Prior to 1992, the water quality monitoring activities included, but were not limited to:

- HSCER, 1988 – 150 wells sampled and analyzed for VOCs, SVOCs, chlorinated pesticides and polychlorinated biphenyls (PCBs), inorganic compounds and other targeted parameters. Addressed lateral and vertical extent of contamination;
- Casmalia Resources – 13 wells monitored quarterly for VOCs, total dissolved solids (TDS), nitrate, bromide, chloride, nickel, selenium, chromium, total organic carbon (TOC), dissolved organic carbon (DOC), and total organic halogens (TOX); and
- HSIR, 1989 – 118 wells sampled and analyzed for VOCs, TDS, nitrate, bromide, chloride, nickel, selenium, chromium, TOC, DOC, and TOX. 78 wells analyzed for Appendix IX constituents listed in 40 CFR 264, and other selected parameters including those stipulated by the RWQCB.

Beginning in 1992, the USEPA conducted several targeted sampling events. The USEPA data included:

- USEPA, 1992 through 1994 – 23 wells sampled and analyzed for VOCs, SVOCs, TOC, TOX, TDS, metals, and general water quality parameters. Data collected over this period were summarized in a Technical Memorandum (CH2MHill, 1996). Sampled wells were primarily at the site boundaries and within the off-site drainages;
- USEPA, 1994 – PSCT-2, PSCT-3, and PSCT-4, and SW-17 sampled and analyzed for VOCs, SVOCs, TOX, purgeable organic halides (POX), DOC, chlorinated pesticides and PCBs, organophosphorus pesticides, para-chlorobenzene sulfonic acid, metals, TDS, and general water quality parameters. The results were summarized in the National

Enforcement Investigations Center (NEIC) report dated April 19, 1995 (USEPA, 1995); and

- USEPA, 1996 – 8 wells sampled and analyzed for VOCs and SVOCs. Sampled wells included RAP-1A, RAP-1B, RAP-3A, C5, A2B, B3M, RP-64B, and RP-100A (USEPA, 1996a).

Beginning in 1997, the CSC, as part of the RGMEW, conducted 22 semiannual sampling events. Sampling occurred in accordance with RGMEW Field Sampling Plan (ICF Kaiser, 1997) or subsequent revised versions of the Field Sampling Plan (Harding Lawson Associates, 2000b and Harding ESE, 2001a). Samples were analyzed for chemicals of potential concern (COPCs) that include 206 compounds identified in the 40 CFR 264 Appendix IX – Groundwater Monitoring list and 23 additional unlisted compounds detected in samples collected from the on-site liquid control features. The compounds hydrazine, perchlorate, and nitrosodiphenylamine (NDMA) were added to the analyte list for select wells starting in November 1999.

In January 2009 the CSC requested a number of modifications to the RGMEW scope of work, which have now been incorporated into the ongoing groundwater monitoring program at the Site (MACTEC, 2009a).

Semiannual (SA) sampling events completed by the CSC are summarized below.

- SA Event No. 1 – September 1997 (ICF Kaiser, 1998a);
- SA Event No. 2 – Sampled June 1998 (ICF Kaiser, 1998b);
- SA Event No. 3 – Sampled October 1998 (ICF Kaiser, 1999);
- SA Event No. 4 – Sampled April 1999 (Harding Lawson Associates, 1999);
- SA Event No. 5 – Sampled November/December 1999 (Harding Lawson Associates, 2000b);
- SA Event No. 6 – Sampled July 2000 (Harding ESE, 2001i);
- SA Event No. 7 – Sampled May 2001(Harding ESE, 2001j);
- SA Event No. 8 – Sampled October 2001 (Harding ESE, 2002);
- SA Event No. 9 – Sampled April 2002 (MACTEC, 2003a);
- SA Event No. 10 – Sampled October 2002 (MACTEC, 2003b);
- SA Event No. 11 – Sampled May 2003 (combined with previous report dated October 2003);
- SA Event No. 12 – Sampled October 2003 (MACTEC, 2004);
- SA Event No. 13 – Sampled April 2004 (MACTEC, 2005);
- SA Event No. 14 – RI Groundwater Sampling Event No. 1 – Sampled October 2004 through March 3, 2005 (combined with previous report dated July 22, 2005);
- SA Event No. 15 – RI Groundwater Sampling Event No. 2 – Sampled March 21 through May 12, 2005 (MACTEC, 2006a);
- SA Event No. 16 – Sampled November 2005 (combined with previous report dated December 12, 2005) (MACTEC 2006a);
- SA Event No. 17 – Sampled April/May, 2006 (MACTEC, 2007);
- SA Event No. 18 – Sampled October 2006 (combined with previous report dated September 20, 2007);
- SA Event No. 19 – Sampled April 2007 (MACTEC, 2008);
- SA Event No. 20 – Sampled March 2008 (MACTEC, 2008);
- SA Event No.21 - Sampled April/May 2008 (MACTEC, 2009b); and,
- SA Event No.22 - Sampled October /November 2008 (MACTEC, 2009b).

2.2.6.3 Current Status of Site Monitoring Well Network

Many of the groundwater monitoring wells, piezometers, and other borings and casings drilled and installed by Casmalia Resources in the 1970s and 1980s were in poor condition or no longer in existence when the CSC began the RGMEW in 1997. Many of the wells and piezometers were in poor condition or no longer in existence due to their age and damage or destruction as a result of remediation activities performed by Casmalia Resources in the 1980s. Beginning in 1999, the CSC performed the following activities in response to an August 3, 1999 letter by EPA:

- Located and inspected all onsite wells
- Performed field investigation activities to assess identify and condition of wells
- Repaired wells, as necessary, to meet minimum standards agreed to by EPA and CSC
- Resurveyed the position and elevation of all wells

The CSC submitted a series of draft well inventory reports with updated information and to respond to EPA comments on the Draft Report and follow-up revised reports. The CSC submitted a Final Well Inventory Report (MACTEC, 2006b) that was approved by EPA. The Final Well Inventory Report is a stand-alone report that documents the condition and construction of the monitoring well network, not including the wells and piezometers installed as part of the RI. The report includes tables that document the history and status of each well, well construction details, boring and well logs, and a comprehensive map of all site wells. Additional history and details of the monitoring well inspection and repair program are provided in the Final Well Inventory Report.

The CSC submitted to the USEPA in December 2002, a Draft Well Inventory Report (MACTEC, 2002b). The report compiled information requested by the USEPA associated with chemical quality sampling points and water level monitoring locations that are currently, or have historically been, part of the RGMEW at the Site. The Draft Well Inventory Report presented field activities and research conducted to resolve the USEPA's questions and issues associated with the monitoring well network at the Site.

The objectives of the well survey efforts were to confirm that the physical data associated with chemical quality monitoring wells and water level monitoring points in the network were valid and representative of conditions at the site, and to comply with USEPA Data Quality Objectives (USEPA, 2006). The CH2MHill *Well Inventory Report* (CH2MHill, 1997) discussed work performed in 1994 for the USEPA at the Site. The CH2MHill report discusses a well inventory conducted in November and December 1994. A subsequent well inventory was conducted by ICF Kaiser Engineers in 1997 (ICF Kaiser, 1999: Appendix Table A-1, Summary of Well Construction Details). A comparison of the data collected during these two earlier well inventories identified well maintenance deficiencies and differences in the well construction details, locations, and measured depths of several wells. Based on these data, the USEPA requested an additional well inventory be conducted to resolve discrepancies and identify needed repairs, and then repair wells as needed.

To resolve the discrepancies and collect the required data to prepare a complete well inventory for the Site, a field survey team consisting of MACTEC and CH2MHill representatives collectively physically located wells at the Site, documented the condition of the wells, measured the total depth of the wells, and compared the information to the site-related documents.

The initial survey was completed in 1999, and a follow-up survey was completed in 2000. Disparities encountered between these well surveys were identified in the RI/FS Work Plan (Appendix K – Tables 1 – 6 and Figure K-1), and recommendations were presented for implementation as part of the RI field activities.

2.2.6.4 Surface Water Quality Monitoring

Surface-water quality monitoring data has been collected and reported as part of water quality monitoring activities conducted at the Site. Prior to 1992, the surface water quality monitoring activities included:

- HSCER, 1988 – Standing surface water features within a 1-mile radius of the Site were sampled and analyzed for VOCs, SVOCs, chlorinated pesticides and PCBs, inorganic compounds, and other targeted parameters; and
- HSIR, 1989 – Standing surface water features within a 1-mile radius of the Site were sampled and analyzed for VOCs, TDS, nitrate, bromide, chloride, nickel, selenium, chromium, TOC, DOC, and TOX. Water samples were analyzed for Appendix IX constituents listed in 40 CFR 264, and other selected parameters including those stipulated by the RWQCB.

Beginning in 1997, the CSC, as part of the RGMEW, conducted and reported 20 semiannual sampling events. Sampling occurred in accordance with RGMEW Field Sampling Plan (ICF Kaiser, 1997) or subsequent revised versions of the Field Sampling Plan (Harding Lawson Associates, 2000b and Harding ESE, 2001a). Surface water samples collected from the existing stormwater runoff collection ponds and treated liquid impoundments were analyzed for COPCs that include 206 compounds identified in the 40 CFR 264 Appendix IX – Groundwater Monitoring list and 23 additional unlisted compounds detected in samples collected from the on-site liquid control features. Since 1997, the semiannual surface water quality monitoring activities were conducted in parallel with the groundwater level and groundwater quality monitoring events summarized above.

2.2.6.5 Surface Water Level Monitoring

Surface water level monitoring data was collected and reported as part of site operation and maintenance activities. Beginning in October 1992, water level monitoring of the five ponds has been generally conducted on a daily basis as part of site maintenance and operation activities. The CSC took over site responsibilities on September 26, 1996. Site operation and maintenance information, including pond water levels collected since September 26, 1996, have been reported in Quarterly Progress Reports and submitted quarterly to the USEPA.

2.3 Previous Site Investigations

This section provides an overview regarding the overall purpose, objectives, and scope of prior and ongoing investigations conducted at the Site. Data from investigations completed at the Site provide the basis for the current understanding of the extent of soil and groundwater contamination at the Site. The scope of investigations proposed in the RI/FS Work Plan was based on the findings of investigations completed up to that point (i.e., 2004). Summary information for investigations completed since that time is briefly discussed below for completeness.

Three primary historical site characterization investigations have been conducted at the Site:

- Hydrogeologic Assessment Report (HAR) (Canonie Environmental, 1987);
- Hydrogeologic Site Characterization and Evaluation Report (HSCER) (Woodward-Clyde Consultants, 1988a); and
- Hydrogeologic Site Investigation Report (HSIR) (Woodward-Clyde Consultants and Canonie Environmental, 1989).

Each of these investigations was performed in response to agency requests for information about the Site. Following is a brief description of each of these investigations. In addition, there have been several subsequent investigations and studies that were considered in the developing the hydrogeologic conceptual site model and other aspects of the RI/FS Work Plan.

2.3.1 Pre-EPA Assessment Activities

The HAR was the first comprehensive study to describe conditions at the Site in relation to the waste disposal activities. The scope of the HAR focused on the southern portion of the site, where early waste disposal activities took place. The investigation was conducted in May 1987, and a report was submitted to the CRWQCB in November 1987 (Canonie Environmental, 1987).

The basic focus of the HAR was to assess the hydrogeology of the Site in terms of the presence or potential for migration of wastes and/or waste constituents through the subsurface. The HAR also provided a comprehensive characterization of the wastes in each of the existing surface impoundments, identified the owners of the Site, described the climatology of the Site, described the nature of surface waters at the Site, and described the relationship of the Site to off-site wells and regional water resources.

2.3.1.1 Hydrogeologic Site Characterization and Evaluation Report

The HSCER provided further characterization of the Site and substantial additional information on the hydrogeological conditions and on the nature and extent of soil and groundwater contamination. Investigations for the HSCER were conducted by Woodward-Clyde Consultants over the period spanning May 1986 through November 1987. The work conducted helped to further delineate the nature and extent of soil contamination at and surrounding the Site, and to further refine the site hydrogeologic model that was in development at the time.

2.3.1.2 Hydrogeologic Site Investigation Report

The HSIR provided an update to the Hydrogeologic Summary Report (HSR) (Woodward-Clyde Consultants and Canonie Environmental, 1988). The HSIR primarily utilized and summarized information from all the previous investigations and work conducted at the Site up to that point. However, the HSIR also included results of additional water and soil investigations conducted for CAO 88-145 (revised CAO 88-76). The HSIR represents the most comprehensive compilation of technical information available at that time regarding hydrogeologic conditions and the nature and extent of soil and groundwater contamination at the Site.
As part of the HSIR, background concentrations for selected organic chemicals and inorganic metals were developed. From the background sampling data, Threshold Limit Values (TLVs) were developed, and the background levels established were evaluated to determine appropriate concentrations for each chemical constituent for use in conjunction with closure of the surface impoundments, and for characterization of the lateral and vertical extent of

contaminated soil at the Site. These concentrations were/are referred to as Target Closure Levels (TCLs).

2.3.1.3 Brierley & Lyman Studies

Brierley & Lyman Inc. published Final Construction Drawings for the PCTs and PSCT (Brierley & Lyman, 1989a and 1991b). The packages were provided to fulfill the requirements of the CRWQCB CAO 88-61 Task i. The packages included drawings with specifications noted for required construction materials.

In addition to the construction drawings, Brierley & Lyman submitted a report titled "Preliminary Evaluation of the Effectiveness of the Plume Capture Collection Trenches" (Brierley & Lyman, 1989c), and a follow-up report titled "Performance Evaluation of the Effectiveness of the Plume Capture Collection Trenches" (Brierley & Lyman, 1990h). The purpose of the reports was to describe the hydrogeologic impact of each of the collection systems from the time they were constructed through November 1989. The reports concluded that operation of the PCT-B and PCT-C collection systems was creating localized depressions in the groundwater table in the vicinity of the extraction sumps, and they recommended continued operation with no operational changes.

Brierley & Lyman also prepared and submitted Closure Certification Reports for some of the former ponds and pads at the Site (Brierly & Lyman, 1990b-g, 1991a-l). The agencies never formally approved these reports although agency personnel were present for the various site inspections and walkthroughs associated with pond closure.

Brierley & Lyman also conducted sampling in the West Canyon (includes both the RCRA Canyon area and West Canyon Spray area designated in the RI/FS Work Plan) to evaluate the nature and extent of contamination due to waste disposal practices (Brierley & Lyman, 1990i).

2.3.2 EPA Response Activities

2.3.2.1 Final USEPA Report on 1995 Stormwater Discharge

The USEPA released stormwater from the Site to Casmalia Creek in 1995. The USEPA (in conjunction with the USFWS and USEPA's Emergency Response Team) prepared a report detailing their analysis of environmental impacts associated with the off-site stormwater discharge. The assessments included impacts on the environment, impacts to known special-status species, and impacts to the receiving surface water (i.e., Casmalia Creek).

The final USEPA report on the 1995 stormwater discharge (USEPA, 1996b) concluded that the 1995 stormwater discharge had no adverse impacts on either the special-status species or the creek habitat.

2.3.3 CSC Site Work Activities

2.3.3.1 Part 1 EE/CA Work Plan Studies

The CSC submitted a series of Engineering Evaluation/Cost Analysis (EE/CA) Work Plans to the USEPA.

The Part 1 EE/CA Work Plan included a conceptual site model for hydrogeology and for risk assessment at the Site, a plan for evaluating existing data available for the Site, a plan for performing additional site investigations as necessary to characterize the Site for purposes of the baseline risk assessment, and a plan for performing an engineering evaluation and cost analysis of response actions for the EE/CA Area.

The draft Part 1 EE/CA Work Plan was the basis for the CSC's work in preparing an EE/CA Report (URS, 2000) that ultimately became the EE/CA Action Memorandum (prepared by USEPA in April, 2001). The EE/CA Report proposed capping three landfills and the interstitial areas between these landfills. EE/CA Area cap construction was completed by the CSC during 2001-2002.

2.3.3.2 Summer 2000 Field Activities

Between May and September 2000, at the direction of the USEPA, the CSC installed and developed seven new chemical water quality wells and 25 new piezometers at the Site. These monitoring points were installed to provide data in areas of the Site where the USEPA had identified potential data gaps. The results of these activities were submitted to the USEPA in the report titled *Well and Piezometer As-Built Report, Summer 2000 Field Activities* (Harding ESE, 2001h).

The data use objectives associated with this work fell generally into two categories: chemical quality wells and piezometers. Chemical quality wells were installed to provide chemical water quality and hydraulic head data to augment the existing groundwater quality monitoring network in monitoring the distribution of contaminants at the Site and to further refine the Hydrogeologic Conceptual Site Model (HCSM). Piezometers were installed to provide both lateral and vertical hydraulic head data to augment the existing groundwater water level monitoring network.

2.3.3.3 Interim Liquids Investigations

In 2001, the CSC conducted specific site investigations in response to USEPA requests, as first outlined in a March 24, 2000, letter from the USEPA to the CSC. The CSC and the USEPA agreed to a scope of work that addressed the USEPA's March 24 demands in an October 2000 Interim Liquids Agreement signed by both parties. Three separate work plans were prepared and investigations were completed to address the areas of concern noted below:

- The potential "Low Area" within the P/S Landfill;
- The Gallery Well construction and status, including the location of the clay barrier; and
- The construction of Sump 9B and potential dense non-aqueous phase liquids (DNAPLs) in the immediate vicinity.

The work plans described activities that were to be conducted to evaluate the specific concerns at the areas noted above (Harding ESE, 2001c, 2001d, and 2001e, respectively). The field work was completed in early 2001 and reports were submitted to the USEPA in July and October 2001.

2.3.3.3.1 P/S Landfill Potential "Low Area" Investigation

The objective of this investigation was to evaluate the presence of a potential "low area" in the excavated sub-grade of the P/S Landfill and the potential presence of DNAPLs that may be associated with that potential low area.

Under the agreement reached with USEPA in the Interim Liquids Agreement (ILA), CSC was to determine if a low area existed, and to identify whether DNAPL is present in the potential low area. The CSC proposed to accomplish this by conducting cone penetrometer testing (CPT) and installing piezometers using direct-push technology (DPT) in the P/S Landfill in the vicinity of the potential low area. The results of this investigation were submitted to the USEPA in the *Report of Findings, Pesticide Solvent Landfill Low Area and Gallery Well/Clay Barrier Investigations* dated July 31, 2001 (Harding ESE, 2001f).

2.3.3.3.2 Gallery Well and Clay Barrier Investigations

The Gallery Well and clay barrier investigation work plan described five separate activities as listed under the "Gallery Well." The work objectives and included activities are listed below:

- Delineating the location and extent of the clay barrier that is located downgradient of the Gallery Well;
- Confirming the depth and, as necessary, cleaning out any materials in the Gallery Well;
- Installing a dedicated pump to remove DNAPL from the Gallery Well;
- Installing additional piezometers along the upgradient side of the existing clay barrier; and
- Lowering the liquid action-level in the Gallery Well.

The results of these activities were included in the *Report of Findings, Pesticide Solvent Landfill Low Area and Gallery Well/Clay Barrier Investigations* dated July 31, 2001 (Harding ESE, 2001f). While the CSC completed the activities specified in the ILA work plans, the exact location, depth, and alignment of the P/S Landfill clay barrier were not adequately determined by this work. Additional work conducted as part of the RI field investigations confirmed the location, alignment, and character of the P/S clay barrier. The findings of this additional work are presented in Appendix J of this report .

2.3.3.3.3 Sump 9B Investigation

The Sump 9B investigation included:

- Lowering the liquid action-level in Sump 9B;
- Installing a companion well adjacent to Sump 9B; and
- Monitoring for the presence of DNAPL in the area immediately adjacent to Sump 9B.

The results of the Sump 9B investigation were submitted to the USEPA in the *Summary Report for the Sump 9B Work* dated October 4, 2001 (Harding ESE, 2001g).

2.3.3.4 P/S Landfill Cap Design

The *Revised Final Pesticides Solvent Landfill Cap Design Report (Final Design Report)* was prepared by Foster Wheeler Environmental Corporation and GeoSyntec Consultants for the CSC to present the proposed design of the cap and modified buttress for the P/S Landfill at the site (Foster Wheeler/GeoSyntec, 1999).

2.3.3.5 P/S Landfill Cap Construction Completion Report

The CSC submitted a draft *Pesticides/Solvent Construction Completion Report* (Foster Wheeler, 2002) to the USEPA to comply with the requirements of the Casmalia Consent Decree and Statement of Work. The Construction Completion Report provided USEPA certifications that the P/S Landfill cap was constructed in conformance with the approved specifications and provided USEPA as-built drawings for the completed construction work. The report also includes field and laboratory test data collected to document conformance with the plans and specifications. The USEPA provided comments on the draft P/S Landfill As Built Report that were addressed by the CSC and incorporated in an addendum to the As Built Report (Foster Wheeler, 2002) the CSC submitted to the USEPA.

2.3.3.6 EE/CA Area Landfill Cap Design

The *Revised Final EE/CA Area Cap Design Report (Final Design Report)* was prepared by Foster Wheeler Environmental Corporation and GeoSyntec Consultants for the CSC to present the proposed design of the caps and buttresses for the Heavy Metals/Sludges (M/S), Caustics/Cyanides (C/C) and Acids Landfills and adjacent interstitial areas (collectively referred to as the EE/CA Area Cap) at the site (Foster Wheeler/GeoSyntec, 2001). This revised design report was submitted to address modifications to the original final design when waste was unexpectedly encountered at shallow depths on the C/C Landfill. The design for this landfill was modified as discussed in Design Change Request – DCR07 that was submitted to the EPA in 2001 (Foster Wheeler/GeoSyntec, 2001).

2.3.3.7 EE/CA Area Cap Construction Completion and As-Built Report

The EE/CA Area Cap Construction Completion and As-Built Report (Ford, 2003) was submitted by Ford Construction Company which includes an appendix entitled Construction Quality Assurance Report, EE/CA Area Closure (Vector, 2003) by Vector Engineering to inform the CSC and USEPA that the EE/CA Area Cap had been constructed and completed in general accordance with the plans and specifications.

2.3.3.8 Groundwater Data Summary Report

The CSC prepared and submitted the *Groundwater Data Summary Report* (Harding Lawson Associates, 2000a), pursuant to the requirements of the Consent Decree Statement of Work. The report was prepared in response to USEPA concerns associated with the CSC's groundwater monitoring program, including QA/QC, data presentation and data interpretation. The USEPA provided the CSC with their comments on the Groundwater Data Summary Report in their letter dated August 8, 2001 (USEPA, 2001).

The objective of this report was to provide a summary of groundwater quality and hydrogeologic data collected at the Site by various parties since 1992. The data summarized in the report consisted of available groundwater chemical data, groundwater water-level data, and hydrologic data collected at the Site between 1992 and 2000. The then most recent chemical data considered in the report were collected in November/December 1999 as part of the 5th semiannual sampling event conducted under the RGMEW.

2.3.3.9 Landfill Cap Surface Water Runoff Collection Pond Design and Completion Report

As described in Section 2.2.4.1, the CSC constructed a small unlined collection basin in a portion of the Central Drainage Area in 2003 to collect stormwater from the P/S Landfill and EE/CA Area caps (Figure 2-3) (Boston Pacific, 2003).

2.3.3.10 Pond Water Management

The CSC implemented a pond water management program following the 1997/98 El Nino winter to reduce and maintain pond water volume in the five onsite ponds at safe levels so that they would not overtop their berms. The pond water management program is documented in a Pond Water Management Plan (CSC, 2001) and follow-up revisions, through Revision 8 (CSC, 2001, 2003a, 2003b, 2004).

The CSC removed water through a combination of spray irrigation, spray misting, and truck road dust control watering from 1998 through 2006. This irrigation and misting included:

- Spray irrigation of RCF water to the former Pond M and Pond T area from 1988 to 2004
- Spray misting of A-Series pond water on its northeastern bank from 2001 to 2004
- Spray misting of Pond 18 water on it's northern bank from 1998 to 2006

The CSC used additional RCF pond water for construction of the P/S Landfill cap in 1999 and construction of the EE/CA Area cap in 2001 and 2002.

The CSC initially discharged clean stormwater from the P/S Landfill and EE/CA Area caps offsite to the B-Drainage in spring 2006 to test the small unlined collection basin in the Central Drainage Area that collects clean stormwater runoff (Figure 2-3). The CSC began routine offsite discharge of clean cap stormwater during the 2008/09 winter under the General NPDES permit.

2.3.3.11 Biological Species Surveys

The USEPA requested that a biological species and habitat survey (BSHS) be conducted at the Site in conjunction with the CSC's work on the EE/CA Area cap design/construction.

The findings of the surveys are summarized in the following reports:

- *Updated Sensitive Species Report* (Dames and Moore, November, 2000) – This report was submitted by the CSC to the RWQCB as required by the NPDES Discharge Permit #99-034;
- *Draft Biological Species and Habitat Survey Report* (Hunt & Associates, 2001) – This report was submitted by the CSC to the USEPA. Surveys were also conducted in 2002 for the tiger salamander (Hunt & Associates, 2002); and
- *Updated Biological Species and Habitat Report* (Harding ESE, 2001b) – This report was submitted to the USEPA as required under the EE/CA cap construction work plan. Surveys were conducted in 2002 for plants and birds as well (MACTEC, 2002a).

2.3.4 RI/FS Activities

In compliance with the terms of the Consent Decree, the CSC prepared additional work plans and reports related directly to the RI/FS process. These documents include the following:

- Remedial Investigation/Feasibility Study Work Plan (CSC, 2004);
- Interim Progress Report (CSC, 2005a);
- NAPL Memorandum (CSC, 2006);
- Phase II and III RI Sampling Plans (CSC, 2005b and 2007); and
- Tier 2 Ecological Risk Assessment Sampling and Analysis Plan (CSC, 2009).

These documents are briefly described below.

2.3.4.1 RI/FS Work Plan

The final RI/FS Work Plan was developed during the period 2001 through 2004 through a series of iterative draft documents and related agency comments. The CSC prepared and submitted three draft versions of the Work Plan prior to submittal of the final document in June 2004. The final Work Plan document incorporates the issues identified in agency comments on prior draft versions, and presents the scope of work and investigative methods completed during performance of RI field investigations and the risk assessment process.

In developing the Work Plan, a series of historical aerial photograph reviews were conducted to assess how Site activities and conditions evolved over time. These studies helped provide a better understanding of historical Site features, activities, and conditions, and were used to help define the nature of work planned for the RI. Under the direction of the USEPA and the CSC, a series of four aerial photograph studies were conducted between 2001 and 2003 by ERI, a USEPA contractor. These studies included the following:

- Review of six site-wide photographs from the period 1974 to 1989 (ERI, 2001)
- Review of eight site-wide photographs from the period 1977 to 1988 (ERI, 2003a)
- Review of eleven site-wide photographs from the period 1970 to 1992 (ERI, 2003b); and
- Review of selected photographs of the Burial Trenched Area, P/S Landfill barrier, and pre-site drainages (ERI, 2003c)

The RI/FS Work Plan identified areas of the Site and surrounding area where historical information indicates similar prior settings, uses, operations, facilities, and/or waste management and disposal practices. These areas of common history are identified as “study areas” in the Work Plan. The specific investigations conducted during RI field activities within each individual study area were developed based on an understanding of the historical uses of these areas.

The following study areas were identified in the evaluation.

2.3.4.1.1 Soil and Sediment Study Areas

- Capped Landfills;
- PCB Landfill;
- RCRA Canyon Area;
- West Canyon Spray Area;
- Burial Trench Area;
- Central Drainage Area;
- Liquids Treatment Area;

- Maintenance Shed Area;
- Administration Building Area;
- Roadways;
- Remaining On-Site Areas;
- Off-Site Areas;
- Stormwater Ponds; and
- Treated Liquids Impoundments.

2.3.4.1.2 Surface Water and Groundwater Study Areas

- Stormwater Ponds;
- Treated Liquids Impoundments;
- Northern Groundwater Area;
- Southern Groundwater Area; and
- Off-Site Surface Water and Groundwater.

These study areas are referenced throughout this report and are depicted in Figure 2-11.

2.3.4.2 Interim Progress Report

Upon completion of the majority of RI field sampling activities identified in the Work Plan, the CSC prepared an Interim Progress Report (IPR), which was submitted to the USEPA in February 2005. A series of IPR addenda and follow-up errata were subsequently prepared and submitted to the USEPA in response to agency comments received on the initial IRP document, and subsequent addendum and errata submittals. These addendum and errata submittals primarily provided additional data summary and presentation formats to assist USEPA review of the Phase I investigation findings. IPR addendum and errata submittals are briefly summarized in the following sections:

2.3.4.2.1 IPR Addenda

- **IPR Addendum #1** (May 30, 2005) – Provided follow-up and additional information in response to the USEPA's comments (dated April 15, 2005) on the initial February 2005 IPR submittal, including revisions to text, tables and or figures relating to IPR appendices A, B, and R;
- **IPR Addendum #2** (June 20, 2005) – Provided some additional tables and figures, summarizing RI activities and findings relating to IPR Appendix B, as requested by an email from the USEPA dated June 9, 2005;
- **IPR Addendum #3** (July 8, 2005) – Provided tables summarizing site-wide RI statistics data in a different format, as requested by an email from the USEPA dated June 27, 2005;
- **IPR Addendum #4** (July 19, 2005) – Provided the same reformatted statistics tables of RI data (this time sorted by Study Area), as requested in an email from the USEPA dated July 12, 2005;
- **IPR Addendum #5** (August 12, 2005) – Provided boxplots and bubble diagrams of select organic and inorganic constituents detected in soil during the RI program, as requested in an email from the USEPA dated July 19, 2005; and
- **IPR Addendum #6** (November 30, 2005) – Responded to USEPA's remaining comments (dated September 26, 2005) on the draft IPR and subsequent addenda.

2.3.4.2.2 IPR Errata

- **IPR Errata #1** (April 14, 2006) – Prepared in response to USEPA comments dated September 26, 2005 on the IPR and subsequent IPR Addenda submittals. Provided revisions to select text sections, figures and tables and appendices of the IPR document, including portions of the main IPR report as well as portions of IPR appendices A, B, C, F, G, M, and R;
- **IPR Errata #2** (April 21, 2006) – Provided additional revisions to select figures for Appendix G – Groundwater Chemistry, that were originally issued in IPR Errata #1;
- **IPR Errata #3** (June 2, 2006) – Prepared in response to USEPA' s conditional approval letter for IPR, dated May 6, 2006. Presented a revised Appendix H and responses to final agency comments relevant to text, tables and /or figures contained in IPR appendices B, E, F, G, J, M, N, O, and R; and
- **IPR Errata #4** (June 28, 2006) – Prepared in response to USEPA's September 26, 2005 comments on the IPR, and provided an updated version of IPR Appendix N – Offsite Well Survey.

Final comments on the IPR and addenda were received in a letter from the USEPA dated March 6, 2006. The Final IPR, which incorporated responses to these final USEPA comments, was then prepared and submitted to the USEPA on April 14, 2006. The USEPA subsequently conditionally approved the IPR in a letter dated May 9, 2006.

2.3.4.3 NAPL Memorandum

The CSC summarized the findings of the NAPL and other groundwater investigations in the *Interim Progress Report* (IPR) submitted to EPA in February 2005. In their September 26, 2005, comments on the IPR, the USEPA requested that the CSC synthesize the available data specifically regarding the presence of DNAPLs in the Lower Hydrostratigraphic Unit (LHSU), assess the potential for migration of site DNAPL, and document that information in a memorandum (CSC, 2006). The DNAPL memorandum was prepared to address EPA's comments and summarized all of the data collected at the Site for both DNAPL and light nonaqueous-phase liquid (LNAPL).

The memorandum served as the "first cut" at assembling the information needed to: (1) describe the presence of site NAPLs and (2) assess remedial alternatives for site groundwater (which will be discussed in more detail in the future FS).

2.3.4.4 Phase II and III RI Sampling Plans

In response to USEPA comments on the IPR and related addenda, the CSC prepared and submitted two Phase II sampling plans, including the Final Fall 2005 Phase II RI Sampling Plan, dated November 18, 2005, and the Final Spring 2006 Phase II Sampling Plan, dated May 25, 2006. The Phase II Sampling Plans outlined additional field data collection activities designed to address agency comments. Planned Phase II field activities encompassed the collection of additional soil, soil vapor, and groundwater and surface water samples from specific areas of the Site where Phase I findings indicated the need for further characterization. In response to the USEPA comments on requested interim data summary information resulting from Phase II investigations, the CSC prepared and submitted the Revised Final Phase III Sampling Plan, dated March 27, 2007 The Phase III Sampling Plan outlined a limited subsurface investigation

program to be completed in a specific portion of the Site where Phase II investigations had not adequately delineated impacts initially encountered during Phase I investigations..

2.3.4.5 Tier 2 Ecological Risk Assessment Sampling and Analysis Plan

After completing and reporting the Tier 1 ERA in the draft RI Report (CSC, 2008), the CSC prepared the *Next Steps for Ecological Risk Assessment* memorandum (Next Steps Memo; ARCADIS, 2008) and accompanying Tier 2 ERA Sampling and Analysis Plan (CSC, 2009). These documents outlined additional studies and methods to further evaluate pathways, receptors, and chemicals of interest (COIs) driving risk at the Site in order to refine risk estimates, and were designed to make the ecological risk assessment more Site-specific and less generic. Details of the methods are provided in the Tier 2 ERA Sampling and Analysis Plan (CSC, 2009).

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3.0 SUMMARY OF MEDIA AND STUDY AREA INVESTIGATIONS

In this section, the CSC has briefly reviewed the various activities that were completed as part of Phase I, Phase II, Phase III RI sampling, and the Tier 2 ERA sampling program. These major investigative phases are identified below, along with their applicable planning documents.

- **Phase I Investigations**: Phase I Investigations were completed during the Summer of 2004 into the first quarter of 2005, and were conducted in accordance with the scope of work outlined in the USEPA-approved *Final RI/FS Work Plan* (CSC, 2004). In addition, the scope of Phase I geophysical work originally proposed in the RI/FS Work Plan was modified in accordance with the *Final Geophysical Survey Plan - Phase II RI/FS Work Plan Supplement* (CSC, 2005a).
- **Phase II Investigations**: Phase II investigations were completed in two parts during the period extending between Fall of 2005 and the Summer of 2006, and into January 2006. This work was conducted in accordance with several USEPA-approved work plan documents, including *Revision 4 – Fall, 2005 Phase II RI Sampling (Soil Vapor, Surface Drainage Water, and Background Soil* (CSC, 2005b), and the *Final Spring 2006 Phase II RI Sampling Plan for Soil Sampling, Soil Gas Surveys, Clay Barrier Sampling, Geologic Boring, and Well and Piezometer Installation* (CSC, 2006). Additionally, Phase II groundwater sampling activities were outlined in a sampling matrix table entitled *Fall Phase II Groundwater Sampling, November 18, 2005* (CSC, 2005c).
- **Phase III Investigations**: Phase III investigations were completed during the Spring 2007, and were conducted in accordance with the USEPA-approved *Rev. Final Phase III RI Sampling Plan for Follow-up RISBON-59 Soil Sampling* (CSC, 2007a). Supplemental soil vapor sampling and geophysical investigations, including CPT and piezometer installation work, were also conducted as an adjunct to the Phase III investigations, and were conducted during Fall 2007 in accordance with the USEPA-approved *Final Plan for RI Follow-up to the P/S Landfill Seismic Refraction Study* (CSC, 2007b), and the *RI Sampling Plan for Follow Up Soil Vapor Surveys* (CSC, 2007c), respectively.
- **Tier 2 Ecological Risk Assessment Sampling Program:** Focused sampling of soil, sediment, and tissue (plants, invertebrates, small mammals, and aquatic invertebrates) was conducted during the spring of 2009 to provide additional Site-specific data to refine the findings of the Tier 1 ERA. These additional studies were conducted in accordance with the USEPA-approved Tier 2 ERA Sampling and Analysis Plan (CSC, 2009).

As noted in all of the sampling memorandums, these activities were completed to conform to the QA/QC and sampling requirements described in Sections 4 and 5 of the RI/FS Work Plan. The major investigative phases completed as part of the RI are discussed in more detail in the following sections, and copies of these above-referenced planning documents are provided in Appendix Y (electronic format).

3.1 Introduction

This section of the RI Report presents the scope of the RI sampling programs conducted at the Site and the final schedule for the RI work, and reviews the change process that the CSC and USEPA followed to document any deviations from the approved RI/FS Work Plan.

3.1.1 Scope of Phase I, Phase II, and Phase III and all Other Follow-Up RI Sampling Activities

Section 5 of the RI/FS Work Plan and the above-referenced sampling plans describe in detail the various activities the CSC completed as part of the RI process. Those primary RI/FS tasks include:

- Collect Soil and Sediment Samples;
- Collect Soil Vapor Samples;
- Collect Surface Water Samples;
- Collect Tissue Samples (plants, soil invertebrates, small mammals, and aquatic invertebrates) and Co-located Soil and Sediment Samples
- Install Wells and Collect Groundwater Samples;
- Install Piezometers and Measure Water Levels;
- Perform Sampling of Existing Wells/Piezometers;
- Assess Geologic Mapping in RCRA Canyon;
- Perform Gamma Walk-Over Survey in RCRA Canyon;
- Determine the Elevation of the Top and Lateral Limits of Clay Barrier;
- Conduct Non-aqueous Phase Liquid (NAPL) Investigations;
- Conduct Light Non-aqueous Phase Liquid (LNAPL) and Residual NAPL Evaluations;
- Conduct Free-Phase Dense Non-aqueouse Phase Liquid (DNAPL) Evaluations;
- Conduct Lower HSU DNAPL Evaluation
- Review and Validate Chemical Data;
- Enter Data into Project Database;
- Conduct Background Analysis;
- Summarize Site Soil and Sediment Chemistry;
- Summarize Soil Vapor Chemistry;
- Summarize Surface Water Chemistry;
- Summarize Groundwater Chemistry;
- Summarize Tissue Chemistry and Co-located Soil and Sediment Samples;
- Evaluate Historical Hydrologic Budget;
- Update Existing Hydrologic Budget;
- Summarize Groundwater Flow Information*;*
- Collect Monitored Natural Attenuation Data;
- Conduct Off-Site Well Survey; and
- Perform Physical Evaluation of Historical Data.

The details of the scope of work that each of these tasks required are presented in Sections 4 and 5 of the RI/FS Work Plan and in the other above-referenced sampling plans.

General RI/FS data needs by study area and media are identified in Table 3-1, and the overall data objectives for media-specific sample types are summarized in Tables 3-2 and 3-3. The sampling was completed in several separate RI sampling programs, which are discussed below. We have summarized the extent or scope of the various phases of RI sampling for each of the sampling activities below.

The nature of samples collected and tested during the RI is presented in a series of summary tables, as listed below:

- **Table 3-4:** Summary of Soil and Sediment Sampling and Chemical Testing Program By Area;
- **Table 3-5:** Summary of Soil Vapor Sampling and Chemical Testing Program By Area;
- **Table 3-6:** Summary of Surface Water Sampling and Chemical Testing Program By Area;
- **Table 3-7:** Groundwater Sampling and Analysis Summary;
- **Table 3-8:** Soil Vapor, Soil, and Sediment Sample Distribution by Depth; and,
- **Table 3-9:** Soil Vapor, Soil, Sediment, and Surface Water Sample Distribution by Study Area and Analyte.
- **Table 3-10:** Tier 2 ERA Tissue Sampling and Chemical Testing Program by Study Area

Detailed tables summarizing all samples collected and the chemical/physical testing performed for all media, as well as the actual sample or task results for each of these activities, are introduced and discussed in more detail in the appendices listed in Section 1.3 of this RI Report.

3.1.2 As-completed RI Sampling Schedule

The various phases of RI sampling are discussed below, and the overall "as-completed" RI schedule is presented in Figure 3-1. The CSC has also attached the Daily Reports summarizing the daily Phase I RI sampling completed as Appendix S to this RI Report. As-completed sampling programs are summarized in Tables 3-1 through 3-10 of this RI Report.

3.1.2.1 Phase I RI Sampling

The CSC met with the USEPA and other regulatory agencies and interested parties at the Site on June 29, 2004, and held a kick-off meeting in which the CSC discussed the Phase I RI schedule, plans for oversight, meetings and information exchange requirements, and details of the change process planned for use during sampling. The CSC began the Phase I RI sampling work on July 19, 2004, and continued the bulk of the various RI activities through the end of November 2004. A few additional samples associated with stormwater runoff were collected into the first quarter of 2005. The Phase I sampling program was completed in general accordance with Table 4-4 from the RI/FS Work Plan.

3.1.2.2 Phase II RI Sampling

The CSC completed the Phase II RI sampling in two periods: the first period occurring in the Fall of 2005 and the second period beginning in July 2006. The Fall 2005 sampling was limited to some soil gas surveys, surface water sampling, and some background soil sampling. The 2006 Phase II RI sampling work began July 17, 2006, and continued through the end of September 2006. Some additional Phase II well and piezometer installation work extended into January 2007.

3.1.2.3 Phase III RI Sampling

The CSC completed a portion of the Phase III RI sampling in the Spring of 2007. This sampling included some soil boring sampling near previous sampling done at the RISBON-59 location that was completed as follow-up to that earlier sampling. The Phase III RI sampling work began on April 16, 2007, and continued through the first week of May 2007.

The CSC also completed some limited confirmation soil vapor sampling on October 12, 2007. This sampling included re-occupying three soil vapor sample locations and resampling them with splits sent to the laboratory originally used to analyze for 1,3 Butadiene using TO-15 and another laboratory to analyze for the same constituent but using TO-15 SIM, which we believe is a more accurate methodology.

3.1.2.4 Seismic Refraction Follow-Up Surveys

The CSC completed some cone penetrometer test (CPT) surveys and piezometer installation in the P/S landfill as follow-up to the previous seismic refraction surveys that were completed on the landfill in the Fall of 2007. This follow-up work included the completion of a series of instrumented CPTs and the installation of four piezometers at the locations that USEPA had identified as possible “low spots“ or closed depressions in the clay contact contour under the P/S Landfill.

The Seismic Refraction Follow-Up program is described in the Seismic Refraction Follow-Up Plan referenced earlier in this RI Report. The specific details of the program (e.g., number of CPTs and piezometers, locations, depths) are described in that document.

3.1.2.5 Tier 2 Ecological Risk Assessment Sampling Program

The Tier 2 ERA was conducted to further evaluate pathways, receptors, and COIs driving risk at the Site in order to refine risk estimates. This included additional studies and methods designed to make the ecological risk assessment more Site-specific and less generic.

The Tier 2 ERA sampling program is described in the [Tier 2 Ecological Risk Assessment] Sampling and Analysis Plan (CSC, 2009). The specific details of the program (e.g., location, nature, and number of samples to be collected, analytical methods) are described in that document.

The Tier 2 ERA Sampling and Analysis Plan (CSC, 2009) included the following additional data collection and further evaluation efforts to further refine the ecological risks at the Site :

- Tissue sampling (plants, soil invertebrates, small mammals, and aquatic invertebrates); and
- Co-located soil and sediment sampling,

A Tier 2 assessment was conducted to further evaluate pathways, receptors, and risk drivers or COIs based on the results of the Tier 1 assessment. The Tier 2 assessment was conducted by building on the results of the Tier 1 assessment and incorporating Site-specific tissue and bioaccumulation data. The objectives of Tier 2 were to provide valuable information for refining risks, reduce the overall uncertainty in the risk estimates by incorporating Site-specific information into exposure estimates, and to provide information for making risk management decisions.

The results of the Tier 2 assessment are discussed in detail in Section 9 and Appendix U of this RI Report. As those sections note, we have been able to further evaluate the areas of the Site that showed unacceptable risks, and narrow the areas of concern as well as the COIs.

The “as-completed” Tier 2 ERA tissue sampling program is summarized in Table 3-10 of this RI Report.

The final "as-completed" schedule for all of the above-described RI work activities is shown on Figure 3-1 attached to this RI Report. The CSC has again also provided the Daily Reports summarizing the daily Phase III RI sampling completed as part of the updated Appendix S to this RI Report.

3.1.3 RI/FS Work Plan Change Control

Section 11.7 of the RI/FS Work Plan described the change control procedures that the CSC would follow during the RI process. That text noted:

> *"Certain aspects of the work described in this RI/FS Work Plan may change during the course of this project. Whenever this occurs, the CSC will notify the USEPA and other agencies of changes either verbally, via e-mail or in written letters. If requested by USEPA, the CSC will prepare amendments to this Work Plan describing the changes and the rationale for the changes. In the event the Work Plan is amended, the CSC will proceed with the RI/FS work impacted by the revision only after receiving USEPA approval of the amendments*."

The CSC discussed the change process with the USEPA prior to the start of the RI work, and summarized that process in a memorandum which noted:

> *"The CSC will generate and track all project submittals (including those discussed below) by unique tracking number. The tracking number will reference the relevant RI/FS Work Plan section or standard operating procedure (SOP) and paragraph number.*
>
> *The RI Field Manager will be responsible for copying and distributing all submittals to the appropriate representatives as discussed below.*
>
> ***RFIs***
> *To request information or to document clarifications regarding the RI tasks or RI SOPs, the CSC will prepare a Request for Information (RFI) using a standard form similar to the form generated for the EE/CA Area Cap Construction project previously completed at the Casmalia Site. The RFI will be provided to the CSC's Project Coordinator (Corey Bertelsen), RI Field Manager (David Meyer), EPA Project Manager (Lynda Deschambault), and EPA's oversight representative. To indicate that the EPA oversight representative is aware that a particular issue has been raised and will be resolved by the RFI process, the EPA oversight representative will initial RFIs and RFI responses before the RI Field Manager distributes them. RFIs typically address wording clarifications on the SOPs or tables, details not specified in the RI/FS Work Plan or SOP, or minor edits or changes to the above.*
>
> ***RICH or Changes***
> *While completing the RI field tasks, the CSC's contractors, CSC's Project Coordinator, or the RI Field Manager may suggest changes to the RI/FS Work Plan or SOPs. Changes are material project revisions such as modifications of: SOPs, changes in sampling suites, changes in sampling locations, revisions to previously approved labs or analytical methodology. The RI Field Manager will assign each written change request with a unique number on a RI Change (RICH) form for each change being considered.*

RICH packages will include a description of the requested change, details depicting the change, and other justification and/or calculations supporting the change. RICH forms must be signed by the CSC's Project Coordinator and EPA's Project Manager before changes can be implemented. The RI Field Manager will track changes on a standard form similar to the form generated for the EE/CA Area Cap Construction project previously completed at the Casmalia Site and will distribute the RICH package to the Contractors performing the work, CSC Project Coordinator, EPA's Project Manager, and EPA oversight representative. As requested, the RI Field Manager will also provide copies to the State Agencies. EPA will coordinate the State Agencies participation in the RICH process."

The CSC submitted five RFIs and 15 RICH forms to the USEPA during Phase I, Phase II, and Phase III of the RI sampling. Those clarifications and changes included the following:

- RFI-001 QA requirements for TO-15 soil gas analytical;
- RFI-002 Add two pesticides to 8141 chemical list;
- RFI-003 Type 6 sample depth clarification;
- RFI-004 Additional CPTs for PSCT-1 Low Area – reissued as RICH-011;
- RFI-2009-01 Modification of plant tissue selection hierarchy
- RICH-001.2 Alternate soil extraction method;
- RICH-002 SOP 1.9 edits;
- RICH-003 Remove sampling locations SCL-05, 06;
- RICH-004.2 Modify soil ethylene glycol sampling;
- RICH-005.2 Add soil blank sampling requirements;
- RICH-006 Allow use of peristaltic pump for surface water;
- RICH-007.2 Use MIP to finish NAPL survey work;
- RICH-008.2 Delete piezometer and video for install;
- RICH-009.3 8015 sample collection method (Encore);
- RICH-011 Complete CPTs in potential low area;
- RICH-012.2 Revise methodology of clay barrier work;
- RICH-013 Shaving cream test method;
- RICH-014 Delete MW-04;
- RICH-015 Revised PCB Congener Sampling; and
- RICH-016 Modified Soil Vapor Analytical Method.

RICH-010 was prepared but negated during the RI and was thus not formalized. The CSC has attached a complete set of all of the RFIs and the USEPA-approved RICH forms to this RI Report in Appendix Q.

As discussed with the USEPA, the RI Report was prepared so that the details of the RI activities and the primary data results for each of the various sampling or RI activities are documented in the appendices. The appendices review the sampling or RI activity, describe the details of the sampling program, discuss any deviations in those procedures from those in the approved RI/FS Work Plan, and describe the sampling results.

In the paragraphs below, the CSC introduces each of the appendices and provides an overall summary of the field work activities, by media or study area, that were completed as either Phase I, Phase II, or Phase III or the Seismic Refraction Follow-Up RI sampling.

3.2 Background Soil (Appendix A)

As discussed in the RI/FS Work Plan, background concentrations of chemicals in soil were previously evaluated in earlier investigations conducted at the Site (in studies primarily conducted by the owner/operator). Soil borings and test pits were completed in upgradient, off-site areas during these earlier site investigations to assess the background chemical and geochemical properties of the three stratigraphic units present at the Site. As part of the CSC's Phase I and Phase II RI sampling, the CSC collected new background soil data which was compared with the existing data and used in the risk assessments included in this RI Report.

From this background soil data set, background concentrations have been established in accordance with USEPA and CalEPA guidance (USEPA, 2002; CalEPA, 1997). These background concentrations and their development are described in more detail in the Human Health Risk Assessment (Section 8 and Appendix T) and Ecological Risk Assessment (Section 9 and Appendix U), as well as in Appendix A (Background Soil) included in this RI Report. As agreed to by the USEPA and as summarized in the discussion on risk assessments, chemicals on-site at background concentrations should not require remediation. Site-specific background concentrations represent the lowest concentration that the CSC could reasonably be expected to achieve for individual chemicals during remediation.

During the Phase I and Phase II RI sampling, the CSC collected soil samples at various depths and analyzed those samples for a variety of constituents including VOCs, SVOCs, inorganics, PCBs, Dioxin/Furans, and other potential COPCs.

Appendix A presents the details of the data collected during RI sampling for background soil, and includes a map that depicts historical and RI background sampling locations (Figure A-1). The appendix also presents the preliminary statistics regarding calculated background concentrations for various constituents in the soil at Casmalia. These background concentrations are subsequently used in the Human Health Risk Assessment and Ecological Risk Assessments completed for the Site.

3.3 Soil and Sediment Sample Summary (Appendix B)

As part of Phase I, Phase II, and Phase III RI sampling activities, the CSC collected on- and off-site soil samples and site pond and off-site drainage sediment samples at the Site to further define the nature and extent of site-related contamination and to evaluate potential health risks to human and ecological receptors. As discussed in the RI/FS Work Plan, the soil samples were tested both for chemical analysis and for physical properties needed for risk assessment, groundwater modeling, the TI evaluation, and/or the FS.

The soil samples were collected at a combination of random and authoritative locations within the various study areas. Random samples from surface (0 to 6 inches) and shallow (5 feet) depths were collected to evaluate potential human and ecological risks across the site. In areas of suspected contamination, authoritative samples were collected from surface and subsurface soils.

The CSC also collected bottom sediment samples using continuous core sample collection methods at 0 to 1 feet, 3 feet, and 5 feet, in each of the stormwater ponds and treated liquid impoundments. Like the soil samples, the pond sediment samples were analyzed for a variety of constituents. The sediment samples were also analyzed for grain size and TOC for use in the ecological risk assessment.

Appendix B presents the details of the data collected during RI sampling of site soils and sediments, and includes maps depicting all RI soil and sediment sampling locations (Figures B-1, B-6, and B-21a). A summary of the samples, locations, and analytical suites that the soils were sampled for is shown in Tables B-1 and B-20 in Appendix B of this RI Report.

3.4 Soil Vapor Investigation (Appendix C)

As discussed in the RI/FS Work Plan, the CSC collected soil vapor data at various locations throughout the site to evaluate the inhalation exposure pathway for on-site workers and burrowing terrestrial mammals, and for potential off-site human receptors. Because the CSC expected the soil vapor concentrations to be greatest adjacent to the major site sources, the data collection program targeted collecting data as close to the source areas as practicable and focused on the landfill areas of the Site.

The CSC collected the soil vapor data at depths representing the 0- to 10-foot-depth interval as well as depths of 20 feet (during the Phase II soil vapor sampling). These depths were chosen as a reasonable depth from which to model worker exposures and because 10 feet is the greatest depth where animals are likely to burrow. The soil vapor samples were collected using guidelines from the advisory on active soil gas investigations prepared by the DTSC and the Los Angeles RWQCB (DTSC and LARWQCB, 2003).

Appendix C presents the details of the data collected during the various phases of RI soil gas surveys, and includes a map depicting all soil vapor sampling locations (Figure C-1). The CSC soil vapor samples to assess potential soil vapor migration from the primary source areas to other on-site areas or to potential off-site areas. The primary source areas included:

- The Capped Landfills Area;
- The PCB Landfill (which is currently slated for a presumptive capping remedy);
- The Liquids Treatment Area;
- The Central Drainage Area (which encompasses former ponds and pads that were historically slated for a “landfill” closure remedy – this is the area south of the capped landfills and north of the PSCT that the CSC and the USEPA discussed capping over the past years); and
- The Burial Trench Area.

Following the Phase I soil vapor sampling, the CSC collected six additional soil vapor samples as part of Phase II sampling activities along the northern perimeter of the landfills that were colocated with three previous locations completed during Phase I sampling. After completing that sampling, the CSC did not feel that they had completely defined the aerial extent of the elevated soil vapor concentrations in the North Drainage and so we completed three more soil vapor samples at step-out locations even further than the earlier samples.

Finally, to assess whether the elevated concentrations of 1,3 Butadiene that these step-out soil vapor sample locations continued to show were real, the CSC reoccupied the last three step-out locations and took additional soil vapor samples, which we sent to two separate laboratories for analysis.

All of this sampling and the sampling results are discussed in Appendix C.

3.5 Surface Water Data (Appendix D)

As part of Phase I and Phase II RI sampling activities, the CSC collected surface water samples to supplement existing data to evaluate potential exposures to human and ecological receptors to on-site pond water and surface water runoff in Zone 1 as well as water that may be present in the drainages within Zone 2. The RI sampling augmented existing information on surface water chemistry that was available from the previous NPDES Permit application as well as earlier site studies. All surface water pond samples were collected in accordance with the specifications and procedures outlined in the RGMEW Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP), and tested for full Appendix IX analyses.

The location and identity of surface water samples are listed in Table D-1 and shown on Figure D-1 in Appendix D attached to this RI Report. Appendix D presents the details of the surface water sampling program, and summarizes results of the surface water analyses conducted as part of RI.

The surface water sampling program included collection of surface water or stormwater runoff samples from the following locations:

Surface Drainages

- **A-Drainage**: One sampling event was conducted in the A-Drainage during a heavy rain event in March 2005;
- **North Drainage**: Three sampling events were conducted in the North Drainage, including one during the dry season in August 2004, and two during the rainy season in November 2004 and March 2005;
- **Casmalia Creek / C-Drainage**: Three sampling events were conducted in the Casmalia Creek / C-Drainage, including one during the dry season in August 2004, and two during the rainy season in November 2004 and March 2005 (contemporaneously with those completed for the North Drainage); and,
- **RCRA Canyon**: Three sampling events were conducted in the RCRA Canyon drainage during the rainy season in December 2004, March 2005, and December 2006.

Surface Water Impoundments

One sample from each of the five on-site surface water ponds (A-series pond, Pond 13, Pond 18, Pond A-5, and RCF pond) was collected during the RGMEW fourteenth and fifteenth SA sampling events, conducted during October – November 2004 and April 2005, respectively.

3.6 Well and Piezometer Installation (Appendix E)

As proposed in the RI/FS Work Plan, the CSC constructed a number of new groundwater wells and piezometers to both monitor chemical quality at specific locations on the Site and to augment the groundwater level information previously collected during Routine Groundwater Monitoring completed at the Site.
The location and identity of the new wells and piezometers are listed in Table E-1 and shown on Figure E-1 in Appendix E of this RI Report. Appendix E provides the as-built construction details of the well and piezometers that were installed.

3.7 Groundwater Level Data (Appendix F)

As part of the RI process noted above, the CSC measured and reported groundwater levels from both existing wells and piezometers and from new wells and piezometers that were constructed for the RI/FS. Appendix F presents the details of the groundwater level data that were collected as specified in the RI/FS Work Plan, and includes maps depicting RGMEW water level monitoring locations (Figures F-1 and F-2).

Using these groundwater level data, in conjunction with information regarding the physical geologic environment of the Site and surrounding area, the CSC constructed a site-wide three-dimensional groundwater flow model (GW Flow Model) according to the approach and scope presented in the RI/FS Work Plan. The CSC provided the USEPA a number of revisions and improvements to the GW Flow Model over the last 18 months and discussed its structure and calibration in a number of meetings and memorandums. The CSC has used the calibrated GW Flow Model (in conjunction with empirical hydrogeologic, flow, and water quality data) to evaluate site-wide and local flow conditions, the hydraulic effectiveness of current liquids extraction, and potential effectiveness of alternate site remedies. As noted in the RI/FS Work Plan, the groundwater model will not be used to model contaminant fate and transport but will be used as a tool to assess contaminant transport.

The site-wide model is capable of simulating:

- Flow within and between the upper and lower hydrostratigraphic units;
- Flow in and out of the entire Zone 1 area including all existing extraction facilities;
- The area from the north ridge to the North Drainage;
- Flow to Casmalia Creek;
- Other groundwater-surface water interactions including all ponds; and
- Horizontal and vertical flow around the extraction facilities.

The CSC used a finite difference model (USGS MODFLOW or MODFLOW Surfact) to prepare the groundwater model. The calibrated Groundwater Flow Model is discussed in more detail in Appendix F of this RI.

3.8 Groundwater Chemistry (Appendix G)

As described in the RI/FS Work Plan, the CSC installed new wells and collected groundwater samples in specific site locations that were identified as potential data gaps. The newly constructed wells were developed during the RI field efforts and sampled during the regular RGMEW sampling events following installation and development.

The CSC installed the wells in accordance with the procedures set forth in the Sampling Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) (Appendices A and B) of the RI/FS Work Plan and in accordance with the appropriate State well design guidance documents referenced in the SAP and Standard Operating Procedures (SOPs).

Once the wells are installed and developed, water levels were measured using a sounder. Water levels were recorded daily for one week, weekly for one month, and monthly in all new wells after initial development until equilibrium with the surrounding aquifer formation was established.

Appendix G presents the analytical results from the new chemical quality wells or additional wells for the RI/FS Work Plan, and includes a map depicting upper Hydrostratigraphic Unit (HSU) and lower HSU chemical water quality monitoring locations (Figure G-1). Appendix G discusses the RI chemical quality sampling and puts these results into context with the groundwater sampling results collected as part of the RGMEW at the Site.

3.9 RCRA Canyon Outcrop Assessment (Appendix H)

In the RI/FS Work Plan, the CSC summarized the geologic data that had been collected during previous investigations at the Site. As part of the RI Sampling program, the CSC reviewed the existing geologic information reported on the bedrock outcrop area in RCRA Canyon (which had originally been obtained and reported as a part of the HSIR) and confirmed and field-verified that data by completing a RCRA Canyon Outcrop Assessment. The CSC utilized a registered geologist experienced in field techniques including identification and characterization of faults, lineaments, and fractures and performed a field confirmation. The CSC evaluated the existing HSIR information on RCRA Canyon geology including the faults and lineaments previously mapped in the study area, and confirmed these features in the field. The results of the field confirmation were provided to the USEPA in the IPR.

Appendix H attached to this RI Report presents the results of the RCRA Canyon Outcrop Assessment or survey, and includes a map depicting the area evaluated (Figure H-2). As described in more detail in the appendix, the CSC completed all of the assessments of the RCRA Canon Outcrop as discussed in the RI/FS Work Plan and compared the geologic data they collected against previous studies completed at the Site.

3.10 Gamma Walk-over Survey (Appendix I)

As described in Section 4.7.4 of the RI/FS Work Plan, as part of the Phase I RI activities the CSC assessed the presence of low-level radioactivity that would normally be associated with former oil spreading areas in RCRA Canyon. To establish background gamma readings, the CSC first conducted a walk-over gamma survey in off-site areas deemed umimpacted by the site's activities (where background soil samples were collected). The CSC completed the walk-over gamma surveys using a sodium iodide (NaI) detector.
The CSC established walk-over transects for the surveys with the USEPA's approval. The locations or transects for the gamma readings were slightly adjusted from those first proposed in the Work Plan to accommodate the steep slopes in the RCRA Canyon drilling mud disposal areas. The NaI detector was used to record the gamma readings and the CSC downloaded the data, together with the output from a GPS device, to generate records of readings at various locations in the survey area.

Appendix I presents the results of the gamma survey that was completed, and includes a map depicting the transects completed (Figure I-1). As described in more detail in the appendix, the CSC completed the background survey of the RCRA Canyon and compared those results with two off-site baseline survey lines that we had first performed. Comparison of the background transects to the RCRA Canyon transects indicated there were no "hot spots" in the RCRA Canyon Oil Spreading areas.

3.11 Clay Barrier Investigation (Appendix J)

As provided for in the RI/FS Work Plan, the CSC completed a CPT drilling program to establish the depth and location of the P/S Landfill Clay Barrier during Phase I RI activities. As follow-up to the Phase I RI work, the CSC also conducted additional sampling of the clay in the barrier and analyzed the permeability of the clay in-situ during Phase II RI activities. The proposed CPT drilling and sampling program was designed to identify the location of the black adobe clay barrier (both lateral and vertical barrier limits) and to confirm the permeability of the barrier as constructed.

The CSC was able to intersect the clay barrier near the Gallery Well, and at locations on either side of the Gallery Well, using only vertical geoprobe borings and was able to define the elevation of the top of the barrier at three locations over the clay barrier.

Appendix J presents the details of the Phase I RI clay barrier investigations that the CSC completed as specified in the RI/FS Work Plan, and includes a map depicting drilling and sampling locations, and the interpreted position of the clay barrier (Figure J-3). As described in more detail in the appendix, the CSC identified the top and extent of the clay barrier located at the southern boundary of the Pesticides/Solvents (P/S) Landfill.

3.12 CPT Signature Comparison (Appendix K)

During previous investigations, the CSC used CPTs to evaluate the depth of the native claystone underlying waste and/or alluvium materials. At that time, the CSC reviewed tip resistance data or responses from previous on-site CPT activities with the USEPA's contractor (Mark Wuttig of CH2M Hill) and generally agreed that an increase in tip resistance (Qc) to 200 tons per square foot (tsf) (over a several foot increment) and positive pore pressure (P_w) represented reaching the contact between the base of the waste and the top of the native claystone. Tip resistance generally increases with depth as a function of the materials encountered. Pore pressures typically vary between negative and positive as the probe is advanced through the subsurface and generally show positive and increasing pore pressures when advanced through the contact into the lower HSU.

In order to confirm the CPT methodology, the CSC completed a program to evaluate CPT signatures and assess their effectiveness in identifying the upper HSU/lower HSU contact during the Phase I RI activities. The investigations included pushing 18 CPTs colocated with existing boreholes with existing good quality lithologic data on HSU contact depths. The validity and degree of uncertainty to be applied to the CPT method was determined based on calibration of the observed CPT response with known lithologic conditions at the adjacent recently installed and cored confirmation boreholes. The correlation demonstrates that that in most cases the contact identified on the boring log was within one to several feet of the CPT-derived contact, and that this method is best applied in locations where the transition zone between the weathered and unweathered zones is relatively thin.

Appendix K presents the results of the CPT signature/lithology correlation work completed as specified in the RI/FS Work Plan, and includes a map depicting the locations used in this comparison (Figure K-1). As described in more detail in the appendix, the CSC compared CPT signatures with over 18 locations with known lithology to identify a correlation between the CPT signature and the upper HSU/lower HSU clay contact.

3.13 Geophysical Surveys (Appendix L)

The geophysical surveys proposed in the RI/FS Work Plan provided a means to investigate whether or not the contact between the unweathered claystone and waste beneath the P/S Landfill (the weathered claystone was excavated prior to placement of waste) included a closed depression or a “low spot” where DNAPL might accumulate, rather than flow along the contact to the toe of the landfill where it would be collected and removed by the existing Gallery Well. The “low spot” issue has been a discussion point between the CSC and the USEPA since 2000, when the USEPA first expressed its concerns that such a depression, which had been previously reported by other agencies, might exist.

The RI/FS Work Plan proposed the use of geophysics to assess the depth and configuration of the clay contact. Geophysics was used in a phased approach that included:

- A Pilot Study;
- A Phase I Seismic Refraction Production Survey; and
- A Phase II Seismic Refraction Production Survey.

3.13.1 Pilot Study

The Pilot Study was designed to test the performance of the seismic refraction, seismic reflection, and micro-gravity methods for delineating the clay contact at the toe of the P/S Landfill. The Pilot Study was performed in order to determine if seismic refraction, or other surface geophysical methods, could effectively assess subsurface conditions at the P/S Landfill, which is composed of a heterogeneous mixture of fill material including both crushed and intact drums of waste. The Pilot Study details are presented in the RI/FS Work Plan and in a separate Geophysical Experimental Plan that was submitted to the USEPA in 2004 (Appendix L, Attachment L-3). The geophysical Pilot Study was completed as part of Phase I RI activities.

3.13.2 Phase I Seismic Refraction Production Survey

Following the Pilot Study, the CSC performed a site-wide Phase I Seismic Refraction Production Survey to investigate areas beyond the P/S Landfill for other potential low spots in the clay contact. The Phase I survey covered the Burial Trench Area, Central Drainage Area, and selected areas south of the Perimeter Source Control Trench (PSCT). These areas were chosen on the basis of previous site usage and the potential for the existence of DNAPL in the subsurface. The Phase I Refraction Survey was performed immediately after the Pilot Study to take advantage of the seismic field crew and equipment that were already mobilized to the site; and, because the Phase I refraction work covered areas outside the P/S Landfill, there were no concerns that buried refuse would degrade the accuracy of the results. The Phase I refraction work indicated three potential low spots, one of which was investigated with CPT borings, however, a low spot was not found. The potential low spots indicated by the seismic data were, therefore, attributed to localized variations in the near-surface soil or variations in weathering patterns of the claystone. It should be noted that the USEPA did not perform a detailed analysis of the Phase I results.

The Pilot Study and Phase I Production Survey findings were presented to the USEPA in February 2005 as Appendix L of the Interim Progress Report (IPR). The Pilot Study suggested that seismic refraction could potentially delineate the claystone contact; however, as noted by the USEPA in their response to the IPR, it was agreed that seismic reflection and micro-gravity

could not reliably delineate the contact, so no additional geophysical surveys were planned using those techniques. The Phase I Seismic Refraction Production Survey details are presented in the RI/FS Work Plan and in a separate Geophysical Experimental Plan that was submitted to the USEPA in 2004 (Appendix L, Attachment L-3). The Phase I Seismic Refraction Production Survey was completed as part of Phase I RI activities.

3.13.3 Phase II Seismic Refraction Production Survey

On the basis of the Pilot Study results, the CSC completed a Phase II Seismic Refraction Production Survey as part of Phase II RI activities. The Phase II refraction work comprised a grid of 14 seismic lines centered on the landfill toe. Its purpose was to expand the data coverage provided by the two Pilot Study refraction lines so that a 3-dimensional picture of the claystone contact surface could be generated. The Phase II Work Plan was developed using the draft-and-review process and was also facilitated by numerous discussions between the USEPA and CSC in an effort to optimize data coverage and subsurface resolution while maintaining a practicable field program.

The discussions focused primarily on the number of seismic lines and on shotpoint spacing along the seismic lines. The USEPA originally proposed a Phase II survey with 24 lines and 40-foot shotpoint spacing. The CSC contended that fewer lines were needed because the survey objective was to verify the presence or absence of the reported low spot, the approximate location of which was already known on the basis of a 1988 contour map prepared by Canonie and Associates. The CSC also believed that an 80-foot shotpoint spacing would provide sufficient resolution, given that the survey would be performed using a 96-channel seismic system with a 10-foot geophone spacing. Eventually, it was agreed that a 14-line survey would be performed with shotpoints spaced 40 feet apart within the actual landfill toe, where the low spot was reportedly located, and 80 feet apart beyond the landfill boundary. It is worth noting that both parties readily agreed to use 10-foot geophone spacing. The Phase II Seismic Refraction Production Survey was completed as part of Phase II RI activities. The final approved Phase II RI/FS Work Plan Supplement, Revised Draft, Geophysical Survey Plan is included in Appendix L, Attachment L-6, as well as in Appendix Y that includes Work Plans for the Phase II and Phase III RI investigations.

To evaluate the refraction data, the CSC prepared tomographic models showing velocity layering in the subsurface along each of the seismic lines. These models were provided to the USEPA, along with the raw refraction data, in earlier submittals so that the USEPA could perform independent modeling and analysis. Although the CSC's and USEPA's modeling was performed separately, it is worth noting that both parties used the same agreed upon inversion parameters for the number of horizontal and vertical smoothing passes, as well as the number of iterations run.

The CSC's approach to analyzing the refraction survey results focused on identifying the contact on the tomographic velocity models, with the idea that if the contact could be correlated to a specific and unique velocity signature, or to a narrow velocity range, then the clay contact configuration could be mapped in three dimensions by following this contour (the "iso-velocity" contour) through the grid of 16 intersecting tomographic velocity models (the 14 Phase II models plus the two from the Pilot Study). To establish a velocity signature for the contact, the CSC annotated its tomographic models with the position (depth) of the claystone contact as interpreted from existing borehole core samples and CPT borings located along or near the seismic lines.

When the borehole claystone surface depths were plotted on the tomographic models, the velocities found at the contact ranged from a low of approximately 3,200 feet per second (fps) to a high of 6,000 fps (see Table L3-3). As such, a unique iso-velocity contour representing the claystone surface could not be established. Regardless, each tomographic model was evaluated in a qualitative fashion to identify potential low spots in tomographic inversion (velocity) layering that might indicate a depression in the physical claystone contact. To further assess the reliability of using the tomographic models, the travel times and apparent depths at intersection points of the seismic models were compared (or matched) at certain velocity contours. Two velocity contours were used for the comparison (3,400 fps and 5,400 fps). Vertical discrepancies (mis-ties) ranged from 0 feet to over 25 feet were noted. On the basis of this analysis, the uncertainty of the clay contact depth as indicated by the tomographic models was estimated to be approximately 10 feet. Additionally, the CSC's analysis to this point suggested that the velocity contours on the tomographic models did not conform to the contact, in which case, the models would not yield an accurate 3-dimensional rendering of the contact surface. However, the CSC prepared a preliminary contour map of the 5,400 fps iso-velocity surface to determine if any conclusions could be drawn by assessing its general form.

Using independent tomographic models, the USEPA, through its geophysical consultant at the Idaho National Laboratory (INL), prepared an alternate interpretation, which was presented in a letter dated May 3, 2007 (Appendix L, Attachment L-5). Briefly, the USEPA prepared contour maps of the 5,200, 5,400 and 5,600 fps iso-velocity surfaces using a 3-dimensional kriging (gridding) algorithm on iso-velocity contour elevations extracted from the tomographic models. The USEPA contour maps suggested three potential low spots: one west of the Gallery well, another north of the Bench 1 road, and a third north of the Bench 2 road. These potential low spots were in part defined by linear ridges that align with the bench roads spanning the P/S Landfill. The CSC believes that the ridges may be artifacts of near-surface (high) velocity anomalies (seismic pull-up) associated with compacted road fill and that the imaged ridges do not actually represent claystone surface topographic features in the claystone surface.. However, at the request of the USEPA and to verify seismic imaging, the CSC performed intrusive follow-up work to the Phase II refraction survey by advancing a series of CPT borings and installing four piezometers in the P/S Landfill at the locations identified on seismic models as suspected low spot in the claystone contact. The CPT and piezometer follow-up work was completed in the fall of 2007, and the CSC is continuing to monitor the liquid levels in the installed piezometers.

Appendix L presents the results of the Pilot Study, Phase I, and Phase II RI Geophysical Surveys work completed as part of the RI activities, and includes maps depicting the various survey lines completed. Appendix L also provides a preliminary assessment of the intrusive follow-up work to the Phase II Seismic Refraction Production Survey.

3.14 UVIF/MIP NAPL Investigations (Appendix M)

As discussed in the RI/FS Work Plan and as part of Phase I RI activities, the CSC completed a Ultraviolet Induced Fluorescence/Membrane Interface Probe (UVIF/MIP) survey at the Site to assess the potential presence of NAPLs. The CSC used direct-push technology (CPT equipped with a UVIF module) and a cone penetrometer with pore pressure measurement to evaluate the presence of residual NAPL at several areas of concern throughout the Site.

The UVIF/MIP survey proposed in the RI/FS Work Plan originally intended to primarily use the UVIF signature to identify possible NAPL presence at approximately 50 locations across the site in the various different study areas. The CSC first obtained a UVIF response profile from near

Sump 9B and the Gallery Well where DNAPL is known to be present. The CSC also obtained a UVIF response profile in a non-source area from a nearby off-site location to aid in determining a “background” response profile for contaminated local soils. As discussed in the RI/FS Work Plan, the UVIF response profiles from these locations were intended to serve as a benchmark for the UVIF response profiles obtained at the other 50+ locations where we planned the UVIF survey. As part of the program, the CSC also planned to perform a MIP survey using a CPT rig at approximately 8 locations where we also conducted UVIF surveys so that we could compare and contrast the data collection abilities of the two technologies.

After beginning the initial investigations in the field (i.e., after completing approximately 10 locations), the CSC reported the colocated UVIF and MIP data results to the USEPA. Following review of that data and discussions with the USEPA, it was agreed that the MIP technology was much more sensitive to the presence of hydrocarbons than the UVIF technology. As such, the bulk of the NAPL survey was completed using the MIP technology. In addition to the three benchmark NAPL assessment locations, the CSC conducted UVIF or MIP surveys on eight probe locations in the Central Drainage Area, five probe locations in the Burial Trench Area, seventeen probe locations in the areas south of the PSCT, six probe locations in the RCRA Canyon, two probe locations in the Liquids Treatment Area, and two probe locations in the Maintenance Shed Area. The complete UVIF/MIP sampling program is summarized in Appendix M of this report.

When the MIP data indicated a possible presence of residual NAPL at a particular location and depth, the CSC collected soil samples from the depth intervals where the MIP profiles indicated possible NAPL as a part of the sampling program. The soil samples were analyzed for modified Appendix IX suites. Additional soil samples were also collected and tested for total organic carbon (TOC) and fraction organic carbon (FOC) content, specifically for use in performing a numerical evaluation of NAPL potential based upon the reported concentrations of contaminants present in impacted soil samples. These additional samples were collected at positions generally located away from areas that are known to be impacted by organic chemicals, so as to provide a reasonable estimate of background levels of TOC and FOC at the site. Jointly, there chemical data were then used to complete “chemical partitioning calculations” to assess whether DNAPL or LNAPL may be present (Appendix M, Attachment M-1). The chemical partitioning calculations were completed on soil sample locations agreed to by the USEPA as part of follow-up to the IPR.

Appendix M presents the results of the UVIF and MIP surveys (as well as the associated soil sampling that resulted from that work) as specified in the RI/FS Work Plan, and includes a map depicting the locations where these surveys were completed (Figure M-1). As described in more detail in the appendix, the CSC completed UVIF or MIP surveys at approximately 58 locations on-site to identify any areas with residual NAPLs (DNAPL or LNAPL).

3.15 Off-site Well Survey (Appendix N)

Previous studies discussed in the RI/FS Work Plan identified a number of water wells within a 3-mile radius of the Site. The CSC completed a survey of the known existing wells and conducted a search for any additional water supply wells as part of the Phase I RI activities.

Appendix N presents the results of the off-site well survey that the CSC completed in accordance with the approved RI/FS Work Plan, including updated information about the wells within a 3-mile radius of the Site and a map depicting the locations of these wells (Figure N-1).

3.16 Monitored Natural Attenuation Evaluation (Appendix O)

As part of the Phase I and Phase II RI activities, the CSC conducted a monitored natural attenuation (MNA) study at the Site to better assess the possible use of monitored natural attenuation in the Southern Groundwater Area as a viable remedial option. As discussed in the RI/FS Work Plan, the scope of the study included collecting key MNA parameters in groundwater and completing a preliminary scoping evaluation of MNA at the Site.

The data of MNA parameters collected included:

- VOCs;
- Alkalinity as $CaCO_3$;
- Nitrate;
- Nitrite;
- Sulfate;
- Sulfide;
- Ferrous Iron;
- Manganese;
- Temperature;
- pH;
- Redox potential (Eh or ORP);
- Manganese;
- Chloride as Cl;
- Total Organic Carbon (TOC);
- Methane, ethane, and ethene;
- Presence of hydrocarbon-degrading bacteria;
- Dissolved Oxygen;
- Carbon Dioxide; and
- Conductivity.

Appendix O presents the analysis of existing MNA data either previously available at the Site or collected as part of the RI work, and includes a map depicting the upper and lower HSU MNA study areas (Figure O-1). Appendix O summarizes the MNA data graphically on charts and includes specific charts that display field parameters (pH, Eh, EC, T, and DO) and electron receptors (nitrate, sulfate, ferrous iron, manganese). The charts are used to assess the variability of these constituents, which are sensitive to sampling methodology.

As described in more detail in Appendix O, the CSC completed a preliminary MNA analysis of site groundwater so this might be considered in the future FS of the RI/FS.

3.17 Biological Species and Habitat Surveys (Appendix P)

The USEPA previously requested that a number of species or habitat surveys be conducted at the Site to support the CSC's work on the EE/CA Area cap design/construction, as part of the application for a NPDES Discharge Permit for the Site, and finally, as part of applying for and supporting the General Permit that the CSC acquired for the Site. The purpose of the various biological or habitat surveys was to collect comprehensive presence/absence data for special-status flora and fauna species for the above uses as well as for planning and completing the risk assessments and RI/FS for the Site.

The surveys were completed during all four seasons at the Site. Prior to commencing the surveys, a desktop review of information concerning flora and fauna in the areas of the site was conducted to determine potential special-status and sensitive species potentially present at the site. The list of potential species was discussed and approved by the USEPA, the USFWS, and the DFG. The survey schedules for the site were determined based on the life history of flora and fauna potentially occurring at the site.

Appendix P is a summary of all of the previously completed Biological Species and Habitat Surveys conducted for Casmalia as reported in a number of separate submittals to the USEPA and the other agencies.

3.18 Data Validation and Data Management (Appendix R)

The CSC prepared an electronic database that includes all of the RI sampling data collected during Phase I, Phase II, and Phase III sampling. The database is attached to this RI Report and has been previously provided to the USEPA and the other regulatory agencies on a number of occasions throughout the RI process.

Appendix R of the RI Report provides USEPA a summary of the data management and data validation process that the CSC used to record the RI data. The appendix provides a general summary of significant data qualifiers for the various RI activities or media and introduces the electronic database. Appendix R also provides a summary of tentatively identified compounds (TICs) that were reported in samples of the various media.

3.19 RI Daily Activity Reports (Appendix S)

Included in this appendix are copies (in electronic format) of all daily activity reports prepared during RI field sampling activities, encompassing Phase I through Phase III sampling efforts. Included in each report is a description of each day's sampling activities, including a summary of the locations visited and samples collected, as well as a forecast for the next day's anticipated field sampling activities. These daily activity reports were provided to USEPA oversight personnel on a daily basis.

3.20 Baseline Human Health Risk Assessment (Appendix T)

The detailed methods, findings and conclusions of the human health risk assessment are presented in Appendix T. Included are descriptions of the risk assessment approach and methods, including a review of pertinent Site background information, a review and evaluation of the data used and the COPCs considered in the risk assessment, a description of exposure and toxicity assessment findings, and the characterization of risks posed to potential human receptors.

3.21 Ecological Risk Assessment (Appendix U)

The detailed methods, findings and conclusions of both the Tier 1 and Tier 2 ecological risk assessments are presented in Appendix U. Included are descriptions of the risk assessment approach and methods, the Site environmental setting, including biological species and habitat evaluations, a review and evaluation of the data used and the COPCs considered in the risk assessment, exposure and effects assessment, and a characterization of risks to potential ecological receptors.

3.22 Historical Aerial Photograph Review (Appendix V)

Included in Appendix V are copies of four historical aerial photograph reviews performed between 2001 and 2003 by ERI under the direction of USEPA and CSC. These reviews encompassed the examination of multiple historical aerial photographs of the Site and directly surrounding area from the period 1974 to 1992. The findings of these reviews were used to support development of the scope of Site investigations outlined in the RI/FS Work Plan.

3.23 Historical Topography Review (Appendix W)

Appendix W presents a detailed review of the evolution of Site topography through the period 1959 -1993, encompassing natural pre-Site development conditions through active disposal operations and into post-disposal conditions. Change in land surface elevations, drainage alignments and site improvements are documented in a series of tables and detailed cross-sections. Electronic versions of historical topographic maps of the Site and directly surrounding area for the years 1959, 1974, 1979, 1985, 1987, and 1993 are also presented.

3.24 COPC and EPC Supporting Tables (Appendix X)

Appendix X presents a series of tables summarizing the prevalence of chemicals detected in the various environmental media on a Site-wide and study area-specific basis, and identifying those chemicals considered to be COPCs. Chemical-specific information included on these tables includes the number of samples tested, the number of detects, the range of reported concentrations and frequency of detection, among other factors. Also presented is a decision tree and detailed statistical evaluation of chemical data for all environmental media used to support development of exposure point concentrations for use in the human health and ecological risk assessments.

3.25 Follow-Up Work Plans – Phase II and III Remedial Investigation (Appendix Y)

Appendix Y presents electronic copies of the principal planning documents used to guide all Site sampling and investigations performed as Phase II and Phase III follow-up work to that completed during Phase I in accordance within the original RI/FS Work Plan. These various investigative phases are described in Section 3.0 and 3.1, and the applicable planning documents are cited in the References section, below.

3.26 References

Casmalia Steering Committee (CSC), 2009. [Tier 2 Ecological Risk Assessment] *Sampling and Analysis Plan*. March.

Casmalia Steering Committee (CSC), 2007a. *Rev. Final Phase III RI Sampling Plan for Follow-up RISBON-59 Soil Sampling*. March 27.

Casmalia Steering Committee (CSC), 2007b. *Final Plan for RI Follow-up to the P/S Landfill Seismic Refraction Study*. June 29.

Casmalia Steering Committee (CSC), 2007c. *RI Sampling Plan for Follow Up Soil Vapor Surveys.* July 20.

Casmalia Steering Committee (CSC), 2006. *Final Spring 2006 Phase II RI Sampling Plan for Soil Sampling, Soil Gas Surveys, Clay Barrier Sampling, Geologic Boring, and Well and Piezometer Installation*. May 25.

Casmalia Steering Committee (CSC), 2005a. *Final Geophysical Survey Plan - Phase II RI/FS Work Plan Supplement*. September 21.

Casmalia Steering Committee (CSC), 2005b. *Revision 4 – Fall 2005 Phase II Sampling – Soil Vapor, Surface Drainage Water, and Background Soil*. November 18.

Casmalia Steering Committee (CSC), 2005c. *Fall Phase II Groundwater Sampling,* November 18.

Casmalia Steering Committee (CSC), 2004. *RI/FS Work Plan*. June 3.

Cal/EPA, 1997. Selecting Inorganic Constituents as Chemicals of Potential Concern at Risk Assessments at Hazardous Waste Sites and Permitted Facilities, Final Policy. Prepared by Human and Ecological Risk Division, Department of Toxic Substances Control, Cal/EPA.
Department of Toxic Substances Control and California Regional Water Quality Control Board (DTSC and LACRWQCB), 2003. *Advisory – Active Soil Vapor Investigations*. http://www.grac.org/Soil_Gas_Advisory.pdf. January 13, 2003.

USEPA, 2002. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. EPA 540-R-01-003. September 2002.

4.0 PHYSICAL CHARACTERISTICS OF SITE AND STUDY AREAS

This section presents an overview of physical Site characteristics ascertained during Site investigations and closure activities. Both surface and subsurface characteristics are presented. A summary discussion of Site history, including the Site development, former operations, facilities, waste management practices, closure activities, and prior Site investigations, is provided in Section 2 of this report. The descriptions presented in this section have been updated with the most recent information available, including data developed during the Remedial Investigation.

4.1 Surface Features

4.1.1 Site Boundaries

The former Casmalia Hazardous Waste Facility is located on the south-facing flank of the Casmalia Hills. Casmalia Canyon and Creek, and an unnamed surface drainage, flank the Site on the west and north-northeast, respectively (Figure 2-1). Both drainages are relatively broad and eventually empty into Shuman Canyon and Creek. Casmalia Creek merges with Shuman Creek approximately 2 miles south of the Site and approximately 1 mile west of the town of Casmalia. Shuman Creek empties into the Pacific Ocean, approximately 4 miles west of the confluence with Casmalia Creek. The unnamed drainage located to the north and northeast of the Site has been referred to as the North Drainage in previous project documents. Three unnamed surface drainages exit the southern facility boundary, and have also been identified in previous documents, from east to west, as the A-Drainage (southeast corner), the B-Drainage (south-central boundary), and the C-Drainage (southwest corner). The B- and C-Drainages are tributaries to the larger Casmalia Canyon and Creek (Figure 2-1).

The Consent Decree (USEPA, 1997) has separated the Site and surrounding areas into two distinct parts: Zone 1 (the approximately 252-acre former waste disposal area) and Zone 2 (surrounding lands). Zone 1 is fenced, and encompasses all former operational areas of the Site. Zone 2 extends outward from the limits of Zone 1 encompassing adjacent surrounding lands (Figure 2-1). The detailed description of these areas, as defined in the Consent Decree, is provided in Section 2.1 of this RI Report.

4.1.2 Physiography

The Site is located within the southern portion of the Coast Range geomorphic province of California. The Site occurs within the Santa Maria Basin, a triangular-shaped basin, bounded on the south by the Santa Ynez Mountains and on the east and northeast by the San Rafael Mountains, and extends offshore to the west. The predominant Site topography and surrounding hills are characterized by rounded hills and slopes of gentle to moderate steepness. Valleys are typically broad with streams cut into alluvial valley fill sediments.

The Site slopes generally toward the south and is situated along the south-facing slopes of the Casmalia Hills. Surface elevations within the Site range from 835 feet above mean sea level (msl) at the crest of a ridge, which forms the northern facility boundary, to 375 feet msl at the southern boundary, which is located at the foot of two small hills that rise to the south of the Site. Approximately 1.2 miles north and east of the facility, the Casmalia Hills gradually rise to heights of approximately 500 feet above the highest portion of the facility, located along the

northern Site boundary. The Casmalia Hills are one of a series of three ranges of low west-northwest-trending hills that form the southern border of the Santa Maria Valley.

4.2 Meteorology

The Site has a generally mild coastal climate characterized by morning fog and afternoon winds. Site meteorological data have been collected at three locations: the A-Drainage, the B-Drainage and the North Perimeter Ridge. The meteorological stations were established as a part of the landfill cap construction programs and were sited to be consistent with EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements, 1995. Data have been collected since mid-1999 through approximately late 2008. Meteorological data collected at these locations includes wind speed, wind direction, and air temperature. Precipitation and evaporation data are also collected from instrumentation located just north of the administration building.

Representative Site data reflecting daytime hours from 2006 and 2007 include monthly temperature, wind speed, and wind direction are summarized in Table 4-1. Temperature data for the one-year period from June 2006 through May 2007 ranged from 33 degrees Fahrenheit (°F) to 85°F during the Fall and Winter (September through February) and from 40°F to 89°F during the Spring and Summer (March through August). Average monthly temperatures at the Site during this period ranged from a low of 51°F during January to a high of 64°F during July. During the winter months, temperatures can drop below freezing during the night and early morning, but usually by mid-morning, temperatures rise above freezing to thaw any ice or frost that may have formed.

In general, onshore flow predominates during daytime hours, causing winds to blow primarily from the southwest up both Shuman and Casmalia Canyons from the Pacific Ocean. At night, the winds reverse and blow from the northeast and northwest. These conditions are consistent with a thermally driven land-sea breeze circulation pattern. During periods of strong high atmospheric pressure in the Santa Maria Valley, gusty northeasterly winds may occur, bringing hot dry air from the Central Valley.

Monthly rainfall and evaporation data collected at the Site are available for the period 1983 through the present. Monthly rainfall and evaporation measurements from 1996 through 2007 were collected following SOP 5-6 – Precipitation and Evaporation Measurement (included in Appendix A of the RI/FS Work Plan), and the data is summarized in Table 4-2. Per these data, the average annual rainfall is approximately 17.2 inches. Most of the rain occurs between October and May, clearly defining the wet season. The average annual evaporation during this period is approximately 49.7 inches. Therefore, the Site has a net annual average evaporative loss rate of approximately 32.5 inches.

Site rainfall patterns are influenced by the El Niño/La Niña-Southern Oscillation (ENSO), a climatic pattern that occurs on average every five years, but over a period which varies from three to seven years. ENSO causes extreme weather such as floods, droughts and other weather disturbances in many regions of the world. In Southern California, El Niño is characterized by above average precipitation and La Niña by below average precipitation. The 1997/98 winter where 32.65 inches of rain fell at the Site was a strong El Nino event. The lowest yearly rainfall observed at the Site is 8.58 inches during the 2001/2 rainfall season.

4.3 Surface Water Hydrology

Summarized in this section are the surface water features and hydrologic factors extant at the Site and directly surrounding area. Included are brief descriptions of historical and current on-Site surface water drainage, current surface water impoundments, and off-Site surface water drainages proximal to the Site boundaries.

4.3.1 On-Site Surface Water Drainage

4.3.1.1 Current On-site Surface Water Drainage

The majority of Site surface water is collected and stored in on-Site ponds. Water on the western side of the Site is directed to the A-Series pond, though Ponds A-5 and 18 also collect water draining from the lands adjacent to them. The RCF Pond receives most other Site surface water runoff, with the exception of runoff from the P/S, Metals, Caustic/Cyanide, and Acids Landfills. Historically, the Central Drainage was the outlet for the former canyons within which the P/S, Metals, Caustic/Cyanide, and Acids Landfills were constructed. These landfills are now capped with impermeable membranes and surface water runoff is controlled and temporarily staged in the Central Drainage Area collection basin located at the toes of these landfills (Figure 2-3).

4.3.1.2 Historical Changes in On-Site Surface Water Drainage

Surface water drainage within the Site limits has changed through time as development of the Site progressed. The evolution of Site drainage through time is illustrated in a series of figures depicting how surface water drainage pathways have changed in response to the general progression of Site development through the time period 1959 (pre-development conditions) through 1987 (Figures 4-1 through 4-6). Changes in Site surface water drainage patterns through this period, and their implication regarding the potential for off-Site discharge of Site-related runoff, are briefly discussed below.

Pre-development conditions in the Site vicinity reflect several relatively undisturbed, natural drainages descending in a generally southerly direction from a pronounced northwest-southeast trending drainage divide (Figure 4-1). This northerly divide coincides with the current northern Site boundary, and served to separate the watershed for the North Drainage, located to its northeast, from the watersheds lying to its south and southwest. Natural drainage within the limits of the future Site area flowed toward the south from this northern divide and into what are identified as the current B-Drainage and lower C-Drainage. Drainage from the western portion of the future Site area, within what is now identified as RCRA Canyon, is separated from the upper reaches of the C-Drainage by a prominent north-northeast-to-south-southwest trending topographic divide. A more subtle topographic divide occurs in the southeastern corner of the future Site area, which served to separate the Site from the A-Drainage draining toward the east. These principal topographic divides remained largely unchanged through the development history of the Site, and serve to effectively isolate surface water runoff within the Site area from that within the North-Drainage, the A-Drainage, and the upper C-Drainage (Figures 4-1 through 4-6).

Conditions depicted in the 1974 map first indicate that drainage from the central and eastern portions of the Site is blocked by an “existing dam,” which would tend to prohibit surface water runoff from the early disposal areas into off-Site areas and contain it on-Site (Figure 4-2).

Continued expansion of Site disposal areas indicated in the 1979 map show that drainage from the northerly and easterly portions of the Site is directed into a large basin indicated as “Pond #6,” and that the construction of “drainage storage” basins in the area of the current RCF Pond, the elevated embankment for NTU Road, and Pond 13 across the southern limit of the Site effectively prohibited surface runoff from the developed Site area into the B-Drainage (Figure 4-3). Surface drainage from the future RCRA Canyon area remains separated from the active disposal areas on the 1974 and 1979 maps by an existing topographic divide, and appears to flow unimpeded from this still undeveloped area into the lower C-Drainage.

Continued development through the 1980s provided further control of surface water runoff within the Site boundaries in the form of land surface contouring to direct runoff into additional control structures and detention basins. Maps from 1982 onward indicate that as disposal operations expanded to the west to encompass the RCRA Canyon area, grading and construction of an earthen embankment and flanking drainage collection basins at the southwestern corner of the Site (roughly corresponding with the current locations of the A-Series Pond), effectively prohibited surface water runoff from the exiting Site into the C-Drainage (Figures 4-4 through 4-6). Continued development of landfill areas and disposal ponds and pads within the northern portion of the Site during the 1980s served to further control Site runoff, such that literally all surface runoff within the Site area is controlled and directed to storage and impoundment facilities. Surface runoff within the comparatively undisturbed RCRA Canyon area is contained entirely within the Site boundaries throughout the development period of the 1980s.

Site topographic conditions extant in 1993, following the completion of prior cleanup activities, are largely the same as they are today, and are such that all Site surface water runoff is completely contained within the Site boundaries (Appendix L, Attachment 1 – 1993 topographic map).

4.3.2 On-Site Storm Water Runoff Collection Ponds and Liquid Treatment Impoundments

There are currently five ponds at the Site. Of these ponds, three (RCF, A-Series and Pond 13) are exclusively utilized as collection and containment facilities for Site watershed storm water runoff. Two ponds (Pond A-5 and Pond 18) are currently or have historically been utilized for collection and containment of treated extracted liquids from on-Site treatment facilities. Beginning in October 1992, water level monitoring of the five ponds has been generally conducted on a daily basis as part of routine Site maintenance and operation activities. The CSC took over Site responsibilities on September 26, 1996. Site operation and maintenance information, including pond water levels collected since September 26, 1996, have been reported in Quarterly Progress Reports and submitted to the USEPA. Pond surface water levels are measured using in-pond staff gauges. The staff gauges are constructed to measure increments to the nearest foot; however, readings are estimated and recorded to the nearest tenth of a foot. Variations in pond levels, volumes and total dissolved solids (TDS) concentrations recorded in each of these on-Site ponds during the period 1998 through mid-2009 are presented in Figure 4-7.

4.3.2.1 RCF Pond

The RCF Pond is the primary storm water containment pond for the Site, located in the south-central portion of the Site, along the southern Site boundary. The RCF Pond was constructed in the areas of former Surface Impoundments 2, 3, 4, 9, 10 and 11. The RCF Pond was originally designed to maintain a RWQCB requirement to contain Site-derived surface water runoff

volume for the 24-hour probable maximum precipitation event, estimated at 13.25-inches of rainfall. The capacity of the RCF Pond is approximately 138 million gallons. At full capacity the water surface elevation is approximately 441 feet above mean sea level (msl), and is estimated at 19 acres of water surface area. In May 2009, the RCF Pond water surface elevation was measured at 24.9 feet below freeboard (416.1 feet above msl). Measured TDS values for the RCF Pond during the period 1995 through mid-2009 have ranged between 4,680 to 26,000 mg/L, with concentrations generally increasing through time (Figure 4-7).

4.3.2.2 A-Series Pond

The A-Series Pond is a storm water pond located in the southwestern portion of the Site. The A-Series Pond was constructed in the areas of former Surface Impoundments A-1, A-2, A-3 and A-4. The capacity of the A-Series Pond is approximately 115 million gallons. The pond is used to collect storm water runoff from the western watershed area of the Site as well as overflow from the RCF and A-5 ponds. At full capacity the elevation is approximately 448 feet above MSL, and is estimated at 12 acres of water surface area. In May 2009, the A-Series water surface elevation was measured at 22.6 feet below freeboard (425.4 feet above msl). Measured TDS values for the A-Series Pond during the period 1995 through mid-2009 have ranged between 6,760 to 28,000 mg/L, with concentrations generally increasing through time (Figure 4-7).

4.3.2.3 Pond 13

Pond 13 is a storm water pond located in the most southern area of the Site. Pond 13 currently collects storm water from areas outside the boundary of the Site. The capacity of the Pond 13 is approximately 7 million gallons. At full capacity the elevation is approximately 403 ft above MSL and is estimated at 2 acres of water surface area. In May 2009, the Pond 13 water surface elevation was measured at 19.7 feet below freeboard (383.3 feet above msl). Measured TDS values for Pond 13 during the period mid-1998 through mid-2009 have ranged between 3,140 to 43,000 mg/L, with concentrations generally increasing through time (Figure 4-7).

4.3.2.4 Pond A-5

Pond A-5 is a former surface impoundment used to store treated extracted liquids from on-Site treatment facilities. Currently Pond A-5 collects storm water from approximately 50 acres north of the pond. Pond A-5 is located in the western area of the Site just south of the RCRA Canyon area. The capacity of the Pond A-5 is approximately 10 to15 million gallons. At full capacity the elevation is approximately 469 feet above msl, and is estimated at 2.6 acres of water surface area. In May 2009, the Pond A-5 water surface elevation was measured at 21.7 feet below freeboard (447.3 feet above msl). Measured TDS values for Pond A-5 during the period 1995 through mid-2009 have ranged between 7,580 to 39,000 mg/L, with concentrations generally increasing through time (Figure 4-7).

4.3.2.5 Pond 18

Pond 18 is a surface impoundment currently used to store treated extracted liquids from the on-Site PSCT groundwater treatment facility. Pond 18 is located in the southern area of the Site just north of the RCF Road. The capacity of the Pond 18 is approximately 5 million gallons. At full capacity the elevation is approximately 472 feet above msl, and is estimated at 1.6 acres of water surface area. In May 2009, the Pond 18 water surface elevation was measured at 18.7 feet below freeboard (453.3 feet above msl). Measured TDS values for Pond 18 during the

period 1995 through mid-2009 have ranged between 7,200 to 40,000 mg/L with concentrations generally increasing through time (Figure 4-7).

4.3.2.6 Historical Pond Levels, TDS Concentrations, and Management

Casmalia Resources created the largest two stormwater ponds (RCF and A-Series) from combining several former surface impoundments. Figure 2-10 shows the Site in 1988 during surface impoundment closure activities that involved removal of pond subgrade material for remediation. The numerous impoundments were relatively dry at this time. After Casmalia Resources finished remediation activities in the late 1980s, stormwater runoff and extracted subsurface liquids from the PCTs filled the five current ponds through the early 1990s. EPA released stormwater in 1995 from the RCF and S-Series Pond to Casmalia Creek because the ponds were full and in danger of overtopping. After 1995, the ponds filled again rapidly when 32.65 inches of rain fell during the 1997/98 El Nino winter (Figure 4-7, Table 4-2).

The CSC implemented a pond water management program following the 1997/88 El Nino winter to reduce pond levels. The CSC removed pond water through a combination of spray irrigation, spray misting, and truck road dust control watering from 1998 through 2006. The CSC removed and used additional pond water for P/S Landfill cap construction in 1999 and EE/CA Area cap construction (Metals, Caustics/Cyanide, and Acids landfills) in 2001 and 2002. Together with natural evaporation, these actions progressively reduced the total pond water volume from over 150 million gallons at the end of the 1997/98 El Nino winter to less than 50 million gallons in 2005. The total volume increased moderately when 22.64 inches of rain fell during the 2004/05 El Nino winter (Figure 4-7, Table 4-2).

The CSC constructed a small unlined collection (retaining) basin in 2003 in the Central Drainage Area that collects clean stormwater runoff from the P/S Landfill and EE/CA caps (Figure 2-3). The CSC initially discharged clean stormwater from the landfill caps off-Site to the B-Drainage in spring 2006 to test the system and began routine off-Site discharge during the 2008/09 winter under a General NPDES permit. The total pond water volume has steadily decreased since the 2004/05 El Nino winter, in part due to this off-Site discharge to the B Drainage (Figure 4-7).

The TDS of the five on-Site ponds decreased during the 1997/98 El Nino winter through dilution of low TDS stormwater runoff. The TDS of the ponds has steadily increased since the 1997/98 winter through evaporation (Figure 4-7). Annually, the TDS decreases in the winter and spring from stormwater runoff dilution and then increases in the summer and fall due to evaporation. As of October 2009, the TDS concentrations in Pond A-5, A-Series Pond, RCF, and Pond 13 was 43,000, 36,000, 34,000, and 40,000 mg/L, respectively (Pond 18 was not sampled).

4.3.3 Off-Site Surface Water Drainages

Surface water runoff from those areas directly surrounding the Site flows into one of four surface drainages identified as the North Drainage, the A-Drainage, the B-Drainage, and the C-Drainage (Figure 2-1).

The A-Drainage area historically and presently flows toward the east-southeast from the southeast corner of the Site, conveying surface runoff to a man-made drainage swale that supports flow only in response to rainfall events. Runoff through the A-Drainage ultimately flows into Shuman Creek and the Pacific Ocean.

The B-Drainage is a shallow topographic depression trending to the south from Pond 13. The B-Drainage is an ephemeral feature that conveys runoff only in response to rainfall events. The drainage extends approximately one-half mile to the south of the Site where it joins Casmalia Creek, a perennial stream that flows southeasterly through the C-Drainage (see below). The B-Drainage is bounded to the east and west by small hills that direct surface water and groundwater into it, and was the historical outlet for surface water flowing through the Central Drainage Area prior to the modifications made during Site development activities (see Section 4.3.1.2). The B-Drainage naturally drains runoff that falls outside the southern Site boundary; however, in 2008 a wetland area was constructed within the upper reaches of this drainage to receive periodic runoff from the capped landfills area that is temporarily impounded within the Central Drainage Area collection basin and transferred to the head of the B-Drainage via pipeline. The floor of this drainage is filled with loose alluvial deposits consisting of weathered claystone.

The C-Drainage consists of Casmalia Creek, a perennial stream that drains the watershed located west and northwest of the Site. Casmalia Creek flows to the southeast and eventually joins Shuman Creek approximately 1.8 miles south of the Site. Schuman Creek, in turn, flows westerly toward the Pacific Ocean. The C-Drainage bounds the southwest corner of the Site and historically, and presently, drains surface water that primarily falls outside the western Site boundary. This drainage is characterized by a thin alluvial veneer overlying weathered claystone.

The North Drainage is located directly north and upgradient of the Site boundary, and conveys surface runoff in a southeasterly direction from the watershed lying north of the Site toward Shuman Creek, which ultimately drains into the Pacific Ocean. Based on observations made by CSC Site personnel, the North Drainage area is an ephemeral drainage that conveys surface runoff only in response to rainfall events.

4.4 Geologic Setting

Casmalia Resources investigated the regional and local geology through numerous Site-specific field investigations. Casmalia Resources drilled several hundred borings, installed several hundred groundwater monitored wells and piezometers, and performed other Site investigation work to assess the Site's geology, hydrogeology, and nature and extent of contamination. The results of this work is documented in several reports, including the Hydrogeologic Site Characterization and Evaluation Report (HSCER – Woodward-Clyde Consultants, 1988a), Geologic Siting Criteria Assessment (GSCA – Woodward-Clyde Consultants, 1988b), and Hydrogeologic Site Investigation Report (HSIR – Woodward-Clyde Consultants and Canonie Environmental, 1989). The geologic setting below is from information in these reports.

The geological setting of the Casmalia Landfill facility is relatively homogenous; that is, the landfill sits atop an uplifted block of Neogene shallow marine sediments, the Todos Santos Member of the Sisquoc Formation. The Todos Santos Member of the Sisquoc Formation consists predominantly of fine grained silts and clays which have subsequently harden to claystone. As such, the pristine (unweathered) claystone forms "basement" material. The Site and surrounding hills provided a source of alluvium eroded into local canyons and lowlands, and fill material for landfill activity. In situ weathering (soil development) of the Todos Santos Member has resulted in the formation of a "weathering rind" that covers much of the Site claystone.

A detailed geologic investigation of the facility and surrounding area was performed as a part of the Geologic Siting Criteria Assessment (GSCA) requirements for a Class I facility, Casmalia Resources conducted (Woodward-Clyde Consultants, 1988b). The GSCA focused on assessment of Site seismicity and the potential for rapid geologic change, and included detailed studies, exploratory trenching investigations, and mapping of faults and lineaments within 3,000 feet of the facility (Section 3.0, Figure 3-1, Woodward-Clyde Consultants, 1988b). These studies identified regional and local geologic structures faults and lineaments.

Additional detailed Site investigations have involved characterization of physical properties of geological materials including fractures, and geochemistry were performed as a part of the HSCER (Section 5.3, Pages 5-27 through 5-43, and Section 8.0, Pages 8-1 through 8-24, – Woodward-Clyde Consultants, 1988a). Geologic mapping of Site alluvium fill and siltstone and geologic and geophysical borehole logging was conducted. The fracture investigations included surface mapping and borehole logging of fracture occurrence, density, and aperture characteristics.

A detailed discussion of the pertinent results of regional and local geological investigations performed by various investigators (Dibblee, 1950 and 1989; Woodring and Bramlette, 1950; Woodward-Clyde Consultants, 1988a and 1988b; Woodward-Clyde Consultants and Canonie Environmental, 1989; McClelland Consultants, 1989, Harding Lawson Associates, 2000 and Harding ESE, 2001h) was presented in the RI/FS Work Plan. The reader is referred to the RI/FS Work Plan or the original source documents for details of these earlier geologic investigations. Salient findings of these past investigations are briefly summarized below.

4.4.1 Regional Geology

The Site is located on a topographic (structural) ridge within the Santa Maria Basin. The Santa Maria Basin is a triangular-shaped synclinal basin, bounded on the south by the Santa Ynez Mountains and on the east and northeast by the San Rafael Mountains. The shape of the landforms in the area has been governed by accretion of the California landmass and Neogene tectonic activities associated with the San Andreas transform fault system. The base of the Santa Maria Basin is formed by the Upper Jurassic Franciscan Formation. Up to 27,000 feet of Tertiary-age marine and non-marine sediments are present in the Santa Maria Basin. Geologic formations present within the Santa Maria Basin, include the Knoxville, Lospe, Point Sal, Monterey, and Sisquoc. The surface expression of the regional geology is presented in Figure 4-8 (portion of regional geologic map, based on USGS Orcutt and Casmalia quadrangles – Dibblee, 1989). Detailed geologic conditions within the Site and directly surrounding areas detailed presented in Figure 4-9 (Site geologic map – Woodward Clyde Consultants, 1988a). Note Quaternary Terrace Deposits are indicated atop the two hills that lie immediately south of the Site; these Terrace deposits likely represents alluvium deposited (and subsequently eroded) during an earlier phase of (Casmalia Hill) uplift and not related to current surficial alluvium that occupies canyon gullies and the valley floor. The regional stratigraphy and structural relationships are depicted in Figures 4-10 and 4-11.

The Monterey and Sisquoc Formations comprise the upper 6,300 feet of sediments in the Santa Maria Basin. At the Site, the upper Miocene Monterey Formation is present at approximately 1,300 feet beneath ground surface (Section 4.2, Page 4-2, Woodward-Clyde Consultants, 1988a and 1988b). The Monterey Formation is approximately 5,000 feet thick and is composed of interbeds of porcelaneous shale, chert, limestone, diatomaceous shale, and diatomite. Oil and gas are locally produced from fractured sections of the Monterey Formation including areas lying to the east and north of the Site.

Conformably overlying the Monterey Formation is the upper Miocene to middle Pliocene Sisquoc Formation. The Sisquoc is formally divided into two members: the lower Todos Santos Claystone Member, and the upper Tinaquaic Sandstone Member (Woodring and Bramlette, 1950). On-Site, the Todos Santos Claystone Member is present at the surface and extends down to approximately 1,300 feet. The Todos Santos Claystone Member is comprised of porcellaneous shale, platy shale, claystone, diatomite, and siltstone. The upper Tinaquaic Sandstone Member of the Sisquoc Formation is not present at the Site.

4.4.2 Local Geology

The following sections summarize the identified surface and near-surface geologic units present at the Site. Site surface geologic conditions are depicted on the Site geologic map provided in Figure 4-9. This map is taken directly from the HSCER (Figure 5-1-1; Woodward-Clyde Consultants, 1988a) and is based on Site conditions in the mid-to-late 1980s, before Casmalia Resources began pond closure remediation activities. Although Casmalia Resources removed a large volume of former pond subgrade material and placed these materials into the current landfills in the late 1980s, the overall interpretation of the surface geologic conditions depicted in Figure 4-9 is applicable to current conditions.

4.4.2.1 Alluvium, Colluvium, and Fill

Typical of California hillside geology, the Site's hillside has undergone weathering and erosion to provide colluvium and alluvium sediment that was deposited within the hillside canyons and valley floor. Much of the original colluvium and alluvium once present at the Site has subsequently been redistributed during Site development and operational activities. Colluvium is present as thin layers in undisturbed areas and has been documented on the hillsides surrounding the Site, ranging in thickness from 5 to 10 feet with some deposits up to 20-feet thick. Discontinuous, localized deposits of alluvium have been reported at the Site. Engineered fill is present throughout the Site as dikes, berms, environmental barriers, and solid waste disposal units. Fill material was also placed in association with landfill capping activities, and as buttresses at the toe of some landfills. Fill was generally derived from excavation of on-Site soils and consists of silty clay and pebble-to-cobble size fragments of claystone and silty claystone (McClelland Consultants, 1989).

4.4.2.2 Claystone

Sediment of the Todos Santos Claystone Member of the Sisquoc Formation was original deposited in a (Miocene to Late Pliocene) marine continental margin slope environment, as indicated by diatomaceous fossil types. At the Site, the claystone has been informally divided into weathered and unweathered stratigraphic units. The differentiation between the two units is based on the presence or absence of weathering (i.e., difference in color, degree of fracturing and type of secondary mineralization).

Within the facility, the weathered claystone is exposed across 90 percent of the Site and ranges in thickness from 15 to 65 feet. The thicker sections of weathered claystone occur in areas of topographic highs, particularly in the northern portions of the Site and gradually thin to the south. The weathered claystone is yellowish-gray to pale olive to olive-gray, and ranges from massive to faintly bedded. Secondary mineralization appears most frequently as hematite staining on fracture and joint surfaces and commonly as well-developed gypsum infilling of fractures and joints (Woodward Clyde Consultants, 1988a). Primarily, the weathered claystone represents the development of a soil profile in a semi-arid environment. Surface exposure of

the Todos Santos formation has lead to dilation. Rocks undergoing dilation typically expand in the direction of pressure release (Schaetzl and Anderson, 2005). Pore spaces are noted to contain gypsum, and as such, salt and gypsum weathering, and expansion of the rock as it is wetted, heated and dried has resulted in rock disintegration.

The weathered claystone is generally pervasively fractured. While much effort has been exhausted to define fracture and jointing patterns within the weathered claystone, inherently the weathered claystone is predominantly the result of physical and diagenetic alteration of the surface exposure of the Todos Santos Claystone. As such, observed fracture patterns are surficial in nature (that is, to the depth of fresh unweathered claystone). Observed "structural trends" within the weathered claystone show wide variation; due to the processes that formed fractures within this unit, structural features within the unweathered claystone overprint the structural relationship developed due to regional tectonic influences. Notably, diagenetic alteration of the (unweathered) claystone leads to the development of secondary porosity due to alteration of primary mineral constituents, which tends to increase soil porosity; and the formation of weathering precipitates (i.e., hematite and gypsum) which results in porosity reduction.

The unweathered claystone is exposed in less than 10 percent of Site outcrop and typically lies at depths of 15 to almost 100 feet beneath the ground surface. The unweathered claystone is up to 1,300 feet thick and conformably overlies the Monterey Formation. The unweathered claystone is olive-black to gray olive-green (wet), and medium bluish-gray (dry) in color. Grain-size analysis determined that the majority (64 to 86.5 percent) of the claystone is comprised of very fine silts and clays with minor amounts of sand and silt; with pure smectite or illite/smectite being the dominant clay minerals. Due to the high silica content within the mineral grains that constituent the Todos Santos Formation, the sediment is classified as porcelaneous claystones (Woodward Clyde Consultants, 1998b). Secondary mineralization consisting of iron and manganese discoloration and gypsum infilling of fractures was observed in a small percentage of core samples. The unweathered claystone is significantly less fractured than the overlying weathered claystone.

4.4.3 Regional Structure

The Site is located on a topographic high area in the Casmalia Hills within the transition zone between the Transverse Range geomorphic province to the south and the Coast Range geomorphic province to the north and northeast. The region is characterized Neogene faulting and folding. Major folds mapped in the vicinity of the Site include the Purisima Anticline, the Santa Maria Syncline, the Pezzoni Anticline, and the Graciosa Anticline (Figure 4-10). The northeastern limb of the San Antonio Anticline has been mapped roughly parallel to the Site's southwestern boundary. The trend of the Casmalia Anticline has been mapped toward, but not necessarily through, the Site (Figure 4-10). Most folds in the region generally trend to the northwest, and some are locally exploited for oil and gas production.

Major faults mapped in the vicinity of the Site include the Lion's Head Fault, the Pezzoni Fault, the Casmalia Fault, and the postulated Orcutt Frontal Fault (Figure 4-10). The Site is located on a several-mile-wide crustal block between the Lion's Head and Orcutt Frontal faults. Maximum credible earthquake calculations for the two faults closest to the Site, the Lion's Head and Orcutt Frontal Fault, range from 6.6 to 7.1 (McClelland Consultants, 1989). Minimum recurrence intervals for the Orcutt Frontal Fault range from 200 to 2,000 years based on slip rates, and from 2,000 to 100,000 years based on lack of evidence for ground surface fault rupture (Woodward-Clyde Consultants, 1988f). Tectonic models of the area postulate the crustal block

bounded by the Lion's Head and Orcutt Frontal Faults has undergone structural deformation during the Cenozoic, but the crustal block is behaving in a rigid manner and undergoing little internal deformation (Woodward-Clyde Consultants, 1988f).

4.4.4 Site Structural Features

Geologic evaluations of the Site by Casmalia Resources and the CSC have included mapping and analysis of local structural features including bedding, faults, lineaments, and fractures. Salient information from these investigations is summarized below. Site surface geologic conditions are depicted on Figure 4-9. Casmalia Resource and the CSC obtained detailed information on subsurface bedding and fractures by careful drilling, coring, and logging of several borings across the Site. These subsurface investigations are briefly summarized below, followed by a summary of the subsurface structural features determined from these borings. This information is important to understand because structural features control groundwater flow and contaminant transport at the Site.

4.4.4.1 Subsurface Investigations to Characterize Site Structural Features

Casmalia Resources

Casmalia Resources continuously cored and logged one vertical boring (CB-4) and three inclined borings (CB-5I, CB-6I, CB-7I) in 1987, which were drilled up to a depth of approximately 225 feet bgs. The core was oriented. Logging of retrieved core included measuring fracture orientation, depths, attitude (strike and dip), widths, and infilling material type. Video logs and borehole geophysical logs were run that included natural gamma-ray and induction logs (Table E-3). Original core logs are provided in the HSCER and the CSC's Final Well Inventory Report. Figures from the HSCER of fracture frequencies and aperture widths versus depth are provided in Attachment E-7 of this RI Report.

Casmalia Resources performed a detailed geologic investigation of the facility and surrounding area as a part of the Geologic Siting Criteria Assessment (GSCA). This work included excavation, cleaning, geologic logging, and photo and videotape documentation of 6,800 feet of exploratory cuts and trenches on and adjacent (within 200') to the facility to locate and characterize bedrock faults, shears, and fractures. The trenches included two north-south side-hill cuts at RCRA Canyon totaling 900 and 1,060 feet, respectively. This shallower subsurface trenching information complements the deeper corehole information in the interpretation of subsurface conditions.

Casmalia Steering Committee

The CSC cored and logged boreholes for 16 piezometers (RGPZ series) in 2000 as part of the RGMEW. These borings were drilled up to approximately 250 feet bgs. The core was not oriented. Logging of retrieved core included measuring fracture depths, dip, and infilling material type. Downhole video logs and borehole geophysical logs were run that included gamma logs, e-logs, and acoustic logs. The core and borehole geophysical logs are provided in the *Well and Piezometer As-Built Report, Summer 2000 field Activities* (Harding ESE, 2001). Figures of fracture frequencies with depth are provided as Figures E-23 through E-26.

The CSC cored and logged coreholes RISB-1 and RISB-2, and RI monitoring wells and piezometers installed using air rotary drilling from 2004 through 2006. These borings were drilled up to approximately 250 feet bgs. The core was not oriented. Logging of retrieved core

included measuring fracture depths, dip, and infilling material type. Downhole video logs were run for most borings. Borehole televiewer logs were run for select borings (RG-11B2, RGPZ-10B2, RIPZ-10D, RIPZ-16, RIPZ-17, RISB-01, RISB-02). Gamma logs were also run on deeper boreholes. The core logs are provided in Attachment E-9. The borehole televiewer and gamma logs are provided in Attachment E-2. The CSC's borehole geophysical subcontractor (Welenco) prepared the following graphs and tables which are included in Attachment E-2 for each geophysical log:

- Dual induction gamma ray log
- Optical televiewer borehole image log and interpreted dips log
- Optical televiewer bedding and fracture data table
- Fracture analysis log and stereograms
- Dip data interpretation table and azimuth Rose diagram
- Dip data structural interpretation log, stereogram, and interpretation table

The CSC consolidated this information onto Figures E-3, E-4, and E-5. Figure E-3 presents Rose diagrams of fracture and bedding dips in each borehole. Figures E-4 and E-5 present the structural interpretation logs and fracture analysis logs in each borehole. Table 4-3 lists the fracture and bedding plane orientations (dip-azimuth and dip) measured by the optical televiewer for the unweathered claystone. Figures 4-12 and F-13 illustrate these orientations as a whole for all boreholes and by individual borehole, respectively.

The CSC prepared additional Schmidt and Rose diagrams from the bedding and fracture data for the purpose of evaluating the orientations collectively, as well as by depth relative to each of the HSUs. The bedding and structure data sets were grouped by depth below the HSU contact, at depth intervals corresponding to the depths of the MODFLOW groundwater flow model layers (i.e., 0-25 feet below HSU contact, corresponding to Model Layer 4 – see Appendix F). These additional Schmidt and Rose diagrams are shown on Figures E-6 through E-21. In order to evaluate fracture frequency, the cumulative numbers of fractures from the televiewer logs for each deep boring were plotted against depth for each borehole and are presented in Figure E-22. Similar plots of cumulative fractures versus depth for borings completed during the Summer 2000 drilling program were first presented in the RI/FS Work Plan and are republished as Figures E-23 through E-26 for reference.

The CSC completed a geologic assessment of the RCRA Canyon side hill cuts originally excavated and logged by Casmalia Resources as part of the GSCA. The assessment was performed to confirm and field verify the previous data collected by Casmalia Resources and integrate these data into the understanding of Site structural features. The results of this assessment are provided in Appendix H. This appendix also includes selected maps, cross sections, Schmidt plots of fractures and joints, and a rose diagram of fractures and joints in the unweathered claystone from the GSCA report.

4.4.4.2 Bedding

The Todos Santos Formation (unweathered claystone) is massive to faintly bedded, and is characterized by low-dipping (3 to 20 degrees) to essentially flat bedding planes with variable strike directions. In general, bedding inclinations are steepest in the southern and western areas (5 to 20 degrees) and decrease to the north (3 to 5 degrees). Regional geologic mapping depicts the San Antonio Syncline roughly paralleling the southwest boundary of the Site and the Casmalia Anticline trending northwest toward the Site (Figures 4-9 and 4-10). Bedding plane

attitudes do not support the presence of either structure in the near-surface beneath the Site; however, the structures may be relatively deep, or located adjacent to the Site. Stratigraphic correlations based on gamma ray signatures suggest that the Site is underlain by broad undulations or low-amplitude flexures with a maximum dip of 3 degrees (Section 5.3.2, Page 5-28, Figure 5.1-1, Woodward-Clyde Consultants, 1988a).

Bedding features were also measured using an optical televiewer (Appendix E) of both the Upper and Lower HSU units and identified on the basis of lamina and color changes (see Table 4-3 and Figures 4-12 and 4-13). For all televiewer boreholes, the unweathered claystone bedding dip generally ranges from 1° to 19° over and dip-azimuth from 10° to 135°. The unweathered claystone median dip and dip-azimuth for all measured bedding features was 9.2° at an azimuth of 73°. This is consistent with the orientations documented on Figure 4-8 (Dibble Geologic Map) in the vicinity of the North Ridge, Burial Trench, P/S Landfill, and Metals Landfill areas. In the western portion of the North Ridge area (Wells RGPZ-10B-2, RIPZ-10D, RIPZ-17, and RG-11B-2), bedding is characterized by an average dip of 8.6°. In boring RISB-01, on the eastern side of the North Ridge, televiewer indicates that the average dip of bedding increases to 17.4°. In the center of the Site near the Burial Trenches, wells RIPZ-15 and RIPZ-16 show that bedding angles tend to decrease to an average dip of 7.3°. In the central drainage, bedding within RISB-02 maintained an average dip of 19.4 degrees with the exception of two features at approximately 205 and 206 feet bgs. Though identified as bedding on the televiewer logs, the planes that dip 76 and 79.1 degrees to the north east, respectively, are more likely fractures. Only four bedding planes were identified in the Upper HSU all in RISB-01.

Strike of the Upper and Lower HSU low-angle beds is variable; the Upper HSU beddings exhibit with a mean dip direction to the south-southwest, while Lower HSU bedding dips predominantly to the northeast at the dip directions noted above. Within the Lower HSU, 50 percent of the bedding planes identified occurred between 0 and 75 feet below the HSU contact and 40 percent occurred between 75 and 150 feet below the HSU contact.

By the very nature of the weathered claystone matrix, groundwater flow through “bedding planes” is likely in the Upper HSU. However, groundwater flow through bedding planes in the Lower HSU is not likely; within this unit, primary bedding is described as lamina indicating primary bedding planes have not been buckled to create flowpaths. Further downhole video logging of numerous boreholes drilled by the CSC and by Casmalia Resources show that where water enters the boreholes, it is generally associated with fracturing and not stratigraphic features. Observations for boreholes drilled by the CSC are provided on geologic logs in Appendix E for the RI boreholes and in the Well Inventory Report (MACTEC, 2006) for earlier boreholes drilled by the CSC. Observations for boreholes drilled by Casmalia Resources are provided in the HSCER and HSIR (Woodward-Clyde Consultants and Canonie Environmental, 1988, 1989).

4.4.4.3 Faults

Faults and shear zones were characterized through a series of investigations including aerial reconnaissance of lineaments and ground-truthing of identified lineaments, and excavation and logging of 6,800 feet of cuts and trenches. Based on these investigations, numerous minor, discontinuous faults and shear zones have been mapped in surface exposures and excavations at the Site. Stratigraphic displacements ranging from 0.1 to 5 feet have been observed, although the faults are typically short and cannot be traced laterally for more than a few tens of feet. Evaluation of Quaternary deposits, surface geomorphic expressions, and comparison of the local fault orientations to the regional tectonic stress regime suggest that no faults within

200 feet of the Site have been active in Holocene time (Section 5.3.3, Page 5-29, Woodward-Clyde Consultants, 1988a).

4.4.4.4 Lineaments

Lineament analyses identified four major and numerous minor lineaments within the vicinity of the Site. Major lineaments include Casmalia Creek and the A-, B-, and C-Drainage Areas. No offset strata were observed in Casmalia Creek; this lineament is interpreted to be the result of differential erosion. The A-, B-, and C-Drainage lineaments, and some of the numerous small discontinuous lineaments, are similar in orientation to the trends of faults and fractures mapped at the Site. No major lineaments and no features exhibiting Holocene movement are located within a 200-foot radius of the Site (Section 5.3.3, Page 5-32, Woodward-Clyde Consultants, 1988a).

4.4.4.5 Fractures

Site-Specific Data

As summarized above, analysis of fractures and fracture patterns in the Todos Santos claystone at the Site has been conducted as a part of the current RI studies, as wells as during several prior Casmalia Resources' Site investigations. Early investigations by Woodward-Clyde Consultants and Canonie Environmental included surface mapping of outcrops in RCRA Canyon and across the Site (Figure 4-9), as well as the logging of fractures observed in core from both vertical and inclined borings (CB-4, CB-6I, CB-7I). The CSC obtained additional fracture data from core collected during borings and well installations and borehole geophysics performed as components of the RGMEW and the RI. Further, the CSC performed a literature and field review of the RCRA Canyon outcrop assessment performed by Woodward-Clyde Consultants, as a specific task of the RI and is documented in Appendix H.

During the early studies, surface mapping was used to characterize fractures in the weathered claystone. Core from borings was used to characterize fractures in the unweathered claystone, as surface exposures of the unit were not available. Fracture apertures were measured in core samples using a feeler gauge. Disturbed core may have biased the measured apertures, and in-situ aperture sizes are likely smaller than those measured ex situ due to the release of compressive stress and disturbance during drilling and measurement. Fracture orientations were plotted on stereographic projections and Rose diagrams (HSCER Figures 5.3-1 and 5.3-2 [weathered] and 5.3-3 and 5.3-4 [unweathered]) to evaluate trend frequencies and to compare trends in the weathered and unweathered claystone. The cumulative number of fractures versus depth for the inclined borings was also plotted and presented as HSCER Figure 5.3-8. From that data it was concluded (Woodward-Clyde Consultants, 1988a):

- The weathered claystone is more pervasively fractured than the unweathered claystone;
- The predominant fractures in the weathered claystone have high angle dips (greater than 60 degrees), the strikes of which most frequently trend east-northeast and west-northwest;
- Within the unweathered claystone, there is a wide range of fracture orientation and no discernible predominant orientation of fractures;
- Some common fracture orientations occur in both the weathered and unweathered claystone, typically northeast- to east-northeast striking near vertical fractures;

- The density and degree of fracturing within the unweathered claystone varies between both distant and adjacent sampling locations;
- The frequency of occurrence of fractures with apertures greater than 0.1 mm decreases at depths 100 feet below the weathered/unweathered claystone contact; and
- Clay constitutes the dominant mineral type of fracture infilling at depths 40 feet below the weathered/unweathered claystone contact.
- Video logging of boreholes show that where water enters the borehole, it is generally associated with fracturing and not stratigraphic features. Observations for boreholes drilled by the CSC are provided on geologic logs in Appendix E for the RI boreholes and in the Well Inventory Report (MACTEC, 2006) for earlier boreholes drilled by the CSC. Observations for boreholes drilled by Casmalia Resources are provided in the HSCER and HSIR and HSCER). (Woodward-Clyde Consultants and Canonie Environmental, 1988, 1989)

Observations of fracture density and size from these earlier studies were generally confirmed during coring activities completed in 2000 (Harding ESE, 2001h). Plots of the cumulative number fractures against depth within borings completed during the 2000 drilling program were first presented in the RI/FS Work Plan and are republished in Appendix E as Figures E-23 through E-26. The total depths investigated vary by boring, as do the explored depths within individual HSUs, which makes direct comparisons fracture density versus depth difficult. However, the figures clearly illustrate that the degree and density of fracturing varies widely between locations. The figures also illustrate that while the frequency of fractures decreases with depth in some borings, while other borings contain numerous fractures to the total depth explored (250 feet bgs maximum).

During the Phase I and Phase II RI drilling investigations from 2004 to 2006, planar attitudes of bedding and fracture features noted in the core samples, geophysical logs, and optical televiewer images were analyzed to determine their orientations. Initial structural analyses of bedding and fractures were performed at eight locations using the geophysical logs and televiewer surveys. Fracture and bedding orientations were plotted on Schmidt lower hemisphere stereographic projections and Rose diagrams to evaluate trends. All fractures and dip orientations identified on the televiewer logs are summarized in Appendix E of this report, as summarized above. After review of the initial analyses, additional Schmidt and Rose diagrams were created from the bedding and fracture data for the purpose of evaluating the orientations collectively, as well as by depth relative to the HSUs. The bedding and structure data sets were also grouped by depth below the HSU contact. To evaluate fracture frequency, the cumulative numbers of fractures from the televiewer logs for each deep boring were plotted against depth for each borehole. The results of the RI structural analysis are in agreement with those of previous studies. The results show the following:

- Significantly more fractures were observed in the weathered claystone, than in the unweathered claystone. Plots of the cumulative number fractures against depth within borings completed during the 2004 to 2006 RI drilling program are consistent with the findings of the 1987 (Casmalia Resources) and 2000 (CSC) drilling programs. The degree and density of fracturing varies widely between locations.
- For the Lower HSU, while the frequency of fractures decreased with depth in some borings, other borings contain fractures to the total depth explored (250 feet bgs maximum depth drilled).
- The continuity between fractures may limit the extent of potential fluid pathways on a Site-wide scale while the continuity on a local scale is sufficient to transmit groundwater,

especially where higher groundwater gradients exist to drive groundwater through the generally lower permeability fractures in the Lower HSU. These areas of higher gradients occur primarily in the upland areas, such between the North Ridge and the PSCT.

Review of the stereographic projections indicates fractures generally tend to be either sub vertical or sub horizontal (though some or many of the features identified as subhorizontal fractures are likely bedding planes). Within the unweathered claystone, the subvertical fractures tend to strike northeast and dip to the northwest and southeast, but with some variability. The results of the additional structural analysis completed during RI borehole investigations are detailed in Appendix E and illustrated on Figures E-53 through E-73.

As noted above, the CSC conducted a review of geologic conditions in the RCRA Canyon Area as part of the RI field program. Areas of exposed bedrock were examined and geologic data collected as part of this effort. Observations and field data collected during this assessment indicate that the geologic units and nature and orientation of structural features exposed in the RCRA Canyon are consistent with those reported during prior studies completed at the Site. The findings of RCRA Canyon Area geologic reconnaissance are detailed in Appendix H of this report.

As noted above, the CSC performed optical televiewer video surveys to assess the dip and dip-direction of fractures and bedding planes at the Site. Optical logging was performed in 8 boreholes (RGPZ-10B-2, RIPZ-10D, RG-11B2, RIPZ-15, RIPZ-16, RIPZ-17, RI-SB-1, and RI-SB-2); views of the Upper HSU were performed in boreholes RGPZ-10B-2, RIPZ-10D, RG-11B2, RIPZ-17, and RI-SB-1, the lower HSU was viewed in all boreholes. The results of the televiewer surveys are presented in Table E-9. Table 4-3 lists the fracture and bedding plane orientations (dip-azimuth and dip) measured by the optical televiewer for the unweathered claystone. Figures 4-12 and 4-13 illustrate these orientations as a whole for all boreholes and by individual borehole, respectively.

Fractures within the Upper HSU (weathered claystone) display highly variable dip within boreholes, with the dip generally less than 30° (observed dips within boreholes showing higher angles at depth e.g., RG-11B2). The dip-direction of Upper HSU fractures is also highly variable. Within this unit, no “bedding planes” were observed indicating that structure features observed within the Upper HSU is predominantly the result of weathering effects which has overprinted any pre-existing structural grain.

Within the lower HSU (unweathered claystone), fractures are observed to display primarily relatively steep dips (predominantly between 50° and 90°) with a significant population of fractures also displaying less steep dips (predominantly between 0° and 20°). Fractures dips between these two populations also occur (between 20° and 50°). Dip directions are also variable, but predominant dip-directions occur to the northwest, northeast, and southeast for the more steeply dipping fractures (greater than 20°) and occur to the northeast and east for the less steeply dipping fractures(less than 20°). The dip direction of the more steeply dipping fractures is variable and not uniformly consistent with the regional strike indicating that the steeper fractures observed at the Site are secondary features. The dip direction of the less steep fractures observed in several boreholes is more consistent with the bedding dip directions. The shallow dip directions observed in borehole RI-SB-2 (at depth between ~60 to 150 ft bgs) are towards the east-south east and these shallower-dipping fractures may be indicative of a primary fracture, and was the interval in which DNAPL was observed with the

borehole. As noted above, bedding planes were predominantly observed feature within the lower HSU, with bedding planes generally observed at less than 20°, which consistent with surface observations.

With regard to fractures acting as DNAPL pathways within the Lower HSU, the fractures predominantly display steep angles to the horizontal (greater than 50°) but also display a population of less steep angles (less than 20°). The greater frequency of more steeply dipping fractures would favor DNAPL flow to greater depth; however the presence of the less steeply dipping fractures makes horizontal flow a potentially significant component of flow. On a Site-wide basis, this general distribution of fracture orientations makes the likelihood relatively low that DNAPL will be transmitted to the surface because DNAPL will move downward into the more steeply dipping fractures as it migrates laterally along the more shallow dipping fractures. Given the thickness of the unweathered claystone (> 1,000 feet), generally small aperture of fractures and the lack of interconnectivity between fractures on a Site-wide scale, significant fluid movement of DNAPL to shallower intervals above the unweathered claystone at any appreciable rates is unlikely. Within the Lower HSU, fractures are observed to decrease with depth in some boreholes while they are present throughout the depth of other boreholes. Therefore, the depth to which DNAPL migration occurs is not known. At depth, it is likely that fractures ultimately lead to dead-ends. As such, attempts to delineate DNAPL within such an environment would prove futile and counter-productive, as the installation of boreholes may lead to creation of additional flowpaths.

Regional Data

In an independent study entitled Relationships Among In-Situ Stress, Fractures and Faults, and Fluid Flow: Monterey Formation, Santa Maria Basin, California, Finkbeiner et al. (1997) reviewed the televiewer logs of four oil wells in the vicinity of the Site. The study, though focused on the oil-rich Monterey Formation, included the Sisquoc Formation, of which the Todos Santos Sandstone is a member. “Well D” in the Orcutt field is of particular interest due to its proximity, east of the Site. By analyzing stress induced well-bore “breakout,” the ambient stress field at each well was determined in order to compare the mean horizontal stress direction against fracture orientation. It was noted that the apparent apertures of the fractures observed in the televiewer log had been amplified by spalling as a result of drilling; a caveat worth noting as regards the Site-specific investigations. It is not known whether “spalling” effects affected the CSC’s data collection program.

In contrast to relatively uniform horizontal stress directions, fracture orientation, dip, and frequency were determined to vary between locations and within each well. Fractures within the Sisquoc in Well D were characterized as dipping between 30 and 60 degrees in the southeasterly direction. Differential fracturing within a single well was determined to be lithology dependant, as soft beds such as mudstones (claystones) are characterized by widely spaced shear fractures, whereas harder, less ductile beds such as cherts and dolomites are characterized by an abundance of joints. The lack of evidence for the systematic development of stress-induced fracture sets within the relatively ductile claystone of the Monterey and Sisquoc Formations in the region suggest that regional wide-scale interconnectivity of fractures (within the unweathered claystone) at the Site may be unlikely, given the observed variation in on-Site fracture orientation.

Summary

Although regional data for the Sisquoc Formations suggest that regional wide-scale interconnectivity of fractures within the unweathered claystone at the Site may be unlikely, the interconnectivity of fractures on a Site-wide and more local scale is uncertain. The degree of fracture interconnectivity on a Site-specific scale will govern to a large degree the transport of both dissolved-phase and dense nonaqueous phase (DNAPL) liquids away from contaminant sources areas as demonstrated by the nature and extent of contamination identified at the Site. However, the movement of dissolved-phase and DNAPL beyond the Site boundaries now appears limited due to the operation of control features. The primary transport mechanism into and through the Lower HSU is fracture flow.

A total of 408 boreholes have tested over 25,000 feet of Lower HSU material; correlation of fractures between adjacent boreholes is difficult, indicating that there is uncertainty in assessing the interconnectivity of fractures throughout the Site. Although the likelihood of an interconnected fracture system being present within the Lower HSU on a Site-wide scale, the interconnectivity of fractures on a local scale is more likely. One example occurs in the Central Drainage Area where DNAPL transport along fractures in indicated between either the P/S Landfill or Sump B-9 southward to boreholes RGPZ-6C/6D and RGPZ-7C/7D. Within this portion of the Site, both dissolved-phase and DNAPL groundwater contamination occurs more than 100-feet below the contact between the weathered claystone (Upper HSU) and unweathered claystone (Lower HSU). Another example is the presence of dissolved-phase VOCs detected in RIPZ-16 in the Burial Trench Area. RIPZ-16 is screened approximately 100 feet below this contact. The primary transport mechanism for contaminants to reach these wells in the Central Drainage Area and Burial Trench Area is through interconnected fractures within the Lower HSU.

The depth to which fracture flow may occur is difficult to explore due to the high angle dip associated with fractures; the one example where fracture flow is noted (above), the fractures are measured to have at relatively shallow dip at approximately 7 to 24 degrees. Even though Site topography is steep, fractures containing NAPL have not been observed to daylight, and several historic surface seeps have stop flowing since capping and flow control measures have been instituted at the Site.

4.5 Hydrogeology

4.5.1 Regional and Site Hydrogeologic Setting

The Site is located in the Casmalia Hills, a topographic high separating two groundwater basins. The Santa Maria Valley groundwater basin occurs to the north and east, and the San Antonio Valley Creek groundwater basin lies to the south (Figure 4-14). The Site lies between these two basins but drains to the Shuman Creek watershed, and is formally associated with the San Antonio hydrologic unit.

The southern boundary of the Santa Maria Valley groundwater basin lies approximately 2.5 miles north of the Site. Consolidated non-water-bearing Tertiary rocks form the boundaries of the basin (Worts, 1951), which isolate the basin from the Casmalia Hills. Groundwater flow in the Santa Maria Valley basin follows the surface topography. At the southern boundary of the basin near the Casmalia Hills, groundwater flow is to the north away from the Site, and then westward to the Pacific Ocean.

The northern boundary of the Site is approximately 2.5 miles from San Antonio Valley Creek groundwater basin. This groundwater basin also has consolidated non-water-bearing Tertiary rocks that form its boundaries; the groundwater flow follows surface topography. At the northern boundary of the basin, groundwater flows southward away from the Casmalia Hills, then westward to the Pacific Ocean.

The Shuman Creek watershed drains the Casmalia Hills in the vicinity of the Site and mostly is isolated by hill top ridges from the adjacent Santa Maria Valley and the San Antonio Valley Creek groundwater basins. The Site is underlain by the Tertiary-age Todos Santos Member of the Sisquoc Formation. These Tertiary marine rocks are generally considered non-water-bearing compared to the unconsolidated sediments found within the nearby alluvial valleys and basins. However, minor amounts of water are contained in the upper weathered portion of the Todos Santos and within joints and fractures in the lower unweathered Todos Santos. However, as noted at the Site during RGMEW events, well recovery following purging of wells screened within the unweathered Todos Santos claystone take several months or longer to occur, indicating that the unweathered claystone has a very low permeability. Groundwater flow beneath the Site generally follows topography; groundwater flows south off-Site, then west via Shuman Creek towards the Pacific Ocean.

4.5.1.1 Water Classification

The Central Coast Regional Water Quality Control Board (RWQCB) has identified several beneficial uses for the surface waters (and therefore, associated groundwater) of the Shuman and Casmalia Creek watersheds in the San Antonio hydrologic unit. The beneficial uses include agricultural, municipal, and recreational use, as well as supporting various fresh, warm water wildlife habitats (RWQCB, 1994).

4.5.1.2 Inventory of Water Wells within a 3-mile Radius

The most current well inventory study was conducted in 2006 as part of the Remedial Investigation, and identified 38 water wells within a 3-mile radius of the Site (Appendix N, Figure N-1). Based on well permits from 1926 to present, and contact with current property owners, the following data was derived for well status and usage. Agricultural and irrigation uses predominate (21 wells), followed by domestic (3 wells); the remaining 14 wells include two industrial wells, two test wells, and ten wells of unknown use and status. A total of 34 owners were contacted during the 2006 well inventory, confirming 13 properties with no wells, 14 properties with wells, and combined 34 existing wells. URS has received no owner conformation regarding the existence of the remaining four wells; however, permit records indicated that two of these wells were abandoned. The methodology and findings of the 2006 well inventory survey are detailed in Appendix N of this report.

4.5.2 Site Hydrogeologic Physical Characteristics

Surface and subsurface Site physical hydrogeologic characteristics influence groundwater flow. In addition to natural physical features, physical features constructed as part of historical waste disposal and remediation activities by Casmalia Resource and more recent remediation activities performed by the CSC also influence groundwater flow. The hydrogeologic characteristics of both the natural and constructed conditions are evaluated below within the geological framework presented above.

Casmalia Resources and the CSC investigated the Site hydrogeologic conditions through numerous Site-specific field investigations. Casmalia Resources drilled several hundred borings, installed several hundred groundwater monitored wells and piezometers, and performed other Site investigation work to assess the Site's geology, hydrogeology, and nature and extent of contamination. The results of this work by Casmalia Resources are presented in many previous reports, including the HAR, HSCER and HSIR. The CSC supplemented this historical work with additional Site-specific work performed as part of the RGMEW and RI. The CSC is currently performing semiannual, monthly, and continuous monitoring of selected wells as part of the RGMEW. The CSC's drilling, monitoring well installation, piezometer installation, and hydropunch installation methodology, data and investigation results for the RI work are provided in Appendix E. This appendix includes a figure that shows the contact elevation between the Upper HSU and Lower HSU and several figures that illustrate structural geologic information.

Figure 4-15 illustrates the location of all current Site wells and piezometers. The wells and piezometers shown on Figure 4-15 include those still in existence installed by Casmalia Resources in the 1970s and 1980s, those installed by the CSC from 1998 through 2008 as part of the RGMEW, and those installed by the CSC from 2004 through 2007 as part of the RI. Many of the groundwater monitoring wells, piezometers, and other borings and casings installed by Casmalia Resources in the 1970s and 1980s are no longer in existence and are not shown on Figure 4-15. Casmalia Resources destroyed many of these older wells during remediation activities performed in the late 1980s. The wells and piezometers installed by Casmalia Resources shown in figures contained within the HSCER and HSIR. As described in Section 2.2.6.3, the CSC's Final Well Inventory Report (MACTEC, 2006) is a stand-alone report that documents the condition and construction of the current monitoring well network, except the newer RI wells and piezometers. Appendix E provides as-built information for the newer RI wells and piezometers and table that summarizes the construction details of the current monitoring well network.

4.5.2.1 Vadose Zone

The vadose zone in the vicinity of the Site occurs in both the weathered and unweathered claystone, and includes local alluvium, colluvium, and fill deposits. The vadose zone is laterally extensive with maximum thickness of greater than 150 feet in the north and northeastern portions of the Site. The thickness decreases to less than 30 feet in the south and in West Canyon.

Infiltration and flow characteristics of the vadose zone were investigated in the field at two locations at the Site (Woodward-Clyde Consultants and Canonie Environmental, 1989). The purpose of the study was to evaluate the hydraulic conductivity and characteristics of groundwater flow, and to assess methods to monitor vadose zone moisture. The study used two ponded plots: one located in the weathered claystone, and the other located in the transition into the unweathered claystone.

The study reported that water, when ponded, will saturate and flow along the fractures beneath the test plots within the vadose zone in the weathered claystone. The infiltration rate was 5.4×10^{-5} centimeters per second (cm/sec), approximating the effective saturated hydraulic conductivity. The infiltration rate was approximated at 3.6×10^{-5} cm/sec for the transition to the unweathered zone. Dye tracer introduced to both test plot ponds indicated some dispersion into the claystone matrix. However, the fractures appeared to conduct the bulk of the water at both plots. At the unweathered claystone plot, moisture penetrated the matrix approximately 7.6 cm

after 162 days of ponding conditions. These data were used to estimate a saturated vertical hydraulic conductivity for the matrix of 1.2×10^{-9} cm/sec.

The distribution of moisture was measured at the Site in 1988 to assess conditions beneath the surface impoundments (Figure 4-6 in Woodward-Clyde Consultants and Canonie Environmental, 1989). Moisture profiles were developed from samples collected at 5-foot vertical intervals. Two general trends were noted:

- The fill material moisture content ranged from 35 to 50 percent in the southern portion of the Site. The high moisture content demonstrates the higher water retention capacities of the fill compared to the underlying claystone, and the influence of near-surface infiltration and pond seepage; and
- The weathered claystone moisture contents ranged from approximately 30 to 40 percent; and, based on water level measurements, increased near the contact with the unweathered claystone.

4.5.2.2 Site Hydrostratigraphic Units

The Todos Santos Member of the Sisquoc Formation (Todos Santos) is laterally and vertically extensive across the Site. As described in Section 4.4.2.2, the near surface portion of the unit is extensively weathered. The near surface portion of this unit is observed to have a distinctly different hydrologic and chemical character (primarily from the differing types of materials found within fractures) as compared to the deeper unweathered unit. The HSCER Figure 5.3.11, Fracture Filling Type Versus Depth at Core Boring Locations, indicates the following:

- Iron, Manganese, and Gypsum dominates fracture filling from ground surface to approximately 50 feet bgs (approximately coincident with the weathered/unweathered claystone contact); and
- Clay dominates fracture filling below approximately 50 feet bgs (approximately coincident with the weathered/unweathered claystone contact).

Based on the degree of weathering, two hydrostratigraphic units (HSUs), an Upper and Lower HSUs have been informally defined for the Site. The Upper HSU consists of the weathered and transition zone claystone; the Lower HSU consists of the unweathered claystone. For a more detailed description of the Site Stratigraphic Characteristics, refer to Section 5.2 of the HSCER.

Overlying the weathered claystone is discontinuous surficial clayey soils, colluvium, alluvium, and fill. These materials are hydrogeologically distinct from the claystone and are not included in the Upper HSU as these surficial fill materials are discontinuous across the Site.

Previous reports suggested perched water may exist in the vadose zone. Perched water is associated with hydraulic conductivity differences at contacts between fill/Upper HSU, Upper HSU/Lower HSU, and geologic features such as fractures and bedding planes. Perched water was laterally discontinuous over distances of several feet to several tens of feet and was vertically discontinuous over distances of less than an inch to several feet. Perched water was identified in the northern portion of the Site, generally along the northeast ridge top within the weathered bedrock zone.

In RCRA Canyon, local seeps occur. This moisture is associated with local geological features that appear to be above the water table (Figure 4-16). During the wet season, however, the

seeps appear to correspond with the water table based on water-level measurements collected at Well SW-46.

4.5.2.2.1 Surficial Material

Surficial deposits on-Site include clayey soils, colluvium, alluvium, and artificial fill ranging from a few feet to up to 50 feet thick. These near-surface deposits have been reworked over a majority of the Site. The alluvium generally consists of silty clay, and is confined to drainages, where it has been observed on historical photographs. Fill consists of predominantly disturbed claystone with varying amounts of admixed alluvium. The thickest deposits are found in the central portion of the Site where extensive excavation and backfilling occurred.

The surficial deposits are in hydraulic communication with the underlying weathered claystone. Based on aquifer testing, these deposits are more permeable than the claystone, with surficial deposit hydraulic conductivities that range from 3.3×10^{-3} to 8.9×10^{-4} cm/s (Section 7.2, Page 7-7, Woodward-Clyde Consultants 1988a). Because these deposits are generally unsaturated, they are of lesser importance to the Site-wide groundwater flow. However, due to their higher conductivities, when saturated, they could provide important potential contaminant pathways.

4.5.2.2.2 Upper Hydrostratigraphic Unit

The Upper HSU consists of the weathered and highly fractured claystone, as described in Section 4.4.2.2. The thin, approximately 2- to 5-foot transition zone between the weathered and unweathered claystone is included in the Upper HSU. The Upper HSU is found beneath 90 percent of the Site and ranges in thickness from approximately 30 to 60 feet. The Upper HSU is generally thicker in the higher topographic areas, although the unit is mostly to completely unsaturated in some of the topographically higher areas of the Site. The Upper HSU is poorly transmissive and the HSIR cites a geometric mean hydraulic conductivity of 6.8×10^{-5} cm/sec. The hydraulic properties of the Upper HSU are further discussed below.

4.5.2.2.3 Lower Hydrostratigraphic Unit

The Lower HSU consists of the unweathered claystone at the Site. The top of the unit generally follows the surface topography. The unit is estimated to be approximately 900 to 1,300 feet thick and is underlain by Monterey shale. The Lower HSU has a much lower fracture density compared to that of the Upper HSU, as discussed in Section 4.4.2.2. Although groundwater flow occurs through fractures, most groundwater in this unit is in the matrix porosity. The Lower HSU is expected to approximate a porous medium on a large scale (hundreds of feet or more). This unit is less transmissive than the Upper HSU, with a geometric mean hydraulic conductivity of 1.3×10^{-6} cm/sec (Section 4.2.2, Page 4-7, Woodward-Clyde Consultants and Canonie Environmental, 1989). The hydraulic properties of the Lower HSU are further discussed below.

4.5.2.2.4 Site-wide Upper HSU/Lower HSU Contact Elevations and Lithology

The CSC refined the interpretation of the elevation of the structural contact surface separating the Upper and Lower HSUs based on information gained from the RI well and piezometer borehole data (Appendix E) along with CPT data obtained during the confirmation soil boring and NAPL investigation tasks (Appendices K and M). Figure E-2 presents the CSC's current interpretation of the UHSU/LHSU contact elevation.

Lithology confirmed during drilling, coring, and borehole geophysics performed during the RI includes the following:

- Localized brown and gray fill and alluvium, consisting of clayey gravel, clayey and silty sand, sandy clay, and lean clay
- Shallower yellowish to grayish brown and olive brown weathered claystone
- Deeper dark gray unweathered claystone.

The distinction between the weathered (Upper HSU) and unweathered claystone (Lower HSU) is apparent with respect to color, presence and concentration of iron oxides, claystone density and degree of consolidation, and degree of fracturing. Typically, a 1 to 4-foot transition zone is noted between the weathered mudstone and the underlying unweathered mudstone, although transition zone thickness can range up to 13 feet as observed in boring RISB-01. Often, an intermediate color charge (from more yellowish brown to darker olive or grayish brown) is observed in this transition zone. These transitions are apparent in both the optical televiewer logs and core samples (Attachments E2 and E3). For logging and characterization purposes, the HSU contact depth/elevation is taken to be base of the transition zone.

The Upper HSU/Lower HSU contact is generally a subdued expression of ground surface elevation. The Upper HSU is thickest along the ridge tops and thinnest along the valley bottoms. The contact contours shown in Figure E-2 are for a Site-wide interpretation, and actual local details will vary depending on Site-specific conditions. These locals variations can be important to groundwater flow and the transport of both dissolved-phase and non-aqueous phase liquids contamination. One important area is where dense non-aqueous phase liquids (DNAPLs) could potentially be present (currently or in the past) or known to currently exist. Possible depressions in the surface of the Lower HSU may be locations where DNAPL could pool and accumulate in the subsurface. Specifically, within the P/S Landfill, the Gallery Well and well RIPZ-13 are located along the axis of the pre-development drainage channel; an area where the depth to the HSU contact mimics the pre-existing channel. Both the pre-development channel and HSU contact surface run-off to the south.

4.5.2.2.5 Surface Geophysical Surveys to Further Assess Upper HSU/Lower HSU Contact

The CSC performed surface geophysical surveys and targeted follow-up intrusive work at the following Site areas to attempt to refine the understanding of the Upper HSU/Lower HSU contact elevation where pooled DNAPL could potentially occur:

- Areas Outside of the P/S Landfill, including the Burial Trench Area, Central Drainage Area, and selected areas south of the Perimeter Source.
- Within the south end of the P/S landfill

The methodology, data, and investigation results for this work are provided in Appendix L. This appendix includes figures that show the seismic line locations, instrumentation locations, and results. The results include cross sections integrating subsurface seismic interpretations integrated with the follow-up intrusive work, which included running Cone Penetrometer Test (CPT) borings and installing piezometers.

Areas Outside of the P/S Landfill

At areas outside of the P/S Landfill, the CSC performed a Phase I seismic refraction production

survey in 2004 along 16 seismic lines totaling 22,000 feet in length through the Burial Trench Area, Central Drainage Area and at selected areas south of the Perimeter Source Control Trench (PSCT, Figure L-8). The CSC analyzed the seismic refraction data by preparing "tomographic" computer models by depicting the velocity layering along each of the seismic lines and then correlating the velocity layers to geologic layers. The tomographic models showed potential depressions in velocity layering indicative of potential low spots in three areas.

After the Phase I seismic production survey was completed, the CSC performed a follow-up intrusive survey to further assess the potential depressions by performing CPT borings. No such depressions were identified based on the CPT results and typically the depths predicted by the interpretation of the seismic refraction survey data were greater than depth of the HSU contact recognized from of insitu CPT tip resistance.

South Half of P/S Landfill

Within the south half of the P/S Landfill, the CSC performed an initial Pilot Study in 2004 to test the applicability of seismic refraction, seismic reflection, and micro-gravity methods to resolve subsurface contrasts along two 1,200-foot lines crossing in the P/S Landfill (Figure L-1). The Pilot Study demonstrated that useful subsurface information could be obtained at the P/S Landfill using seismic refraction; however, the Pilot Study also showed that seismic reflection and microgravity would not provide useful information.

The CSC subsequently performed a Phase II seismic refraction production survey in 2005 over a grid of fourteen 960-foot seismic lines centered on the toe of the P/S Landfill (Figure L-25). The CSC and EPA each separately analyzed the CSC's seismic refraction data by preparing tomographic models by depicting the velocity layering along each of the seismic lines and then correlating the velocity layers to geologic layers (Idaho National Laboratory analyzed the data for EPA). The CSC and EPA tomographic models resulted in independent interpretations. EPA's results are provided in a May 4, 2007 letter to the CSC, which is included mass Attachment L-5. The EPA results indicated potential "low areas" within the study area and requested the CSC to perform CPT borings and install piezometers at the following four locations in the south half of the P/S Landfill to further assess the elevation of the top of the unweathered claystone.

- RIPZ-27, located on Gallery Well Road, 8 feet north of the Gallery Well
- RIPZ-38, located on Gallery Well Road, 50 feet west of the Gallery Well
- RIPZ-13, located on Bench 1 Road, 150 feet north of the Gallery Well
- RIPZ-39, located on Bench 2 Road, 300 feet north of the Gallery Well

The CSC performed this follow up work in 2007. The CSC determined the top of the unweathered claystone (Lower HSU) from the CPT tip friction signatures, compared these elevations with the tomographic model results developed by the CSC and EPA, and annotated the tomographic models with "ground truth." (i.e., the depth of the claystone contact as interpreted from boreholes and CPTs). Comparison of the CPT-derived elevations with the tomographic model results developed by the CSC and EPA show the following:

- RIPZ-27 – The CPT-derived contact elevation is within one foot of the CSC tomographic elevation but lower than EPA tomographic elevation.

- RIPZ-38 – The CPT-derived contact elevation is 6.21 feet higher than the contact elevation at the Gallery Well and higher than the HSU contact elevations determined at this location by both the CSC and EPA geophysical models.
- RIPZ-13 – The CPT-derived contact elevation is higher than the CSC tomographic elevation but lower than the USEPA tomographic elevation.
- RIPZ-39 – The CPT-derived contact elevation is higher than the HSU contact elevations determined by both the CSC and EPA geophysical models.

The CSC found that the velocity at the known contact ranged from a low of approximately 3,200 feet per second (fps) to a high of 6,000 fps (see Table L-3). The CSC concluded that a representative velocity for unweathered claystone immediately below the HSU surface is ill-defined and an iso-velocity surface representing the claystone surface could not be established with confidence. On the basis of the wide range of velocities associated with the contact, the CSC's believes that the contact does not conform to a single iso-velocity contour model and therefore, an accurate 3-dimensional representation of the contact surface cannot be determined with certainty from the refraction data.

The CSC does not believe that the contact conforms to a single iso-velocity contour model and their tomographic modeling does not indicate any low area(s) in the P/S Landfill. EPA believes, the overall tomographic velocity profiles could be consistent with the suspected conditions in the P/S Landfill and a potential "low area" in the claystone contact at the south half of the P/S Landfill. For example, Seismic Refraction Line P2SL-6 shows a potential "low area" at a velocity of 3,200 to 3,450 fps (yellow color) at the total depth of RIPZ-13 (Figure L-29). Although the total depth of RIPZ-13 is shallower than the Canonie "low area" elevation contour, the EPA believes the seismic refraction data may suggest that conditions consistent with a "low area" may occur. However, the seismic velocities in the range of 3,200 to 3,450 fps are typical of unsaturated sediment (Holzer, 2010); if unsaturated conditions exist within the potential low spot, then the NAPL movement into fractures below the HSU contact is unlikely due to the complexity of fluid flow within a partially saturated media.

4.5.2.2.6 Remediation Features

Several remediation features constructed by Casmalia Resources and the CSC and currently being operated by the CSC influence groundwater flow and contaminant transport at the Site. These include liquids subsurface clay barriers, extraction facilities, the current on-Site ponds, and the landfills. Their as-built and operating conditions are briefly described below.

Subsurface Clay Barriers and Liquids Extraction Facilities

Subsurface clay barriers and liquid extraction facilities exist as follows (generally from north to south):

- PCB landfill clay barrier.
- P/S Landfill clay barrier and Gallery Well extraction well.
- Sump 9B extraction well
- Road Sump extraction sump
- Perimeter Source Control Trench (PSCT) extraction wells
- Former Pond 20 clay barrier
- RCRA Canyon clay barrier
- Clay barriers and associated extraction facilities at the B- and C-Drainage

- Perimeter Control Trench (PCTs) extraction wells at the A-, B-, and C-Drainages

The construction and operation of these facilities is relatively well known, which are described in Section 2. As further described below, the CSC investigated the location, height, and permeability of the P/S Landfill clay barrier because of its importance on influencing groundwater flow and contaminant transport.

On-Site Ponds

The on-Site ponds include the three stormwater runoff ponds (RCF, A-Series Pond, Pond 13), two treated liquids ponds (Pond A-5 and Pond 18), and the small unlined collection basin that collects clean stormwater runoff from the P/S Landfill and EE/CA Area caps. The construction and operation of these facilities is relatively well known, which are described in Section 2.

Landfills

On-Site landfills include the four landfills capped by the CSC between 1999 and 2002 (P/S, Metals, Caustics/Cyanides, and Acids landfills) and a fifth landfill that currently has an interim soil cover (PCB Landfill). The former RCRA Landfill no longer exists. The P/S Landfill and EE/CA Area (Metals, Caustics/Cyanide, and Acids landfills) cap systems include (bottom to top): low permeability subgrade layer, 60 mil HDPE geomembrane barrier layer, geocomposite drainage layer, and a 2-foot thick vegetative soil layer. The P/S Landfill low permeability subgrade layer consists of a 2-foot thick compacted low permeability soil layer (processed and compacted claystone) and the EE/CA Area cap subgrade layer consists of a geosynthetic clay linter (GCL). An access road and drainage system is constructed on top of the cap. As further described below, these caps have been effective at reducing rainfall recharge, lowering liquid levels within and in the immediate vicinity of the landfills, and reducing liquids extraction rates from the P/S Landfill.

P/S Landfill Clay Barrier. The CSC conducted RI activities to confirm the position and alignment of the barrier, determine the hydraulic conductivity of the clay barrier material, and define the elevation of the top of the P/S Landfill clay barrier. These activities included initially estimating the limits of the barrier by reviewing historical aerial photographs and then drilling and collecting soil samples to confirm the elevation and alignment of the barrier. The CSC measured select clay barrier samples in the laboratory for permeability. The CSC's investigation methodology and investigation results for the clay barrier investigation are provided in Appendix J. The clay barrier identified in August 1981 aerial photography is shown in Figure J-1 and J-2. The borings confirming the clay barrier position and cross sections through the clay barrier are shown in Figures J-3 through J-5. The physical properties measured from the clay barrier samples are summarized in Table J-4.

P/S Landfill Bottom. Casmalia Resources prepared contour maps of the estimated "base grades" of the P/S, Metals, Caustics/Cyanides, and Acids landfills, (Canonie, 1988). Landfill pre-construction topography from 1979 is also available. As described in Section 2.2.3.1.1, the five landfills at the Site were generally started at the south end of a canyon and the native materials were excavated to bedrock (i.e., the unweathered claystone) to form the base of the landfills. Wastes were then placed at the base of the landfills and excavated native materials were placed over the wastes as interim cover.

The Canonie (1988) estimated base grade map indicated that the south end of the P/S Landfill contained a "low area" shown by the enclosed 490-foot elevation contour. The area contained

within this contour is approximately 150 feet long (south to north) and 125 feet wide (east to west) for a total area of approximately 20,000 square feet. Assuming a 10-foot height, this equates to a volume of approximately 200,000 cubic feet. If present, this area could be a potential location for DNAPL to pool and potentially enter underlying fractures within the claystone subgrade. However, insitu testing of the suspected low area could not be verified by two Cone Penetrometer Testing (CPT) surveys. The limited number of CPTs performed during these two surveys indicate that the P/S landfill bottom is V-shaped, consistent with a channel/canyon bottom. However, the number of CPTs performed is not sufficient to map the bottom elevation of the P/S Landfill with sufficient density to verify that localized depressions do not exist that may contain mobile, free phase DNAPL.

The CSC performed CPT at five locations in 2001 at the southern end of the P/S Landfill as part of the CSC's assessment of the potential "low area" (Harding ESE, 2001). The CSC pushed CPTs at the following locations until tip refusal was encountered:

Location	Depth Pushed (feet, bgs)	Location	Comment
CPT-LA-01	77.1	Bench 1 Road, 50 ft east of CPT-LA-05	--
CPT-LA-02A	77.6	Bench 1 Road, 10 ft east of CPT-LA-05	--
CPT-LA-03	93.7	Bench 1 Road, 20 ft west of CPT-LA-05	--
CPT-LA-04	77.9	North of Gallery Well	--
CPT-LA-05	97.0	Bench 1 Road, near current RIPZ-13	Piezometer PZ-LA-01 installed

The results of these CPTs are used to help assess the bottom of the P/S Landfill together with the RI surface geophysics and follow-up intrusive work.

The CSC conducted the surface geophysics and follow-up intrusive work described above in Section 4.5.2.2.3 to define the configuration of the bottom of the P/S Landfill. The following figures show the following select CSC seismic refraction cross sections superimposed with the 1979 topography, Canonie (1988) estimated base grade, the clay barrier, piezometers installed by the CSC, and the Gallery Well:

- Figure 4-17, Phase II Seismic Line P2SL-4 (west-east along clay barrier)
- Figure 4-18, Phase II Seismic Line P2SL-6 (north-south through RIPZ-13)
- Figure 4-19, Phase II Seismic Line P2SL-14, (west-east through RIPZ-13)

Comparison of the CPT-derived HSU contact elevations with the Canonie (1988) estimated base grade elevations show differences. The CPT-derived elevations do not indicate a potential "low area" as suggested by Canonie (1989). Comparison of the CPT-derived elevations to the Canonie (1989) estimated base grade map shows the following:

- RIPZ-27 – The CPT-derived contact was encountered at a depth of 77.65 feet bgs (elevation 481.86 feet amsl). This elevation is within one foot of the HSU contact elevation at the adjacent Gallery Well (481.23 feet amsl) and about. The 1988 Canonie estimated base grade map did not indicate an elevation for the landfill at the location of well RIPZ-27.
- RIPZ-38 – The CPT-derived contact was encountered at a depth of 75.5 feet bgs (elevation 487.44 feet amsl). This elevation is 6.21 feet higher than the HSU contact

elevation at the Gallery Well (481.23 feet amsl); the 1988 Canonie estimated base grade map did not indicate an elevation for the landfill at the location of well RIPZ-38.

- RIPZ-13 – The CPT-derived contact elevation was encountered at a depth of 97.00 feet bgs (elevation 498.75 feet amsl). This elevation is 17.52 feet higher than the contact elevation at the Gallery Well (481.23 feet amsl); the 1988 Canonie estimated base grade is 490 feet amsl, which is almost 10 feet lower than the HSU contact elevation interpreted from CPT boring RIPZ-13.
- RIPZ-39 – The CPT-derived contact elevation was encountered at a depth of 123.00 feet bgs (elevation 512.11 feet amsl), the 1988 Canonie estimated base grade is approximately 500 feet amsl, which is slightly more than 10 feet lower than the HSU contact elevation interpreted from CPT boring RIPZ-39.

The difference between the CPT-derived contact elevations and the 1988 estimated base grade elevation contour map indicates uncertainty with the 1988 base grade elevations. Similarly, the current number of control points provided by CPT borings and other installed piezometers into the contact are not sufficient to evaluate the contours of the contact. There could be a larger "low area", several smaller "low areas", or no "low areas" present at the south end of the P/S Landfill. To definitely define this, an additional intrusive investigation to the contact would be necessary to assess the configuration of this contact.

The CSC's current interpretation is that a "low area" does not exist as portrayed in the Canonie (1988) estimated base grade map. The CPT data collected to verify the inferred low area suspected from both the Canonie map and seismic velocity models failed to do so, instead the CPT data indicates that the contact between the fill/LHSU sloped in towards the central axis of the pre-development channel/canyon topography.

4.5.2.3 Hydraulic Conductivity Testing

Water Bearing Units

Casmalia Resources conducted numerous historical field and laboratory tests to investigate the hydraulic properties of the water-bearing units at the Site. The results are discussed in more detail in the RI/FS Work Plan, and summarized below. The investigations included:

- 274 laboratory tests on core samples;
- 29 slug tests during the HSCER;
- 34 slug tests prior to the HSCER;
- 33 packer tests conducted in open boreholes;
- 10 long-term pump tests (injection or extraction);
- 2 long-term field infiltration tests; and
- Ongoing performance testing of extraction facilities.

As noted in the HSCER, the packer and pumping tests were focused on wells and hydrostratigraphic zones with logged fractures. Uncertainties in aquifer hydraulic property values and distribution exist due to the heterogeneous nature of the fracture system, as well as difficulties in performing in-situ tests and the potential inapplicability of porous media flow and aquifer testing theory to the fracture flow/dual porosity system, however, the hundreds of tests performed to date provide a Site-wide three-dimensional distribution of hydraulic conductivity values from which both interconnectivity and rates of groundwater flow and solute transport can be estimated.

Over 350 permeability tests (core permeameter, slug, pumping, or packer) have been performed to date. The laboratory and field measurements were performed on samples from a total of 165 different borings/wells, which comprises testing of over 40 percent of the identified Site wells/borings. Active aquifer testing (slug tests with some pump tests) were performed for a total of about 61 wells/piezometers, which represents roughly one quarter (¼) of the total number of wells/piezometers at the Site. The areal distribution from where Site hydraulic data was obtained is illustrated on Figure 4-20, core sample testing (lab test) and slug testing was performed at relatively uniformly distributed and densely-spaced locations, and the pump and packer tests were conducted at distributed locations. The test locations were distributed across the entire Zone 1 area, including locations in/beneath many of the landfill cells. Additional tests were performed in off-Site areas including the North Slope, off-Site A-, B-, and C-Drainages. The tests also were vertically distributed almost equally between the Upper and Lower HSUs.

The results of the field hydraulic conductivity investigations can be summarized as follows:

- The hydraulic conductivity values are log-normally distributed;
- The highest hydraulic conductivity occurs in the fill and alluvial material, followed by the weathered claystone and the unweathered claystone; and
- There are no Site-wide or areal trends in hydraulic conductivity within the geologic units at the Site. The apparent anisotropy observed in the laboratory data may be due to the limitations of laboratory methods for determining horizontal hydraulic conductivity using core samples.

Generally, the results of the investigations provided consistent estimates for the hydraulic conductivity of approximately 10^{-5} cm/s in the Upper HSU and approximately 10^{-6} cm/s in the Lower HSU. The calculated minimum, geometric mean, and maximum horizontal hydraulic conductivities for all 104 field tests (packer, slug and pump tests) by HSU are summarized below:

- Upper HSU:
  - Minimum Upper HSU horizontal hydraulic conductivity: 1.8×10^{-09} cm/sec
  - Geometric Mean Upper horizontal HSU hydraulic conductivity: 1.05×10^{-05} cm/sec
  - Maximum Upper HSU horizontal hydraulic conductivity: 8.9×10^{-03} cm/sec
- Lower HSU:
  - Minimum Lower HSU horizontal hydraulic conductivity: 1.70×10^{-11} cm/sec
  - Geometric Lower Upper horizontal HSU hydraulic conductivity: 1.03×10^{-06} cm/sec
  - Maximum Lower HSU horizontal hydraulic conductivity: 6.3×10^{-04} cm/sec

Figure 4-21 presents statistical analyses of the hydraulic conductivity test data by test type (core permeameter, slug, pumping, or packer) and HSU. Note that for the Upper HSU, tests of alluvium are differentiated from tests of weathered claystone. In general slug test and pump test data for the Upper HSU yielded higher permeabilities than either the permeameter or packer tests. A similar relationship was observed for the Lower HSU tests, and these Lower HSU values are generally less than the permeabilities estimated for the Upper HSU. Vertical permeability testing of core samples from Upper and Lower HSU boreholes yielded slightly lower hydraulic conductivity values. The geometric mean horizontal hydraulic conductivity values differ slightly from those reported in the HSCER as the geometric means of all available

long-term test data (6.8 x 10^{-5} cm/sec and 1.5 x 10^{-6} cm/sec in the Upper and Lower HSUs, respectively).

Evidence from various investigations indicates that fractures control hydraulic conductivity in the Upper and Lower HSUs. However, parameters such as fracture length, aperture, orientation, degree and nature of infilling, and interconnectivity are highly variable. This variability is enough to mask the expected general correlation of fracture density with higher hydraulic conductivity.

Table 4-4 presents a summary of the relative permeability ranking of selected wells based on results of core, slug, packer, or pump testing, and responses after purging events. In addition to the core, slug, packer, or pump permeability tests, preliminary estimates of relative permeabilities of other wells were developed based on pumping and drawdown performance during purging associated with the 2001 RGMEW sampling events. For these wells, water level and flow rate data were collected and short term specific capacities and associated relative permeabilities estimated. Relative permeabilities for each HSU for both the calculated hydraulic conductivities and sample purge performance were developed by evaluating the distribution of values (Figures 4-22 and 4-23, and Table 4-4) and assigning low, medium, and high relative permeabilities. The relative permeabilities for the Upper and Lower HSUs are illustrated on Figures 4-24 and 4-25, respectively, from which the apparent interconnectivity of the fracture flow system can be hypothesized.

Clay Barriers

The clay barrier located at the toe of the P/S landfill was constructed in 1981-82 is approximately 200-feet long, 13-feet thick and up to 50 feet deep extending a minimum of 4-feet into the underlying claystone (Harding ESE, 2001d). The clay barrier was constructed from local borrow of a very dark gray to black, hard adobe-type clay containing small rootlets and small pale brown claystone fragments (Appendix J). The measured hydraulic conductivity of three samples collected by the CSC in a 2004 investigation from the P/S Landfill clay barrier range from 2.57 x 10^{-8} to 4.3 x 10^{-8} cm/sec (Table J-4), which is consistent with an engineered compacted fill of low permeability.

4.5.2.4 Porosity

The claystone units at the Site are characterized by two types of porosities: the fracture porosity and the matrix (or bulk) porosity. The fracture porosity in the Upper HSU was estimated as ranging from 6 percent to 25 percent based on data from an infiltration test at IP-1. However, this value appears to be too high to represent fracture porosity based on the observed fracture density. Comparison with the literature for fracture porosities in clay-rich sedimentary formations also indicates that the true fracture porosity may be less than 1 percent (Freeze and Cherry, 1979). In addition, as shown in Table 4-5, the fracture porosity estimated by the infiltration test is much higher than fracture porosities estimated using field hydraulic conductivity data.

Matrix porosities were calculated using laboratory experiments on 27 samples from the Upper HSU and 23 samples from the Lower HSU. Mean effective matrix porosities were 44 percent and 48 percent in the Lower and Upper HSUs, respectively. These values appear reasonable given the clayey nature of the HSUs. Comparable values established in the literature range from 30 to 70 percent for clayey deposits and 5 to 25 percent for sedimentary rocks (Freeze and Cherry, 1979).

4.5.3 Site Groundwater Flow Conditions

Groundwater flow at the Site is influenced by rainfall infiltration and surface water recharge to the groundwater system, the physical characteristics of the subsurface materials through which groundwater flows, and groundwater discharge through evapotranspiration, groundwater extraction or direct discharge as seeps, streams, or ponds. Casmalia Resources and the CSC investigated these Site groundwater flow conditions through numerous Site-specific field investigations and numerical groundwater flow modeling.

Casmalia Resources installed several hundred groundwater monitored wells and piezometers, and performed other Site investigation work to assess the Site's groundwater flow. The results of this are presented in many previous reports, including the HAR, HSCER and HSIR. Casmalia Resources conducted two-dimension groundwater flow modeling which is presented in the HSIR.

The CSC built on the historical work by Casmalia Resources with additional Site-specific work performed as part of the RGMEW and RI. The CSC is currently performing semiannual, monthly, and continuous water and NAPL level monitoring as part of the RGMEW. For the RI, the CSC installed additional piezometers and groundwater monitoring wells, collected additional water and NAPL level data, and conducted Site-wide three-dimensional groundwater flow modeling. The modeling was performed to integrate the large amount of hydrogeologic data to further evaluate the Site-wide and local flow conditions and the hydraulic effectiveness of the current liquid extraction systems. The CSC's water and NAPL level monitoring methodology, data, and evaluation results for the RGMEW and RI data are provided in Appendix F (Groundwater Flow).

The water table contour map in Figure 4-26 and hydrogeologic cross section in Figure 4-27 illustrate typical horizontal and vertical groundwater flow patterns and gradients at the Site, these figures were constructed based on December 2008 groundwater monitoring data. A comprehensive set of the following figures in Appendix F more fully depict hydrogeologic conditions, and in the analysis of groundwater flow conditions below:

- Site-wide groundwater elevation contour maps (Figures F-3 through F-17)
- Groundwater elevation versus ground elevation regressions (Figures F-18 through F-21)
- Site-wide hydrogeologic cross sections A-A' through F-F' (Figures F-22 through F-28)
- Liquids extraction area groundwater elevation contour maps (Figures F-29 through F-32)
- NAPL information, which is discussed in Section 5 (Figures F-33 through F-46).
- Water balance information (Figures F-47 and F-48)
- MODFLOW model domain, layering, and simulated flow paths (Figures F-49 and F-50)

A comprehensive set of hydrographs for piezometers, monitoring wells, and extraction wells are provided in Attachment F-1. Site water budget information is provided in Attachment F-2. The groundwater flow modeling input and calibration results are documented in Attachment F-3. The groundwater flow model input and calibration is briefly described below, followed by an evaluation of the Site-wide and local groundwater flow conditions.

In addition, a summary of the Site groundwater chemistry is also provided below for context to the groundwater flow analysis. A more complete evaluation of the groundwater chemistry is provided in Section 5 and Appendix G.

4.5.3.1 Groundwater Flow Model

The CSC developed a three-dimensional, numerical groundwater flow model for the Site to assist in the characterization of current groundwater flow conditions and to evaluate the potential effectiveness of alternative remedial measures as part of the Feasibility Study (Figure 4-28). A brief description of the model is presented in this section and a more detailed discussion of the model development, calibration, and results is included in Attachment F-3. The results are used to interpret Site-wide and local groundwater flow conditions below.

Groundwater Flow Model Development

As specified in the RI/FS Work Plan, the CSC used the United States Geologic Survey (USGS) finite -difference groundwater flow model code MODFLOW-2000 and the particle tracking code MODPATH to simulate three-dimensional groundwater flow at the Site. The flow model was developed using Site-specific geologic and hydrologic data, and calibrated to groundwater flow conditions at the Site. To simulate the variability in hydrologic conditions, steady-state flow models were constructed and calibrated to simulate two different historical periods: March 2001 and March 2004. The March 2001 model represents “wet” or “high groundwater” conditions, based on high rainfall and inferred recharge rates preceding this period, high extraction system pumping rates, and peak historical groundwater elevation conditions, based on water level hydrographs. The March 2004 model represents “dry” or “low groundwater” conditions after several below-average rainfall years between late 2001 and early 2004. Most of the model calibration runs were performed using the March 2004 data, because more water level data were available during this period than during March 2001.

Seven model layers were used in the model to simulate the vertical and horizontal groundwater flow within and between the Upper and Lower HSUs (Figure F4-29). The model layer geometries were developed on the basis of the Upper/Lower HSU contact surface (Figure E-2). Model layers 1 through 3 were used to simulate the Upper HSU, with the base of model layer 3 corresponding to the Upper/Lower HSU contact surface, and model layers 4 through 7 were used simulate the Lower HSU.

Recharge rates were estimated using the EPA “Hydrologic Evaluation of Landfill Performance” (HELP) model. The input parameters and results of the HELP model simulations are described in detail in Attachment F-2. Net recharge estimated using the HELP model ranged from around 3 to 50 percent of annual rainfall. Minor adjustments to these recharge rates were made during model calibration. These recharge rates used in the calibrated models are shown in Figure 4-30.

The horizontal and vertical hydraulic conductivities assigned to the model layers were based on pre-RI field hydraulic testing (slug, packer, and pumping tests) and adjusted during model calibration. Heterogeneous horizontal and vertical conductivities were used in model layers 1 through 4 (Upper HSU and upper portion of Lower HSU), while uniform horizontal and vertical conductivities were used in model layers 5 through 7 (Lower HSU). A comparison of the hydraulic testing results and the conductivity values used in the calibrated models is shown in Figure 4-31.

Groundwater Flow Model Results

The contoured model head solutions from the calibrated March 2004 model are shown in Figures 4-32 to 4-38 for Layers 1 through 7, respectively. The model head solutions for model

layers 1, 2, and 3, which represent the Upper HSU are similar (Figures 4-32 through 4-34), with only a few feet of head difference between the layers at most locations. Accordingly, the overall horizontal hydraulic gradients in each of layers 1, 2, and 3 are similar.

Figures 4-39 through 4-45 show the contoured head solutions from the calibrated March 2001 model for Layers 1 through 7, respectively. Consistent with the with the observed groundwater elevations, the model head solutions from the March 2001 model ("wet" conditions) are slightly higher than the head solutions from the March 2004 model ("dry" conditions).

Manual interpretations and MODFLOW model simulated interpretations of surface water and groundwater data are used to develop the CSM, which is described in Section 4.8.4. The calibrated head solutions from the March 2004 and March 2001 MODFLOW models simulate flow conditions that are consistent with the manual interpretation of surface water and groundwater elevation data and the CSM (Section 4.8.4). In the Upper HSU, the model simulates convergent groundwater flow into the relatively high permeability aquifer materials in the central drainage at and downgradient (south) of the waste landfills (Figures 4-32 through 4-34 and Figures 4-39 through 4-41). Groundwater flow to the PSCT is also indicated by the head solution contours, which "V" and converge into the trench alignment. Upper HSU flow also converges into the northern edges of the pond boundaries. Flow to the North Drainage, A-Drainage and B- and C-Drainages and Casmalia Creek is also indicated by the contoured head solutions for model layers 1, 2, and 3.

In the Lower HSU, groundwater flow at the western edge of the North Ridge moves along and away from the ridge to the North Drainage and Casmalia Creek and into Zone 1 (Figures 4-35 through 4-38 and Figures 4-42 through 4-45). In the upper portion of the Lower HSU (model layer 4) convergence of flow to the PSCT and to a lesser degree to the PCTs is inferred from the simulated heads and contours, as is flow toward the creeks. With increasing depth, the head field in each model layer is smoother, reflecting the homogenous conductivities assigned to layers 5, 6, and 7, which represent the lower portion of the Lower HSU (Figures 4-43 through 4-45).

Groundwater and surface water features and flow conditions are described below based on the "manual" and model simulated interpretations of surface water and groundwater data. Model simulated particle track figures developed in Attachment F-3 are presented in Figures 4-46 (F3-84), 4-47 (F3-86), and 4-48 (F3-95) to help evaluate groundwater flow conditions in the Upper HSU and Lower HSU. Figures 4-46 (F3-84) and 4-47 (F3-86) are for the Upper HSU for the March 2004 and 2001 conditions. For these simulations, particles are started at the north part of the Site where portion of the Upper HSU are unsaturated. Figure 4-48 (F3-95) is for the Lower HSU (Layer 6) for the March 2004 conditions. For this simulation, the particles are started in Layer 6 between the landfills and the PSCT. The particles for all three simulations generally move southward, consistent with the overall groundwater flow direction.

4.5.3.2 Groundwater and Surface Water Features and Flow Conditions

Groundwater beneath the Site occurs primarily as surficial underflow and has historically fed Casmalia and Shuman Creeks through the A-, B-, and C-Drainages, which are discussed in Section 4.3. The natural groundwater flow system is largely governed by topography and the HSU contact surface (Figure E-2) as illustrated by the groundwater elevation contours on the Water Table Contour Map (Figure 4-26) and Site-wide Cross-Section D-D' (Figure 4-27). The correlation between groundwater elevation and topography is further illustrated on Regression of Water Table versus. Elevation graphs (Appendix F, Figures F-18 through F-21). Shallow

groundwater flow is now actively managed and contained on-Site by several manmade control features such as clay barriers, landfill caps, rainwater and treated liquid storage ponds, and multiple liquid extraction facilities as noted above. Liquid extraction facilities include the Gallery Well, Sump 9B, Road Sump, the PSCT (and extraction points PSCT-1, -2, -3, and -4), and the Perimeter Control Trenches (PCTs PCT-A, -B, and -C). The liquid extraction facilities are used to maintain liquid levels at or below specified levels, thus maintaining a cone of depression which affects the groundwater gradient in the nearby area (PSCT-3 and the Road Sump are not routinely pumped).

Overall, the groundwater flow system has remained essentially constant between 1997 and 2009. Seasonally, except for the capped P/S Landfill and EE/CA Areas, groundwater elevations increase in response to winter rainfall and then decrease during the remaining summer dry season. Over the period of RGMEW monitoring groundwater elevations have seen a net decrease; this is largely due to the effects of capping landfill cells and groundwater capture by the PSCTs. Although groundwater elevations change in response to climatic conditions, the overall Site-wide lateral groundwater flow directions do not appear to be affected significantly by seasonal recharge.

Natural groundwater storage is limited, though it has been augmented by the addition of refuse and fill material to landfill cells constructed within historical natural drainage features. Changes in groundwater storage over time are directly related to precipitation. There has been a net decrease in storage over time that is the result of a combination of recent dry years and decreased infiltration due to the capping of landfill cells and the management and collection of surface runoff between the capped areas (Appendix F, Table F-5).

As described above, divergent flow from the North Ridge results from rainfall recharge and the three dimensional hydraulic conductivity distribution in the subsurface. The CSC constructed the groundwater flow model with a “no flow” boundary along the North Ridge to simulate this feature. Using this boundary condition, the model head solutions simulate divergent groundwater flow from the North Ridge northward to the North Drainage and southward through Zone 1. Using this boundary condition, the groundwater flow conditions in the Upper HSU and Lower HSU simulated by model are consistent with the Site-wide groundwater flow conditions described above.

4.5.3.2.1 Site-wide Groundwater Flow

Groundwater at the Site exists primarily as surficial underflow and has been demonstrated to closely follow surface topography (Appendix F, Figures F18 through F-21). Groundwater flow is structurally controlled by the contact separating the more permeable Upper HSU from the less permeable Lower HSU (Figure F-2). In general, the HSU contact elevation is a subdued expression of surface topography, with the contact elevation occurring at shallower depths in the drainage bottoms and at deeper depths along the ridge tops.

North Ridge

The North Ridge is a natural recharge area and groundwater flow divide. Rainfall infiltrates into the subsurface along the North Ridge and moves vertically downward and laterally outward either northward toward the North Drainage or southward across the Zone 1 Site area (Figure 4-26). Groundwater also recharges the North Ridge area in the Site vicinity from off-Site lateral groundwater recharge (inflow) from the west along the ridge.

Downward vertical groundwater gradients occur along the North Ridge and are shown in Cross Section A-A' (Figure F-24). The water table elevation along the North Ridge mostly occurs below the HSU contact where the Upper HSU is unsaturated (dry), as shown in Figures F-6 and F-11. Although the hydraulic conductivity is relatively low, infiltrating groundwater moves downward in response to the strong downward vertical gradients in this area. These downward gradients approach and exceed 0.5 ft/ft along the North Ridge, as demonstrated at the following well clusters for December 2008 data (see Cross Sections A-A' through E-E'):

North Ridge Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
West Area	RGPZ-2B	RGPZ-2C	52.86	0.64	F1-L4
West Area	RGPZ-2C	RGPZ-2D	42.96	0.58	F1-L4
Middle Area	RIPZ-10B	RIPZ-10C	42.86	0.78	F1-L5
Middle Area	RIPZ-10C	RIPZ-10D	15.22	0.18	F1-L5
Middle Area	RGPZ-13C	RGPZ-13D	23.17	0.38	F1-L11
East Area	RP-111B	RP-111D	12.93	0.25	F1-L23

The groundwater elevations have remained steady between 1997 and 2009 except for seasonal variations in response to rainfall patterns (see noted hydrographs). Horizontally, the location of the divide is conceptually along the North Ridge but its exact location is not quantified. Actual infiltration rates, HSU contact elevation, and subsurface hydraulic conductivity distribution will influence the actual divide location.

RCRA Canyon Area

From the North Ridge above the RCRA Canyon, groundwater moving southward will preferentially move through the more permeable Upper HSU and converge into the RCRA Canyon (Figures 4-26, 4-46, and 4-47). Vertically downward gradients occur in the upper RCRA Canyon and vertically downward gradients occur in the lower RCRA Canyon to the south (see Cross Section B-B'). Some groundwater monitoring wells on the RCRA Canyon are under artesian conditions (i.e., the water level in the well is above ground surface). Groundwater seeps can occur in certain areas in response to the upward gradients. Groundwater will flow southward along RCRA canyon and discharge to Pond A-5. Groundwater elevations have remained steady between 1997 and 2009 except for variations in response to rainfall patterns (see hydrographs).

PCB Landfill and Burial Trench Area

From the North Ridge above the PCB Landfill, groundwater moving southward will preferentially move through the more permeable Upper HSU, PCB Landfill materials, and Burial Trench Area towards the PSCT in the vicinity extraction well PSCT-4 (Figure 4-26, 4-46, and 4-47). Some groundwater from the PCB Landfill and eastern part of the Burial Trench Area may move towards the P/S Landfill. Strong vertically downward groundwater gradients occur throughout the PCB Landfill and Burial Trench Area as demonstrated at the following well clusters for December 2008 data (see Cross Section C-C'):

Burial Trenches Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
North Area	RP-2B	RP-2C	27.58	0.20	F1-U14, F1-L15
North Area	RP-2C	RP-2D	44.94	0.69	F1-L15
Middle Area	RIPZ-29	RIPZ-15	41.52	0.36	None, F1-L38
South Area	RIPZ-30	RIPZ-16	24.88	0.25	None, F1-L38

A clay barrier exists at the southern toe of the PCB Landfill. However, this barrier is not significant in affecting horizontal groundwater flow because it does not extend downward from ground surface to the HSU contact. From the Burial Trench Area, groundwater will flow southward toward the PSCT in the area of PSCT-4. Groundwater extraction at PSCT-4 and groundwater flow patterns along the PSCT is further described below. Groundwater elevations in the PCB Landfill and Burial Trench Area have remained steady between 1997 and 2009 except for variations in response to rainfall patterns (see above hydrographs).

P/S Landfill, Other Landfills, and Central Drainage Area

From the North Ridge above the capped P/S Landfill and the other capped landfills (Metals, Caustic/Cyanide, and Acids), groundwater moving southward will preferentially move through the more permeable Upper HSU and landfill cells which follow the original topography of the canyons in which the cells were constructed (Figure 4-26, 4-46, and 4-47). Some groundwater from the PCB Landfill and eastern part of the Burial Trench Area may move towards the P/S Landfill.

Vertically downward groundwater gradients occur at the northern parts of the four capped landfills as the downward gradients propagate southward from the North Ridge. Historically, groundwater level data have indicated that these downward gradients continued to the southern limits of the landfills, as demonstrated by well pairs in the Metals Landfill (WP-8S/WP-8D), Caustic/Cyanide Landfill (RG-9B/RP-95D), and Acids Landfill (RP-26C/RP-26D). The CSC's capping of the P/S Landfill in 1999, capping of the EE/CA Area landfills (Metals, Caustic/Cyanide, and Acids) in 2001 and 2002, and subsequent maintenance of this approximate 40 acre contiguous impermeable cap has eliminated most rainfall infiltration. Eliminating infiltration has reduced the magnitude of the downward gradients at the landfills and led to an upward vertical gradient at the toe of at least two of the landfills (Metals and Caustic/Cyanide). The vertical gradients at Metals Caustic/Cyanide, and Acids landfill toe well clusters are as follows for December 2008 data (see Cross Section C-C'):

Landfill Toe Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Metals	WP-8S	WP-8D	-10.84	-0.23	F1-U5, F1-L19
Caustic/Cyanide	RG-9B	RP-95D	-2.13	-0.01	F1-U6, F1-L19
Acids	RP-26C	RP-26D	40.05	0.30	F1-L21

Groundwater elevations in these and other nearby wells historically responded to rainfall prior to capping. Since 2002 when the EE/CA Area landfill capping was completed, the groundwater elevations in the following wells (1) permanently decreased from approximately 10 up to 25 feet and (2) stopped responding seasonally to rainfall (see hydrographs of these wells and the companion Lower HSU, which showed a similar response):

Well	Hydrograph	Location
SW-48	F1-U4	Metals-Caustics/Cyanide Interstitial Area
WP-8S	F1-U5	Metals Landfill Toe
RG-9B	F1-U6	Caustics/Cyanide Toe
RG-8B	F1-U20	Acids Landfill Toe
SW-31	F1-U9	Central Drainage Area

Groundwater from the EE/CA Area Cap landfills will flow southward and converge to the Central Drainage Area (Figures 4-46 and 4-47). The reduction in groundwater elevations from capping has reduced the volume of liquids migrating from these landfills relative to historical conditions before the CSC capped these landfills.

Except for the Gallery Well extraction well, no monitoring wells or piezometers existed in the P/S Landfill to document the changes in liquid levels before the CSC constructed the cap in 1999. Instead of using liquid levels, the change in liquids extraction rate from the Gallery Well can be used to assess the effectives of the cap in eliminating recharge to the landfill. As shown in Figure 4-49, the Gallery Well extraction rate fluctuated seasonally in response to recharge before 2002. Since 2002, the annual Gallery Well extraction rate has decrease by greater than 50 percent and it no longer fluctuates significantly in response to rainfall because of the cap.

The vertical groundwater gradients at the P/S Landfill are shown in Cross Section D-D' for December 2008 data (Figure 4-27). This cross section shows that the strong vertically downward gradients propagate from the North Ridge southward toward the southern half of the landfill. The vertical gradient direction and magnitude at the southern end of the landfill is not known because there are no well clusters screened at different depths to determine actual vertical gradients, as with the other landfills. The regional interpretation in Cross Section D-D' is that the overall vertical gradient at the south part of the landfill is moderate and slightly downward. A localized upward gradient is shown at the Gallery Well, but this upward gradient is interpretative and not based on actual water level data from wells.

Natural to vertically upward groundwater gradients occur in the Central Drainage Area as demonstrated at the following well clusters for December 2008 data (see Cross Section C-C'):

Central Drainage Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
South Area	RGPZ-6B	RGPZ-6C	-0.54	-0.01	F1-U11, F1-L20
South Area	RGPZ-6C	RGPZ-6D	-2.85	-0.04	F1-L20
South Area	RG-3B	RGPZ-7C	-2.07	-0.03	F1-U11, F1-L20
South Area	RGPZ-7C	RGPZ-7D	0.04	0.00	F1-L20

These upward gradients in the Central Drainage Area are suppressed by groundwater extraction at Sump 9B, the Road Sump, and the PSCT. Historically, the shallow water table between the P/S Landfill and PSCT-1 would emerge as seeps during winter months when seasonal rainfall recharges and increases the water table elevation. Extraction from the PSCT facilities eliminates these seeps from forming between the P/S Landfill and PSCT-1.

From the Central Drainage Area, groundwater will flow southward toward the PSCT in the area of PSCT-1. Groundwater extraction by Sump 9B and the PSCT extraction facilities is discussed

below. Groundwater elevations in the Central Drainage Area have remained steady between 1997 and 2009 except for variations in response to rainfall patterns (see above hydrographs).

Former Ponds and Pads Area and Surface Water Ponds

Groundwater moving southward from the RCRA Canyon, southward from the PSCT trench area, and locally derived from infiltrating precipitation will flow southward across the Former Ponds and Pads Area toward the surface water ponds. Under static conditions, the ponds may be a source of recharge to groundwater or act as a groundwater sink and receive base flow, depending on the water level within the ponds relative to the level of the adjacent water table.

Surface water from Pond A-5 will seep to the A-Series Pond while water from Pond 18 will seep into both the A-Series Pond and the RCF. Surface water from the RCF will seep into Pond 13. The A-Series Pond, RCF, and Pond 13 provide a source of recharge for much of the water extracted from the extraction wells at the head of the C Drainage perimeter capture trench (C-5, RAP-1C), B Drainage perimeter capture trench (RAP-1B), and certain parts of the A Drainage perimeter capture trench (RAP-1A, RAP-2A, RAP-3A). For example, the water level in the RCF Pond during December 2008 was approximately 42 feet higher than the water level maintained in extraction point RAP-3A in PCT-A, which is less than 200 feet from the southern perimeter of the pond. However, the mechanism for the majority of water loss from ponds is through the yearly evaporative cycle.

Off-Site Drainages

Groundwater naturally exits the Site via one of four routes: the North Drainage, the A-Drainage, the B-Drainage, and the C-Drainage (Figure 2-1).

The A-Drainage conveys water largely from east of the Site boundary, however, groundwater flowing through the eastern portion of the Site that might naturally travel through the drainage is presently captured by RAP-1A (discussed below). Surface water from the RCF and groundwater from the hill to the south (that separates the A and B Drainages) likely recharge extraction wells RAP-1B and RAP-1C (discussed below). An upward groundwater gradient exists at the PCT-A area. Moderate vertically downward to upward gradients occur downgradient along the A-Drainage as demonstrated at the following well clusters for December 2008 data (see Cross Section E-E'):

A Drainage	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Extraction Well	RAP-1A	RP-101C	-4.75	n/a	F1-E4 / F1-U22, F1-L36
Trench Area	MW-18C	MW-18D	3.11	0.01	F1-U22, F1-L36
A Drainage	RP-65B	RP-65C	-11.49	-0.07	F1-U24, F1-L37
A Drainage	RP-73B	RP-73D	1.75	0.02	F1-U23, F1-L37
A Drainage	RP-108A	RP-108B	-0.71	-0.06	F1-U24

The B-Drainage was likely the historic outlet for water flowing from the Central Drainage prior to modifications performed during past Site operations. Currently, groundwater that would naturally flow though the B-Drainage is captured by RAP-1B (discussed below). Extraction from well B-5 is currently not performed. Surface water from Pond 13 and groundwater from the two hills to the south (that separate A, B, and C Drainages) likely recharge extraction by RAP-1B (discussed below). An upward gradient exists at the PCT-B extraction well area and mostly

vertically upward gradients occur downgradient along the B Drainage as demonstrated at the following well clusters for December 2008 data (see Cross Section C-C'):

B Drainage	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Extraction Well Area	B-5	MW-13D	-15.23	-0.11	F1-U27, F1-L31
B Drainage	RP-75B	RP-75C	-12.86	-0.27	F1-U29, F1-L33

The C-Drainage bounds the southwest corner of the Site and historically, and presently, drains water that primarily falls outside the western Site boundary. Groundwater flowing through the southwestern portion of the Site that would naturally flow through the C-Drainage is pumped by RAP-1C (discussed below). Surface water from the A-Series Pond and groundwater from the hill to the south (that separates the B and C Drainages) likely recharge C-5 (discussed below). An upward groundwater gradient exists at the PCT-C extraction well area and mostly vertically upward gradients occur downgradient along the C Drainage as demonstrated at the following well clusters for December 2008 data (see Cross Section C-C'):

C Drainage	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Extraction Well	C-5	MW-7C	-38.74	n/a	F1-E5 / F1-U35, F1-U35
Trench Area	MW-7C	MW-7D	-0.83	-0.01	F1-U35, F1-L27
Trench Area	RP-13B	MW-6D	-3.29	-0.03	F1-U33, F1-L26
Casmalia Creek	RP-72A	RP-72B	-4.60	-0.19	F1-U39
Casmalia Creek	RP-72B	RP-72D	5.04	0.06	F1-U39, F1-L29

The North Drainage bounds the Site to the north and drains water outside the Site boundary. As described above, the location of the groundwater flow divide is conceptual along the North Ridge and its exact location is not quantified. Actual infiltration rates, HSU contact elevation, and subsurface hydraulic conductivity distribution will influence the actual divide location. Most, if not all, of the on-Site Zone 1 groundwater flows south across the Zone 1 area and does not flow north toward the North Drainage. From the North Ridge flow divide, groundwater will move southward toward the North Drainage (Figure 4-26). Similar to groundwater flow conditions within the landfill proper, slight vertically upward gradients occur at the toe of the slope of the North Drainage surface perennial creek (Unnamed Drainage). Near the Site, neutral to slight downward gradients exist beneath the North Drainage towards the east as demonstrated at the following well clusters for December 2008 data (see Cross Sections D-D' and E-E'):

North Drainage	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Middle Drainage	RP-41A	RP-41B	-2.49	-0.08	F1-U2, F1-L10
Middle Drainage	RP-41B	RP-41D	-4.96	-0.02	F1-L10
Lower Drainage	RP-109B	RP-109D	1.41	0.01	F1-U2, F1-L10
Lower Drainage	RP-110B	RP-110D	10.35	0.12	F1-U25, F1-L10

Groundwater discharges to the North Drainage as seeps or weak springs in response to the horizontal and upward groundwater gradients. Groundwater flow within the North Drainage is east along the drainage direction. Groundwater elevations have remained steady between

1997 and 2009 except for variations in response to rainfall patterns (see hydrographs noted above).

4.5.3.2.2 Landfill Caps

RCRA-equivalent caps or covers have been placed atop the P/S, Metals, Caustic/Cyanide, and Acids landfill cells across an approximate 40 acre contiguous area (construction occurred between 1998 and 2002) to prevent rainfall and surface water from infiltrating through the waste into the underlying HSUs. Rainwater falling onto the capped landfills now flows as overland surface flow to the small collection (retaining) basin at the toes of the landfill cells. The retaining basin was constructed in 2003 (Figure 2-3). Prior to landfill capping, rainfall infiltrated into the subsurface landfill waste materials or ran off as surface water that was diverted and collected within the Run-off Collection Facility (RCF). Since capping was completed in 2002 and beginning with the 2008/09 winter, stormwater captured in the retaining basin is now routed to an off-Site wetland constructed within the B-Drainage area.

As described above, since 2002 when the landfill caps were completed, the groundwater elevations measured in wells within and immediately surrounding the capped landfills decreased by approximately 10 to 25 feet and stopped responding to seasonal rainfall. The lower of groundwater elevations has reduced the volume of liquids migrating through these landfills relative to historical conditions. In turn, the volume of groundwater flowing into the Central Drainage Area has been reduced since the capping of the P/S, Metals, Caustic/Cyanide, and Acids Landfills due to the reduced infiltration. Also, infiltration into the Central Drainage Area has been reduced by the diversion of rainwater from non-capped areas between the landfill cells via constructed drainage channels to the constructed wetland or ponds.

4.5.3.2.3 Seeps

Ephemeral seeps have been observed in several locations across the Site (Figure 4-16), however, due in part to dry conditions in recent years, none have been observed since 2004. Known seeps include:

- A seep historically occurred at the base of the P/S Landfill in the vicinity of Sump 9B. Installation and extraction of liquids from Sump 9B has eliminated the seep from emerging in this area.
- A seep known as the “9B Road Seep” historically occurred seasonally during the rainy winter months south of Sump 9B immediately west of the road traveling from PSCT-1 to Sump 9B approximately 35 feet north of PSCT-1, which prompted the installation of the “Road Sump” extraction point. Liquids extraction from the Road Sump has eliminated the seep from emerging in this area;
- A seep on the southern face of the Pond A-5 dike historically occurred in response to water seeping through the dike from Pond A-5 to the A Series Pond. This seep has been controlled by the lowering of the water level in Pond A-5;
- A seep known as the Pond 18/RCF Pond Seep has been observed on the eastern side of the road to the treatment area in response to water seeping from Pond 18 to the RCF. This seep still occurs; and
- At the bottom of the RCRA Canyon, natural seeps occur from vertically upward groundwater gradients that are a result of the artesian hydrogeologic conditions described above for the RCRA Canyon. These seeps still occur.

4.5.3.2.4 Gallery Well

As described above, groundwater from the North Ridge and potentially from the PCB Landfill and eastern part of the Burial Trench Area recharges the P/S Landfill (Figures 4-46 and 4-47). Groundwater and contaminated liquids move southward in the P/S Landfill until encountering the subsurface clay barrier at the toe of the landfill. The clay barrier and Gallery Well liquids extraction system is designed to control contaminated liquids from migrating outside of the landfill cell.

The subsurface clay barrier was constructed below the toe of the P/S Landfill in 1980. The barrier is approximately 13 feet wide and 50 feet deep at its deepest point and reportedly extends a minimum of 4 feet into the unweathered claystone bedrock. A partially constructed buttress embankment to protect the toe area of the P/S Landfill was built over the clay barrier, and extends approximately 30 feet above the clay barrier. A collection gallery and associated extraction point (the Gallery Well) was installed adjacent to the upgradient face of the clay barrier to facilitate removal of contaminated liquids. The Gallery Well consists of an approximately 5 to 6-foot diameter gravel filled pit with a casing in the center of the pit to allow for the pumping of contaminated liquids and groundwater. The Gallery Well extends to a depth approximately 75 feet below the top of the buttress embankment. Extracted fluids from the Gallery Well are currently taken to a permitted, off-Site disposal facility.

As described above, the CSC conducted RI activities to define the elevation of the top of the P/S Landfill clay barrier, confirm the actual position and alignment of the barrier, and to determine the physical characteristics of the barrier material (Appendix J). The clay barrier identified in August 1981 aerial photography is shown in Figure J-1 and J-2. The borings confirming the clay barrier position and cross sections through the clay barrier are shown in Figures J-3 through J-5.

As illustrated in cross-section on Figure F-37 of Appendix F, liquid extraction from the Gallery Well maintains the liquid levels along the Gallery Well bench below the upper limit of the clay barrier. The CSC's current liquids extraction action level is as low as the Gallery Well can be practically pumped. The historical and current action levels for the Galley Well as operated by the CSC are presented in Table 2-7 and summarized below:

Year	Gallery Well (ft, BOTC)	Comment
1997 - 1999	30	none
1999	34	Action lowered by 4 feet. Casing raised due to area grade change.
2000 - 2010	63	Action level lowered from 34 to 63 feet in increments during 2000.

Liquid extraction rates over time from the Gallery Well are presented on Figure 4-49 and liquid extraction levels are presented on Hydrographs F1-E1 and F1-U7 along with liquid levels of other piezometers within the P/S Landfill. As described above, since 2002, the annual Gallery Well extraction rate has decreased by greater than 50 percent and the extraction rate no longer fluctuates significantly in response to rainfall due to the placement of the impermeable caps.

The impact of pumping the Gallery Well upon the horizontal hydraulic gradient is illustrated on Figure F-29 of Appendix F where the 500-foot and 520-foot contours reflect the depression cone, indicative of a capture zone that extends to the south of the clay barrier. This capture zone is also inferred as shown by the water table on Cross Section D-D' (Figure 4-27).

Although the clay barrier is constructed of low permeability material and inhibits liquids flow; model simulated particle tracking results suggest that contaminated landfill liquids may bypass and escape into the Central Drainage Area around the east end the clay barrier (Figures 4-46 and 4-47).

The impact of pumping the Gallery Well upon the vertical hydraulic gradient is illustrated by the equipotential lines on Cross Section D-D' (Figures 4-27). As described above, this cross section shows that the strong vertically downward gradients propagate from the North Ridge southward toward the southern half of the P/S landfill. The vertical gradient direction and magnitude at the southern end of the landfill is not known because there are no well clusters screened at different depths to determine actual vertical gradients. The regional interpretation in Cross Section D-D' is that the overall vertical gradient at the southern part of the landfill is moderate and slightly downward. A localized upward gradient is shown at the Gallery Well, but this upward gradient is interpretative and not based on gradient data from well clusters. While the true nature of the liquid gradients may vary, the Gallery Well acts to reduce hydrostatic stress within the saturated landfill and on the Clay Barrier.

4.5.3.2.5 Sump 9B and Road Sump

As described above, liquids extraction from Sump 9B and the Road Sump controls the seeps that seasonal occurred in the Central Drainage Area between the base of the P/S Landfill and PSCT-1. This liquid extraction also suppresses natural hydraulic gradients and reduces groundwater flow towards the PSCT.

Sump 9B is a gravel filled collection trench and associated extraction point installed approximately 200 feet downgradient (south) of the Gallery Well and upgradient of the PSCT. Sump 9B consists of a circular sump, approximately 27 feet deep and 12 feet wide. Extending approximately 100 to 150 feet westward from the sump is a shallow trench estimated to be 8 to 12 feet deep. The sump and trench are filled with gravel to approximately 6 feet below grade and covered with compacted fill material. An extraction point is installed at the deepest portion of the sump. Fluids removed from the sump currently are taken to a permitted, off-Site disposal facility.

The flat topography near Sump 9B promotes infiltration of rainfall runoff and groundwater recharge with groundwater encountered at only a few feet below ground surface. The increased groundwater recharge occurring in the Sump 9B vicinity counteracts the hydraulic impact of groundwater extraction. The local groundwater contours illustrated on Figure F-29 of Appendix F do not indicate the presence of a distinct capture zone associated with extraction at Sump 9B. During current pumping conditions, the water level in Sump 9B is usually maintained between 20 and 23 feet btoc (below top of casing), while the action level is 20 feet btoc. The CSC's current liquids extraction action level is as low as Sump 9B can be practically pumped. The CSC's historical and current action levels are as follows (Table 2-8):

Year	Sump 9B (ft, BTOC)
1997 - 2000	6
2000 - 2003	15
2003 - 2010	20

Liquid extraction rates over time from Sump 9B are presented on Figure 4-49 and liquid extraction levels are presented on Hydrographs F1-E2 and F1-U10 along with liquid levels of other piezometers within the Sump 9B area. The impact of groundwater extraction at Sump 9B is reflected in the observed drawdown in the five surrounding shallow piezometers, one monitoring well, the deeper "Companion Well," and inferred convergent flow toward the Sump.

The shallow water table near Sump 9B is illustrated in cross-section on Figure 4-51 and evidenced by a seep (the 9B Road Seep) that was observed south of Sump 9B in June 1998 (Figure 4-16). Consequently, in 1998 a collection sump was constructed near the seep, and is designated as the Road Sump. The Road Sump is operated on an as needed basis and, therefore, does not have a persistent hydraulic impact. Liquids extracted from the Road Sump are treated at the PSCT Granular Activated Carbon (GAC) Treatment System and discharged into Pond 18.

4.5.3.2.6 Perimeter Source Control Trench

As described in Section 2.2.3.2, Casmalia Resources constructed the Perimeter Source Control Trench (PSCT), a continuous collection trench approximately 2,650 feet long and nominally 3 feet wide. The design and construction of the PSCT is described in a Construction Report prepared by Brierly and Lyman (1989a). The PSCT is designed to intercept subsurface liquids migrating from north to south across the Site. These liquids originate from groundwater flow from the North Ridge, landfills, Burial Trench Area, and Central Drainage to the north.

The PSCT was installed in 1990, on an approximate east to west alignment, across most of the central portion of the Site and is situated downgradient of the five inactive landfill areas and the Burial Trench Area. The PSCT was excavated to depths ranging from approximately 13 to 65 feet, depending upon the depth at which unweathered claystone bedrock was encountered during construction. The major components of the PSCT include the placement of a filter fabric against the native alluvial or fill soils, a permeable gravel backfill, random backfill above the gravel, a low permeability cap to minimize water infiltration, and four collection sumps and associated extraction points. The gravel backfill extended approximately 10 feet above the highest level of groundwater seepage observed during excavation.

The four collection sumps were constructed by excavating pits into unweathered claystone bedrock, that is, the Lower HSU. The sumps were filled with gravel and screened casings to facilitate liquid removal. Liquid seepage collected in the PSCT flows along the bottom of the trench toward the center of each sump. Engineered divides isolate flow between the individual sumps. When liquid levels exceed the level of the flow divides, liquids flow along the base of the trench to the lowest point in the system, located at extraction point PSCT-1. Currently, liquids are extracted from the PSCT-1, PSCT-2, and PSCT-4 sumps in this barrier system. Action and operating water levels in these three sumps are currently below the Upper/Lower HSU Contact. PSCT-3 is also equipped with a dedicated extraction pump; however, liquid levels in the sump never reach the required action level of 51 feet btoc. Although liquids are not extracted from PSCT-3, the bottom of the trench in this area is below the natural water table elevation so the trench has the effect of liquids extraction because liquids gravity flow along the trench from PSCT-4 towards PSCT-3, as well as flow toward PSCT from the north and south. The CSC's current liquids extraction action levels are as low as the PSCTs can be practically pumped. The CSC's historical and current action levels are presented in Table 2-9 and summarized below:

Year	PSCT-1 (ft, BOTC)	PSCT-2 (ft, BTOC)	PSCT-3 (ft, BTOC)	PSCT-4 (ft, BTOC)
1997 - 2000	22	not pumped	not pumped	43
2000 - 2001	45	not pumped	not pumped	51
2001 - 2010	45	52	55	52

Liquids extracted from the PSCT are treated at the PSCT GAC Treatment System and discharged into Pond 18. Liquid extraction rates over time from PSCT-1 through -4 are presented on Figure 4-49 and liquid levels are presented on Hydrographs F1-E3. Groundwater levels are also presented on Hydrographs F1-U12, F1-U13, F1-U16, and F1-U18 along with water levels of other wells and piezometers in vicinity of the PSCT extraction sumps.

In June 1998, four wells were installed to delineate the capture zones downgradient of the PSCT extraction wells. Wells RG-1B and RG-1C are approximately 25 feet south of PSCT-1 and well RG-2B and RG 4B are approximately 25 and 50 feet downgradient of PSCT-4, respectively. Well RG-1C is completed in the Lower HSU and the remaining three wells are completed in the Upper HSU. Additional piezometers adjacent to the PSCT were installed during 2000 as part of RGMEW activities and in 2004 and 2006 as part of RI activities to delineate these capture zones.

Figure F-29 of Appendix F shows the water table elevation in the vicinity of the Central Drainage, along the PSCT, and the horizontal impact of groundwater extraction at PSCT-1, PSCT-2, and PSCT-4. Cross Sections C-C' (Figure F-25) and D-D' (Figure F-26) show the vertical groundwater gradients across PSCT-4 (Burial Trench Area) and across PSCT-1 (Central Drainage Area), respectively. Cross Section F-F' shows the vertical gradients along the length of the PSCT. As further described below, analysis of available groundwater elevation data indicates that the PSCT captures most groundwater migrating from north to south across the Site within the Upper HSU.

PSCT-1: During December 2008, the water level in well RG 1B (25 feet south of PSCT-1) was 14.86 feet higher than that measured in PSCT-1 and the water level in adjacent Upper HSU piezometer RIPZ-18, wells RIMW-2, and RG-7B, all located farther downgradient than well RG-1B, were 0.82, 8.69, and 0.70 feet higher, respectively, than that measured in well RG-1B. The December 2008 water levels demonstrate a northern horizontal gradient into PSCT-1 from the south indicating that the PSCT in this area captures southward groundwater flow within the Upper HSU. Hydrograph F1-U12 shows that the water levels in wells RIPZ-18, RIMW-2, and RG-7B have consistently been higher than the water levels at wells RG-1B and PSCT-1. This inferred capture by PSCT-1 is supported by the model simulated particle tracks for the 2001 (wet) conditions (Figure 4-46). However, the 2004 (dry) model simulated particle tracks pass through the trench in this area indicating some uncertainty during drier conditions when a recharge mound from precipitation may not be present to the south of PSCT-1 (Figure 4-47). The bypass of the trench may be an artifact of the model, i.e., the model seeks a continuum, when in actuality the trench likely runs dry. This is consistent with the historical water levels where the well RG-7B water level is higher than well RG-1B water level in 2001 (wet) but lower than the well RG-1B water level in 2004 (dry).

Upward vertical groundwater gradients occur at PSCT-1 as demonstrated at the following well clusters for December 2008 data (see Cross Sections D-D' and F-F'):

PSCT-1 Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Extraction Well	PSCT-1	RG-1C	-21.73	n/a	F1-E3 / F1-U12, F1-L24
Extraction Trench Area	RG-1B	RG-1C	-6.87	-0.12	F1-U12, F1-L24

The water level in adjacent Lower HSU well RG-1C near well RG-1B was approximately 6.87 foot higher than that measured in the well RG-1B during December 2008. These water level differences demonstrate the continued presence of an upward groundwater gradient near PSCT-1. Although an upward gradient exists, the model simulated particle tracks indicate that groundwater within the Lower HSU may pass beneath the PSCT (Figure 4-48). Any groundwater flow under the PSCT would be relatively small due to the low hydraulic conductivity of the Lower HSU.

PSCT-2: Sufficient piezometers do not exist to demonstrate hydraulic capture at PSCT-2. Although several piezometers exist (RIPZ-6, -7, -11, and -19), the rapid change in ground surface and HSU contact elevations in this area makes the capture zone assessment uncertain. Hydrograph F1-U13 shows the historical water levels at these piezometer locations. During December 2008, an apparent horizontal inward gradient to the extraction well from the south was observed with downgradient piezometers RIPZ-19 and RIPZ-11, which exhibited water levels 12.90 and 1.71 feet higher, respectively, than PSCT-2. Two additional piezometers RIPZ-6 and -7 located south of PSCT-2 did not indicate an inward gradient to the extraction Sump, however, piezometer RIPZ-6 was not in equilibrium and piezometer RIPZ-7 was dry during December 2008. Lithologic observations during drilling and installation of piezometers RIPZ-6 and -7 indicated extremely ”tight” drilling conditions in the area south of PSCT-2, consistent with the ongoing non-equilibrium of water levels in those wells associated with their installation and initial development in 2004.

Downward vertical groundwater gradients occur at PSCT-2 as indicated by December 2008 data (see Cross Section F-F’). The model simulated particle tracks indicate that groundwater within the Lower HSU may pass beneath the PSCT in this area (Figure 4-48). Any groundwater flow under the PSCT would be relatively small due to the low hydraulic conductivity of the Lower HSU.

PSCT-3: During December 2008, the water level in piezometer RIPZ-20 (south of PSCT-3) was 3.89 feet higher than that measured in PSCT-3. However, the water level in adjacent Upper HSU well WP-3S was 6.78 feet lower than at piezometer RIPZ-20 and 2.89 feet lower than at PSCT-3. This indicates that the horizontal capture zone may be localized around PSCT-3. Hydrograph F1-U18 shows that these relative water level differences have been historically similar.

Slight downward vertical groundwater gradients occur at PSCT-3 as demonstrated at the following well clusters for December 2008 data (see Cross Sections C-C’ and F-F’):

PSCT-3 Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Extraction Well	PSCT-3	RGPZ-16D	2.04	n/a	F1-E3 / F1-U18, F1-L18
Trench Area	RGPZ-15B	RGPZ-16D	4.70	0.03	F1-L18
Trench Area	RP-55C-2	RGPZ-14D	1.17	0.02	F1-L18

The model simulated particle tracks indicate that groundwater within the Lower HSU may pass beneath the PSCT in this area (Figure 4-48). Any groundwater flow under the PSCT would be relatively small due to the low hydraulic conductivity of the Lower HSU.

PSCT-4: At PSCT-4, an inward gradient to the extraction well from the south was observed during December 2008, with downgradient well RG-4B exhibiting a water level 13.77 feet higher than that in PSCT-4. Downgradient well RG-2B (between PSCT-4 and well RG-4B) was dry during the December 2008 monitoring event. The total depth (TD) elevation of dry well RG-2B is above the well elevation RG-4B, as such, a dry reading from well RG-2B does not assist in demonstrating capture. An inward gradient toward the extraction point was not indicated in downgradient well RIMW-5 during December 2008, as the water level there was 4.49 feet lower than that in PSCT-4; consistent with historical data. Hydrograph F1-U16 shows the historical water levels at these locations. The inferred capture by PSCT-4 is supported by the model simulated particle tracks for the 2001 (wet) and 2004 (dry) conditions (Figures 4-46 and 4-47).

As expected, the December 2008 water levels in piezometers RIPZ-9 and RIPZ-16, both upgradient of the PSCT, indicated an inward gradient to the extraction well consistent with the southward groundwater flow direction north of the trench (water levels 12.77 and 14.86 feet higher than PSCT-4, respectively).

Slight upward groundwater gradients occur at PSCT-4 as demonstrated by the two closest piezometers pairs (RGPZ-3C/RGPZ-3D and RG-4B/RGPZ-4C) near PSCT-4 (see Cross Sections C-C' and F-F'):

PSCT-4 Area	Well 1	Well 2	Vertical Water Level Difference (feet)	Vertical Gradient (ft/ft)	Hydrograph
Extraction Well	PSCT-4	RGPZ-3D	-14.38	n/a	F1-E3 / F1-U16, F1-L16
Trench Area	RGPZ-3C	RGPZ-3D	0.07	0.00	F1-L16
Trench Area	RG-4B	RGPZ-4C	-0.90	-0.01	F1-U16, F1-L17
Trench Area	RP-3B	RP-3D	3.82	0.05	F1-U17, F1-L17

The model simulated particle tracks indicate that groundwater within the Lower HSU may pass beneath the PSCT in this area (Figure 4-48). Any groundwater flow under the PSCT would be relatively small due to the low hydraulic conductivity of the Lower HSU.

4.5.3.2.7 Plume Capture Collection Trenches (PCTs)

As described in Section 2.2.3.2, Casmalia Resources constructed the following perimeter control trenches (PCTs) at the head of the A-, B-, and C-Drainages to intercept groundwater at the Site boundary and prevent off-Site migration of groundwater contaminants; features of each PCT, include:

- A-Drainage (PCT-A) – A "Plume Capture Trench" with three extraction wells (RAP-1A, RAP-2A, RAP-3A) was installed in 1989.
- B-Drainage (PCT-B) – A subsurface clay barrier and extraction trench system with one extraction well (B-5) was installed in 1972/1973. A "Plume Capture Trench" with one extraction well (RAP-1B) was installed in 1989 immediately downgradient of the initial system.

- C-Drainage (PCT-C) – A subsurface clay barrier and extraction trench system with one extraction well (C-5) was installed in 1982 along the southern extent of the current-day A-Series Pond. A complementary "Plume Capture Trench" with one extraction well (RAP-1C) was installed in 1989 along the western extent of the current-day A-Series Pond.

The design and construction of the B- and C- Drainage clay barrier and extraction trench systems are described in Construction Reports prepared by Penfield & Smith (1973; 1982). The design and construction of the PCTs are described in the Construction Report prepared by Brierly and Lyman (June 1989b). In 1990, Brierly and Lyman evaluated the performance of the PCTs (Brierly and Lyman, 1990). An updated analysis of the hydraulic effectiveness of the PCTs was also presented in the Technical Memorandum (ICF Kaiser, 1998), and compared to the Brierly and Lyman study. The CSC's current liquids extraction action levels are as lows as the PCT's can be practically pumped. The CSC's historical and current action levels are as presented in Table 2-10 and summarized below:

	PCT-A			PCT-B	PCT-C	
Year	RAP-1A (ft, BTOC)	RAP-1B (ft, BTOC)	RAP-1C (ft, BTOC)	RAP-2A (ft, BTOC)	RAP-3A (ft, BTOC)	C5 (ft, BTOC)
1997 - 2009	36	65.8	59.8	51.7	49.5	75
2009 - 2010	29	61	55	45	44	77

Liquid extraction rates over time from PCT-A through -C are presented on Figure 4-50 and liquid extraction levels are presented on Hydrographs F1-E3 and F1-E4.

PCT-A: In 1981, a subsurface clay core barrier was constructed along the eastern and southern perimeter of former Pond 20. Records of field inspections conducted during construction indicate that the excavation for the clay core of the barrier wall was 15 feet wide and extended into firm claystone bedrock. In 1990, a gravel filled trench (PCT-A) and associated groundwater extraction points (RAP-1A, RAP-2A, and RAP-3A) were installed to collect and pump groundwater at the southeast corner of the facility. The extraction points were constructed as an additional means for intercepting groundwater flowing toward the A-drainage area (Figure F-30, Appendix-F).

Groundwater flow at the southeastern perimeter of the Site is directed into the A-Drainage due to the presence of a prominent hill south of the Zone 1 boundary that separates the A-Drainage from the B-Drainage. Groundwater recharge through this hill causes a reversal of the flow gradient immediately south of the Site boundary. This topographically induced groundwater barrier is complemented by the presence of the PCT-A, which extends eastward across the head of the A-Drainage.

Water levels in all three PCT-A extraction wells are generally maintained between 10 to 30 feet lower than the prevailing water levels immediately downgradient of the PCT. This generally demonstrates the reversal in groundwater gradients by the operation of PCT-A, and the effective prevention of groundwater movement from the Site into the A-Drainage. During December 2008, the water level in piezometer RIPZ-4 (25 feet south of RAP-1A) was 10.1 feet higher than the water level measured in well RAP-1A and the water level in adjacent downgradient Upper HSU piezometer RIPZ-3 (25 feet south of RIPZ-4) was 0.69 feet lower than piezometer RIPZ-4. As noted above for the A-Drainage, the water levels for wells MW-18C and MW-18D located near well RAP-1A indicate neutral to upward vertical gradients. Hydrograph

F1-U12 shows that the water levels in piezometers RIPZ-3 and RIPZ-4 have consistently been within 1-foot of one another and that the vertical gradient has been consistently neutral to upward.

The 2001 (wet) and 2004 (dry) model simulated “reverse” particle tracks indicate that the source of groundwater to well RAP-1A is immediately to the north and east of the upgradient hillside (Figures F3-88 and F3-99). The modeling indicates that RCF surface water is not a source of recharge to well RAP-1A. This observation is supported by a difference in general chemistry concentration trends between RCF surface water (Graph G1-29) and well RAP-1A extracted liquids (Graph G1-25). These chemistry trends would be similar if on-Site RCF surface water were a source of recharge to well RAP-1A.

Unlike well RAP-1A, much of the extracted groundwater at wells RAP-2A and RAP-3A likely originates from the nearby RCF Pond and the hill south of PCT-A. The water level in the RCF Pond during December 2008 was approximately 42 feet higher than in well RAP-3A, which is less than 200 feet from the southern perimeter of the pond. The 2001 (wet) and 2004 (dry) model simulated “reverse” particle tracks show that RCF surface water is a source of recharge to well RAP-2A and RAP-3A. This observation is consistent with chemistry trends between surface water and groundwater (i.e., the extracted liquids concentrations (Graphs G1-26 and G1-27) increase with RCF surface water concentration increases (Graph G1-29). In addition, the general chemistry concentrations in the A-Drainage downgradient wells do not show increases consistent with RCF surface water concentration increases, further supporting that on-Site RCF surface water is not moving off-Site (see respective G1 graphs).

Hydrographs of groundwater elevations at the three PCT-A extraction points and nearby observation wells are presented in Attachment F-1. As illustrated on Hydrographs F1-U22 and F1-U25 measured water levels in the extraction wells indicate seasonal water level variations are minimal between the RGMEW monitoring events from September 1997 to March 2009.

PCT-B: In 1973, a subsurface clay barrier was installed directly downgradient from Pond 13 between the two low hills flanking the head of the B-Drainage. This clay barrier was constructed to restrict groundwater flow entering the B-Drainage area. The barrier is reported to be 8 feet wide and approximately 50 feet deep, extending about 4 feet into unweathered claystone. In addition, a 1-foot wide gravel perimeter trench (PCT-B) and a former extraction point (B-5) were constructed downgradient of the clay barrier to assist in groundwater collection and removal. The pump in well B-5 has since been removed and there are no current plans to replace it.

PCT-B contains an extraction well (RAP-1B), which is directly south of Pond 13 in the B-Drainage. Figure F-31 of Appendix F shows the December 2008 water table surface in the vicinity of PCT-B. During December 2008, the groundwater elevation in well RAP-1B was 1.65 feet lower than the groundwater elevation in well B-5. The lower water level in PCT-B does not indicate that the facility is effective in preventing off-Site groundwater flow because it is downgradient (south) of well B-5. In addition, the water level in piezometer RIPZ-2 (located 25 feet south of well RAP-1B) is 0.28 feet lower than the water level in well RAP-1B, which does not support an interpretation of capture. Hydrograph F1-U27 shows the water levels in wells B-5, RAP-1B, and RIPZ-2. The water level in well RAP-1B has historically been maintained at a much lower elevation (~350 feet msl) than the December 2008 level (379.39 feet, msl). Maintaining a lower extraction level would induce stronger capture. However, a significant source of recharge to well RAP-1B has been surface water from Pond 13 and/or the RCF based on the similarity in general chemistry concentration trends between Pond 13 surface water

(Graph G1-17), RCF surface water (Graph G1-29), and well RAP-1B extracted liquids (Graph G1-26).

As noted above for the B-Drainage, the water levels located near RAP-1B indicate upward vertical gradients. These upward gradients in the drainage bottom may in part be induced by rainfall recharge on the neighboring hillsides causing groundwater flow to converge at the drainage bottom.

Although complete groundwater capture is not definitely demonstrated, the general chemistry concentrations in the B-Drainage downgradient wells do not show increases consistent with Pond 13 or RCF surface water concentration increases, supporting that on-Site Pond 13 or RCF surface waters are not moving off-Site (see respective G1 graphs).

Groundwater flow in the vicinity of PCT-B is further impeded by the reversal in groundwater gradients that occur immediately south of the Site. The two prominent hills in Zone 2 on either side of the B-Drainage, where the topography rises to an elevation of more than 150 feet above the topographic elevation of the southern perimeter of Zone 1. These topographic highs result in corresponding increases in groundwater elevation on either side of the B-Drainage. The net result is that groundwater gradients are oriented northward towards the Zone 1 Site boundary, or directed into the B-Drainage. Thus, the head of the B-Drainage serves as a groundwater divide, preventing groundwater from flowing past PCT-B. The eastern and western edges of PCT-B terminate within these adjacent hills.

Hydrographs of groundwater elevations in RAP-1B and nearby observation wells are presented in Attachment F-1. As illustrated on Hydrograph E5, measured water levels in the RAP-1B well between the RGMEW monitoring events from September 1997 to March 2009 are observed to fluctuate between about 350 feet elevation to 383 feet elevation, there is no apparent seasonal trend to the observed variation in water levels within well RAP-1B, suggesting that the observed fluctuation may be related to pumping cycles in the well.

PCT-C: A perimeter control feature consisting of a clay barrier and a separate extraction trench was constructed southwest of the A-Series Pond to intercept groundwater migrating southwest from Zone 1 toward the C-Drainage and Casmalia Creek (Appendix F, Figure F-32). The extraction trench is 305 feet long and was constructed at the western end of the clay barrier. One sump and extraction well RAP-1C was constructed within the trench. The clay barrier is over 1,000 feet long and was constructed at the south edge of the current-day A-Series Pond. A subsurface liquids collection system consisting of perforated horizontal pipe connected to one extraction well (C-5) exists along the length of the clay barrier. The close proximity of the A-Series Pond to PCT-C makes it difficult to achieve the target water levels while water levels in the A-Series Pond remain high.

December 2008 and historical water levels in PCT-C and adjacent observation wells indicate that, under normal operations, a significant capture zone exists south of PCT-C and horizontal gradients are reversed. The water level in piezometer RIPZ-20 (located 25 feet south of well C-5) is 3.89 feet higher than the water level in well RAP-1C. However, the water level in well RIMW-9 (25 feet south of well RIPZ-20) is 0.88 feet higher than well RIMW-9, which may not support an interpretation of capture. Hydrographs F1-U34 and F1-U35 show the water levels in the RAP-1C and C-5 area wells, respectively. The water levels in wells RAP-1C and C-5 are currently being maintained at historically low levels. A significant source of recharge to wells RAP-1C and C-5 has been surface water from the A-Series Pond based on the similarity in

general chemistry concentration trends between A-Series Pond surface water (Graph G1-2), RAP-1C extracted liquids (Graph G1-27), and C-5 extracted liquids (Graph G1-7).

As noted above for the C-Drainage, the water levels located near wells RAP-1C and C-5 indicate upward vertical gradients. These upward gradients in the drainage bottom may in part be induced by rainfall recharge on the neighboring hillsides causing groundwater flow to converge at the drainage bottom.

Although complete groundwater capture is not definitely demonstrated, the general chemistry concentrations in the C-Drainage in downgradient wells do not show increases consistent with A-Series Pond surface water concentration increases, supporting that on-Site A-Series Pond surface waters are not moving off-Site (see respective G1 graphs).

At the southeastern end of the clay barrier, groundwater is impeded by a reversal in the groundwater gradient due to the hill between the B- and C-Drainages. Groundwater flow past the western end of the clay barrier is prevented by groundwater extraction from the PCT-C trench. Thus, PCT-C appears to be effectively preventing off-Site migration of groundwater in this vicinity.

Hydrographs of groundwater elevations in wells RAP-1C and C-5, and nearby observation wells are presented in Attachment F-1. As illustrated on Hydrograph E5, measured water levels in wells RAP-1C and C-5 between the RGMEW monitoring events from September 1997 to March 2009 are observed to fluctuate between about 377 feet elevation to 420 feet elevation, there is no apparent seasonal trend to the observed variation in water levels within wells RAP-1C and C-5, suggesting that the observed fluctuation may be related to pumping cycles in the wells

4.5.3.3 Groundwater Flow Velocities

Ranges of horizontal groundwater flow velocities have been calculated using representative hydraulic conductivities, hydraulic gradients, and porosities for the Upper and Lower HSUs (ICF Kaiser, 1998a). Flow velocities were estimated using Darcy's Law. The range of hydraulic conductivities used represents the highest and lowest Upper HSU values estimated from all permeameter, slug, pumping, and packer tests conducted. The mean value is the geometric mean of values from all tests conducted. Representative hydraulic gradients were calculated for the Upper HSU both north and south of the PSCT. Fracture porosities were estimated from infiltration test IP-1 and literature.

The following table summarizes representative groundwater velocities using combinations of the aquifer hydraulic parameters. The low velocities were estimated from low hydraulic conductivity and high fracture porosity values. The medium velocities were estimated from the medium hydraulic conductivity and fracture porosity values, and the high velocities were estimated from the high hydraulic conductivity and medium low fracture porosity values. In accordance with EPA's June 18, 2003 comments, the high velocity estimates were recalculated using this combination of parameter values. However, because aquifer permeability appears to be a function of fracture intensity, it is unlikely that the highest velocities presented below are realistic, as it is unlikely that an aquifer zone would simultaneously exhibit both high hydraulic conductivity and low fracture porosity.

HSU Subarea	Hydraulic Gradient (cm/cm)	Hydraulic Conductivity (cm/sec)		Fracture Porosity		Fracture Flow Rate (feet/year)	
Upper HSU North of PSCT	0.2	low mean high	1.8×10^{-09} 1.05×10^{-05} 8.9×10^{-03}	low medium high	1 5 25	low medium high	1.49×10^{-05} 0.4 1,840
Upper HSU South of PSCT	0.08	low mean high	1.8×10^{-09} 1.05×10^{-05} 8.9×10^{-03}	low medium high	1 5 25	low medium high	5.96×10^{-06} 0.2 735
Lower HSU	0.1	mean	1.03×10^{-06}	estimated	1	mean	0.1

Aquifer tests performed on wells completed in fill or alluvium yielded hydraulic conductivity values ranging from Note the high velocity estimates presented above likely are not representative of actual flow and transport rates, as it is unlikely that the highest hydraulic conductivity values used in the calculations are representative of the system as a whole or exist along any extended flow path through the system. Moreover, the actual groundwater flow rates through fractures occur along three-dimensional flow-paths, and are not equivalent to the two-dimensional velocity between two locations at the Site. To determine the equivalent velocity between any two locations on a plan view map, the flow path tortuosity must be taken into account.

As described in the HSCER (Section 9.3.3.1, Page 9-33, Woodward-Clyde Consultants, 1988a), potential solute transport rates also were estimated based on Carbon-14 isotope age-dating of groundwater in the Lower HSU, as well as on observed contaminant migration in the Upper HSU.

HSU	Solute Transport Rate
Upper HSU	10 ft/year
Lower HSU	0.15 to 0.9 ft/year

The comparability between the solute transport rate and the matrix groundwater flow rate in the Lower HSU indicates the importance of diffusion and adsorption in solute transport.

The large hydraulic conductivity contrast between the Upper and Lower HSUs, and decreased fracture density suggest that the groundwater flux rate in the Lower HSU is less than 10 percent that of the Upper HSU, although there is a possibility that significant fluxes could occur between the HSUs.

Order of magnitude estimates of groundwater velocity also were calculated between well pairs in the Lower HSU using the Carbon-14 data (ICF Kaiser, 1998a). The velocities between wells RP-1D and RP-4D and between wells RP-4D and RP-6D were 0.9 ft/yr and 0.2 ft/yr, respectively.

4.5.3.4 Summary of Groundwater Chemistry

Groundwater in the Site vicinity is naturally of poor quality, due to low flow rates resulting in extended contact with the aquifer materials and high evaporation. TDS concentrations measured at locations up-gradient and cross-gradient of the Site range from 900 to 12,000 milligrams per liter (mg/L). The marine origin of the claystone and the slow migration rate of the groundwater result in a chemistry that includes significant concentrations of seawater

constituents. These constituents include cations; sodium, magnesium, potassium, and calcium, and anions; chloride and sulfate. The slow movement of groundwater through the rock allows dissolution of these constituents from the claystone into groundwater at high concentrations. Similar observations have been made regarding the historical data for iron, manganese, barium, copper, zinc, nickel, cadmium, antimony, selenium and other trace metals. Groundwater is generally of the sodium-chloride type in the Upper HSU, and the sodium-chloride or sodium-sulfate type in the Lower HSU. Near the landfill cells and PSCT, groundwater tends to be more of the magnesium-sulfate variety.

As a result of Site historical operation as a Class I landfill, Site groundwater is impacted by a wide variety of organic and inorganic chemicals. Site related groundwater contamination is generally limited to Zone 1 (on-Site). Most of the contamination within Zone 1 exists north of the PSCT although elevated concentrations of organics and inorganics also exist south of the PSCT.

Volatile organic compounds (VOCs) are the most prevalent and mobile organic contaminants, and therefore, used to characterize Site contamination as a whole for organic compounds. Semi-volatile organic compounds (SVOCs), polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), herbicides, pesticides, and dioxins/furans are also present, among others. Contaminants are also present as light non-aqueous phase liquids (LNAPLs) and dense non-aqueous phase liquids (DNAPLs). Free-phase (mobile) LNAPLs and DNAPLs have only been directly measured in piezometers and wells in the Central Drainage Area and Pesticides/Solids Landfill, but are suspected to be present at residual amounts in the Burial Trench Area based on observations during drilling, dissolved concentrations, and historical use.

Elevated concentrations of metals, arsenic, selenium, cadmium, and nickel are likely related to Site activities; these metal exits on-Site at concentrations above drinking water primary maximum contaminant levels (MCLs). Iron and manganese also occur at elevated concentrations but do not have primary MCLs, but do occur at concentration above their respective secondary MCLs. These six metals exceed their primary and secondary MCLs across broad areas of the Site. Arsenic is used as the proxy dissolved metal to characterize Site metals' contamination.

4.5.3.4.1 Summary of Contamination

Organic Contamination

Groundwater contamination is predominantly located within the Zone 1 Site boundary; sporadic, low level contamination occurs within Zone 2. In the Upper HSU, VOC contamination zones are separated by the PSCT. The Zone 1 area north of the PSCT contains the majority of the dissolved phased VOC contamination and all of the known NAPL contamination. The northern extent of the Upper HSU contamination from east to west occurs in the western portion of the Caustic/Cyanide Landfill, the western half of the Acids Landfill, the southern portion of the Metals Landfill, the northern portion the P/S Landfill and at the Burial Trench Area south of the PCB Landfill (Appendix G, Figures G-21 through G-25). The eastern extent of VOC contamination is delineated by several monitoring wells near the eastern extent of the PSCT and North Ridge wells, while the western extent of the VOC contamination is delineated by RI monitoring wells on the North ridge and west of the PSCT. The VOC plumes in the Upper HSU beneath the Landfills converge and flow into the Central Drainage Area and into the PSCT in the PSCT-1 area. The VOC plume in the Upper HSU in the Burial Trench Area flows south into

the PSCT in the PSCT-4 area. The distribution of VOC contamination in the Upper HSU is consistent with groundwater flow directions (Appendix F).

The P/S Landfill and Central Drainage Area are the only areas of the Site where both DNAPL and LNAPL in the Upper HSU were observed during drilling, gauged in routine liquid level monitoring, and inferred based on the concentrations of dissolved compounds. The Central Drainage Area is the only area of the Site where DNAPL was gauged in routine liquid level sampling and inferred based on the concentrations of dissolved compounds. There is also an area of contamination located in the Burial Trench Area that extends to the southern portion of the PCB Landfill; fluids within this area flow towards the PSCT. The Burial Trench Area was investigated for the presence of DNAPL and LNAPL, and although dissolved VOC concentrations are relatively high, no NAPL are observed in wells or piezometers during RGMEW liquid level monitoring. Any NAPL in the Burial Trench Area is likely at residual levels.

Based on the distribution and concentrations north and south of the PSCT; the PSCT appears to contain the majority of VOC contamination in the northern areas. Together with naturally occurring attenuation process, the PSCT acts to prevent contaminant movement to areas south of the trench.

Upper HSU VOC contamination in groundwater south of the PSCT is the highest near PSCT-1 and PSCT-4. The contamination in these two areas is typically one to two orders of magnitude lower in concentration than the concentrations observed in the Burial Trench Area and the Central Drainage Area. Most of the VOC contamination in the area south of PSCT-1 and PSCT-4 was likely present before the PSCT was installed. The area downgradient of the PSCT was formerly used to store liquids in ponds, and Site-related impacts to this area have been reported in previous documents (Woodward Clyde Consultants and Canonie Environmental, 1989). Although the data are limited, pond closure and the subsequent construction of the PSCT appear to have resulted in stable or declining concentrations of organic compounds in most monitoring wells in the area downgradient of the PSCT. Therefore, detection of organic compounds downgradient of the PSCT likely reflects pre-existing contamination rather than contamination due to plume migration. The VOC contamination sharply declines north of the current Ponds and is generally not detected south of the five remaining Ponds.

The majority of the sampling locations in Lower HSU did not indicate the presence of VOCs. However, VOCs are detected within the following four areas of the Lower HSU:

- North Ridge
- Burial Trench Area;
- Central Drainage Area (including the southern edge of the Acids Landfill)
- Along the PSCT, including at extraction wells PSCT-1, PSCT-3, and PSCT-4.

The area associated with the least amount of contamination of the four areas in the Lower HSU is along the North Ridge and PSCT, which have concentrations typically below the MCL/PRG. The Central Drainage Area exhibits the highest levels of VOC contamination in the Lower HSU, and is the only area in the Lower HSU where mobile DNAPL is present. The Lower HSU VOC contamination in the Central Drainage Area appears related to overlying Upper HSU VOC contamination present within the southern portion of the P/S Landfill and between P/S Landfill and PSCT-1 area.

Metals

Dissolved concentrations of Arsenic and other metals are elevated within the Upper HSU of Zone 1 but are generally not elevated in Zone 2. The higher concentrations of metals in the Upper HSU are located within the Burial Trench Area and the Central Drainage Area. These elevated metals are also present in extracted liquids and in the Ponds. Pond 13 has the highest concentrations of dissolved metals of the surface water features sampled. Metals concentrations in the Lower HSU are lower than in the Upper HSU; the highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the border of Zone 1 and Zone 2. The metal concentrations in the Lower HSU do not obviously appear to coincide with the elevated Upper HSU concentrations. It is not clear if the elevated metals in the Lower HSU under the North Ridge are from Site-related impacts. Elevated metals also occur in the Lower HSU at the Burial Trench Area, Central Drainage Area and along the PSCT where there are elevated VOCs.

General Chemistry

General chemistry of groundwater is also affected by Site impacts. General chemistry includes total dissolved solids concentrations and the major ion concentrations (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate alkalinity), dissolved oxygen, pH and oxidation reduction conditions. Overall groundwater is mostly sodium-chloride type water. TDS concentration in the off-Site alluvium along Casmalia Creek is less than 2,000 ppm. TDS in off-Site weathered and unweathered claystone is variable and often exceeds 5,000 ppm and can exceed 10,000 ppm. The TDS of impacted groundwater is not always higher than background conditions because of dilution from rainfall infiltration. The highest TDS occurs in liquids extracted from the Gallery Well which can range from approximately 15,000 ppm to 20,000 ppm with a pH of less than 5. Other than the Gallery Well, the highest elevated TDS concentrations range from 10,000 ppm to 15,000 ppm. This dissolved oxygen level in groundwater is less than 1 mg/L in the most impacted areas north of the PSCT.

The highest TDS concentrations at the Site are in surface water of the five ponds. The TDS is elevated through evaporation and exceeds 20,000 ppm in most ponds. Salts and metals increase over time because these are terminal ponds with no outflow. TDS concentration increase year-to-year, with temporary dilution during winter storm water runoff events.

4.5.3.4.2 Radionuclides and Stable Isotopes

Casmalia Resources investigated radionuclide and stable isotopes in Site groundwater to determine groundwater age and areas of recharge. The results of this work are presented in the HSCER (Woodward-Clyde Consultants, 1988a). The CSC collected and analyzed groundwater samples from select wells to confirm the prior results and built on this dataset to further determine groundwater age. The results are summarized below and discussed in more detail in Section 3.2 of Appendix G.

As described below, there is uncertainty in the age dating methods used. For example, the maximum age estimates using ^{14}C range from 2,700 to 5,200 years before present (ybp, “present” equals 1950A.D), for the Upper HSU and 24,900 to 42,300 ybp for the Lower HSU. This may indicate that groundwater in the Lower HSU cannot be affected by Site related contaminants. However, as described in Section 5, both organic and inorganic contaminants are observed in the Lower HSU, particularly between the North Ridge and the PSCT where there are strong vertically downward hydraulic gradients into the Lower HSU. While a useful

exercise, the age dating data contain sufficient uncertainty that they cannot be used as an interpretive tool without other Site information on the nature and extent of contamination.

Historical Studies

The relative age of groundwater in the Upper and Lower HSU was previously estimated using ^{3}H and ^{14}C dating techniques. Detailed descriptions of the studies are presented in the HSCER (Woodward-Clyde Consultants, 1988a), in Section 9.3.3 (pages 9-33 through 9-39). Groundwater velocity calculations, based on the groundwater age dating, are presented in the HSCER in Appendix C.8. A summary of the data presented in the HSCER, including wells sampled, screen depth, water levels, TDS data, and the results of the ^{14}C and ^{3}H testing, is included in Appendix G – Figure G-37 (this data is also presented graphically in Appendix G – Figure G-38).

^{14}C analysis was completed to provide better resolution of the groundwater age, particularly for the Lower HSU. The maximum age estimates range from 2,700 to 5,200 years before present (ybp, "present" equals 1950A.D), for the Upper HSU and 24,900 to 42,300 ybp for the Lower HSU. Measurements of ^{14}C indicate that most of the carbon in groundwater was derived from dissolution of carbonate minerals, resulting in an over estimate of the ages. Three models were applied to correct the ages, resulting in values ranging from 0 to 2,700 ybp for the Upper HSU, and 1,670 to 39,600 ybp for the Lower HSU. The range of ages calculated for the Lower HSU suggests that the groundwater in the deepest screened portion of the Lower HSU is not ancient connate seawater, but may be up to 39,600 years old.

Order of magnitude estimates of groundwater velocity were calculated between well pairs in the Lower HSU using the ^{14}C data. The first pair included well RP-1D on the North Ridge above the former RCRA Landfill and well RP-4D to the south-southeast, generally between Pond 18 and RCF Pond. The second pair included well RP-4D and RP-6D to the south-southeast, south of the PCT-B trench. The groundwater velocity between RP-1D and RP-4D was calculated to be 0.9 feet per year (ft/yr) and the groundwater velocity between RP-4D and RP-6D was calculated to be 0.2 ft/yr (Woodward-Clyde Consultants, 1988a). The research and consulting community clearly recognizes that ^{14}C age dating techniques for groundwater produce estimated results that include a certain degree of uncertainty. The CSC believes that the spatial coverage and the methods used, associated with work presented in the HSCER, are sufficient and appropriate.

The ^{3}H concentrations generally are higher at shallow depths within the Upper HSU and decrease with depth in the Lower HSU. Groundwater may be interpreted as being younger than 1953 if there are significant ^{3}H concentrations. In generally, the ^{3}H concentrations will decrease with depth as the ^{3}H decays, dilutes with mixing, and attenuates by other naturally occurring mechanisms. The ^{3}H results for the Upper HSU indicated the presence of younger "post-bomb" water. The Lower HSU results were near or below the detection limit for ^{3}H activity, demonstrating the groundwater in some of the deepest wells in the Lower HSU is older than 1953 and is "pre-bomb." Low levels of ^{3}H in the Lower HSU do not necessarily mean that the groundwater is older than 1953. The lower ^{3}H levels may be consistent with ^{3}H decay, dilution, and other natural attenuation effects along the groundwater flow path. Appendix G – Figure G-38 presents existing Site ^{3}H data plotted versus depth, which reveals a distinct trend of decreasing ^{3}H with depth.

Current Studies

In order to compare with existing data collected during the HSCER scope of work, and as discussed with the EPA, the CSC collected additional groundwater samples for, ^{14}C, carbon-13/carbon-12 ($^{13}C/^{12}C$), and ^{3}H analyses. The samples were collected from wells and piezometers RGPZ-2C, RGPZ-2D, RGPZ-15B, RGPZ-16D, RP-62B-1, RP-62D-2, RP-65B, RP76A, RP-107D, and SW-31. Appendix G – Figure G-39 illustrates the current and historical ^{14}C, $^{13}C/^{12}C$, and ^{3}H results collected at the Site dating from the HSCER. Additional information associated with the wells that were sampled is also provided on Appendix G – Figure G-39. Results are summarized below and laboratory reports are included in Appendix G – Attachment G-3.

Well	**HSU**	**Sampling Event**	^{3}H **Units**
SW-31 (original)	Fill/Lower	14th SA/RI	2.80
SW-31 (duplicate)	Fill/Lower	14th SA/RI	2.73
RP-76A	Alluvium	14th SA/RI	0.32 (average of duplicates)
RGPZ-15B	Lower	14th SA/RI	0.09
RP-107D	Lower	14th SA/RI	0.00
RGPZ-2C	Lower	14th SA/RI	0.01
RGPZ-16D	Lower	14th SA/RI	0.05
RP-65B	Upper/Lower	14th SA/RI	0.29 (average of duplicates)
RGPZ-2D	Lower	15th SA/RI	-0.03
RP-62B-1	Lower	15th SA/RI	0.06
RP-62D-2	Lower	15th SA/RI	-0.11
Gallery Well	Upper/Lower	19th SA	226

According to the ^{3}H results tabulated above, well SW-31 is producing water most likely formed within the last 35 years, possibly during the late 1960s, whereas all other wells, with the exception of the Gallery Well, produced groundwater samples with lower ^{3}H results that may predate the atomic bomb, and are therefore considered “old” waters. Previous studies determined that groundwater extracted from wells developed in fill resulted in the largest ^{3}H content and that concentrations decreased with depth. Values for ^{3}H in the Upper HSU indicate the presence of some “post-bomb” water, while values from the Lower HSU are an order of magnitude lower than those from the Upper HSU. The samples collected from wells RGPZ-2D and RP-62D have negative tritium unit (TU) values implying that if there is any “post-bomb” water present in the Lower HSU, it has been diluted to the point of being immeasurable. ^{3}H levels are commonly elevated in landfill leachate, and therefore, the high ^{3}H value observed for the Gallery Well is not considered unusual. Elevated ^{3}H levels in landfill leachate are generally attributed to the disposal of luminescent paints or of self-luminescent exit signs, or dials and gauges within the landfill.

The following are the ^{14}C results for the eleven samples, each of which provided adequate amounts of carbon for accurate measurements:

Well	HSU	Sampling Event	Apparent ^{14}C Age (years BP)	Conventional ^{14}C Age (years BP)	$^{13}C/^{12}C$ Ratio (o/oo)
SW-31 (original)	Fill/Lower	14th SA/RI	9,690 +/- 60	4,800	-11.7
SW-31 (duplicate)	Fill/Lower	14th SA/RI	9,560 +/- 70	4,700	-11.6
RP-76A	Alluvium	14th SA/RI	3,850 +/- 40	0	-12.9
RGPZ-15B	Lower	14th SA/RI	22,510 +/- 160	18,600	-3.2
RP-107D	Lower	14th SA/RI	33,740 +/- 580	28,300	+2.4
RGPZ-2C	Lower	14th SA/RI	28,480 +/- 300	23,300	+1.3
RGPZ-16D	Lower	14th SA/RI	32,150 +/- 460	26,000	-1.4
RP-65B	Upper/Lower	14th SA/RI	10,930 +/- 60	7,300	-3.2
RGPZ-2D	Lower	15th SA/RI	32,400 +/- 390	27,300	-0.10
RP-62B-1	Lower	15th SA/RI	23,650 +/- 240	19,500	2.8
RP-62D	Lower	15th SA/RI	28,510 +/- 130	23,600	0.20
Gallery Well	Upper/Lower	19th SA	354.8 +/- 1.3	128	+7.48

Note: Before Present (BP); o/oo is per mil or parts per thousand

According to the ^{14}C results tabulated above, all groundwater samples considerably predate the atomic bomb. The results are consistent with the previous studies (Woodward-Clyde Consultants, 1988) which measured some ^{14}C activity in all groundwater samples collected and determined that groundwater in the Lower HSU beneath the Site is most likely thousands of years old, but less than 40,000 years old, with ages ranging from 0 to 36,000 years BP.

Additionally, the $^{13}C/^{12}C$ results tabulated above are consistent with previous results indicating that much of the carbon present in groundwater beneath the Site is derived from dissolution of aquifer minerals, with the exception of the anomalous results from the Gallery Well. Like the ^{3}H results discussed above, landfill leachate typically has a unique isotopic signature relative to nearby groundwater. Leachate from a mature landfill is typically enriched in the heavier ^{13}C isotope as a result of biodegradation and methanogenesis. ^{14}C activity is also frequently elevated in landfill leachate, and the younger calculated age is likely a result of the decomposition of modern (synthetic) organic matter disposed of within the landfill.

As a follow-up to the age dating sampling and analysis work completed as provided in the RI/FS Work Plan, the CSC subsequently analyzed nitrogen-15/nitrogen-14 ($^{15}N/^{14}N$), and oxygen-18/oxygen-16 ($^{18}O/^{16}O$) ratios of dissolved nitrate in an attempt to identify the recharge area(s) of groundwater in the Gallery Well. The CSC performed this work without the knowledge of EPA. The CSC collected samples from well SW-44 in the Upper HSU of the Burial Trench Area, well RP-68C-2 in the Lower HSU between the PCB and P/S Landfills, and the Gallery Well. In theory, groundwater from different areas should contain unique isotopic signatures as a result of fractionation due to local microbial activity and other factors. The signature observed in the Gallery Well could then be compared to the potential source areas. However, the isotopic ratios within the sample collected from the Gallery Well could not be determined due to a low nitrate concentration and, therefore, comparisons to other samples could not be made. Laboratory results are included in Attachment G-3. The isotope results for wells SW-44 and RP-68C-2 were as follows:

Well	Sampling Event	$^{15}N/^{14}N$ Results
SW-44	19th SA	Delta N-15 of dissolved nitrate: 24.5
SW-44	19th SA	Delta O-18 of dissolved nitrate: 22.5
RP-68C-2	19th SA	Delta N-15 of dissolved nitrate: 12.9
RP-68C-2	19th SA	Delta O-18 of dissolved nitrate: 31.5
Gallery Well	19th SA	Delta N-15 of dissolved nitrate: NA
Gallery Well	19th SA	Delta O-18 of dissolved nitrate: NA

4.6 Demography and Land Use

4.6.1 Regional Land Use

The area near the Site is sparsely settled, and land use consists primarily of agriculture, cattle grazing, and oil field development. Oil fields in proximity to the Site include the Casmalia Oil Field, the Orcutt Oil Field, the Guadalupe Oil Field, the Santa Maria Valley Oil Field, and the Jesus Maria Oil Field. Agricultural activities within the region consist primarily of dry land farming of wheat and beans, with minor areas devoted to production of grapes, tomatoes, strawberries, and other grain crops.

4.6.2 Nearby Populations

Population centers in proximity to the Site include the City of Santa Maria, located approximately 10 miles northeast of the Site; the City of Guadalupe, located approximately 8 miles north of the Site; and the City of Lompoc, located approximately 16 miles south-southeast of the Site. Several small unincorporated towns are located closer to the Site, including the town of Casmalia (approximately 1.2 miles south of the Site), Betteravia (approximately 4.75 miles to the north-northeast), and Orcutt (approximately 5.25 miles to the east). The large but sparsely developed Vandenberg Air Force Base lies approximately 1.25 miles west and 1.75 miles south of the Site. The primary residential area for Vandenberg Air Force Base is approximately 8 miles south of the Site.

4.7 Ecology

4.7.1 Site Habitats

The CSC reviewed information from previous reports (Dames & Moore, 1998) as well as from recent surveys to identify habitat types, sensitive species, and other flora and fauna that occur or potentially occur at the Site. The USEPA initially requested that the CSC conduct a biological species and habitat survey (BSHS) for the Site prior to commencing construction of RCRA landfill caps on the EE/CA area. The BSHS (Appendix P) was completed to satisfy the requirements for evaluating presence/absence survey for protected (special-status species) and flora and fauna. Since that work was performed, the CSC completed additional biological species and habitat surveys for use in planning and completing the RI/FS for the Site. These types of surveys provide sufficient information for the initial phases of the Ecological Risk Assessment, which rely on the identification of representative species and functional groups present or likely to be present on-Site (RI/FS Work Plan, Section 7.0). The BSHS report intended to synthesize the results of the surveys conducted within and proximate to the Site between fall 2000 and spring 2005. Data included in this report were extracted from previously presented BSHS interim reports, as well as from recent 2004-2005 survey efforts not previously presented.

Biological surveys of the Site were conducted in the Spring of 2001 and were repeated in the Fall of 2001, and some additional follow-up surveys were completed in the Spring of 2002, Fall of 2002, and Spring of 2003, and in 2004-2005 as detailed in the BSHS. Additional surveys, including bat, bird, California red-legged frog, and California tiger salamander surveys, were conducted as well. The purpose of these surveys was to identify the types of habitat present at the Site and the potential for these habitats to support special-status and sensitive species. The biological surveys were timed to coincide with the peak flowering periods of annual and perennial plants. Surveys were also conducted for the potential presence of mammals, amphibians, reptiles, and birds (based on the timing of migration and nesting). A final BSHS report was submitted to USEPA in November 2008 following completion of the additional surveys and addressing all comments received on October 15, 2008. The final BSHS report is included as Appendix P in this Draft Final RI Report.

In cooperation with the California Central Coast Regional Water Quality Control Board (RWQCB), California Department of Fish and Game (CDFG), US Fish and Wildlife Service (USFWS), and USEPA, the CSC developed a list of 39 known or potentially occurring species of concern within or proximate to the Site. The list of species are described in Appendix P and presented in Table P-1 of Appendix P. Generally, this list of potentially occurring special status species was developed by consulting the California Native Diversity Database (CNDDB) maintained by the CDFG (2007) and by seeking the observations of regional experts.

The Site contains two general habitat types: upland (terrestrial) habitat and aquatic habitat. These habitat types are described in the following sections.

4.7.1.1 Terrestrial Areas

The terrestrial portions of the 252-acre Site are predominantly disturbed, sparsely vegetated, and annually grazed non-native grassland. Upland habitat occurs primarily in the northern portion of the Site (Hunt & Associates, 2001) and includes:

- Non-native (ruderal) annual grassland;
- Disturbed coastal sage scrub; and
- Bare ground (primarily a result of construction activities at landfills).

Several contaminated areas in the upland and northern portion of the Site are being remediated by capping. Therefore, at the time of the Fall 2001 plant surveys, many of the areas were bare ground and included the Borrow Area North of PCB Landfill, Heavy Metals Landfill, and Caustics/Cyanides Landfill (Harding, 2001b). The northern portion of the Site contained construction equipment, staging areas, and several roads, with all those areas being bare ground and devoid of vegetation. Although the capped areas can provide habitat that is utilized by receptors (i.e., exposure pathways may exist), these areas were not quantitatively evaluated in the Ecological Risk Assessment (Section 9) because the vegetated soils that overlie the cap are clean and consequently do not pose a risk to ecological receptors. Exposures to ecological receptors from the capped areas of the Site can be considered minimal to unlikely once all capping is complete and as long as the landfill caps are adequately maintained.

4.7.1.2 Freshwater Areas

The majority of aquatic habitat is located in the southern portion of the Site and consists of large impoundments for the collection of surface-water runoff (Hunt & Associates, 2001). These include the RCF Pond, the A-Series Pond, and Pond 13. Other ponds (A-5 and 18) are planned

to be closed. Surface-water runoff is the primary source of water for the ponds. Riparian vegetation is not present along the edges of any of the five ponds on-Site. This is likely due to the abrupt and steep topography change immediately adjacent to the water's edge. Weedy grasses and forbs are present along the borders of the ponds; however, the pond borders also contain gravel, debris, and unvegetated soil. A few V-ditches, drainages, and catchment basins are located in the central portion of the Site.

4.7.1.3 Off-Site Areas

Terrestrial habitat off-Site is similar to that on-Site with the exception that it is utilized for cattle grazing, agricultural purposes, and oil field development, and thus of lower quality than that on-Site.

Freshwater areas off-Site include riparian areas associated with Casmalia Creek and Shuman Creek. Casmalia Creek is located within 0.25 mile of the west boundary of the Site and receives surface-water runoff from upland areas on-Site. Because of the proximity of the Casmalia Creek to the Site and the potential for the creek habitat to support species that could also inhabit the Site, biological surveys were conducted in the riparian habitat of the creek. Casmalia Creek merges with Shuman Creek approximately 2 miles south of the Site and approximately 1 mile west of the town of Casmalia; Shuman Creek empties into the Pacific Ocean approximately 4 miles west of the confluence with Casmalia Creek.

4.8 Conceptual Site Model

The CSC developed a conceptual site model (CSM) of the Casmalia Site based on the results of historical investigations and refined over time as the CSC developed new data as part of the RGMEW, RI/FS Work Plan scoping activities, and performing the RI activities. The CSM is a summary of information included in the previous sections and elsewhere in this report, and presents the CSC's current understanding of the physical and chemical conditions at the Site. The CSM is graphically illustrated in the following figures that transects through key Site areas and summarized in the following text.

- *Figure 4-51, CSM (P/S LF, CDA, FPP, and RCF)*
- *Figure 4-52, CSM (PCB LF, BTA, FPP, and RCF)*
- *Figure 4-53, CSM (RCRA Canyon, Pond A-5, A-Series Pond, and C Drainage)*
- *Figure 4-54, CSM (PSCT-1, FPP Area, and B-Drainage)*

These CSM transects were selected to illustrate the range of physical and chemical conditions at the Site that are important with respect to characterizing the Site's physical characteristics, nature and extent of contamination, and fate and transport of contamination. The details of these CSMs are further presented in Sections 4, 5, and 6, respectively.

4.8.1 Site Features

The Site is located on the south flank of Casmalia Hills located in the southern extend of the Coast Range geomorphic province. The topography of the Site is relatively steep, dominated by a northwest-southeast trending ridge (the North Ridge) along the northern boundary. The Site ranges in elevation from 835 feet msl along the North Ridge and slopes to 375 feet msl at the southern boundary (Figures 4-51 through 4-54). During historical operations, natural drainages on the southern flank of the North Ridge were excavated to unweathered bedrock and landfill

cells were created within the enlarged canyons. These include the current P/S Landfill (Figure 4-51), PCB Landfill (Figure 4-52), Metals Landfill, Caustics Cyanide Landfill, and Acids Landfill.

Numerous liquid containment ponds and evaporation pads have existed in the lower elevations of the central and southern areas of the Site, though most have been removed and capped. Five ponds currently occupy the southern Site area within the footprint of former ponds and pads. These include the RCF Pond and Pond 13 (Figures 4-51 and 4-54), the A-Series Pond and Pond A-5 (Figure 4-53), and Pond 13.

South of the Site border, prominent hills at the southwestern and southeastern corners define three drainages (A-, B-, and C-Drainages) through which surface water and groundwater naturally exit (Figures 4-51 through 4-54).

4.8.2 Meteorology

The Site is located Southern California, and subject to a Mediterranean climate typified by warm to hot summer period and mild winters. During the period from June 1997 to March 2009 Site water budget information has been gathered, and indicates a net loss in the water storage has occurred. The Site's average annual rainfall is approximately 17 inches. While average annual evaporation is approximately 50 inches. As such, the Site has a net annual average evaporative loss rate of approximately 33 inches. Site rainfall patterns are influenced by the El Niño/La Niña-Southern Oscillation (ENSO). Annual rainfall can exceed 20 to 30 inches or be less than 10 inches. The 1997/98 winter where 32.65 inches of rain fell at the Site was a strong El Nino event.

4.8.3 Geology

The geology of the Site is dominated by massive to faintly bedded Todos Santos Claystone bedrock. The upper 30 to 60 feet of the claystone (informally referred to as the Upper HSU) has been eroded, physically weathered and diagenetically altered, resulting in the formation of a weathered rind of claystone with (pseudo-)fracture porosity. The weathered claystone has significantly greater fracture porosity than the underlying unweathered claystone (informally referred to as the Lower HSU). At the Site, the Todos Santos claystone is approximately 1,300 feet thick and underlain by the oil-rich Monterey Formation. Alluvium occurs atop the claystone and within present and former drainages. Site operations have removed the weathered claystone from some areas (i.e. beneath the landfill cells) and emplaced refuse and other fill material in others (i.e. the landfill cells).

4.8.4 Hydrogeology

Two hydrostratigraphic units have been defined for the Site as indicated above. The distinction between the Upper and Lower HSUs is atypical, as the units are not separated by an aquitard or aquiclude, but rather, are defined by the degree of weathering of the claystone. The Upper HSU has moderate to low hydraulic conductivity (~10^{-5} cm/s) while the Lower HSU has low hydraulic conductivity (~10^{-6} cm/s). Site-wide groundwater flow and contaminant migration at the Site is now controlled by a series of east-west oriented clay barriers and extraction trenches constructed within the Upper HSU and anchored within the Lower HSU and pumped sump-wells.

Groundwater generally flows from the northern border of the Site on the North Ridge to the lowlands in the south. The water table closely follows topography and horizontal gradients are

accordingly steep in the hilly northern portion of the Site. Except under the North Ridge where the Upper HSU is unsaturated (dry), the water table typically, occurs in the weathered claystone, where the fracture porosity is greater than the matrix and fracture porosities of the underlying unweathered claystone. Groundwater seeps have been observed in several locations across the Site, though none have been observed since 2004, indicative of a loss of groundwater storage (since capping landfill cells).

The North Ridge is a natural recharge area and groundwater flow divide. Rainfall infiltrates into the subsurface along the North Ridge and moves vertically downward and laterally outward either northward toward the North Drainage or southward across the Zone 1 Site area. The location of the groundwater flow divide is conceptual along the North Ridge and its exact location is not quantified. Strong downward vertical groundwater gradients occur along the North Ridge. Although the hydraulic conductivity is relatively low, infiltrating groundwater moves downward in the Lower HSU in response to the strong downward vertical gradients in this area.

From the North Ridge above the RCRA Canyon, groundwater moving southward will preferentially move through the more permeable Upper HSU and converge into the RCRA Canyon. Vertically downward gradients occur in the upper RCRA Canyon and in the lower RCRA Canyon to the south (Figure 4-53). Groundwater will flow southward along RCRA canyon and discharge to Pond A-5 to the south.

From the North Ridge above the PCB Landfill, groundwater moving southward will preferentially move through the more permeable Upper HSU, PCB Landfill materials, and Burial Trench Area towards the PSCT in the vicinity extraction well PSCT-4 (Figure 4-52). Some groundwater from the PCB Landfill and eastern part of the Burial Trench Area may move towards the P/S Landfill. Strong vertically downward groundwater gradients occur throughout the PCB Landfill and Burial Trench Area.

From the North Ridge, above the capped P/S Landfill and the other capped landfills (Metals, Caustic/Cyanide, and Acids), groundwater naturally flows through the enlarged drainages that define the landfill cells, toward the Central Drainage Area (Figure 4-51). Groundwater moving southward will preferentially move through the more permeable Upper HSU and landfill cells. Vertically downward groundwater gradients occur at the northern parts of the four capped landfills as the downward gradients propagate southward from the North Ridge. Historically groundwater level data has indicated that these downward gradients continued to the southern limits of the landfills.

The CSC's capping of the P/S Landfill in 1999, capping of the EE/CA Area landfills (Metals, Caustic/Cyanide, and Acids) in 2001 and 2002, and subsequent maintenance of this approximate 40 acre contiguous impermeable cap has eliminated most rainfall infiltration into the capped areas. Elimination of rainfall infiltration reduced the magnitude of the downward gradients of the landfills and has led to an upward vertical gradient at the toe of at least two of the landfills (Metals and Caustic/Cyanide). The vertical gradient at the toe of the P/S Landfill is not known because piezometers to determine the vertical gradient in this area do not exist. Groundwater from the EE/CA Area Cap landfills (Metals, Caustic/Cyanide, and Acids Landfills) will flow southward and converge to the Central Drainage Area (Figures 4-46 and 4-47). The reduction in groundwater elevations from capping has reduced the volume of liquids migrating from these landfills relative to historical conditions. Contaminated liquids within the P/S Landfill are controlled by a clay barrier and the Gallery Well extraction well. Capping of the P/S Landfill has led to a significant reduction in the volume of liquids extracted from the Gallery Well.

Groundwater moving southward through the Central Drainage Area will preferentially move through the more permeable Upper HSU towards the PSCT in the vicinity extraction well PSCT-1 (Figure 4-52). Natural to vertically upward groundwater gradients occur in the Central Drainage Area between the P/S Landfill and PSCT-1.

In the south, prior to Site development, surface water and groundwater naturally exited through the A-, B- and C-Drainages at the southern perimeter of the Site, which ultimately flows to the Pacific Ocean via Shuman Creek. The North Drainage to the north of the Site also ultimately flows to the Pacific Ocean via Shuman Creek. Shallow groundwater flow is now managed by several constructed subsurface features including clay barriers, trenches, and extraction points where fluid levels are maintained at specified levels. Natural to vertically upward groundwater gradients mostly occur in the A-, B-, C- and North Drainages near the Site (Figures 4-52 through 4-54).

The PSCT and related extraction points control migration of groundwater from the landfill cells, Burial Trench Area, and Central Drainage Area to the southern portion of the Site (Figures 4-51 and 4-52). Control of leachate migration from the P/S Landfill into the Central Drainage Area is specifically addressed by impoundment behind a clay barrier and extraction via the Gallery Well (Figure 4-51). Groundwater entering the Central Drainage Area is further controlled by extraction via Sump 9B (Figure 4-51). Evaluation of groundwater flow and chemistry data indicate that the PSCT together with natural attenuation mechanisms is effective at controlling groundwater contaminant migration southward from the northern portion of the Site. One potential exception to the effectiveness of these containment facilities, as further described below, is for DNAPLs that are known to occur in the Upper HSU and Lower HSU of the P/S Landfill and Central Drainage Areas (Figure 4-51). DNAPL's migrate through the subsurface in response to gravity driven-flow and may not be totally contained by the liquid collection systems. Fracture flow paths tend to be steep in angles, and as such, DNAPL flow to depth is likely limited as fracture density decrease with depth. However, the DNAPL within deep fractures will reside in these zones as dead-end storage for an indefinite period of time; attempts to delineate fracture dead end storage zones would likely exacerbate DNAPL distribution as DNAPL encountered while drilling is difficult to contain (e.g., RISB-02 where DNAPL flowed into and partially filled the borehole from fractures encountered at or higher elevation). No DNAPL has been observed to daylight at any surface fracture or seep at the Site.

Five ponds are presently located in the southern portion of the Site which are sources of recharge to groundwater and also act as groundwater sinks that receive base flow, depending on the water level within the ponds relative to the level of the adjacent water table. As noted above, these include the RCF Pond and Pond 13 (Figures 4-51 and 4-54), the A-Series Pond and Pond A-5 (Figure 4-53), and Pond 13. Flow of groundwater through the A-, B-, and C-Drainages to areas off-Site is controlled by extraction points within Plume Capture Trenches (PCT) at the head of each drainage (PCT-A, PCT-B, and PCT-C, respectively). Evaluation of groundwater flow and chemistry data indicate that surface water from the on-Site ponds is a significant source of recharge to each of the PCTs and that the PCTs are effective at controlling groundwater contaminant migration southward from the southern portion of the Site for the B-Drainage (Figures 4-53 and 4-54).

Based on seasonal changes in groundwater elevations (measured from 1997 to 2009), the estimated loss in Site groundwater storage is approximately 9 acre-feet. The rate of loss in groundwater storage is noted to have increased in the periods following the capping of landfill cells, indicating the effectiveness of capping landfill cells to prevent surface water infiltration, however, changes in groundwater storage follow seasonal precipitation.

4.8.5 Contamination (soil, surface water and groundwater, surface soil, soil vapor)

Soil and groundwater contamination at the Site is the result of historical operation as a Class I hazardous waste management facility permitted by the RWQCB. Casmalia Resources began operating the in 1972 and ceased accepting off-Site waste in 1989. Waste disposal units included the following: 6 landfills, 43 surface impoundments, 15 evaporation pads, 2 non-hazardous waste spreading areas, 6 oil field waste spreading areas, 11 shallow injection wells, 6 disposal trenches; and 1 drum burial unit (Figure 2-4). The landfills, spreading areas, injection wells, and disposal trenches were located at the northern half of the Site and most of the surface impoundments and evaporation pads were located at the southern half of the Site. A few of the surface impoundments and evaporation pads were also present in some areas of the northern portion of the Site between the major landfill cells. The Site also had five waste treatment units: an acid/alkaline neutralization facility, a hydrogen peroxide treatment unit, oil recovery and treatment tanks, a wet air oxidation unit, and a temporary pilot-scale powder-activated carbon treatment (PACT) unit.

Casmalia Resources removed the small amount of landfill wastes from the RCRA Canyon from 1988 through 1990 and this landfill no longer exists. Casmalia Resources completed pond and pad closure (remediation) activities in the period from 1989 to 1991. These closure activities included excavating contaminated subgrade soils for the ponds and pads at the southern half of the Site, placing the excavated subgrade soils one the remaining 5 landfills, and constructing the PSCT and PCT extraction trenches. As a result of these activities, most of the current soils and groundwater contamination occurs at the northern half of the Site, north of the PSCT extraction trench. Casmalia Resources apparently did not remediate (excavate) contaminated soils from the RCRA Canyon that resulted from waste spreading and spraying in this area.

The CSC defined several Site study areas for the purposes of performing the RI/FS. Notable study areas that are used in this CSM include the following:

- Capped Landfills – Includes the four existing landfills (Pesticides/Solvents, Metals, Caustic/Cyanide, and Acids) capped by the CSC from 1999 through 2002.
- PCB Landfill – Includes the existing PCB Landfill that is not capped.
- RCRA Canyon Area and West Canyon Spray Area – Includes the former RCRA landfill previously removed and the waste spreading and spraying areas not remediated.
- Burial Trench Area – Includes the 11 shallow injection wells and 6 disposal trenches.
- Central Drainage Area – Includes former ponds and pads mostly not remediated.
- Liquids Treatment Area – Includes several former Casmalia Resources waste treatment facilities and the current CSC extracted liquids treatment facilities.
- Former Pond and Pad Area – Includes former pond and pads mostly remediated.
- Stormwater Pond and Treated Liquids Impoundments – Includes the five ponds at the south part of the Site (A-Series Pond, Pond A-5, RCF, Pond 18, and Pond 13).

Additional CSC study areas include the Maintenance Shed Area, Administration Building Area, Roadways, and the Remaining On-Site Area.

Surface Water and Groundwater

Groundwater in the Site vicinity is naturally of poor quality, due to low flow rates resulting in extended contact with the aquifer materials and a high rate of evaporation. The marine origin of the claystone and the slow migration rate of the groundwater result in a chemistry that includes

significant concentrations of seawater constituents, metals and TDS. Groundwater is generally of the sodium-chloride type in the Upper HSU, and the sodium-chloride or sodium-sulfate type in the Lower HSU. Near the landfill cells and PSCT, groundwater is magnesium-sulfate dominated. One exception to the poor quality of groundwater is within the alluvium along Casmalia Creek. Groundwater in this alluvium is lower in TDS, likely due to percolation of fresh stormwater that flows down the drainage. TDS concentrations in the off-Site alluvium along Casmalia Creek are less than 2,000 ppm. TDS in off-Site weathered and unweathered claystone is variable and often exceeds 5,000 ppm and can exceed 10,000 ppm.

Contamination is predominantly located within the Zone 1 Site boundary, though sporadic, low level contaminant concentrations have been detected within Zone 2 (off-Site). VOCs are the most common, wide spread, and mobile of the organic contaminants present, and are therefore, used as proxy compounds to characterize organic contaminant movement as a whole. Arsenic is the most common and wide spread of the inorganic contaminants present that exceed primary drinking water maximum contaminant levels (MCLs) and are therefore used as a proxy metals to characterize metals contaminant movement as a whole. Heavy metals, SVOCs, PAHs, PCBs, herbicides, pesticides, and dioxins/furans are also present, as well as other chemical compounds.

In the Upper HSU, VOC and inorganic contaminant zones are separated by the PSCT (Figures 4-51and 4-52). The Zone 1 area north of the PSCT contains the majority of the metals, dissolved phased VOC contamination, and all of the known NAPL contamination. The VOC and metals plumes in the Upper HSU beneath the landfills converge and flow into the Central Drainage Area and into the PSCT in the PSCT-1 area. The VOC and arsenic plume in the Upper HSU and in the Burial Trench Area flows south into the PSCT in the PSCT-4 area. There is also an area of contamination located in the Burial Trench Area that extends to the southern portion of the PCB Landfill, which flows into the PSCT. The PSCT prevents contaminant movement to areas south of the trench and contains the VOC and arsenic contamination in the northern areas. VOC and arsenic contamination south of the PSCT is likely the result of former liquid storage ponds in that area that have since been removed.

VOCs are not present in the on-Site ponds or the PCTs at the head of the A-, B-, and C-Drainages, except at very low levels when detected. Unlike the absence of these VOCs, TDS (salts) and metals are significantly elevated within surface water in the five on-Site ponds, groundwater extracted at the PCTs, and other groundwater monitored at other monitoring wells in the vicinity of the ponds and PCTs. TDS and metals concentration have steadily increased since the 1997/98 El Nino winter when a large amount of fresh stormwater runoff filled the ponds to near capacity and diluted TDS and metals concentrations. TDS concentrations in the ponds were below 10,000 ppm in 1998 after dilution. TDS has steadily increased since then through evaporation and currently exceeds 20,000 ppm in most ponds. Salts and metals increase over time because these are terminal ponds with no outflow. TDS concentration increase year-to-year, with temporary dilution during winter storm water runoff events.

In the Lower HSU, dissolved VOCs in groundwater are present within four areas:

- North Ridge
- Burial Trench Area;
- Central Drainage Area (including the southern edge of the Acids Landfill;
- Along the PSCT, including at extraction wells PSCT-1, PSCT-3, and PSCT-4.

The Central Drainage Area contains the highest levels of VOC contamination in the Lower HSU, which appears related to overlying Upper HSU VOC and NAPL contamination present between the P/S Landfill and the PSCT.

Dissolved concentrations of arsenic and other metals in the Lower HSU are lower than in the Upper HSU; the highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the border of Zone 1 and Zone 2. Higher concentrations of metals in the Lower HSU are also located within the Central Drainage Area, Burial Trench Area, and along the PSCT where there are elevated VOCs. Metals concentrations in the Lower HSU do not obviously appear to coincide with elevated concentrations in the overlying Upper HSU. It is not clear if the elevated metals in the Lower HSU under the North Ridge are from Site-related impacts.

Nonaqueous Phase Liquids

The P/S Landfill and Central Drainage Area are the only areas of the Site where both free phase (mobile) DNAPL and LNAPL were observed in the Upper HSU during drilling, are gauged in routine liquid level monitoring, and are inferred based on the concentrations of dissolved compounds (Figure 4-51). The Central Drainage Area is the only area of the Site within the Lower HSU where DNAPL was gauged in routine liquid level sampling and inferred based on the concentrations of dissolved compounds (Figure 4-51). The Burial Trench Area was investigated for the presence of DNAPL and LNAPL, and although dissolved VOC concentrations are relatively high in this area, no wells or piezometers were observed to contain NAPL during liquids level monitoring (Figure 4-52).

Significant volumes of free-phase LNAPL and DNAPL occur within the southern end of the P/S Landfill (Figure 4-51). Measured DNAPL thicknesses at the bottom of the P/S Landfill range from approximately 5 feet in piezometer RIPZ-27 (8 feet north of Gallery Well) and up to 14 feet in piezometer RIPZ-13 (150 feet north of Gallery Well). The liquids extraction pump maintains the DNAPL at a thickness of 2 feet at the Gallery Well. The Gallery Well has historically extracted approximately 3,000 to 4,000 gallons of DNAPL and minor volumes of LNAPL from the P/S Landfill. The rate of DNAPL extraction has been relatively stable for over 10-years, indicating that a significant volume of free phase DNAPL occurs in the landfill. There may be up to and over 100,000 gallons of free-phase DNAPL in the landfill based on: (1) extrapolating the continued extraction of DNAPL at a rate of several thousand gallons per year and (2) volumetric calculations from the measured DNAPL thicknesses in the landfill and the dimensions of the base of the landfill potentially containing free-phase DNAPL.

Several feet of DNAPL are currently present in two Lower HSU piezometers (Figure 4-51). These piezometers (RGPZ-7C and RGPZ-7D) are located approximately 500 feet south of the P/S Landfill and 150 feet north of PSCT-1. The deeper piezometer is screened from 138 to 148 feet bgs, more than 100 feet below the HSU contact. This DNAPL potentially migrated from one of two potential Upper HSU source areas through Lower HSU fractures to arrive at this location and depth (Figure 4-51). One potential DNAPL source is the large volume of known free DNAPL within the P/S Landfill. Calculations indicate that historical and current DNAPL thicknesses in the P/S Landfill exceed the DNAPL pool height required to enter underlying fractures, given measured DNAPL properties and potential fracture widths. The other potential DNAPL source is the area of former Pads 9A and 9B located between the P/S landfill and PSCT-1. The CSC did not identify any potential low areas in the HSU clay contact in this area that could potentially collect a pool of DNAPL or any evidence of free-phase DNAPL or visual observations of obvious mobile or residual-phase DNAPL.

The vertical extent of free phase DNAPL in the Lower HSU is not known with certainty. In addition, the localized horizontal extent of free phase DNAPL in the Lower HSU is uncertain in the area of the P/S Landfill and Central Drainage Area, although the horizontal extent of free phase DNAPL is not believed to extend off-Site. Once DNAPL has entered a fracture or fracture network, progressively smaller aperture fractures will be invaded if the DNAPL is allowed to extend itself vertically while remaining a continuous, interconnected phase. The DNAPL driving head is not only a function of the pool height in the overlying Upper HSU (or P/S Landfill) but also the height of DNAPL accumulated in the fractures beneath this pool. The large DNAPL volume in the P/S Landfill would provide an ongoing source to allow the DNAPL to extend itself. If the P/S Landfill is the source, the free phase DNAPL in the landfill will provide a long-term source for DNAPL migration. However, as indicated above, DNAPL appears to be trapped in fracture zones that ultimately become dead-zones at depth. No DNAPL has been observed to daylight at surface fractures or groundwater seeps.

As described above, neutral to vertically upward groundwater gradients occur in the Central Drainage Area between the P/S Landfill and PSCT-1. The vertical gradient at the toe of the P/S Landfill is not known because piezometers to determine the vertical gradient in this area do not exist. The direction and magnitude of the vertical gradients has changed over time in response to climatic conditions, landfill capping, and liquids extraction. Calculations performed with DNAPL densities and measured vertical gradients at the southern area of the Central Drainage Area and near PSCT-1 indicate that vertical gradients may currently be sufficient to stop downward DNAPL migration in this area. Data to assess vertical gradient conditions under the P/S Landfill are not available.

LNAPL thicknesses up 1 to 2-feet occur in monitoring wells and piezometers within the Central Drainage Area between the P/S Landfill and PSCT-1 (Figure 4-51). Migration of LNAPL southward will be intercepted by either Sump 9B or the PSCT.

Soil, Sediment, and Soil Vapor

Soil contamination attributable to former Site operations is present at many of Site study areas. Available data indicate a comparatively small list of inorganic and organic constituents are responsible for the soil impacts detected. With exceptions, inorganic exceedances in soil are restricted to surface or shallow-to-moderate depth soils (i.e., 0 to 10 feet bgs) in the areas south of the PSCT and west of the PCB Landfill and Burial Trench Area, and typically demonstrate diminishing concentrations with increased depth. These areas include the RCRA Canyon/West Canyon Spray Area and most areas of the Former Ponds and Pads Area. Not including the landfills, high concentrations of organic constituents, principally VOC, PAHs, and/or PCBs, are locally present to the maximum depths explored at locations near former waste management facilities within the Central Drainage Area, select areas of the Former Pond and Pad Subarea, and the Burial Trench Area. Drilling and sampling for chemical analysis was not performed below the HSU contact in many of these areas.

Soil contaminants are interpreted to typically not persist appreciably below the contact between the upper weathered claystone and the underlying lower unweathered claystone due to the lower permeability of the underlying unweathered claystone. This assumption of the lack of contamination in the unweathered claystone may not be valid for areas north of the PSCT where the general contaminant levels are higher.

Sediment, present in the storm water ponds, treated liquids impoundments, and off-Site drainages is impacted by both inorganic (e.g., barium, cadmium, and selenium) and organic

(e.g., 1,1-DCA, MCPP, and PCB TEQ) constituents. Organic compounds are elevated in the storm water and treated liquids ponds on-Site.

Soil vapor at the Site contains elevated VOC concentrations at all sampled locations, including off-Site step-out locations. Initial sampled locations were within the areas with expected elevated VOC concentrations (the interior of the capped landfills were not sampled). Additional step-out locations were then sampled to delineate the extent of VOC in soil vapor. With only a few exceptions, those VOCs detected in off-Site step-out locations were also reported to be present in on-Site sampling locations. Maximum concentrations of VOCs that demonstrate the highest prevalence and reported concentrations, or that may contribute to human health or ecological risks are found along the eastern and northeastern limits of the capped landfills, south of the PSCT below the Maintenance Shed Area, the western limit of the Central Drainage Area and eastern margin of the Burial Trench Area, the southern and western Central Drainage Area, as well as west of the Burial Trench Area, the northwestern limit of the Capped Landfills Area, and two locations along the PSCT south of the Central Drainage Area and Burial Trench Area.

Most of the elevated VOC concentrations likely originate in the primary source areas north of the PSCT, including the Burial Trench Area (Figure 4-52), P/S Landfill and Central Drainage Area (Figure 4-51), and to a lesser extent the other landfills. VOCs may also originate from residual contamination in other areas south of the PSCT, including the Liquids Treatment Area and former Ponds A and B. VOCs may migrate from higher concentration to lower concentration area. Concentrations decrease off-Site from the capped landfills toward the east and toward the north, but are still detectable at the base of the North Drainage. Concentrations also decrease on-Site from the Burial Trench Area toward the west into the RCRA Canyon area and from the PSCT towards the south into the Former Ponds and Pads area.

Discrete, one-time soil vapor samples for the RI were collected from temporary (non permanent) probes, so temporal trends could not be evaluated with respect to VOC concentration changes over time. No general concentration trend with respect to depth was observed at the northern and eastern edges of the capped landfill area, the only locations where multi-depth soil vapor sampling was performed. Conceptually, elevated soil vapor concentrations occur near ground surface downward to the water table (Figures 4-51 and 4-52).

4.8.6 Exposure Pathways

Potential contaminant exposure pathways at the Site have been evaluated in relation to both human health and environmental receptors, and are discussed in detail in Sections 8 and 9, respectively. Human health exposure pathways considered to be potentially complete include:

- Incidental ingestion of soil, sediment, or surface water;
- Contact with soil, sediment, or surface water leading to dermal absorption;
- Inhalation of dust generated from soil or sediment;
- Inhalation of vapors emanating from soil, sediment, or surface waters into outdoor air;
- Inhalation of vapors emanating from soil vapor into outdoor air; and
- Ingestion of beef.

Environmental receptor exposure pathways considered to be potentially complete and significant include:

- Direct contact or uptake of soil by plants and soil invertebrates;
- Inhalation of burrow air by mammals; this also accounts for volatiles from groundwater;
- Incidental ingestion of soil by mammals and birds;
- Ingestion of contaminated prey tissue by mammals and birds;
- Direct contact or uptake of surface water by aquatic plants, aquatic invertebrates, and amphibians;
- Direct contact of seep water by amphibians;
- Direct contact or uptake of sediment by aquatic plants, aquatic invertebrates, and amphibians;
- Incidental ingestion of sediment by birds and mammals;
- Ingestion of surface water by birds and mammals; and
- Ingestion of contaminated prey tissue (aquatic invertebrates) by birds and mammals.

4.9 References

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5.0 NATURE AND EXTENT OF CONTAMINATION

5.1 Introduction

The following sections summarize and integrate the salient findings regarding contaminant nature and extent as determined from the various investigations completed as part of the RI. Details of the RI sampling and analytical program, as well as in-depth discussions of the findings of the investigations comprising the RI, are presented in the various attachments to this report, as follows:

- Appendix A – Evaluates background soil concentrations
- Appendix B – Presents results of soil and sediment sampling
- Appendix C – Presents results of soil vapor sampling
- Appendix D – Presents results of offsite and onsite surface water sampling
- Appendix E – Presents results of NAPL observations during drilling and well installation
- Appendix F – Presents results of NAPL thickness measurements in wells
- Appendix G – Presents results of groundwater and NAPL sampling
- Appendix M – Presents results of UVIF/MIP NAPL investigation

The nature and extent of contamination detected at and immediately surrounding the Site are discussed below by media, and the significance of the various constituents detected is discussed with respect to site characterization as well as potential risks posed to both human and ecological receptors. For each of the media evaluated, the adequacy of site characterization is assessed relative to the definition of the nature and lateral and vertical extent of contamination present. Risks that exceed human health and ecological screening levels (herein referred to as risk-based concentrations - RBCs), are also assessed. The methodology used in development of these site-specific RBCs is discussed briefly below in Section 5.4.1, and described in more detail in Section 8 and Appendix T (human health risk assessment), and Section 9 and Appendix U (ecological risk assessment). As discussed in Sections 8 and 9 and in Appendices T and U, evaluation of potential human health and ecological risks is limited to depths of between 0 and 5 feet bgs, whereas evaluation of the adequacy of site characterization extends to the total depths explored for all media.

5.2 Background Conditions

5.2.1 Soil and Sediment

Casmalia Resources investigated background soil concentrations to support historical pond and pad remediation activities in the late 1980s. The results of this work are presented in the HSCER (Woodward-Clyde Consultants, 1988a). The CSC collected and analyzed additional offsite RI soil samples to further evaluate soil background concentrations. The CSC built on this initial work by incorporating Casmalia Resources' historical background soil concentration data, incorporating the additional offsite RI soil concentration data, and developing current background soil concentration levels. Analysis of the background condition for soil and sediment concentrations of inorganics and background-sensitive organics is developed in Appendix A and summarized here to provide context for discussion of nature and extent of contamination.

The CSC conducted the background analysis to develop a set of background Upper Tolerance Limits (UTLs) for each analyte. The UTLs represent an upper-bound concentration in background soils and were each based on a distributional analysis of RI and historical background samples, with the exception of Tin for which a site-wide ambient distribution was developed using background and on-site data combined. The methods for development of these UTLs are summarized below.

Background datasets include samples taken from both alluvium and weathered claystone. These same strata also occur within the top 5 to 10 feet of study areas across the Site; the depth interval that is most relevant for assessing exposure and risk. For the purpose of comparing Site levels to background both geological strata are included in the background data set including samples from the depth interval of 0 to less than 10 feet below ground surface. Background samples for the two dioxin parameters, mammalian dioxin TEQ and avian dioxin TEQ, included only surface soil samples.

Distribution analysis and UTL calculation for the background dataset involved consideration of several statistical descriptors and graphical evidence, consistent with principles in both CalEPA (1997) and USEPA (2002) background guidance and the RI/FS Work Plan. This analysis is presented in Appendix A.

Background UTLs developed in Appendix A are provided as follows:

Chemical	UTL Value	Units
Aluminum	18000	mg/kg
Antimony	4	mg/kg
Arsenic	22	mg/kg
Avian Dioxin TEQ	16	pg/g
Barium	174	mg/kg
Beryllium	0.91	mg/kg
Cadmium	3.2	mg/kg
Chromium	64	mg/kg
Cobalt	20	mg/kg
Copper	19	mg/kg
Lead	11.9	mg/kg
Magnesium	5500	mg/kg
Mammalian Dioxin TEQ	13	pg/g
Manganese	330	mg/kg
Mercury	0.026	mg/kg
Molybdenum	10	mg/kg
Nickel	49	mg/kg
Selenium	3.3	mg/kg
Thallium	0.64	mg/kg
Tin	65	mg/kg
Vanadium	81	mg/kg
Zinc	104	mg/kg

Earlier RI/FS submittals (IPR May 2005 and November 2005) evaluated metals concentrations in the two stratum separately to determine whether differences were substantial enough or stratum-specific sample size large enough to warrant keeping metals separated between the two stratum. These reports found that some differences between strata could be observed for a subset of the metals; however the added uncertainty caused by reducing the background data sets into smaller subsets did not support the use of these stratum-specific sets for comparison to the Site data sets. Potential differences between the aggregate UTLs (above) and those reflecting only alluvium are further discussed below.

Based on the earlier analysis of RI surface samples (alluvium) and historical background samples (alluvium and weathered claystone), the following metals appeared to have alluvium concentrations shifted upward from claystone concentrations: barium, cadmium, and copper. For these metals a UTL defined specifically for alluvium may be higher than that indicated above for the aggregate soil layer. For arsenic and chromium, alluvium concentrations appeared to be shifted downward from weathered claystone concentrations. A UTL developed specifically for alluvium might therefore be lower than that developed for the aggregate comparison. For cobalt, nickel, vanadium, and zinc, stratigraphy is not expected to significantly impact the value of a UTL specific to alluvium. For the remaining metals represented in both alluvium and weathered claystone, antimony, beryllium, cobalt, lead, mercury, molybdenum, selenium, silver, and thallium, censoring levels (the amount of nondetect values) were too high to allow testing of potential stratum differences.

5.2.2 Off-Site Surface Drainage Water

The CSC sampled surface water in the off-Site A-, B-, C-, and North Drainages during late summer 2004 (late dry season conditions), fall 2004 (initial winter season rainfall conditions), and winter 2005 (mid-winter rainfall conditions) as part of the RI. The CSC's off-Site surface water sampling and analysis methodology, data, and investigation results are provided in Appendix D. Figure 5-1 shows the off-Site surface drainage sample locations, in addition to on-Site surface water sampling locations.

The CSC's evaluation of background conditions for inorganic and organic constituents in the off-Site surface drainage water is presented in Appendix D. This evaluation is summarized here to provide context for discussion of nature and extent of surface water contamination in on-Site areas, and areas situated hydrologically downgradient from the Site.

Background conditions for surface water were established using analytical results for samples collected at three "benchmark" locations that are situated hydraulically upstream of, and removed from, the Site. Benchmark locations included one sampling location in the upper Casmalia Creek, or C-Drainage, (RISWOF-03) and two locations along the North Drainage (RISWOF-02 and RISWOF-06). These "benchmark" locations complement the offsite downstream locations (A-Drainage and lower C-Drainage), on-site stormwater runoff location (RCRA Canyon drainage); and the on-site ponds. Samples were not collected from the B-Drainage because there was no off-Site stormwater flow down this drainage (see Appendix D, Figure D-1).

Analytical results for surface water were evaluated relative to available water quality screening levels, including Federal and California maximum contaminant levels, USEPA Region 9 preliminary remediation goals, and both lowest human health risk and ecological screening levels. These screening levels are presented in Appendix D, Table D-3 (inorganics) and D-4 (organics).

5.2.2.1 Inorganics

A total of 16 out of 27 inorganic constituents were reported in benchmark locations in the North Drainage and upper C-Drainage at dissolved concentrations in excess of one or more screening levels; including, aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, silver, vanadium, and zinc (Appendix D -

Tables D-3 and D-5). Results for dissolved and total inorganic constituents detected in the three benchmark locations are plotted along with results for all other on-Site and off-Site surface water sampling locations for purposes of comparison (Figures 5-1a and 5-1b). With few exceptions, for a given sampling period reported values for these constituents in benchmark locations indicate concentrations the North Drainage are typically elevated relative to those in upper C-Drainage. Screening level exceedences were reported for each of these dissolved constituents in samples collected from the North Drainage, whereas exceedences in the upper C-Drainage were limited to aluminum, arsenic, barium, nickel, selenium, vanadium, and zinc. Ecological screening levels were the most frequently exceeded threshold. Aluminum and arsenic are the only dissolved constituents common to both the North Drainage and the upper C-Drainage that are reported at concentrations that consistently exceed thresholds other than ecological levels. In each location, both these constituents exceed human health screening levels. Aluminum concentrations also exceed the California MCL in both locations. Arsenic concentrations in the North Drainage exceed the Federal MCL and PRG for this constituent, and are approximately four-times higher than those reported for the upper C-Drainage. In addition, dissolved selenium concentrations in the North Drainage also consistently exceed screening levels other than ecological thresholds.

Concentrations of inorganic constituents in benchmark surface water samples are apparently also affected by seasonal variability. For example, lower TDS levels are reported for samples collected during the wet season when flow is affected by stormwater runoff, and higher levels are reported for those collected during the dry season when groundwater base flow may dominate the surface water flow regime (Figures 5-1a and 5-1b). Stormwater runoff is much lower in TDS than groundwater. The seasonal TDS surface water concentrations of the three off-Site drainages were as follows for the following RI samples, which illustrate the seasonal variability:

Period	Date	Casmalia Creek (RISWOF-03)	North Drainage (RISWOF-02)	A Drainage (RISWOF-01)
Summer/Fall	August 2004	778 mg/L	7,112 mg/L	Dry
Winter/Spring	March 2005	364 mg/L	602 mg/L	138 mg/L

TDS concentrations are lower for Casmalia Creek than the North Drainage. The A-Drainage is dry, except during peak storm events. The March 2005 result for the A-Drainage likely represents offsite stormwater runoff with no groundwater contribution.

Field observations indicate surface water in the North Drainage area emerges from weak underground seeps, contributing mineral-rich waters into this drainage. Noted differences in dissolved inorganics concentrations between these two benchmark locations are likely attributable to soil and hydrologic conditions unique to the North Drainage and are affected by seasonal factors relating to rainfall and stormwater runoff. Lower TDS base flow conditions in Casmalia Creek may be derived from alluvium, which may store fresh water from rainfall infiltration, while the higher TDS base flow concentrations in the North drainage may be from older groundwater derived from claystone where alluvium is absent.

5.2.2.2 Organics

Detections of organic compounds in the benchmark locations were mainly limited to several SVOCs and dioxins (Appendix D – Tables D-4 and D-6). Organic constituents common to both benchmark sampling locations include benzo(a)anthracene and n-nitrosodipropylamine. Of the

detected organics, SVOCs (dominantly polycyclic aromatic hydrocarbons [PAHs]) are reported only at relatively low concentrations, slightly in excess of human health and ecological screening levels. Total TEQ concentrations in the benchmark locations exceeded human health and ecological screening levels, possibly indicating contribution from anthropogenic sources unrelated to the Site. Only one poor purging compound, MIBK, exceeded available screening levels, both human health and ecological. No PCBs, pesticides or herbicides were detected in samples collected from benchmark locations in the North Drainage or the upper C-Drainage.

It is important to note that the findings of the human health risk assessment (Section 8 and Appendix T) and the ecological risk assessment (Section 9 and Appendix U) indicate that inorganic and organic constituents detected in excess of available screening levels in benchmark surface drainage water samples do not pose unacceptable exposures to potential receptors.

5.2.3 Groundwater

Groundwater at the vicinity of the Site ranges from brackish to highly brackish (i.e., brackish conditions generally defined as TDS > 1,000 up to ~10,000 mg/L). TDS concentrations in groundwater for all on-Site and off-Site wells, with the exception of water supply wells WS-1 through WS-4, are typically significantly greater than 1,000 mg/L and sometimes approach 20,000 mg/L. TDS concentrations for the water supply wells located along Casmalia Creek typically range between 1,100 and 1,500 mg/L and is considered slightly brackish, with the highest concentration at 3,700 mg/L. The lower TDS concentrations observed in the water supply wells located along Casmalia Creek are due to lower TDS surface water percolation into the creek alluvium.

TDS concentrations are naturally elevated in groundwater contained in the Upper HSU weathered claystone and Lower HSU unweathered claystone. Most monitoring wells are completed in weathered or unweathered claystone, as opposed to alluvium. TDS in offsite weathered and unweathered claystone is variable and often exceeds 5,000 ppm and can exceed 10,000 ppm. Where TDS is naturally elevated, major ions (e.g., chloride, sulfate) exceed their secondary MCLs while metals generally do not exceed their primary MCLs. Additional comparisons between onsite and offsite groundwater concentrations are made in Section 5.4.5.

Well RP-109D, located offsite in the North Drainage and screened in the Lower HSU, is sampled semi-annually as part of the Routine Groundwater Monitoring Element of Work (RGMEW) in order to monitor local background conditions. Of the organic compounds, only occasional estimated concentrations and very low detections of PAHs are observed in this well, which may be related to naturally occurring petroleum deposits, or the direct application of herbicides or pesticides.

5.3 Contaminant Sources

The nature and distribution of contaminants within the various media at the Site are directly related to operational and post-operational activities at the Site, more specifically to the type and location of former waste management facilities and related features formerly or currently present. Such facilities and features constitute the sources of contamination detected in the

environmental media assessed during the RI. Principal contaminant sources at the Site include the following:

- Existing landfill areas;
- Former disposal areas and site facilities that have not previously undergone cleanup; and
- Residual contamination remaining from prior site cleanup efforts.

Of these, the existing landfill areas and untreated former disposal areas represent the most significant continuing sources of contamination at the Site, with residual impacts from prior cleanup efforts being only locally significant. As further discussed below, the nature and distribution of the majority of chemical impacts to the various environmental media are readily attributable to one or more of these sources.

5.4 Affected Media

Investigations completed as part of this RI have assessed the potential presence of chemical impact to all pertinent environmental media at the Site and within the surrounding off-Site area, including the following:

- Soil (surface and subsurface);
- Soil Vapor;
- Sediment;
- Surface Water;
- Groundwater; and
- NAPL.

Drawing on the findings of the various investigations completed, the nature and extent of chemical impacts to these various media are discussed below. The nature and extent of contamination and human and ecological risks posed by this contamination were adequately defined during the RI field sampling and analytical testing activities described in the various attachments to this RI report. A summary of the RBC exceedances by media, location, and constituent is presented in Table 5-1.

5.4.1 Soil

The CSC sampled on-Site and off-Site soils to assess the nature and extent of contamination in surface and subsurface soils. The CSC's soil chemistry sampling and analysis methodology, data, and investigation results for the RI work are provided in Appendix G. This appendix includes figures that spatially post chemistry data next to sampling location wells, cross sections through select locations, cross sections through select areas with posted chemistry data (former RCRA Landfill area and "RISBON-59 Area"), soil boring logs, and an extensive set of box plots illustrating the range of metals concentrations for each study area.

Findings from the RI soil sampling and testing program (detailed in Appendix B) indicate that the majority of the study areas have experienced soil contamination attributable to former Site operations or facilities. Soil impacts are associated principally with former disposal areas or Site facilities that have not previously undergone cleanup. Soil impacts by inorganic and/or organic constituents have been documented in the following study areas:

- Administration Building Area
- Capped Landfills Area;
- RCRA Canyon Area;
- West Canyon Spray Area;
- Burial Trench Area;
- Central Drainage Area;
- Liquids Treatment Area;
- Maintenance Shed Area;
- Roadways Area; and
- Remaining On-Site Area, including the Former Ponds and Pads Subarea.

No soil impacts of significance were encountered in off-Site soils directly adjoining the Site. While high concentrations of organic constituents were detected in one location from within the Capped Landfills Area, these were encountered in a sample collected from depths in excess of 70 feet below ground surface, lying within waste and beneath the engineered cap of the P/S landfill.

To evaluate the presence of elevated constituent concentrations in surface and shallow soil (0 to 5.5 feet bgs), the results of the ERA and HHRA were used to identify constituents that contributed significantly to Site risk. The selected constituents include inorganic chemicals (barium, chromium, copper, and zinc) and organic chemicals (mammalian dioxin TEQ, total PCB congeners, total DDT, MCPP, trichloroethylene [TCE], and tetrachloroethylene [PCE]). The majority of these constituents were identified based on the ERA, with only a few (MCPP, PCE and TCE) identified from the HHRA results.

Risk-based concentrations for these constituents were developed for both ecological and human receptors using the methodologies presented in the ERA and HHRA (discussed in more detail below). The RBCs were then used as Ecological or Human Health Site-Specific Soil Screening Levels for comparison to Site data.

Ecological RBCs (Eco RBCs) for soil/sediment are risk-based values, developed based on ecological exposure and effects assumptions using the standard hazard quotient (HQ) model for assessing risk to ecological receptors (USEPA,1997). Eco RBCs were developed by re-arranging the standard USEPA (1997) HQ equation (See Appendix U) to estimate soil/sediment concentrations based on a target no-observed adverse effects level (NOAEL) HQ of 10 or a target lowest-observed adverse effects level (LOAEL) HQ of 1 for wildlife, and the literature derived screening level for ecological communities (e.g., plants, soil invertebrates). Target HQs or concentrations used in the estimation of Eco RBCs are considered protective of wildlife and ecological communities' populations. The Eco RBCs are based on wildlife for most of the risk drivers except TCE in surface soil, which is based on soil invertebrates and MCPP in sediment, which is based on sediment invertebrates. The Eco RBCs developed for this investigation are Site-specific for the inorganics (i.e., using Site-specific uptake data; see Appendix U) and some of the organics (total PCBs and DDT). For the remaining organics, the Eco RBCs are based on literature-derived exposure and effects data. The exposure assumptions and effect levels or toxicity values used in the model were obtained from guidance documents and widely accepted literature sources as described in Appendix U.

Human health RBCs (HH RBCs) were based on the methods used in the HHRA for evaluating the industrial/commercial worker. To develop the HH RBC an assumption regarding the target lifetime incremental cancer risk and target noncancer hazard index is necessary. For

constituents classified as carcinogens, a target risk of 1 x 10^{-5} was used to derive the HH RBC. This target risk level is the mid-point of the National Contingency Plan (NCP) discretionary risk range of 1 x 10^{-6} to 1 x 10^{-4} used to evaluate risks at Superfund sites. For chemicals classified as noncarcinogens a hazard quotient of 1 was used. The exposure assumptions and toxicity values used in the HH RBC derivation are described in Appendix T. HH RBCs were derived for all of the constituents identified as being potential risk-drivers (both ecological and human health receptors) to facilitate data evaluation. As mentioned above the majority of these constituents were identified based on the ERA, with only a few (MCPP, PCE and TCE) identified from the HHRA results.

Soil samples from throughout the Site were collected and analyzed for a broad suite of chemical constituents. Soil sampling locations, analytical program, and results are detailed in a series of maps and tables in Appendix B. Available data indicate that a comparatively small number of inorganic and organic constituents exceed the Site-specific RBCs. Constituents detected in soil in excess of RBCs are identified below, along with their respective Eco RBC and/or HH RBC values. It should be noted that while there may be a few individual samples in a Study Area that exceed a RBC, the Study Area as a whole may not pose a significant risk due to the use of the 95UCL concentration in the ERA and HHRA. The 95UCL concentration better represents the concentration a receptor may be exposed to on a regular basis. The sample-specific comparison to the RBCs presented in this section is to only provide context to the discussion of nature and extent of constituents across the Site.

Potential Risk-Driving Chemical	Eco RBC Value (mg/kg)		HH RBC Value (mg/kg)
	Surface	Subsurface	
Inorganic			
Barium	900	2,448	1.90E +05
Chromium	73.9	na	6.80E +04
Copper	25.5	14.9	3.80E +04
Zinc	191.5	353	2.90E +05
Organic			
Total DDT	0.0259	0.0275	63
Total Mammalian Dioxin TEQ	6.00E -06	6.00E -06	1.80E -04
Sum of PCB Congeners	0.120	0.110	na
MCPP	347	246	770
Trichloroethylene	0.0100	na	50
Tetrachloroethylene	194	194	110

Notes: na - Chemical not considered a potential risk-driver.
Derivation of RBC values is fully described in Sections 7 and 8 and Appendices T and U.

Detailed discussions regarding the analytical results for soil samples collected throughout each study area are presented in Appendix B. The following discussion summarizes the salient findings from the soil investigation.

A series of figures have been prepared which depict the nature and distribution of these chemicals in soil at concentrations in excess of the site-specific RBCs for barium, chromium, copper, zinc, total DDT, Dioxin TEQ (mammalian), MCPP, Total PCB congeners, PCE, and TCE (Figures 5-2 through 5-11). Constituent concentrations in these figures are illustrated relative to UTLs as well as compound-specific ecological and human RBCs for four depth discrete intervals, including surface soils (zero through 0.5 feet bgs), shallow soils (greater than

0.5 feet through 5.3 feet bgs), medium depth soils (greater than 5 feet through 10 feet bgs), and deep soils (greater than 10 feet bgs). Depiction of constituent concentrations for depths in excess of approximately 5.3 feet bgs is provided for Site characterization purposes only, as concentrations below this depth are not relevant to human or ecological risks due to incomplete exposure pathways.

The nature and distribution of the above listed chemicals are discussed in the following sections.

5.4.1.1 Inorganics

Inorganic chemicals determined to be potential risk driving constituents in soil are discussed relative to UTLs as well as both Eco RBCs and HH RBCs for depths up to approximately 5.3 feet bgs. Inorganic constituent concentrations for depths in excess of approximately 5.3 feet bgs are evaluated relative to UTLs and order-of-magnitude based concentration ranges in order to characterize constituent concentrations at these greater depths.

Exceedances of RBCs for inorganic constituents are much more widely distributed across a larger number of study areas as compared to those for organic constituents. Inorganic constituents detected at concentrations exceeding their respective Eco RBCs in surface and shallow soil (0 to 5.3 feet bgs) include barium, chromium, copper, and zinc. No inorganic constituents were detected in excess of their respective HH RBCs at the Site. The distribution of inorganic constituents at concentrations in excess of RBCs within surface to deep soil across the Site is depicted in Figures 5-2 through 5-5. As can be readily observed in these figures, inorganic constituents are widely present in excess of their respective Eco RBCs for surface soil, and to a lesser extent shallow subsurface soil, in both the RCRA Canyon Area and the West Canyon Spray Area. Eco RBC exceedances in other study areas are typically more localized, occurring in only one to several discrete sampling locations, or in clusters of several nearby sampling locations. Inorganics Eco RBC exceedances in the central Drainage Area are principally limited to the western half of that area between the toe of the P/S Landfill and the PSCT. Inorganic constituents were also fairly common in surface and shallow soils within the Liquids Treatment Area and the Maintenance Shed Area. Inorganics RCB exceedances within the Remaining On-site Area (including the Former Ponds and Pads Subarea) are comparatively rare, with the exception of copper which has a broad scattering of Eco RBC exceedances across this study area. Inorganic constituents are only rarely reported in excess of their respective UTLs in medium to deep soil across the Site (i.e., greater than 5.3 feet bgs), and include only isolated occurrences of barium, chromium, and copper, all situated in study areas located north of the PSCT.

The nature and distribution of these inorganic constituents in soil at the Site are discussed individually below.

5.4.1.1.1 Barium

Widespread Eco RBC exceedances for barium were encountered in surface and shallow soils in the RCRA Canyon area (Figure 5-2). Only isolated Eco RBC exceedances were encountered in other study areas, including the southern and eastern limits of the Maintenance Shed Area, the western portion of the Central Drainage Area, and several isolated locations south of the PSCT. These latter occurrences include a location just east of former Pond A near the PSCT, and three discrete locations just north of the RCF Pond, proximal to former Pond V and Pond B (Figure

5-2). Barium concentrations were also found to exceed the Eco RBC in a single sample from medium depth soils (greater than 5.3 feet through 10 feet bgs), but at a depth where exposure to ecological receptors is unlikely. Barium concentrations reported for the remaining locations are typically at levels below its UTL; however concentrations up to 1,000 mg/kg are locally present across the site. No barium RBC exceedances were encountered at depths in excess of 10 feet bgs, and barium was not found to exceed its HH RBC in any locations, at any depth.

5.4.1.1.2 Chromium

Chromium Eco RBC exceedances in surface soils are locally present along the west margin of RCRA Canyon Area, and in the central portion of the West Canyon Spray Area (Figure 5-3). Similar exceedances are also locally present in the Liquid Treatment Area (Roadway sample within the Liquid Treatment Area) and near the toe of the P/S Landfill within the Maintenance Shed Area and the west portion of the Central Drainage Area. Eco RBC exceedances for shallow soils are limited to two locations in the north central portion of the Liquid Treatment Area. Elevated levels of chromium up to less than 1,000 mg/kg are locally present in medium and deep soil within the Maintenance Shed Area. Chromium concentrations reported for the remainder of locations are typically at levels below its UTL; however, concentrations up to 100 mg/kg are present in a few scattered locations across the Site, including isolated areas in the Maintenance Shed Area, Burial Trench Area, the Liquid Treatment Area, and RCRA Canyon Area. Barium was not found to exceed its HH RBC in any locations, at any depth.

5.4.1.1.3 Copper

Copper Eco RBC exceedances are widespread in surface soil throughout the RCRA Canyon Area and the West Canyon Spray Area (Figure 5-4). Scattered Eco RBC exceedances in surface soil are also present across the Former Ponds and Pads Subarea, and also in small clusters within the Liquid Treatment Area, the Maintenance Shed Area, and at the toe of the P/S Landfill within the western portion of the Central Drainage Area. Eco RBC exceedances for copper in shallow soil are far less widespread than those in surface soil, and include locations where exceedances of both the Eco RBC and the higher UTL value for copper are present. Such exceedances are limited to a few locations lying within the upper reaches of the RCRA Canyon Area, central portion of the West Canyon Spray Area, the Burial Trench Area and clustered locations within the Liquid Treatment Area and the directly adjoining portion of the Remaining On-site Area. Isolated Eco RBC exceedances within shallow soil are also present in a few widely scattered locations within the Former Ponds and Pads Subarea, and one location in the western portion of the Central Drainage Area. For the majority of remaining locations, copper lies at or below its UTL value. With the exception of only one location in the Burial Trench Area, copper concentrations at depths in excess of approximately 5 feet bgs are reported to lie below 100 mg/kg. Copper was not reported to exceed its HH RBC level in any location, at any depth.

5.4.1.1.4 Zinc

Eco RBC exceedances for zinc are limited principally to surface soil within the RCRA Canyon Area and the West Canyon Spray Area, with only rare occurrences encountered in surface soil within portions of the Liquid Treatment Area and Maintenance Shed Area (Figure 5-5). No Eco RBC exceedances are reported for shallow soils at the Site. With only a few exceptions, zinc concentrations at the majority of remaining locations across the Site are reported to lie at or

below its UTL value, regardless of depth. Zinc is not reported to exceed its HH RBC value in any location, at any depth.

5.4.1.2 Organics

Organic chemicals determined to be potential risk driving constituents in soil are discussed relative to both ecological and human health RBCs for depths up to approximately 5.3 feet bgs. Organic constituent concentrations for depths in excess of approximately 5.3 feet bgs are evaluated relative to order-of-magnitude based concentration ranges in order to characterize constituent concentrations at these greater depths.

The distribution of organic constituents at concentrations in excess of RBCs is much more limited than that for inorganics. Organic constituents detected at concentrations exceeding their respective RBCs in surface and shallow soil (0 to 5.3 feet bgs) include total DDT, dioxin TEQ (mammalian), MCPP, total PCB congeners, PCE and TCE. The distribution of organic constituents at concentrations in excess of RBCs within surface to deep soil across the site is depicted in Figures 5-6 through 5-11. Organic constituents were detected in excess of RBCs in portions of the Burial Trench Area, the Central Drainage Area, the Liquids Treatment Area, Maintenance Shed Area, the Roadway Area, and Remaining On-site Area (including the Former Pond and Pad Subarea). Organics RBC exceedances typically occur in isolated single or several clustered sampling locations within these study areas. Of all RBC exceedances detected in surface to shallow soils at the Site, only three discrete surface soil sample locations were found to exceed HH RBCs, with the remainder of location exceeding only their respective Eco RBCs. With the exception of isolated Eco RBC exceedances for MCPP and/or DDT in surface and shallow soil within portions of the Liquids Treatment Area, the Maintenance Shed Area, and the Burial Trench Area, the majority of organics exceedances were encountered in the western portion of the Central Drainage Area between the toe of the P/S Landfill and the PSCT, and within isolated areas of the Remaining On-site Area, including just below the central portion of the PSCT, and north of the western limit of the RCF Pond. Elevated concentrations of organic constituents in medium to deep soil were principally limited to samples collected within the western portion of the Central Drainage Area, as well in a portion of the Former Ponds and Pads Subarea lying, just south of the PSCT, and corresponding with the location of former Pond B.

The nature and distribution of potential risk-driving organic constituents in soil at the Site are discussed individually below.

5.4.1.2.1 Total DDT

Eco RBC exceedances for total DDT in surface soil are present primarily as isolated single occurrences; however they may also locally occur in small clusters of several locations (Figure 5-6). Eco RBC exceedances in surface soil are reported for discrete single sample locations within the Liquid Treatment Area, the Maintenance Shed Area, and a Roadway Area sample adjoining the Burial Trench Area. Eco RBC exceedances for total DDT in surface soil within the Former Ponds and Pads Subarea include scattered discrete locations as well as clusters of two to three sample locations south of the PSCT in proximity to former Ponds G and S, and near the northwest limit of the RCF Pond. Total DDT Eco RBC exceedances in shallow soils are reported for isolated discrete samples in the Burial Trench Area and the western portion of the Central Drainage Area, as well as at several scattered locations within the Former Ponds and Pads Subarea, including one cluster south of the PSCT in proximity to former Pond S. Total DDT was

either not detected or was reported at concentrations below its Eco RBC in the remainder of samples collected from surface and shallow soil at the Site. For medium to deep soil, total DDT was reported at concentrations up to near 1 mg/kg at three discrete locations near the toe of the P/S Landfill within the western portion of the Central Drainage Area. Total DDT was not reported to exceed its HH RBC in any location, at any depth.

5.4.1.2.2 Dioxin TEQ Total Mammalian)

RBC exceedances for dioxin TEQ were limited to isolated sample locations within only three study areas, including the Burial Trench Area, the Maintenance Shed Area, and the Central Drainage Area (Figure 5-7). Dioxin TEQ was reported to exceed its Eco RBC for both surface and shallow soil in only one discrete location, lying within the Burial Trench Area. Dioxin TEQ was reported at concentrations in excess of its HH RBC in surface soil at single, discrete locations within the Maintenance Shed Area and the western portion of the Central Drainage Area, both situated at the toe of the P/S Landfill. Concentrations of dioxin TEQ in the remaining surface and shallow soil sample locations were reported to lie below its Eco RBC. With the exception of one location in the western portion of the Central Drainage Area, dioxin TEQ concentrations for medium to deep soil were all reported at concentrations less than $1x10^{-6}$ mg/kg, below both Eco RBCs and HH RBCs.

5.4.1.2.3 MCPP

MCPP was not detected at the majority of locations sampled throughout the Site, regardless of depth (Figure 5-8). The only exceedance was for a single surface soil sample within the Liquid Treatment Area, which was reported to exceed both the Eco RBC and HH RBC for MCPP. For shallow soil, there were no exceedances of either the Eco RBC or HH RBC for MCPP across the Site. MCPP was only rarely detected in medium depth soil, and where present, was reported at concentrations less than 10 mk/kg only within portions of the Central Drainage Area and Former Ponds and Pads Subarea. MCPP was detected at concentrations greater than 10 mg/kg in deep soil in several locations within the Central Drainage Area at the toe of the P/S Landfill, and in one location within the Burial Trench Area. Two of these locations coincide with the location of former Pad 9B, where samples were reported to contain MCPP at concentrations between approximately 100 to 420 mg/kg.

5.4.1.2.4 Sum of PCB Congeners

PCB congeners were not detected in the majority of samples collected across the Site, regardless of depth (Figure 5-9). No RBC exceedances for PCB congeners were reported for surface soils at the Site. The only Eco RBC exceedance for PCB congeners at the Site was encountered in shallow soil at the location of former Pond B, just south of the PSCT within The Former Ponds and Pads Subarea. All detections of PCB congeners within medium to deep soil at the Site were reported at concentrations below the Eco RBC. As PCB congeners were not found to be a risk-driver for potential human receptors there was no HH RBC established for this chemical.

5.4.1.2.5 Tetrachloroethylene

Tetrachloroethylene (PCE) was not detected in the majority of samples collected across the Site (Figure 5-10). No RBC exceedances for PCE were reported for surface soil. The only location reported to contain PCE at a concentration in excess of both its Eco RBC and HH RBC was a

single sample collected from within the Former Ponds and Pad Subarea at the location of former Pond B, situated just south of the PSCT. PCE concentrations in this same location were reported to be in excess of 1,000 mg/kg in medium depth soil. The only other location reported to contain PCE in excess of 100 mg/kg was a single deep soil sample collected in the western portion of the Central Drainage Area in a position corresponding with former Pad 9A.

5.4.1.2.6 Trichloroethylene

Trichloroethylene (TCE) was not detected in the majority of samples collected across the Site (Figure 5-11). Exceedances of the Eco RBC for TCE were limited to surface soil locations clustered in the central portion of the Site near and below the toe of the P/S Landfill. This includes locations within the western portion of the Central Drainage Area, as well as locations within the Former Ponds and Pads Subarea and Remaining On-Site Area just south of the PSCT. Additionally, one surface soil sample from the Burial Trench Area was also reported to contain TCE in excess of its Eco RBC. No Eco RBC or HH RBC exceedances were reported for shallow soil samples collected across the Site. TCE was reported in excess of 100 mg/kg in a single medium depth soil sample collected from within the limits of former Pond B in the Former Ponds and Pads Subarea, and concentrations of between 10 and 100 mg/kg in three locations within the western portion of the Central Drainage Area, corresponding with former Pads 9A and 9B.

5.4.1.3 Lateral and Vertical Delineation of Soil Impacts

With several notable exceptions, the depth and lateral extent of soil impacts in excess of screening levels have been adequately defined in all soil locations. Elevated inorganic constituents (relative to UTLs) are mostly restricted to surface or shallow-to-medium depth soils (i.e., 0 to 10 feet bgs), and typically demonstrate diminishing concentrations with increased depth. Exceptions to this general condition include high barium concentrations to depths of at least 24 feet bgs in the northern portion of RCRA Canyon, localized occurrences of other elevated inorganics at depths of at least 20 feet bgs in several borings completed in the Maintenance Shed Area, and in excess of 10 feet bgs in portions of the Central Drainage Area.

Soil impacts by both inorganic and organic constituents in the vicinity of location RISBON-59 locally extend to depths of at least 30 feet bgs and 55 feet bgs, respectively. Elevated inorganics were also locally encountered at depths of at least 49 feet bgs along the southeastern margin of the Site, along NTU Road south of the RCF Pond.

High concentrations of organic constituents are also locally present to the maximum depths explored in several borings completed near former waste management facilities within the Central Drainage Area, the Former Pond and Pad Subarea, and the Burial Trench Area. Such cases include elevated organics extending to depths of at least 20 feet bgs near former Ponds A and B, just south of the PSCT, to depths of at least 5 feet bgs in a cluster of shallow borings completed north of the western end of the RCF, to depths of at least 5 feet bgs in a cluster of several shallow soil borings just south of PSCT-1, and to depths of at least 48 feet bgs in the area between the toe of the P/S Landfill south to the PSCT. Deep VOC exceedances at depths of >40 feet bgs in the Liquids Treatment Area are attributable to a collection of these soil samples below the local water table, and likely reflect influences of contaminated groundwater present in the area.

Maximum VOC concentrations were encountered in a boring completed in former Pond B, followed by several deep borings completed in the Burial Trench Area. The maximum depth of soil impacts was encountered in the Burial Trench Area where former deep waste disposal operations have resulted in inorganics exceedances in soils at depths of up to 44.75 feet bgs, and organics exceedances at depths of up to 77.5 feet bgs.

The lateral extent of soil impacts in these above-listed areas is adequately defined by soil samples taken from surrounding borings that do not indicate significant contaminant concentrations. With exceptions, inorganic exceedances in soil are restricted to surface or shallow-to-moderate depth soils (i.e., 0 to 10 feet bgs) in the areas south of the PSCT and west of the PCB Landfill and Burial Trench Area, and typically demonstrate diminishing concentrations with increased depth. These areas include the RCRA Canyon/West Canyon Spray Area and most areas of the Former Ponds and Pads Area. Not including the landfills, high concentrations of organic constituents, principally VOC, PAHs, and/or PCBs, are locally present to the maximum depths explored at locations near former waste management facilities within the Central Drainage Area, select areas the Former Pond and Pad Subarea, and the Burial Trench Area. Drilling and sampling for chemical analysis was not performed below the contact.

5.4.2 Soil Vapor

VOC concentrations above sample quantitation limits were reported at all soil vapor sample locations, including both on-site and off-site step-out locations. A total of 43 individual VOCs were detected at the various sampling locations around the perimeter of the landfills, the Burial Trench Area, and the Central Drainage Area, including chlorinated and aromatic hydrocarbons, acetone, methyl ethyl ketone, and Freon gases. With only a few exceptions, those VOCs detected in off-site step-out locations were also reported to be present in on-site sampling locations.

Chemicals detected in soil vapor that demonstrate some of the highest prevalence and reported concentrations, or that may contribute to human health or ecological risks, include acetone, methyl ethyl ketone, Freon 113, 1,3-butadiene, benzene and tetrachloroethylene. The distributions of these constituents are depicted in Figures 5-12 through 5-17, respectively. Figure 5-18 depicts the distribution of total VOC concentrations at each location for a list of primary chemicals that were frequently detected or are considered COPCs. As shown in Figure 5-18 maximum concentrations of total VOCs are observed at two locations along the PSCT at the southern edge of the Central Drainage Area, at one location at the base of the P/S Landfill along the western edge of the Central Drainage Area and at one location within the Burial Cells unit. Elevated concentrations may also be present within the interior of the Central Drainage Area where LNAPL and DNAPL have been observed, however soil vapor samples were not collected in this area due to the planned remedy which includes a cap cover over the entire Central Drainage Area. Maximum concentrations of individual constituents were encountered along the eastern and northeastern limits of the Capped Landfills Area (acetone and 1,3-butadiene), south of the PSCT below the Maintenance Shed Area (1,3-butadiene and benzene), the western limit of the Central Drainage Area and eastern margin of the Burial Trench Area (Freon 113), the southern and western Central Drainage Area (tetrachloroethylene), as well as west of the Burial Trench Area, the northwestern limit of the Capped Landfills Area, and two locations along the PSCT south of the Central Drainage Area and Burial Trench Area (methyl ethyl ketone). The locations of the samples with elevated concentrations are consistent with previously identified source areas at the site. Two of these samples (RISVBC-03 and

RISVBC-06) were collected within the burial trenches, one sample (RISVCD-01) was located within the boundaries of former Pond R where waste was not removed, and two samples (RISVCD-02 and RISVCD-03) are located near the Perimeter Source Control Trench (PSCT) which has historically contained free product.

Soil vapor samples were collected at three locations in the Capped Landfills Area (RISVCL-03D, RISVCL-05D and RISVCL-08D) at two or more different times. These were discrete, one-time soil vapor samples collected from temporary (non permanent) probes, so temporal concentration trends could not be evaluated. In addition, samples were collected at two depths (7.5 ft and 20 ft bgs) at three locations near the northern Zone 1 boundary in the Capped Landfills Area (RISVCL-03/03B, RISVCL-05/05B and RISVCL-08/08B). No general concentration trend with respect to sample depth is seen. However, Freon 11 and Freon 113 have higher concentrations at depth at sample location clusters RISVCL-05/05B and RISVCL-08/08B located on the northern boundary of the Capped Landfill Area. Conceptually, elevated soil vapor concentrations are interpreted to occur from near ground surface down to the water table in the landfill areas.

Off-site soil vapor samples generally contained similar chemicals as on-site samples but at lower concentrations. A few exceptions to this are the presence of acetone (Figure 5-12) at similar concentrations as nearby on-site samples north of the Capped Landfill Area and in the Northern Drainage and the detection of tetrachloroethylene at relatively low concentrations at off-site locations to the north of the capped landfills and in the Northern Drainage when nearby on-Site samples were non-detect (Figure 5-17).

5.4.3 Sediment

Sediment sampling and testing were conducted in three study areas of the Site where this media occurs, including the three onsite Stormwater Ponds (RCF, A-Series Pond, and Pond 13), the two onsite Treated Liquids Impoundments (Pond A-5 and Pond 13), and in the A-, B-, C-, and North Drainages in the Off-site Area. Sediment sampling in the Stormwater Ponds and the Treated Liquids Impoundments included collection and analysis of pond-bottom sediments, whereas sampling and testing in the Off-site Area included collection and analysis of sediments collected from surface drainage bottoms.

As one or more of the Stormwater Ponds and/or Treated Liquids impoundments may be emptied and closed as part of long-term corrective action at the Site, sediment data for these study areas were also compared to RBCs for soil to assess the significance of potential terrestrial exposure upon closure of these facilities. Concentrations in sediment are depicted in the series of figures for soils prepared to depict the nature and distribution of chemicals at concentrations in excess of the site-specific RBCs for barium, chromium, copper, zinc, total DDT, Dioxin TEQ (mammalian), MCPP, Total PCB congeners, PCE, and TCE (Figures 5-2 through 5-11).

Available data indicate that only MCPP is locally present in on-Site sediments at concentrations in excess of Site-specific sediment RBCs. However, both barium and copper are locally reported in sediment samples in excess of their respective soil Eco RBCs. MCPP is not reported at concentrations in sediment which exceeds its soil RBC. No other organic or inorganic constituents are present in on-Site of off-Site sediment at concentrations above sediment or soil RBCs.

Constituents detected in sediment in excess of RBCs for either soil or sediment are identified below, along with their respective Eco RBC and/or HH RBC values.

Potential Risk-Driving Chemical	Soil Eco RBC Value (mg/kg)	Soil HH RBC Value (mg/kg)	Sediment Eco RBC Value (mg/kg)	Sediment HH RBC Value (mg/kg)
Inorganic				
Barium	900 (surface)	na	na	na
Copper	25.5 (surface)	na	na	na
Organic				
MCPP	na	na	0.002	770

Notes: na - Chemical not considered a potential risk-driver Derivation of RBC values is fully described in Sections 7 and 8 and Appendices T and U

Detailed discussions regarding the analytical results for sediment samples collected within each of the three above-listed study areas are presented in Appendix B. The following discussion summarizes the salient findings from the sediment investigation.

The distribution of MCPP at concentrations in excess of its sediment Eco RBC in on-site surface and shallow sediment samples (0 to 0.5 feet bgs and >0.5 to 5.0 feet bgs, respectively) is depicted in Figure 5-19. Similarly, the distribution of barium and copper at concentration reported in excess of their respective soil/Eco RBCs in on-site surface and shallow sediment samples is depicted in Figures 5-2 and 5-4, respectively. The nature and distribution of detected constituents at concentrations in excess of their site-specific RBCs in both on-site and off-Site sediment is discussed in the following sections.

5.4.3.1 Inorganics

No inorganic constituents were detected in sediments at concentrations in excess of either their Eco RBC or HH RBC for sediments. This includes both pond bottom sediments as well as sediments present and off-site drainages. However, when compared to soil RBCs, sediment samples were locally found to exceed these values for both barium and copper. Several sediment sampled collected from Pond A-5 were reported to have barium (two surface samples) and copper (three surface samples) concentration in excess of their respective *soil* Eco RBCs. Copper was also reported in sediment in excess of its soil Eco RBC in the A-Series Pond (four surface samples), Pond 18 (two surface samples, and one shallow sample), and the RCF Pond (two surface samples and three shallow samples).

5.4.3.2 Organics

The only organic constituent detected above its sediment or soil RBC in sediments at the Site is MCPP, which is reported to exceed its sediment Eco RBC in only single, isolated sediment sampling locations within each the RCF pond, Pond A-5, and Pond 18. No other organic constituents were detected in on-site sediments in exceedance of their respective sediment or soil Eco RBCs or HH RBCs, and no organic constituents were found to exceed RBCs in sediment samples collected from off-site drainages.

5.4.3.3 Lateral and Vertical Delineation of Sediment Impacts

The lateral and vertical extent of chemicals exceeding RBCs in on-site as well as off-site sediment is adequately defined by the available data. This information indicates exceedances of sediment RBCs to be limited to the Eco RBC for organic chemical MCPP only, and that such

exceedances are localized in nature and restricted to localized occurrences within three of the five on-site ponds. When compared to *soil* RBCs sediments are found to locally exceed Eco RBCs for both barium (A-Series pond only), and copper (Pond A-5, A-Series Pond, Pond 18, and the RCF Pond). While exceedances of barium *soil* Eco RBCs are limited to only surface sediment samples in a single pond, exceedances of copper *soil* Eco RBCs are present in both surface and shallow sediment samples in portions of Pond 18 and the RCF Pond.

5.4.4 Surface Water

As summarized in Appendix D of this report, surface water samples were collected and analyzed from four types of locations at and surrounding the Site, including: (1) benchmark locations (i.e., those situated upstream of the Site, including the North Drainage and upper C-Drainage); (2) downstream locations (A-Drainage and lower C-Drainage); (3) on-site location (RCRA Canyon drainage); and (4) on-site ponds, including stormwater ponds and treated liquid impoundments. A detailed discussion of on-site and off-site surface water conditions is presented in Appendix D, and the salient findings of surface water investigations are summarized below.

5.4.4.1 Off-site Drainages

As discussed in Section 5.2.2, inorganic constituents were reported in benchmark locations in the North Drainage and upper C-Drainage areas at dissolved concentrations in excess of one or more screening level, including aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, silver, vanadium, and zinc. For benchmark locations, reported values for inorganic constituents in the North Drainage area are considerably elevated relative to those in the upper C-Drainage area. Field observations indicate surface water in the North Drainage area emerges from weak underground seeps, contributing mineral-rich waters into this drainage. Noted differences in dissolved inorganics concentrations between these two benchmark locations are likely attributable to soil and hydrologic conditions unique to the North Drainage area, and are affected by seasonal variation in stormwater flow.

The reported values for inorganic constituents in samples from the A-Drainage area are considerably lower relative to those in the North Drainage benchmark location, and those few organic constituents detected in samples from this drainage were either reported at concentrations below available screening levels or at lower concentrations than in other locations.

The detected inorganics in samples from the lower C-Drainage area are also generally reported at lower concentrations than those from the North Drainage benchmark locations. Findings from lower C-Drainage samples indicate that this area is elevated with respect to manganese compared to the upper C-Drainage benchmark location. Field observations indicate that ranching operations and land use activities in this area have disturbed the lower C-Drainage which can generally degrade surface water quality. No site-specific studies have been performed to quantify any potential ranching operation effects total and dissolved inorganics concentrations.

Detections of organic compounds in the benchmark locations were mainly limited to several SVOCs and dioxins. Of the detected organics, SVOCs (dominantly PAHs) were reported only at relatively low concentrations, slightly in excess of human health and ecological screening

levels. Total TEQ concentrations exceeded human health and ecological screening levels. The results for these organic constituents indicate that they are the result of contribution from anthropogenic sources unrelated to the Site.

The reported concentration of n-nitrosodipropylamine in the southernmost lower C-Drainage sample location exceeds levels of this compound reported for benchmark locations. Additionally, the presence of carbon disulfide in the lower C-Drainage area is apparently unique to this area.

5.4.4.2 On-site Drainage

For surface water samples collected from the on-site RCRA Canyon drainage, each of the inorganic constituents reported at dissolved concentrations in excess of screening values were also detected in the North Drainage benchmark locations. In general, dissolved inorganic concentrations varied over a relatively small range between the benchmark locations and the RCRA Canyon location. However, arsenic, molybdenum, nickel, and selenium were encountered in the RCRA Canyon drainage at maximum dissolved concentrations when compared to all other surface water drainage sampling locations. While a variety of organic constituents were detected in samples from the RCRA Canyon drainage, each were reported at levels less than or comparable to those reported for benchmark locations. When compared to other surface water sampling locations, including both on-site ponds and off-site drainages, TDS levels in RCRA Canyon stormwater runoff remain relatively consistent, and do not display the drop in concentration during wet season stormwater flow conditions apparent in these other locations (Figures 5-1a and 5-1b).

RCRA Canyon runoff only occurs during peak rainfall events. The TDS of the three RCRA Canyon stormwater samples ranged from 2,582 to 3,490 mg/L. The March 2005 RCRA Canyon stormwater sample TDS concentration is as follows compared to the offsite drainage results:

Period	Date	Casmalia Creek (RISWOF-03)	North Drainage (RISWOF-02)	A Drainage (RISWOF-01)	RCRA Canyon (RISWRC-01)
Summer/Fall	August 2004	778 mg/L	7,112 mg/L	Dry	Dry
Winter/Spring	March 2005	364 mg/L	602 mg/L	138 mg/L	2,582 mg/L

With few exceptions, the available data generally indicate that surface water samples collected in the North Drainage area contain a larger variety of constituents at overall higher concentrations than comparable samples collected from off-site locations situated downstream of the Site. The notable exceptions to this general condition include the presence of arsenic, molybdenum, selenium, and n-nitrosodipropylamine at maximum reported concentrations within surface water from the RCRA Canyon drainage, and the unique presence of acetone and acetonitrile in the RCRA Canyon drainage relative to all other surface water sampling locations.

In summary, surface water data indicate the presence of several naturally occurring inorganic constituents as well as SVOCs (mainly PAHs) and dioxins and furans at concentrations exceeding screening levels, and that these constituents exist in locations situated upgradient and physically removed from the Site.

5.4.4.3 On-site Ponds

The waters within the on-site ponds contain relatively low levels of organic compounds, though some VOCs, SVOCs, and PAHs are commonly detected at elevated concentrations. Concentrations of chlorinated VOCs are generally low to non-detect. Of the inorganic analytes, arsenic, nickel, chromium and selenium are commonly detected at elevated concentrations. Of the ponds sampled, Pond 13 has the highest concentrations of dissolved metals. TDS concentrations within the ponds have historically been higher than those observed in the offsite drainages and RCRA Canyon, due to the concentration of salts within the ponds that occurs as the water within them evaporates. Time-concentration graphs for VOCs and general minerals / TDS within the ponds are presented in Attachments G-1 and G2 to Appendix G.

TDS and metals in the onsite ponds have steadily increased since the 1997/98 El Nino winter when a large amount of fresh stormwater runoff filled the ponds to near capacity and diluted TDS and metals concentrations. TDS concentrations in the ponds were below 10,000 ppm in 1998 after dilution. TDS has steadily increased since then through evaporation and currently exceeds 20,000 ppm in most ponds (Figure 4-7). Salts and metals increase over time because these are terminal ponds with no outflow. TDS concentration increase year-to-year, with temporary dilution during winter storm water runoff events.

Dissolved and total inorganic constituent concentrations within the on-site ponds are plotted along with those for on-site and off-site surface water drainage samples for comparison purposes for the expanded fall 2004 and spring 2005 RI sampling events (Figures 5-1a and 5-1b). With few exceptions, inorganic constituents in surface water within on-site ponds are reported to be elevated relative to those in on-site of off-site drainages. Inorganic analytical results for samples collected from the surface water ponds indicate arsenic, nickel, and selenium were reported with screening level exceedences in all five ponds during semi-annual sampling events conducted during the fall of 2004 and the spring of 2005. Pond 13 was reported with the highest concentrations of these metals. Chromium, manganese, and vanadium were the only other inorganic compounds reported above screening levels. Chromium exceeded the screening level in Pond 13, Pond A-5, and the RCF Pond. Manganese exceeded the screening level in Pond A-5, and vanadium exceeded the screening level in the A-Series Pond and Pond A-5. TDS concentrations in on-Site ponds are uniformly and consistently higher than corresponding concentrations reported for on-Site and off-Site drainages. In general, concentrations of inorganic constituents in the on-Site ponds have gradually increased over time since the 1997/1998 El Nino winter, with annual fluctuations corresponding to seasonal conditions (Appendix D – Attachment D-4).

The majority of the screening level exceedences during the fourteenth and fifteenth semi-annual events were for SVOCs. N-nitrosodipropylamine and n-nitrosopyrrolidine were reported above screening levels in all ponds, with the exception of Pond 18. EDB, methylene chloride, MTBE, tetrahydrofuran, and TCE were the only VOCs reported above screening levels. In general, the surface water ponds have maintained low to non-detect concentrations of chlorinated VOCs over time (Appendix D – Attachment D-4).

The dioxin, OCDD, was reported above the screening level in Pond 13, Pond A-5, and the RCF Pond. No other dioxins, furans, PCBs, pesticides, or herbicides were detected in the surface water pond samples collected during the fourteenth and fifteenth semi-annual event.

Based on general mineral, total dissolved solids (TDS), and pH analytical results, the Pond water is characterized as sodium-chloride type. The general mineral concentrations for all of the surface water ponds have remained stable over time, with the exception of chloride, sodium, sulfate, and TDS. These four general minerals have gradually increased over time until the Fall 2005 sampling event. TDS concentrations in the five ponds are elevated in relation to the surface waters in the nearby drainages and have routinely fluctuated seasonally. The TDS concentrations in each pond have consistently been higher during dry periods that resulted in lower pond water levels relative to wet periods and higher pond water levels. Increased TDS concentrations during periods of lower pond levels are caused by the concentration of salts as the volume of water within the ponds is reduced by evaporation. The lowest TDS concentrations in the five ponds were observed during and immediately following the winter of 1997/1998, when El Nino rains filled the ponds to near capacity. TDS concentrations have generally increased since the El Nino winter, though TDS levels vary seasonally being highest at the end of summer when pond evaporation results in low water levels and TDS is diluted following the winter rains as pond recharge occurs.

General mineral concentrations and organic constituent concentrations over time for the surface water ponds are presented in Appendix D - Attachments D-3 and D-4, respectively. The pH values were generally neutral to slightly basic, ranging from 7.39 to 9.02.

5.4.5 Groundwater

The CSC monitors groundwater quality in select monitoring wells on a semi-annual basis as part of the RGMEW. The Fourteenth and Fifteenth SA events in fall 2004 and spring 2005, respectively, were expanded in scope to provide a more complete picture of conditions at the time of this RI Investigation. In addition, the CSC and EPA sampled select wells during the Ninth and Tenth SA events in spring and fall 2002 for radionuclide analysis.

The CSC's groundwater chemistry sampling and analysis methodology, data, and investigation results for the RI work are provided in Appendix G. This appendix includes figures that spatially post chemistry data next to individual wells, provides iso concentration maps for the Upper HSU and Lower HSU, time-concentration graphs for numerous wells for organic and inorganic constituents, and an extensive set of box plots illustrating the range of metals concentrations for the Upper HSU and Lower HSU for onsite and off-Site areas.

Groundwater contamination is predominantly located within the boundary of Zone 1 with significantly less contamination in Zone 2. Groundwater chemistry and contaminant distribution is influenced by groundwater flow conditions which are described in Section 4. As discussed in Section 4, topography, rainfall recharge, subsurface physical properties, the groundwater extraction facilities (Gallery Well, Sump 9B, PSCT, and three PCTs), and the five ponds (RCF, A-Series, Pond A-5, Pond 18, and Pond 13) influence groundwater flow. These features are described below as they relate to groundwater chemistry and contaminant distribution.

Organic Compounds

VOCs are used to summarize the extent of organic compounds. VOCs are generally more mobile in groundwater relative to the other classes of organic compounds (SVOCs, herbicides, pesticides, PCBs, and dioxins/furans) and the extent of the other classes of organic compounds are generally contained within the extent of VOCs. Therefore, to illustrate the extent of contamination, Figures 5-20 through 5-22 present maps of Total VOC iso concentration

contours with time-concentration graphs of select VOCs (1,1-DCA, 1,1-DCE, cis-1,2-DCE, Freon 113, PCE, trans-1,2-DCE, TCE, and vinyl chloride) posted next to wells for the Upper HSU and Lower HSU. These select VOCs are used because they are the most persistent and wide spread organic compounds. Additional figures in Appendix G post organic chemistry data next to individual wells for these VOCs, other VOCs, other organic compounds (SVOCs, pesticides, PCBs, herbicides, and dioxins and furans) for wells in the Upper HSU and Lower HSU.

Zone 1 (Onsite), Upper HSU. In the Upper HSU, VOC contamination zones are separated by the PSCT. The Zone 1 area is north of the PSCT in the area of the primary source areas and contains the majority of the dissolved phased VOC contamination and all of the known Non-Aqueous Phase Liquid (NAPL) contamination. As further described below, free-phase LNAPL occurs within the P/S Landfill and in the Central Drainage Area and free-phase DNAPL occurs within the P/S Landfill in the Upper HSU.

VOC concentrations north of the PSCT are much higher than south of the PSCT (Figures 5-20 and 5-21). The northern extent of the Upper HSU contamination from east to west occurs in from the Caustic/Cyanide Landfill and Acids Landfill westward through the Metals Landfill, P/S Landfill and to the Burial Trench Area south of the PCB Landfill. When saturated with groundwater, low levels of VOCs occur underneath the North Ridge along these landfills in the Upper HSU, but do not extend northward into the North Drainage. The eastern extent of VOC contamination is delineated by several monitoring wells near the eastern extent of the PSCT, Caustic/Cyanide Landfill and North Ridge. The western extent of the VOC contamination is delineated by several monitoring wells on the North Ridge and west of the BTA and PSCT. Consistent with the groundwater flow direction moving south from the North Ridge groundwater flow divide, the VOC plumes in the Upper HSU beneath the landfills flow south and converge into the Central Drainage Area and into the PSCT in the PSCT-1 area. The VOC plume in the Upper HSU in the Burial Trench Area flows south into the PSCT in the PSCT-4 area. The distribution of VOC contamination in the Upper HSU is consistent with groundwater flow directions.

VOC concentrations south of the PSCT are much lower than north of the PSCT (Figures 5-21 and 5-22). Groundwater extraction from the PSCT intercepts most, if not all, southward VOC contaminant migration north of the PSCT. This is indicated by the distribution and concentrations of compounds detected to the north and south of the PSCT. Upper HSU VOC contamination in groundwater south of the PSCT is the highest south of PSCT-1 and PSCT-4. The contamination in these two areas is typically one to two orders of magnitude lower in concentration than the concentrations north of the PSCT in the adjacent Burial Trench and the Central Drainage Areas. The VOC contamination sharply declines south of the existing on-Site ponds and generally is not detected south the five ponds.

The areas with the highest concentrations of VOCs are located north of the PSCT, with the highest concentrations located within the P/S Landfill, the Central Drainage, the Burial Trench Area (BTA), and near the toe of the Metals, Caustic/Cyanide, and Acids Landfills (Figure 5-20). The concentrations for VOC compounds in the Upper HSU north of the PSCT ranged from below laboratory reporting levels to in excess of 1,000,000 parts per billion (ppb). The time-concentration graphs indicate the following for the areas north of the PSCT:

- Concentrations in the Burial Trench Area (SW-17, RIMW-6, IRMW-7, RIMW-8, SW-44), have been declining over the past several years. This may due to natural attenuation

mechanisms as further described in Section 6 and Appendix O. Concentrations in the downgradient PSCT-4 extraction well appear to be steady-to-declining, which may be related to the declining concentrations in the upgradient wells in the Burial Trench Area.

- Concentrations in the Central Drainage Area and southern areas of the landfills have been relatively steady or increasing over the past several years. This may be because the overall mass of contamination is much greater in this area than the Burial Trench Area. As further described below, several of the wells are completed in areas that have residual or free-phase NAPLs present. Concentrations in the Gallery Well and Sump 9B extraction wells are relatively steady.

The highest VOC concentrations south of the PSCT were detected at concentrations of approximately 25,000 and 10,000 ppb in wells RG-4B and RG-2B, which are located just south of PSCT-4 (Figure 5-21). The wells located just south of PSCT -1, -2, and -3 had VOC concentrations ranging from approximately 100 to 500 ppb, while the rest of the area south of the PSCT in the vicinity of the RCF Pond and Ponds 13 and 18 had VOC concentrations that ranged from below the laboratory detection limits, to approximately 50 ppb. VOCs were below 10 ppb for all other Zone 1 wells, with the exception of well SW-46, located in RCRA Canyon, which had a VOC detection of 23 ppb. The time-concentration graphs indicate the following for the areas south of the PSCT:

- Concentrations immediately south of PSCT-4 (RG-2B, RG-4B) appear to have been relatively steady over the past several years.

- Concentrations for many wells south of PSCT-1, -2, and -3 (RG-1B, RG-6B, RIMW-2, and WP-3S) have been declining over the past several years or relatively steady (RG-7B). This may due to the effectiveness of the PSCT at preventing southward contaminant migration from the northern primary source areas and natural attenuation mechanisms as further described in Section 6 and Appendix O.

- The low-level concentrations in the PCT extraction wells for the A-Drainage (RAP-3A), B-Drainage (RAP-1B), and C-Drainage (C-5) have been declining over the past several years. This may be due to natural attenuation mechanisms and also from dilution from pond water that recharges the PCTs. VOC levels in the ponds are very low to non-detect and the flushing of this water through the Upper HSU has led to the decrease in PCT extraction well concentrations. The low-level concentrations immediately offsite next to the C-Drainage PCT (RP-28B) have also been decreasing.

The area south (downgradient) of the PSCT formerly contained ponds used for liquid impoundment, and Site-related impacts reported in previous documents (WCC and CE, 1989). Prior to construction of the PSCT, concentrations of organic compounds ranging up to thousands of micrograms per liter were detected in the downgradient, southern area. These historical detections of organic compounds suggest that groundwater south of the PSCT was impacted by organic contaminants prior to construction of the PSCT. Although the data are limited, pond closure and the construction of the PSCT appear to have resulted in stable or declining concentrations of organic compounds to the south, as demonstrated by the time-concentration charts in Figures 5-20 and 5-21. Detections of organic compounds downgradient of the PSCT are, therefore, largely attributed to pre-existing contamination rather than to ongoing southward plume migration across the PSCT since EPA begin extraction from the

PSCT in 1992. The progressive lowering of the action level in the PSCT (Table 2-9) has increased the barrier's effectiveness at preventing contaminant migration.

Zone 1 (Onsite), Lower HSU. The majority of the samples collected from the Lower HSU did not contain VOC concentrations in excess of the cleanup levels. However, low concentrations of VOCs occur within the Lower HSU at the following areas: The Central Drainage Area; the Burial Trench Area; the southern edge of the Acids Landfill; along the PSCT; along the North Ridge; and northeast of the Caustic/Cyanide Landfill (Figure 5-21). The PCB Landfill, Burial Trench Area and northern parts of the capped landfills (P/S, Metals, Caustics/Cyanide and Acids) are in areas that extend southward from the North Ridge and are in a broad area that has strong vertically downward groundwater gradients. These gradients and resulting groundwater flow carried VOCs from the higher concentration source areas downward into the lower-permeability Lower HSU.

As shown on Figure 5-22, the highest concentrations of VOCs are located in BTA well RIPZ-16, Central Drainage Area well RGPZ-6D, and well RP-98C, located at the toe of the Acids Landfill. VOCs were also detected in excess of 100 ppb in well RGPZ-2D, which is located at the northwest corner of the site. VOCs were detected in several wells along the PSCT at low concentrations. No Lower HSU total VOCs were detected below the PSCT at concentrations greater than ten ppb with the exception of wells RGPZ-8D, which is located just south of PSCT-1 and well RGPZ-15B, which is located just south of PSCT-3.

The Central Drainage Area contains the largest quantity of VOC contamination measured in the Lower HSU. This contamination appears directly related to overlying Upper HSU VOC contamination present within the P/S Landfill and between the P/S Landfill and PSCT. The area underlying and immediately surrounding the P/S Landfill likely also has higher concentrations of VOCs, but there are no wells installed in the Lower HSU underneath the P/S Landfill to document these conditions. The greatest number of VOC cleanup level exceedances in the Central Drainage Area Lower HSU was detected in piezometer RGPZ-6D. Wells RGPZ-6C and RGPZ-6D are near wells RGPZ-7C and RGPZ-7D which have measurable free-phase DNAPL. It is likely that the high VOCs in wells RGPZ-6C and RGPZ-6D are related to this DNAPL contamination.

The Burial Trench Area contains the piezometer with the second greatest number of VOC exceedances, well RIPZ-16. This contamination appears directly related to overlying Upper HSU VOC contamination from waste placed in the burial trenches and injected into injection wells in and around the burial trenches. Although the nearby well RIPZ-15 did not have measureable VOC contamination, it is likely that other areas within the Lower HSU underlying the Burial Trench Area also contain VOC contamination. No wells in this area have measurable free-phase DNAPL.

The remainder of Lower HSU wells with infrequent to few VOC exceedances occur along the PSCT, along the North Ridge, and northeast of the Caustic/Cyanide Landfill.

Sufficient data do not exist to perform an analysis of the VOC concentrations changes over time for most of the Lower HSU wells because many of the wells were only sampled during the two RI sampling events (2004 and 2005). Most of the wells with longer-term VOC monitoring data are for wells that are outside of the areas affected by VOCs. For these wells, the time series charts show occasional anomalous detections which are not repeatable. The VOC time-series concentration charts for Lower HSU wells and piezometers are provided in Figure 5-22.

Zone 2 (Offsite). In Zone 2, VOC concentrations in Upper HSU wells in the North Ridge, North Drainage, and the A-, B-, and C-Drainages have only infrequently exceeded their respective MCL/PRGs. Of the eleven Zone 2 wells that have had one or more VOC exceedance between September 1997 and October 2008, seven of the wells had only one VOC exceedance during one event, while the remaining four wells had one exceedance during four events (SW-47, North Ridge), one exceedance during two events (B3M, B-Drainage), two exceedances during one event (RP-76A, C-Drainage), and well RP-28B, located in the C-Drainage, had one exceedance during two events and four exceedances during one event. SVOC concentrations have also been only infrequently detected above their MCL/PRGs in Upper HSU Zone 2 wells. One or more VOC and/or SVOC compounds have also been detected infrequently above their MCLs/PRGs in a few Lower HSU wells located in Zone 2. The Lower HSU wells with SVOC exceedances occurred just north and northeast of the Caustic /Cyanide Landfill (5-wells), within the A-Drainage (one well), the B-Drainage (two wells), and the C-Drainage (one well).

Metals

To evaluate inorganic concentration trends in groundwater, “box and whisker” plots (box plots) were generated (Attachment G3-1 through G3-24) for sample data acquired from select wells during the Fourteenth and Fifteenth Semi-Annual (SA) sampling events. The sampled wells were divided into four groups: Offsite Lower HSU, Offsite Upper HSU, Onsite Lower HSU, and Onsite Upper HSU. The offsite groups generally represent background conditions, though with caveats. There are only three wells in the Offsite Upper HSU represented in the box plots and they are all screened within the alluvium of Casmalia Creek. Hence, chemistry in the Offsite Upper HSU wells more closely represents surface water than groundwater within the Upper HSU across the rest of the Site as is evident by the very low TDS concentrations illustrated on Figure 5-23. The Offsite Lower HSU wells group better represents background conditions, though the geochemistry of the deep marine deposited claystone has influenced the groundwater chemistry in this well group as is evident in the elevated potassium and sodium concentrations in Figures G3-18 and G3-21, respectively. It is also worth noting that the Gallery Well is included in the Onsite Upper HSU wells group and leachate from this well is responsible from many of the outlier values plotted for that group. Many of the inorganic constituent concentrations are similar amongst all four groups, though there are differences. Arsenic, calcium, magnesium, manganese, nickel, and selenium concentrations are elevated in the Onsite Upper HSU group. Barium (a common constituent of drilling mud) concentrations were highest in the Offsite Upper HSU wells. Though molybdenum concentrations appear elevated in the Onsite Lower HSU group, this variation is likely the result of increased detection limits during some analyses.

Dissolved concentrations of arsenic and other metals are elevated within the Zone 1 boundary but are generally not elevated in Zone 2. Arsenic is used to summarize the overall extent of elevated metals because it is the most broadly elevated metal within the Upper HSU, it exceeds primary MCLs where elevated, and the extent of the other elevated metals is generally contained within the extent of elevated arsenic. Figures 5-24 and 5-25 present arsenic isoconcentration contours for the Upper HSU and Lower HSU. Similar isoconcentration contours are also provided for nickel (Figures 5-26 and 5-27), cadmium (Figures 5-28 and 5-29), and selenium (Figures 5-30 and 5-31), which are also broadly elevated within the Upper HSU and exceed primary MCLs were elevated and present at spot location within the Lower HSU., these figures are also provided in Appendix G. Manganese isoconcentration contours are also provided in Figure O-11 as part of the Natural Attenuation evaluation in Appendix O.

Upper HSU. The general distribution of elevated metals is similar to the distribution of elevated VOCs in the Upper HSU, except for the ponds and PCTs. The higher concentrations of metals in the Upper HSU are generally located within the Central Drainage Area, similar to the higher concentrations of VOCs north of the PSCT. Elevated levels also occur south of the PSCT. Unlike the general absence of these VOCs in the ponds and PCTs, however, TDS (salts) and metals are significantly elevated within surface water in the five on-Site ponds, groundwater extracted at the PCTs, and other groundwater monitored at other monitoring wells in the vicinity of the ponds and PCTs. Pond surface water is a recharge source to the PCTs. The concentrations of the salt and metals in the ponds that have been increasing due to evaporation since the 1997/98 El Nino winter are causing similar increases in metals and salts in the PCTs and area monitoring wells.

Dissolved concentrations of arsenic, nickel, cadmium, and selenium are the most broadly elevated metals within the Upper HSU. These metals are elevated throughout most of the Zone 1 area (metal isoconcentration Figures 5-24, 5-26, 5-28, and 5-30, respectively) and generally exceed MCLs where elevated (box plots Figures G3-3, G3-17, G3-6 and G3-19, respectively). The highest concentrations generally occur north of the PSCT in the P/S Landfill and Central Drainage Area. Onsite concentration exceedances compared to offsite concentrations and MCLs are as follows:

- Arsenic exceeds 200 ug/L, while offsite concentrations are less than MCL of 10 ug/L
- Nickel exceeds 500 ug/L, while offsite concentrations are less than MCL of 100 ug/L
- Cadmium exceeds 20 ug/L, while offsite concentrations are less than MCL of 5 ug/L
- Selenium exceeds 800 ug/L, while offsite concentrations are less than MCL of 50 ug/L

Iron and manganese are also broadly elevated compared to offsite concentrations, exceeding their secondary MCLs of 300 and 50 ug/L, respectively. Their exceedances are generally correlated with the exceedances for arsenic, nickel, cadmium, and selenium.

Exceedances for additional metals include the following:

- Aluminum, antimony, beryllium, and chromium exceed offsite concentrations and MCLs in select onsite areas.
- Barium, lead, and mercury exceed offsite concentrations in select onsite areas, but do not exceed MCLs.
- Zinc, Silver, Molybdenum, Copper, Tin, and Cobalt exceed onsite concentration in select onsite areas, but do not have MCLs.

The CSC did not perform an analysis of metals concentration changes over time, similar to the VOC analysis. If necessary for the remedy evaluation, the CSC will perform this analysis as part of the Feasibility Study.

Lower HSU. Metals concentrations in the Lower HSU are generally lower than in the Upper HSU. The highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the borders of Zone 1 and Zone 2; and the occurrence for arsenic, nickel; cadmium and selenium are provided in Figures 5-25, 5-27, 5-29, and 5-31, respectively. The elevated metals concentrations in the Lower HSU do not appear to coincide spatially (to the degree that VOCs do) with elevated metals within the Upper HSU concentrations.

General Chemistry

As noted above, groundwater in the vicinity of the Site ranges from brackish to highly brackish (i.e., brackish conditions generally defines as TDS > 1,000 up to ~10,000 mg/L). TDS concentrations are naturally elevated in groundwater contained in the Upper HSU weathered claystone and Lower HSU unweathered claystone. Most monitoring wells are completed in weathered or unweathered claystone, as opposed to alluvium. TDS in both offsite and onsite weathered and unweathered claystone is variable and often exceeds 5,000 ppm and can exceed 10,000 ppm.

The primary components that comprise the total dissolved solids content of groundwater consist of the major cations (sodium, potassium, calcium, magnesium) and major anions (chloride, sulfate, and bicarbonate). Nitrogen species (nitrate or nitrite), pH, dissolved oxygen, and oxidation-reduction potential are also indicators of the generally chemistry conditions of groundwater. Major ions (e.g., chloride, sulfate) generally exceed their secondary MCLs.

The general chemistry of groundwater is influenced by background conditions and potential site impacts. Evaluating the spatial and temporal general chemistry changes can provide insight into the nature, extent, fate, and transport of contamination. The following were prepared to help evaluate these conditions:

- Figures G-14 through G-17 present stiff diagrams posted next to wells for the Upper HSU and Lower HSU to illustrate the major ion composition of groundwater across the onsite and offsite areas in the Upper and Lower HSUs for the fall 2004 and spring 2005 SA sampling events.

- Figures O-10 through O-15 present iso concentration contour maps for nitrate, manganese, sulfate, dissolved oxygen, bicarbonate alkalinity, and chloride for the Upper HSU for the fall 2004 and spring 2005 SA sampling events.

- Appendix G provides time-concentration graphs for major ions and TDS.

Radionuclides

The CSC and EPA sampled and analyzed groundwater samples in October and April 2002 from offsite wells (RP-109B, 109D, RP-75B, and RP-75C) and four onsite wells (WP-8S, RG-8B, PSCT-1, PSCT-4). The samples were analyzed for gross alpha, gross beta, tritium, and gamma spectroscopy in 2002. The results indicate that no radioactive contamination is present in groundwater from these samples. The offsite wells are considered to represent background conditions and the onsite wells are intended to characterize groundwater from the base of the landfills and BTA. All radionuclides identified are naturally occurring radioactive materials at concentrations consistent with unimpacted groundwater.

5.4.6 NAPL

NAPLs occur in the subsurface at the site in the form of light nonaqueous phase liquid (LNAPL) and dense nonaqueous phase liquid (DNAPL). LNAPL is lighter than water and will float on the water table. DNAPL is heavier than water and will sink beneath the water table. The CSC has performed significant investigations to determine the nature, extent, fate, and transport of LNAPL and DNAPL at the site. These include the following:

- Drilling, coring, running borehole geophysics, and installing monitoring wells and piezometers (Appendix E)
- Monitoring LNAPL and DNAPL thicknesses as part of the RGMEW and performing DNAPL recovery tests (Appendix F)
- Sampling and analyzing LNAPL and DNAPL samples for chemical and physical parameters (Appendix G)
- Performing direct-push ultraviolet induced fluorescence/membrane interface probe (UVIF/MIP) investigations (Appendix M)

LNAPL and DNAPL can occur as either a “free phase” or in “residual” form. Free-phase NAPL exists as a continuous phase in either porous or fractured media such that it can move through the subsurface and flow into a well. Free-phase NAPL is also referred to as “mobile” NAPL. Residual NAPL exists in a discontinuous phase in either a porous or fractured media such that it cannot move through the subsurface and flow into a well. Most NAPL begins as a free-phase and ultimately transitions into a residual phase as the NAPL moves through the subsurface and the original NAPL source is depleted. The potential for free-phase NAPL migration will continue unless the mobile source is depleted or removed. Both free-phase and residual NAPL will act as an ongoing source of contamination to groundwater and soil vapor. Additional analysis of the fate and transport of LNAPL and DNAPL is provided in Section 6.

All of the known free-phase NAPL contamination that has been measured in monitoring wells, piezometers, or extraction wells is located north of the PSCT, although evidence of residual NAPL contamination has been observed during various investigations in other areas. Both LNAPL and DNAPL are present as measureable thicknesses in site wells and piezometers in the P/S Landfill and the Central Drainage Area. LNAPL is present in the Gallery Well and 11 piezometers within the P/S Landfill. LNAPL is present in 8 wells and piezometers within the Central Drainage Area. DNAPL is present in the Gallery Well and P/S Landfill piezometers RIPZ-13 and RIPZ-27, installed in August 2007. DNAPL is present in two Lower HSU piezometers RGPZ-7C and RGPZ-7D between the P/S Landfill and PSCT-1.

To date, neither LNAPL nor DNAPL have been measured in any other site wells or piezometers. NAPL has not been detected in the recently installed RI wells and piezometers in the Burial Trench Area (although observations during drilling may suggest NAPL in this area), or in other site wells and piezometers near and downgradient of the other site landfills. The Upper HSU locations in the Central Drainage Area where LNAPL and DNAPL have been observed or inferred generally coincide with an historical site drainage that ran the length of the P/S Landfill and continued into the area that is now the RCF Pond.

The extent of LNAPL and DNAPL is shown in Figures 5-32 through 5-37. Figures 5-32 and 5-33 show the aerial extent of LNAPL and DNAPL in the in the Upper HSU and Figure 5-34 show the aerial extent of DNAPL Lower HSU. Figures 5-35 through 5-37 show the extent of NAPL presented in profile view for the east-west cross section along the P/S Landfill (Figure 5-35), north-south cross section through the P/S Landfill and Central Drainage Area (Figure 5-36), and north-south cross section through the Burial Trench Area (Figure 5-37); the location of cross-sections are presented in Figure 5-38. Figures F-40 through F-43 show LNAPL and DNAPL thicknesses and liquid elevations for wells that monitor NAPL. The physical properties of

LNAPL and DNAPL samples collected by the CSC from site wells and piezometers are summarized in Table 5-2.

5.4.6.1 LNAPL

LNAPL has been detected in the following P/S Landfill and Upper HSU Central Drainage Area wells:

P/S Landfill (from north to south)

- RIPZ-14 located on top of the landfill, 700 feet north of the Gallery Well
- RIPZ-39, located on Bench 2 Road, 300 feet north of the Gallery Well
- RIPZ-13 located on Bench 1 Road, 150 feet north of the Gallery Well
- RIPZ-27 located on Gallery Well Road, 8 feet north of the Gallery Well
- Gallery Well, and adjacent piezometers GW-PZ-W, GWPZ-E1, GW-PZ-E2, GW-PZ-E3, RIPZ-23, RIPZ-24, and RIPZ-38 (these wells are all located at the toe of the P/S Landfill);

Central Drainage Area

- Sump 9B piezometers Sump 9B-PB, Sump 9B-PC, Sump 9B-CW, RIMW-3, RIPZ-25, and RIPZ-31 (all located in the former Pad 9B area)
- RGPZ-5B and RIPZ-8 (located on the former Pond R bench).

Historically, small amounts (less than 0.2 foot) of LNAPL have been measured in RG-3B (in the former Pad 9A area), but LNAPL is no longer observed in this well. Note that LNAPL has not been observed in piezometer RIPZ-26 (former Pad 9A), though, possible LNAPL was identified in soil core samples obtained from RIPZ-26 and also from groundwater samples collected from RGPZ-6B.

P/S Landfill

The LNAPL zone in the P/S Landfill extends from the top of the landfill at RIPZ-14 southward to the Gallery Well. The extent of the LNAPL zone does not imply that the LNAPL is contiguous throughout this area; LNAPL is probably located in discrete zones as influenced by available flow paths and soil properties. Several of the piezometers along the clay barrier (Figure 5-35) and north of the clay barrier within the landfill interior (Figure 5-36) are constructed with the top of the screen below LNAPL and therefore, some of the LNAPL thickness shown in the cross sections in Figures 5-35 and 5-36 may not represent actual thicknesses. LNAPL in these wells may be trapped in the blank casing above the screen. The top of LNAPL in the piezometers along the clay barrier is approximately 10 feet or more below the top of the barrier (Figure 5-35).

The Gallery Well was the only well in the P/S Landfill prior to 1999 to assess liquid levels, including LNAPL. The Gallery Well is screened at the bottom 20 feet of the well. The current action level implemented in 2000 (63 feet BTOC) maintains the pumping liquid level at approximately the mid-point of the screen. The liquid level prior to 2000 (30 feet BTOC) was above the screen. Although the current liquid level is maintained within the screened interval, the extraction pump is near the bottom of the Gallery Well so LNAPL may not be effectively recovered at the Gallery Well.

Along the clay barrier, the CSC installed piezometers GW-PZ-W and GWPZ-E1 in 1999 to assess whether the liquid levels where below the top of the clay barrier (25 feet west and east of

the Gallery Well). The CSC installed GW-PZ-E2 and GW-PZ-E3 in 2003 to further assess LNAPL thicknesses and the liquid levels in relation to the clay barrier (50 and 75 feet east of the Gallery Well). In 2001, the maximum LNAPL thickness in these piezometers was approximately 9 feet in GW-PZ-E3 (Figure F-40). The CSC installed RIPZ-23 and RIPZ-24 next to GW-PZ-W and GW-PZ-E1 in 2004 because the screen elevations for GW-PZ-W and GW-PZ-E1 where below the LNAPL. The CSC installed RIPZ-27 and RIPZ-38 in 2007 to follow-up from the Phase 2 seismic refraction survey in the P/S Landfill to delineate the bottom of the landfill where pooled DNAPL potentially exists. The LNAPL thicknesses have fluctuated over time in these piezometers along the clay barrier (Figure F-40, Table F-6). Current maximum thicknesses are 20.30 feet in RIPZ-27 and 33.59 feet in RIPZ-38 according to June 18, 2010 liquid level measurements (Table F-3).

North of the clay barrier, the CSC installed piezometer RIPZ-14 in 2006 to assess liquid levels at the top of the P/S Landfill and RIPZ-13 in 2007 to follow-up from the Phase 2 seismic refraction survey in the P/S Landfill to delineate the bottom of the landfill where pooled DNAPL potentially exists. The LNAPL thickness in RIPZ-14 has been several tenths of a foot since the piezometers was installed (Figure F-40). However, RIPZ-14 is screened significantly below the water table so this may not represent the true LNAPL thickness (the objective of this piezometer was not to assess LNAPL). The LNAPL thickness in RIPZ-13 was initially 8.88 feet after installation and is currently 4.03 feet according to June 18, 2010 liquid level measurements (Figure F-40; Tables F-3 and F-6).

Central Drainage Area

Based on the LNAPL elevation monitoring, dissolved chemistry analyses, and sample observations, the LNAPL zone in the Central Drainage Area likely extends from the Gallery Well to a location near well RG-3B, approximately 200 feet north of PSCT-1. LNAPL was not observed in wells, piezometers, or deep soil borings drilled downgradient of well RG-3B during the 2000, 2004, or 2006 drilling programs, and has not been observed during subsequent water level measurements. The extent of the LNAPL zone does not imply that the LNAPL is contiguous throughout this area; LNAPL is probably located in discrete zones as influenced by available flow paths and soil properties. The lateral extent of the LNAPL zone may be 300 to 400 feet wide from near piezometer RIPZ-8 to near RGPZ-5B, and possibly narrows to the south.

In the Sump 9B area, the early piezometers and wells installed by the CSC were screened below the water table and potential LNAPL. CSC installed piezometers SUMP-9B-PA, -9B-PB, and -9B-PC in 1999 to assess the hydraulic effect of liquids extraction from Sump 9B. The liquid levels in these piezometers were above the top of the screens in this area. Well RGPZ-5B was installed between Sump 9B and the Gallery Well in 2000 and is screened below the water table. Piezometer SUMP-9B-CW was installed in 2001 as a “companion well” next to Sump 9B. SUMP-9B-CW was screened at the bottom of the Upper HSU to assess for the potential presence of pooled DNAPL in the Sump 9B area, since the bottom Sump 9B is above the HSU contact. The liquid level is above the screen in SUMP-9B-CW. Well RG-3B was installed in 1998 to generally assess the liquid level in the Central Drainage Area. The liquid levels were above the screen in RG-3B.

Recent wells installed as part of the RI were intentionally screened above the water table to assess the potential presence and thickness of LNAPL. These included RIPZ-8, RIPZ-25, RIPZ-26, and RIPZ-31. The thickness of LNAPL in all of the Central Drainage Area Wells

(including the early wells screened below the water table and the RI piezometers screened across the water table) has decreased over time and is currently less than 1 foot (Figure F-40; Tables F-3 and F-6).

5.4.6.2 DNAPL

DNAPL is currently detected in the following P/S Landfill and Central Drainage Area wells:

P/S Landfill (from north to south)
- RIPZ-13 located on Bench 1 Road, 150 feet north of the Gallery Well;
- RIPZ-27 located on Gallery Well Road, 10 feet north of the Gallery Well
- Gallery Well (Upper HSU);

Central Drainage Area
- RGPZ-7C (Lower HSU); and
- RGPZ-7D (Lower HSU).

Figures F5-1, F5-2, and F5-3 in Attachment F-5 provide DNAPL hydrographs for RIPZ-13 in the P/S Landfill and RGPPZ-7C and RGPZ-7D in the Lower HSU. These hydrographs are further referenced below.

P/S Landfill

There is a potentially large volume of free phase DNAPL in the P/S Landfill based on (1) past and current DNAPL extraction rates at the Gallery Well and (2) volumetric estimates from thicknesses of DNAPL measured in the Gallery Well and piezometers within the landfill. The CSC's DNAPL extraction and investigation activities are summarized below, followed by an estimate of the potential volume of free-phase DNAPL in the P/S Landfill.

The CSC continued EPA's liquids extraction from the Gallery Well when the CSC began site work in 1996 (Table 2-6). The CSC calculates the rate at which DNAPL accumulates in the above ground storage tanks by gauging the DNAPL level in the tank on a routine basis. The calculated DNAPL recovery rates from these measurements taken from 2003 through 2010 are shown in Figure F-46. The long term average DNAPL recovery rate is approximately 7 gallons per day, or 2,500 gallons per year. The recent DNAPL recovery rates calculated from the CSC's tank fill gauging data are as follows, which are higher than the long-term average:

2008	4,053 gallons for year
2009	3,663 gallons for year
2010	1,981 gallons for first six months (3,962 gallons on yearly basis)

These recent data indicate that the current DNAPL recovery rate is approximately 4,000 gallons per year based on the above ground storage tank gauging data.

The initial DNAPL thickness in the Gallery Well at the time the CSC continued EPA's liquids extraction from the Gallery Well 1996 is not known. The CSC initially extracted liquids to maintain the liquid extraction level (Table 2-7) by operating the extraction pump approximately 19 feet above the well bottom. The CSC performed a DNAPL recovery test in 1997 by lower the pump to 2.5 feet above well bottom, evacuating the DNAPL, and then measuring DNAPL recovery into the well. The initial DNAPL thickness was 9.2 feet prior to conducting the test.

The CSC removed the DNAPL to a thickness of 2.5 feet on July 9, 1997, and then raised the pump to its original position (19 feet above well bottom) and continued liquids extraction. The DNAPL thickness was approximately 7 to 8 feet during 1998 and 1999 (Figure F-42). Beginning in November 1999 the CSC lowered the pump intake to near well bottom and subsequently the DNAPL thickness has been less than 2 to 3 feet (Figure F-42).

The CSC installed piezometer PZ-LA-01 at the current location of RIPZ-13 as part of the CSC's assessment of the Canonie (1989) potential "low area" (Harding ESE, 2001). PZ-LA-01 was installed to a depth of 97.0 feet in 2001 and RIPZ-13 was installed in 2007 to a depth of 99.4 feet bgs. The objectives of both piezometers were to assess the elevation of the unweathered claystone and potential presence of free phase DNAPL. Both piezometers were installed using direct push methods by first performing CPT testing to determine the depth to the unweathered claystone and then installing the piezometers to the claystone. PZ-LA-01 was installed using PVC casing which failed shortly after installation so no DNAPL thickness measurements are available for this piezometer.

The CSC performed a series of DNAPL "recovery tests" in the Gallery Well from June 2003 through October 2005. The recovery tests were performed monthly for one year and then quarterly for another year. The test involved stopping liquids extraction, measuring the initial rate of DNAPL rise in the well casing, and then calculating the volumetric DNAPL recovery rate. Thickness of DNAPL during pumping and non-pumping conditions ranged from less than 1 foot to approximately 3 feet. The liquid levels measured during several of the tests and calculations of the DNAPL recovery rate are shown in Figures F-44 and F-45. The calculated DNAPL recovery rates for all monthly and quarterly tests are as follows:

Test Date	DNAPL Rate (gal/yr)	Test Date	DNAPL Rate (gal/yr)	Test Date	DNAPL Rate (gal/yr)	Test Date	DNAPL Rate (gal/yr)
6/11/02	13,500	11/13/03	11,200	3/23/04	29,039	3/15/05	9,180
7/31/03	16,500	12/18/03	50,600	4/20/04	5,436	6/29/04	13,872
9/2/03	20,900	1/20/04	13,701	5/21/04	8,191	10/6/05	12,852
10/9/03	13,400	2/24/04	15,041	8/24/04	22,848		

The calculated DNAPL recovery rates from these tests are greater than the rates calculated using the rate at which extracted DNAPL fills the above ground storage tank. Note that during 2004 and 2005, the CSC extracted DNAPL from the Gallery Well at an estimated rate of 10 gallons per day as calculated by the rate at which DNAPL fills the above ground storage tank.

The CSC installed the following four piezometers in the P/S Landfill in August 2007 to follow-up from the Phase 2 seismic refraction survey to delineate the bottom of the P/S Landfill where pooled DNAPL might potentially exist.

- RIPZ-27 located on Gallery Well Road, 8 feet north of the Gallery Well;
- RIPZ-38 located on Gallery Well Road, 50 feet west of the Gallery Well;
- RIPZ-13 located on Bench 1 Road, 150 feet north of the Gallery Well;
- RIPZ-39 located on Bench 2 Road, 300 feet north of the Gallery Well,

These piezometers were installed using direct push methods by first performing CPT testing to determine the depth to the unweathered claystone and then installing the piezometers to the

claystone. Since installation, DNAPL has accumulated in RIPZ-13 and RIPZ-27, but not RIPZ-38 and RIPZ-39 (Figure F-42). DNAPL entered RIPZ-13 and RIPZ-27 slowly after installation before reaching current steady-state thickness of approximately 14 feet and 6 feet, respectively. As shown in Figure F-42:

- DNAPL entered RIPZ-13 immediately after installation (Figure F5-1). The initial DNAPL thickness in RIPZ-13 was 8.3 feet after development (9/14/07). DNAPL slowly increased in thickness over a 3-month period reaching a steady-state thickness of 14.1 feet (12/13/07).

- DNAPL did not enter RIPZ-27 until over 2 years after installation. DNAPL was first measured on December 21, 2009 at a thickness of 2.99 feet and then was measured at thicknesses of 6.33 feet (12/21/09), 4.64 feet (3/9/10), and 3.19 feet (6/18/10).

The thickness of DNAPL in RIPZ-13 remained stable at approximately 14 feet between December 2007 and March 2009. In March and April 2009, the CSC performed a DNAPL purge and recovery test to determine the rate and amount of DNAPL recharge in the immediate vicinity of the well (Figure F5-2). During the eight pumping days of the test, approximately 42 gallons of DNAPL were pumped from the well. During the week of March 23, 2009, the CSC began slowly pumping DNAPL from RIPZ-13 using a Watera pump set near the bottom of the piezometer at a rate of approximately 0.5 gallons per hour. DNAPL slowly decreased to a thickness to 8 feet while the pumping rate was slowly increased. The DNAPL then decreased to less than 3 feet as the pumping rate was increased to above 2 gallons per hour. Pumping stopped on April 2, 2009 with a total recovery of 0.1 gallon of LNAPL, 2.8 gallons of water, and 42.3 gallons of DNAPL. The DNAPL thickness upon completion of the pumping portion of the recovery test was 2.55-feet, which represented a DNAPL drawdown of 11.05 feet from the 13.6-feet pre-pumping thickness (Figure F5-1). The DNAPL thickness in RIPZ-13 recovered to 7.21-feet in a two month period following completion of the purging. The DNAPL level continued to slowly recover over a 1-year period to a thickness of 14.0 feet on June 18, 2010 (Figure F5-1). While the CSC does not believe this was the case, potential “over pumping” effects during the DNAPL recovery testing by pumping the piezometer too hard may have desaturated the DNAPL in the materials around the piezometer screen causing water to preferentially occupy the pore spaces. This would have the effect of block DNAPL flow paths with water and delay DNAPL reentry into the piezometer until DNAPL density-driven flow displaces this water to re-establish a continuous DNAPL flow path.

The potential volume of pooled (free phase) DNAPL [V_{DNAPL}] within the P/S Landfill can be estimated by multiplying the potential area (length [L] x width [W]) over which a DNAPL pool occurs, the DNAPL pool thickness [T], the porosity of the materials in which the DNAPL pool occurs [P], and the percentage of the pore space occupied by DNAPL instead of water, known as DNAPL saturation [S].

$$V_{DNAPL} = L \times W \times T \times P \times S$$

The area over which pooled DNAPL may potentially occur and average height of DNAPL over this area can be estimated using several sets of assumptions or scenarios for the purposes of estimating V_{DNAPL}. Three scenarios are as follows:

1. The area over which DNAPL occurs is limited to vicinity of the Gallery Well (20 feet north-south by 50 feet north-south). The thickness is the current DNAPL thickness in

RIPZ-27 (6 feet), located 8 feet north of the Gallery Well. The porosity and DNAPL saturation are 30 percent each. This scenario assumes that the DNAPL in RIPZ-13 is localized and isolated from the DNAPL being extracted at the Gallery Well.

2. The area over which DNAPL occurs is equivalent to the area contained within the Canonie (1989) estimated base grade 490 foot elevation (msl) contour (150 feet north-south by 125 feet east-west). The thickness is the difference between 490 foot msl (top of low area) and 480 foot msl (bottom of low area). The porosity and DNAPL saturation are 30 percent each. This scenario assumes a more extensive DNAPL pool than Scenario 1.

3. The area over which DNAPL occurs is equivalent to the area contained from the Gallery Well northward to half-way between RIPZ-13 and RIPZ-39 over an east-west distance of 125 feet. The thickness is the average of the current DNAPL thickness in RIPZ-27 (6 feet) and RIPZ-13 (14 feet). The porosity and DNAPL saturation are 30 percent each. This scenario assumes a more extensive DNAPL pool than Scenario 1. The exact distribution of DNAPL within this area is not known, and is not necessarily related to the Canonie (1989) low area.

The scenario assumptions and calculated free-phase DNAPL volumes are as follows:

Scenario 1	Scenario 2	Scenario 3	Unit	Symbol	Parameter
20	150	200	feet	L	Length of DNAPL Pool (north-south)
100	125	125	feet	W	Width of DNAPL Pool (east-west)
5	10	10	feet	T	Thickness of DNAPL Pool (feet)
7.48	7.48	7.48	-	-	Conversion factor (cubic feet to gallons)
30%	30%	30%	%	P	Porosity (percent of total voids)
30%	30%	30%	%	S	Saturation (percent of voids filled by DNAPL)
6,732	**126,225**	**168,300**	**gal**	V_{DNAPL}	**DNAPL Volume (gallons)**

The DNAPL volume estimate for Scenario 1 (6,732 gallons) appears too low given the CSC's current DNAPL extraction rate of 4,000 gallons per year. The DNAPL volume estimates for Scenarios 2 and 3 are similar. These volumes are only estimates and are limited to the assumption made.

Central Drainage Area

In the Lower HSU, following drilling and monitoring well data indicate DNAPL in the Central Drainage Area:

- RGPZ-7C and RGPZ-7D - DNAPL observed in Lower HSU fractures during drilling/coring for piezometer installation in 2000 and DNAPL measured during routine groundwater monitoring from 2003 through 2010.

- RGPZ-6C and RGPZ-6D - DNAPL observed in Lower HSU fractures during drilling/coring for piezometer installation in 2000 and high dissolved-phase concentration of VOCs in groundwater measured during the two RI groundwater monitoring events in 2004 and 2005.

- RISB-02 – DNAPL in Lower HSU fractures during drilling/coring, accumulated DNAPL measured in the bottom of the borehole, and free DNAPL "blobs" actively entering the borehole liquid column during down-hole video logging in 2006.

RGPZ-6C, RGPZ-6D, RGPZ-7C, and RGPZ-7D were originally installed in 2000 to assess hydraulic gradients in response to liquids extraction at PSCT-1. These piezometers are constructed with 10-foot long screens across fractures identified in the field at the followings depths:

Piezometer	Screened Invterval (ft, bgs)	Piezometer	Screened Interval (ft, bgs)
RGPZ-6C	88 - 98	RGPZ-7C	90 - 100
RGPZ-6D	154 - 164	RGPZ-7D	138 - 148

The locations of these four piezometers, and boring RISB-02, where DNAPL was observed within the fracture intervals during drilling/coring are shown in Figure 5-38. The DNAPL observed in the Lower HSU fractures was sometimes noted as a "chemical sheen", "product sheen", or as an actual NAPL. At RISB-02, DNAPL was observed to actively enter the borehole water column from Lower HSU fractures during downhole video logging and accumulate at the bottom of the 253-foot deep boring to a thickness of approximately 15 feet.

Table 5-3 lists the fracture and bedding plane orientations (dip-azimuth, dip) measured by the optical televiewer for the unweathered claystone for RISB-02, and also lists the fracture and bedding intervals where DNAPL was observed during core logging and downhole video logging. Figure 5-39 illustrates these orientations and the intervals where DNAPL was observed. The following summarizes these conditions observed at RISB-02:

- Overall, three intervals were encountered. Interval A contained two higher angle fractures at 46 feet dipping towards the northwest and one higher angle fracture at 52 feed dipping towards the southeast, all without DNAPL. Interval B contained numerous lower angle fractures and bedding planes from 57 feet to 109 feet dipping towards the east and southeast, many filled with DNAPL as further described below. In addition to several lower angle bedding planes and one lower angle fracture, Interval C contained numerous higher angle fractures from 146 feet to 206 feet at several variable dip directions, all without DNAPL. The bottom of the 253-foot borehole contained 15 feet of DNAPL, potentially as a result of DNAPL from Interval B collecting in the borehole bottom.

- From the borehole video, DNAPL was observed to be seeping into the borehole water column from the fractures occurring at 66, 85, and 109 feet and also from bedding plains at 72 feet and 80 feet. DNAPL was observed to be most vigorously observed to be seeping from the 85-foot fracture where DNAPL was activity observed to be moving into the borehole. The white bedding planes with seeping DNAPL appeared to be either primary deposits or secondary mineralization with very small openings not visible.

No DNAPL has been measured in RGPZ-6C or RGPZ-6D, although DNAPL is inferred from the high concentrations of VOCs measured during the two RI sampling events.

DNAPL has been directly measured in piezometers RGPZ-7C and RGPZ-7D since monitoring for DNAPL began in these two piezometers in 2003 (Figure F-42 and F5-3). The DNAPL

thicknesses in RGPZ-7C was initially 8.55 feet in 2003 and had gradually increased to 18 feet in 2010, above the screened interval of this piezometers. The DNAPL thickness in RGPZ-7D was initially 1.31 feet in 2003 and has relatively steady at 1 to 2 feet thick.

The source of DNAPL in observed in the fractures of the five borings and measured in piezometers RGPZ-7C and -7D is uncertain. This DNAPL could have migrated from one of two potential Upper HSU source areas through Lower HSU fractures to arrive at this location and depth (Figure F-38). One potential DNAPL source is the large volume of known free DNAPL within the P/S Landfill. The other potential DNAPL source is the area of former Pads 9A and 9B located between the P/S landfill and PSCT-1.

The CSMs through the P/S Landfill and Central Drainage Area (Figures 4-51 and 4-52) show the two potential source areas (P/S Landfill and former Pad 9A/9B) and the known and potential DNAPL extent in the underlying fracture system of the Lower HSU. The vertical extent of free phase DNAPL in the Lower HSU is not known within the potential DNAPL zone encompassing the P/S landfill and Central Drainage Area. The localized horizontal extent of free phase DNAPL in the Lower HSU within this potential DNAPL zone is not certain, as shown in Figure 5-36.

When projected northward towards the potential DNAPL source areas (P/S landfill or former Pad 9A/9B), the DNAPL-filled fractures and bedding planes appear to pass beneath these areas below the contact elevation of the top of the unweathered claystone (Figures 4-51 and 4-52). This would infer that either of these areas could be the DNAPL source and that DNAPL would have had to travel down a series of interconnected fractures and/or bedding planes to reach the RISB-2 fractures with DNAPL or the RGPZ-7C and RGPZ-7D screens with contain measureable DNAPL. This series of interconnected features would likely have included a combination of higher-dip and lower-dip features.

Fracture interconnectivity in the relatively ductile unweathered claystone may not be laterally extensive enough to provide the necessary flow path for significant migration through the Lower HSU from upgradient in the Central Drainage Area (i.e., from the free DNAPL present at the Gallery Well and southern P/S Landfill area). As discussed in Section 4, fracturing in the Lower HSU does not include readily identifiable patterns that would indicate interconnected sets on a site-wide scale, nor are fractures at depth of sufficient aperture to be substantially transmissive. Although clay infilling further reduces fracture porosity in the Lower HSU, the RISB-2 borehole video clearly shows DNAPL seeping through these types of “lower porosity fractures” within the unweathered claystone.

As further described in Section 6, calculations indicate that historical and current DNAPL thicknesses in the P/S Landfill exceed the DNAPL pool height required to enter underlying fractures, given measured DNAPL properties and potential fracture widths. Once DNAPL has entered a fracture or fracture network, progressively smaller aperture fractures will be invaded if the pooled DNAPL source is allowed to extend itself vertically while remaining a continuous, interconnected phase. This increasing force will act to overcome the apparent “insufficient aperture” that may stop DNAPL flow. The DNAPL driving head is not only a function of the pool height in the overlying Upper HSU (or P/S Landfill) but also the height of DNAPL accumulated in the fractures beneath this pool. The large DNAPL volume in the P/S Landfill could provide an ongoing source to allow the DNAPL to extend itself. If the P/S Landfill is the source, the free phase DNAPL in the landfill could provide a long-term source for DNAPL potentially continue spreading.

Additionally, DNAPL compositional analysis, as summarized below and discussed in detail in Appendix G, indicates that there are both differences and similarities between the constituents of the DNAPL in the upgradient Gallery Well and piezometers RGPZ-7C and -7D. Many VOCs detected in the Gallery Well DNAPL are not present in the DNAPL from piezometers RGPZ-7C and -7D (Figure G-58). Wells RGPZ-7C and -7D are located within the footprint of former evaporation Pad 9A, in an area that previous to construction of the pad, accepted oilfield waste and sludges. Pad 9A and adjacent Pad 9B were utilized to dry liquids and sludges by spreading them over a large area. Materials spread were typically oilfield brines and landfill runoff, and contamination observed below the water table during the closure of Pad 9B necessitated in the construction of Sump 9B. Based on groundwater chemistry and the potential local sources of contamination, the extent of DNAPL in the Lower HSU in this area may include the area around piezometer RGPZ-6D (within the footprint of former Pad 9A). However, the CSC did not identify any potential low areas in the HSU clay contact in this area that could potentially collect a pool of DNAPL or any evidence of free-phase DNAPL or visual observations of obvious mobile or residual-phase. In addition, oilfield waste and sludges would primarily contain lighter-phase NAPL constituents that might result in an LNAPL instead of denser-phase NAPL constituents that would result in a DNAPL.

5.4.6.3 NAPL Physical Properties and Chemistry

The CSC collected and analyzed three samples each of LNAPL and DNAPL present in site wells for physical properties and chemical composition at the following locations:

- LNAPL – Gallery Well, GW-PZ-W, and Sump 9B-PB
- DNAPL – Gallery Well, RGPZ-7C, and RGPZ-7D.

The physical properties analyzed included density, viscosity, NAPL-water interfacial tension, and flash point. The chemistry analyzed included VOCs, SVOCs, PCBs, PAHs, herbicides, pesticides, metals, and cyanide. The LNAPL and DNAPL physical properties are summarized in Table 5-2. The LNAPL and DNAPL chemistry is provided in Appendix G.

Physical Properties

The LNAPL sample from the Gallery Well collected in 2004 had a density was 0.99 gm/cm$^{3.}$

DNAPL density has been tested on several DNAPL samples collected from the Gallery Well and piezometers RGPZ-7C and RGPZ-7D. The four Gallery Well DNAPL samples collected in 1994, 1998, 2003, and 2004 have a relatively consistent density ranging from 1.085 to 1.1 gm/cm^3. The DNAPL samples collected from the RGPZ-7C and RGPZ-7D clusters in 2003 and 2004 also had a relatively consistent density ranging from 1.007 to 1.0194 gm/cm^3. The density of the Gallery Well DNAPL samples is higher than the RGPZ-7C and RGPZ-7D samples.

DNAPL/water interfacial tension was tested on a 1998 sample collected from the Gallery Well. The interfacial tension with DNAPL was tested relative to tap water and to groundwater. The DNAPL/tap water and DNAPL/groundwater interfacial tensions were 7.1 and 2.8 dynes/cm, respectively.

Chemistry

Table G-21 presents the detected concentrations of compounds in the LNAPL and DNAPL samples collected during December 2004. Figures G-40 through G-51 illustrate the LNAPL and DNAPL chemistry of each location. Figures G-52 through G-57 compares the Gallery Well, GW-PZ-W, and SUMP 9B-PZ-B LNAPL concentrations, and Figures G-58 through G-63 compares the Gallery Well, RGPZ-7C, and RGPZ-7D DNAPL concentrations.

On a mass basis, the Gallery Well LNAPL composition is approximately 44 percent VOCs, 5.5 percent SVOCs, and 0.5 percent PAHs, herbicides, and metals, while the Gallery Well DNAPL composition is approximately 38 percent VOCs, 5 percent SVOCs, and 0.5 percent PAHs, herbicides, and metals.

The total concentration of nine VOCs, consisting of total xylenes, PCE, toluene, methylene chloride, ethylbenzene, 1,1,1-TCA, Freon-113, and TCE, were present in LNAPL samples collected from the Gallery Well and piezometers GW-PZ-W and 9B-PZ-B at approximately 34 percent, 22.3 percent, and 25.6 percent, respectively. The total concentration of the nine VOCs present in DNAPL samples collected from the Gallery well and piezometers RGPZ-7C and RGPZ-7D at approximately 40 percent, 27.46 percent, and 1.05 percent, respectively.

Both the LNAPL and DNAPL present in wells contain numerous VOCs and SVOCs. The DNAPL samples collected from the Gallery Well and piezometers RGPZ-7C and RGPZ-7D appear to contain similar ratios of PCE, TCE, xylenes, and toluene, but have different concentrations of other marker constituents. It is reasonable to assume that the DNAPL in the Gallery Well is a mixture of DNAPL chemicals that were disposed of directly into the P/S Landfill. The wastes placed in drums in the P/S Landfill reportedly contained chemical mixtures in addition to single-compound spent solvents or other wastes.

The DNAPL found in and piezometers RGPZ-7C and RGPZ-7D may have migrated from the P/S Landfill wastes or from wastes placed in ponds and pads in the Central Drainage Area. The relative “age” of the DNAPL in the three locations must also be considered in comparing the chemical fingerprints. While the DNAPL in the Gallery Well may be a blend of historically released chemicals and newly released chemicals, the depths at which DNAPL was found in piezometers RGPZ-7C and RGPZ-7D might suggest that the DNAPL is associated with an older release. Further, the chemical composition of the DNAPL found at depth may have been altered or degraded during migration. The exact location of source material for the DNAPL found in piezometers RGPZ-7C and RGPZ-7D is uncertain based on these analyses.

5.4.6.4 Inferred NAPLs

Neither LNAPL nor DNAPL have been directly measured in the Burial Trench Area, but NAPL may be present based on observations made during drilling and groundwater sampling, and the dissolved chemistry analyses. At RIMW-7, LNAPL was inferred during drilling, and DNAPL could be present based on the dissolved-phase chemistry analysis. Only one compound (Freon 113) was noted as a possible DNAPL indicator in the Upper HSU at RIMW-8, and because only one compound exceeded 10 percent of its solubility at that location, the likelihood of DNAPL there is considered to be low. The former burial trenches themselves are the most likely source of any potential NAPLs in this area. The trenches reportedly received between 6,000 and 80,000 pounds of waste; approximately 1.3 million pounds of waste were disposed via injection wells.

Although Figure G-71 indicates potential DNAPL (based on dissolved concentrations) at the toe of the Metals and Caustics/Cyanides Landfills, the CSC does not consider these locations to contain potential NAPL. Only one chemical (Freon 113) exceeded 1 percent solubility in both of these locations, and dissolved concentrations of other NAPL-indicator VOCs were much lower.

Measurable NAPLs have not been detected in any site wells or piezometers beyond those noted in the Central Drainage Area, though evidence of residual NAPL contamination to varying degrees has been reported in RCRA Canyon and at locations south of the PSCT including: former ponds A and B, the former drainage channel between former ponds C and M, and RI boring locations RISBON-59 and RISBON-49. The results of an Ultra-Violet Induced Fluorescence / Membrane Interface Probe (UVIF/MIP) investigation targeted at former ponds where NAPL constituents may have been disposed of, and along the former site drainages indicated only one potential NAPL location at the southern perimeter of the Site (Appendix M). The CSC completed additional investigations in this RISBON-59 area including installation and sampling of RIPZ-37 and RIHP-7, and did not encounter indications of potential free phase NAPL.

5.5 References

Cal/EPA, 1997. *Selecting Inorganic Constituents as Chemicals of Potential Concern at Risk Assessments at Hazardous Waste Sites and Permitted Facilities, Final Policy.* Prepared by Human and Ecological Risk Division, Department of Toxic Substances Control, Cal/EPA.

USEPA, 2002. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites.* EPA 540-R-01-003. September 2002.

USEPA. 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*. U.S. Environmental Protection Agency, Solid Waste and Emergency Response. OSWER 9285.7-25. June 1997.

6.0 CONTAMINANT FATE AND TRANSPORT

This section presents an evaluation of the fate and transport of chemicals detected at the Site. The following discussions identify potential contaminant migration pathways and evaluate the potential for transport of detected chemicals from contaminated media to locations where receptors may become exposed. Section 7 presents details regarding the method used for identification of COPCs used in the human health and ecological risk assessments. As discussed in that section, compounds or compound groups detected in the various environmental media were included on the list of COPCs for the Casmalia site based on the prevalence of detection at the site and in specific study areas, as well as comparisons to background levels and other considerations.

This section generally discusses the fate and transport of all compounds or compound groups detected during the RI. This list of detected chemicals encompasses the subset of constituents that may be of significant human health or ecological concern and could contribute to an unacceptable risk to potential receptors. The method used to identify COPCs from the larger list of detected constituents is described in Section 7 of this RI Report; the potential risks posed by the identified COPCs are discussed in Section 8 and Appendix T (Baseline Human Health Risk Assessment) and in Section 9 and Appendix U (Ecological Risk Assessment).

The following discussion describes the general operative chemical transport and fate processes and, more specifically, how applicable transport and fate processes apply to those constituents detected at the Casmalia site.

6.1 Fate and Transport Processes

Contaminant transport at Casmalia as well as other sites in general is the result of varied environmental mechanisms and is largely a function of:

- The chemical properties and corresponding environmental transport mechanisms of each constituent;
- The nature of the contamination detected. (e.g., contaminants distributed in surface soil are subject to different transport mechanisms than those present in subsurface soil); and
- The physical, chemical, and biological characteristics of the environment where the detected constituents are present.

Each chemical constituent has unique characteristics regarding its mobility and persistence in the environment. These characteristics are the result of the chemical characteristics of each constituent, in conjunction with physical, chemical, and biological mechanisms that may be active in the environment. An overview of the key fate and transport mechanisms involved is presented below.

6.1.1 Intermedia Transfers

Chemicals in the environment are distributed into solid, liquid, and gas phases according to their specific properties and the existing environmental conditions. Environmental media that could be affected by chemical pollutants released into the environment include soil (constituents present as solid phase) and soil pore water, sediment, surface water, groundwater (constituents

present either as dissolved or NAPL phase), and soil gas and indoor/outdoor air (constituents present in gas phase). Intermedia transfer is the movement of chemicals between these different media and phases, examples of which include: (1) leaching of chemicals bound to soil into groundwater; (2) emissions of volatile chemicals from soil into air; and (3) dissolution of NAPL into soil pore water and/or groundwater. Intermedia transfer processes may apply at both the macro and micro levels. For example, soil can be considered as a single medium (phase) on the macro-scale, with potential chemical transfer to air, surface water, groundwater, and terrestrial or aquatic biota[1]. On the micro-scale however, soil can be subdivided into solid soil particles, soil gas, and soil moisture, with chemical transfer of chemicals occurring between these phases. Specific properties that influence the degree of intermedia transfer that occurs are discussed below.

6.1.2 Physical Transport Mechanisms

Physical transport mechanisms that may be active in different environmental media are discussed below.

6.1.2.1 Soil

Transport of chemicals within soil occurs through several mechanisms, including:

- Leaching;
- Particle transport via colloids;
- Volatilization; and
- Burrowing animals (bioturbation).

Leaching occurs when soil contaminants dissolve into soil pore water and then migrate. The primary direction of leachate migration is typically downward, although lateral movement also occurs, especially when barriers to vertical migration are encountered. The degree to which a chemical is leached is strongly influenced by the chemical's tendency to partition to the solid or aqueous phases, which is largely a function of the chemical's solubility and particle affinity.

Water solubility describes the amount of a chemical that will dissolve in a given quantity of water, and thus is a primary determinant in the transport of a chemical in the environment. Highly soluble chemicals can often readily dissolve in water and are thus susceptible to being mobilized from the soil matrix with infiltrating water and migrating to groundwater. The solubility of organic chemicals is typically a function of the hydrophobic nature of the chemical. Many organic chemicals are non-polar and thus do not dissolve readily into water – a polar solution. The solubility of inorganic chemicals is typically a function of the tendency of the chemical to form mineral phases and the relative abundance of the chemical ingredients required to form the mineral phase.

The aqueous concentration of chemicals in soil systems can also be substantially influenced by adsorption reactions to the soil matrix. Adsorption is the ability of a substance to bind to the surface of soil particles as a result of reactions that occur between the chemical and the soil particle surface. The tendency for a chemical to be adsorbed is a function of the nature of the chemical and the site-specific soil properties, and is typically quantified by a distribution

[1] A detailed discussion of potential chemical uptake by terrestrial and aquatic biota is presented in Appendix U, Attachment 1 of this RI Report.

coefficient (K_d). A K_d is a measure of the ratio of chemical mass that partitions to the solid and liquid phases under equilibrium conditions. Inorganic compounds are commonly bound to soil particles as a result of electrostatic interactions. The mineral hydrous ferric oxide (FeOOH) is a dominant sorbent for many inorganic compounds in natural systems, owing to its common presence on soil particle surfaces, high surface area, and amphoteric character. As a result, the site-specific K_d for inorganic compounds is often correlated to the concentration of hydrous ferric oxide in the soil matrix.

Organic compounds are frequently non-polar and thus tend to interact with organic matter commonly associated with the soil matrix. The general tendency of an organic chemical to be adsorbed by soils may be assessed by the chemical's organic carbon partition coefficient (K_{oc}), which describes the tendency of the chemical to partition from water to organic carbon. The site-specific K_d for organic chemicals can be estimated as the product of the fraction of organic carbon (f_{oc}) in the soil matrix and the chemical's K_{oc}.

Transport of constituents also occurs through entrainment in soil pore water of colloidal particles with adhered chemicals. The adsorption of constituents to soil surfaces was summarized above. In general, colloid particles are finely divided solids that are approximately 10 to 10,000 angstroms in size, and are dispersed within a continuous medium (water). Due to their small size, colloids cannot be filtered easily, and generally do not settle due to gravity. The entrained colloidal particles follow the bulk fluid flow patterns in the soil.

Volatilization can significantly affect the distribution of a chemical in the environment. In soils, the result is a decrease in the amount of that chemical in soil as the chemical evaporates to soil gas and ultimately discharges to the atmosphere. The end result is a reduction in chemical concentration in soil over time. Volatilization reactions are most significant in surface soils that are in direct contact with the atmosphere.

Chemical volatility is typically quantified by a chemical's Henry's Law constant. Henry's Law constant may be calculated from the chemical's vapor pressure, molecular weight, and solubility properties. In general, a lower Henry's Law constant, suggests the chemical will be less volatile. Table 6-1 summarizes the values of Henry's Law constant and other pertinent physical and chemical properties of representative constituents detected during the RI.

Bioturbation is the rearrangement of the soil profile by plants and animals. Burrowing animals may physically mix and move contaminated soils as a consequence of their digging activities to forage for food, nest, or breed. Plant root systems may create passageways for air or water movement. Previously buried materials may be released to the ground surface, potentially enhancing contaminant exposure to dispersion via wind and rain. As a result, the potential for movement of impacted soil by their activity may influence the manner by which soils impacted by chemicals of concern are managed to address and prevent long-term exposure concerns.

6.1.2.2 Sediment

Contaminated sediments may be encountered in a number of different environments. Sedimentary environments that are expected to be relevant or present at the Casmalia site include the lacustrine and riverine sedimentary environments; i.e., on-site stormwater and treated liquids impoundments and/or seasonal streams and creeks. The relative importance of fate and transport processes will differ in each of these environments. One of the most important factors in defining the fate and transport processes influencing chemicals present in a

sedimentary environment is the relative energy of the overlying water flow or wind (in the dry season).

Key physical chemical transport mechanisms within these sedimentary environments may include:

- Sediment erosion, deposition, and resuspension;
- Leaching;
- Particle transport via colloids; and
- Burrowing animals (bioturbation).

Of these physical transport mechanisms, leaching, particle transport via colloids and bioturbation has already been described in general terms (Section 6.1.2.1).

Typical characteristics of a lacustrine sedimentary environment include the following:

- A low energy flow of overlying water;
- In general, a depositional environment; however, may be erosional (via wind) during dry season;
- Groundwater interaction that generally decreases with distance from shore; and
- Often fine-grained sediment.

Typical characteristics of a riverine sedimentary environment include the following:

- Overlying water flow of low to high energy;
- Potentially a depositional and erosional (water, or wind during dry season) environment;
- Potential for significant groundwater interaction; and
- Variable sediment characteristics – a mix of fine-grained to coarse-grained sediment materials.

One of the more dominant sediment physical transport mechanisms that controls constituent mobility is re-suspension and erosion of sedimentary particles. Sediment re-suspension and erosion can significantly increase the mobility of persistent chemicals that are strongly sorbed to the surface of soil particles and would otherwise be immobile. For example, under high energy conditions of a stream or creek, significant erosion of the sediment bed can occur, and individual sediment particles can be carried downstream. During this process, sediment particles can be continuously re-suspended and/or reburied by other sediments. During exposure to water, the sediment-borne constituents may also be desorbed to the water phase.

In addition to water, wind may provide sufficient mechanical energy for sediment re-suspension and erosion. Sediment movement by wind will be of particular importance during the dry or summer season when seasonal ponds or streams are free of surface water and dried sediments are exposed to the atmosphere. As in the case of water erosion, the relative distance that sediment particles may be carried by wind erosion is dependent on grain size, with fine-grained sediments likely to be carried much greater distances than coarse-grained materials. Wind erosion may also be significant in that re-deposition of sediment particles downwind may take place over a much broader area, and is not limited to the original lacustrine or riverine environments.

6.1.2.3 Air

Transport of chemicals within indoor/outdoor air occurs through several processes, including:

- Advection;
- Diffusion;
- Particle transport; and
- Volatilization.

Air transport occurs through entrainment of chemical vapors or particulates in the atmosphere and the processes of advection and dispersion. Advection is the movement of a chemical within a fluid – in this case air, but also in other fluids such as soil gas, surface water, and groundwater. The amount of chemical being transported is a function of its concentration in the flowing fluid and the rate of fluid flow. Diffusion is the process by which a chemical in a fluid will move from an area of greater concentration toward an area where it is less concentrated. Diffusion will occur as long as a concentration gradient exists, even if the fluid is not moving, and as a result, a chemical may spread away from the place where it is introduced. Intermedia transfer of chemicals out of the air can occur through precipitation and deposition.

6.1.2.4 Groundwater

Transport of chemicals within groundwater occurs through several processes, including:

- Advection;
- Dispersion;
- Diffusion;
- Particle transport; and
- Volatilization.

Transport of chemicals dissolved in groundwater occurs through advection, dispersion, and to a lesser extent, diffusion. As indicated above, advection is flow of a chemical in a fluid in response to a hydraulic gradient. Dispersion is the mixing of groundwater that occurs due to the tortuosity of the flow pattern in the pore spaces around the soil particles. Diffusion is molecular transport of solutes in a fluid from areas of higher concentration to area of lower concentration. NAPL is transported in groundwater by capillary forces and buoyancy effects associated with density differences between the NAPL and groundwater. LNAPL is less dense than water and tends to float on top of groundwater, while DNAPL is denser than water and tends to migrate downward through groundwater under gravity. Despite the tendency to float on top of groundwater, LNAPL can still be submerged below the water table. This occurs due to capillary forces and other NAPL trapping mechanisms in conjunction with a rising water table.

Chemical transport out of groundwater can occur through volatilization into soil gas or the atmosphere, or groundwater discharge to the surface. In addition, and as mentioned in Section 6.1.2.1, aqueous concentrations of chemicals in groundwater can be substantially influenced by adsorption of chemicals to the soil matrix.

6.1.2.5 Surface Water

Transport of chemicals within surface water occurs through several transport processes, including:

- Advection;
- Dispersion;
- Diffusion;
- Particle transport, either as suspended solids or colloids; and
- Volatilization.

Transport of chemicals within surface water occurs through advection and dispersion of solutes, suspended solids, and colloids. Intermedia transfer can occur if the surface water infiltrates into the subsurface, or through emission of volatile chemicals.

6.1.3 Physical, Chemical, and Biological Transformation Mechanisms

After a chemical is released to the environment, it may be physically, chemically, or biologically transformed, yielding a compound (or compounds) exhibiting different fate and transport characteristics in the environment. Transformation processes may also yield a compound or compounds that exhibit different levels of risk to potentially exposed human and ecological receptors. Active physical, chemical, and biological transformation mechanisms can affect the relative accumulation, transport, and/or transfer of chemical constituents in and between environmental media.

6.1.3.1 Physical Transformation Mechanisms

Physical transport mechanisms include processes such as volatilization and precipitation that promote the transfer of a constituent from one medium to another (intermedia transfer, Section 6.1.1). Other physical transformation mechanisms, such as dissolution, sorption, or retardation, may control the rate of transport or accumulation of constituents within a medium. Dissolution pertains to a chemical (solute) dissolving into a solution (solvent), typically groundwater or surface water. The quantity of the chemical that can dissolve before reaching saturation is dependent on the specific physical properties of the chemical and the solvent, and the environmental conditions present. Sorption processes include adsorption, chemisorption, absorption, and ion exchange. In adsorption processes, chemicals in the gas or liquid phase bind to a solid surface through electrostatic forces. Chemisorption is a similar process but involves chemical reactions rather than electrostatic forces. Absorption occurs when chemicals diffuse into solid materials and bind to interior surfaces. Ion exchange is a process whereby mobile, electronically charged dissolved constituents replace electronically charged chemicals that are bound to solid particles. Retardation occurs during flow in porous media when solutes move more slowly than the water that is transporting them due to sorption interactions. Chemical interactions that affect air transport pertain to how the chemicals become associated with gasses and solid particles, the buoyancy of vapors, and the deposition of particulates. These processes are complex and governed by physical chemistry and thermodynamic factors that are beyond the scope of this report.

6.1.3.2 Biotic and Abiotic (Chemical) Transformations

Numerous chemicals in the environment are subject to naturally occurring biotic (biologically based) and abiotic (non-biologically based) transformation reactions that result in the degradation of the chemical. Many organic compounds are subject to biodegradation reactions under aerobic (in the presence of oxygen) and anaerobic (in the absence of oxygen) conditions. During biodegradation, naturally occurring microorganisms in the subsurface transform a

chemical to another state as a direct or indirect consequence of their metabolic processes. Biodegradation reactions often break down organic chemicals to less toxic forms.

Several naturally occurring abiotic reactions can significantly affect the fate of chemicals in the environment. Common abiotic reactions include photodegradation and hydrolysis. Photodegradation is the process of decomposition of a chemical on exposure to radiant energy such as the action of light, and is most significant to chemicals in surface soil or surface water that is in direct contact with sunlight. Hydrolysis is the degradation reaction of the chemical with components of water (e.g., hydroxyl and hydronium ions) and is thus most important in saturated environments.

6.2 Detected Chemical Groups

Site-specific evaluation of chemical fates and transport mechanisms is important for understanding the degree to which constituents are able to be transported from contaminated media (i.e., primary and secondary sources) to locations where receptors may be potentially exposed. The following sections identify the chemicals or chemical groups that are present in various media at the Site, and discuss the fate and transport mechanisms that appear to control their distribution in the environment.

6.2.1 Detected Chemicals by Media

The COPC list for the Casmalia site was developed from the larger list of detected chemicals as part of the risk assessment processes. COPCs were identified based on the prevalence of the constituents detected in the various environmental media. If the compound was detected in at least 5 percent of the individual samples collected within a given medium, the compound was included on the COPC list for further evaluation. The methodology and results of the COPC selection process are summarized in Section 7 of this RI Report and again referenced in Sections 8 and 9. Additional supporting information regarding COPC identification is also presented in Appendix X. Major chemical analyte classes in the COPC list include VOCs, SVOCs/PAHs, pesticides, herbicides, dioxins/furans, PCBs, and metals. The chemical analyte classes, representative chemicals, and the environmental media where these were detected are summarized in Table 6-2.

6.2.1.1 Relative Mobility of Site Constituents

The transport behavior of chemicals at the site can be qualitatively estimated using simple mathematical models. The governing equations for chemical fate and transport take into account chemical mobility and persistence. A chemical's solubility, sorption, and volatility are related to and used to evaluate mobility, while chemicals with long degradation times are described as persistent. These two aspects of fate and transport for detected constituents are discussed in the paragraphs below.

The principal properties related to chemical mobility are the aqueous solubility, sorption, and volatility-related variables. Multiple sorption parameters are in common use, including the distribution coefficient (K_d), the octanol-water partition coefficient (K_{ow}), and the organic carbon partition coefficient (K_{oc}). The volatility of a chemical is typically expressed in terms of the vapor pressure (Vp) and Henry's Law constant (H_c). Higher solubility and volatility imply a greater potential for migration. Sorption is inversely proportional to solubility, and therefore implies greater retardation and a decreased potential for migration, other factors being equal.

Basic generalizations regarding the above variables for the chemical analyte classes and the representative constituents at the site are indicated in Table 6-3. The high-medium-low values presented in Table 6-3 are intended only as relative terms for comparison of the indicated representative chemicals, and do not reflect any quantitative value or range of values.

6.2.1.2 Relative Persistence of Site Constituents

As summarized in Section 6.1.3, chemical and biological degradation processes, such as biodegradation, hydrolysis, and photolysis, can affect chemical persistence in the environment. Degradation of detected chemical constituents in various environmental media is typically characterized in terms of various kinetic rate constants (e.g., half-life, K_{deg}).

Because of the many complex factors that may affect persistence, the actual rate of chemical degradation is very difficult to predict for a given chemical at a given site. However, a qualitative evaluation of the potential for degradation of a chemical can be made based on the results of laboratory and/or field studies conducted for other locations or as part of other studies. Such a qualitative evaluation was conducted for the contaminants of concern detected at the Site, and the results are summarized in Table 6-4. In this table, the degradation potential for each of the contaminants of concern is indicated for three broad environmental media categories: atmospheric degradation, aquatic degradation, and terrestrial degradation.

6.3 Actions Taken to Disrupt Environmental Transport Pathways

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Some of these actions were taken to eliminate historical sources of contamination. Other actions, some of which remain in effect presently, were implemented to disrupt contaminant transport pathways and mitigate further contaminant migration. These actions include:

- Cessation of Disposal Operations – The site ceased accepting off-site liquid wastes in 1987, and stopped accepting off-site solid waste in 1989. While the majority of landfill areas remain intact, wastes once deposited in the former RCRA Landfill and the former Drum Burial Area were removed and re-deposited in one of the existing landfill areas. Waste removal from the former RCRA Landfill was completed by 1990. Waste removal from the former Drum Burial Area was completed by 1980.
- Surface Impoundment Closure Activities – Closure of existing surface impoundments was implemented in accordance with CAO No. 89-60, issued by the RWQCB. The objective of closure operations was to remove hazardous constituents once present in the former surface impounds to background or other cleanup levels approved by the RWQCB. Surface impoundment closure included liquids removal, bottom sludge removal and contaminated sub-grade removal. Surface impoundment field closure activities were complete by 1991.
- Fuel Tank Removals – two fuel tanks were removed from the southwestern portion of the site near (south of former Pond A-1) in the late 1980s.
- Subsurface Site Liquids Management – Several extraction features remain in operation at the site, including:
    - Gallery Well – subsurface compacted clay barrier walls were installed downgradient of the P/S and PCB Landfills in 1980. The P/S barrier included an extraction point called the Gallery Well. The total depth of this well has been extended over time, most recently in 1999.

- o Sump 9B – a relatively shallow liquid extraction point (gravel-filled collection trench) installed south of the P/S landfill near former Pad 9B, and north of the PSCT.
- o PSCT – the perimeter source control trench, constructed in 1990, was installed downgradient of the landfills. The PSCT is a continuous, approximately 2,650-foot-long gravel-filled trench covered with compacted fill material. It is situated downgradient of the inactive landfill areas and the Burial Cells Unit. The PSCT is designed to intercept subsurface liquids migrating from north to south across the site.
- o PCTs – the perimeter control trenches, including PCT-A, PCT-B, and PCT-C which were constructed in 1990 along the A-, B-, and C- Drainages, respectively. The PCTs were designed to control and intercept groundwater flow toward the A-, B-, and C- Drainages. Extracted liquids are discharged to either the RCF Pond or the A-Series Pond.

- PCB Landfill Clay Barrier – an environmental barrier was constructed along the southwest corner of the PCB landfill in 1980. The purpose of the barrier was to contain leachate liquids originating from within the PCB Landfill. The clay barrier remains in place.
- P/S Landfill Clay Barrier – a clay barrier and extraction point (Gallery Well) were constructed at the toe of the P/S Landfill in 1980. The purpose of the barrier and gallery well was to control leachate migration from the P/S Landfill. The clay barrier and extraction point (Gallery Well) remain in place.
- P/S Landfill cap construction – The Pesticide / Solvent landfill was capped in 1999, effectively eliminating infiltration of surface water which could cause further leaching of hazardous constituents from landfill waste materials.
- EE/CA Area cap construction - the Heavy Metals Landfill, Caustic/Cyanides Landfill, Acids Landfill, and interstitials areas between these landfills were capped in 2001 and 2002, effectively eliminating infiltration of surface water which could cause further leaching of hazardous constituents from landfill waste materials.
- Existing Surface Impoundments – past RWQCB Waste Discharge Requirements dictated zero discharge from the Site. Since 1987, all stormwater runoff and treated groundwater was contained within the site boundary. In November 1999, a National Pollution Discharge Elimination System (NPDES) permit for the Site was adopted by the CRWQCB (Permit No. CA0049972, Order No. 99-034) allowing periodic discharge of treated surface waters if certain on-site conditions were met. A General NPDES permit was also adopted by the CRWQCB for the Site in 2003 (Permit No. CA 0049972, Order No. R3-2004-0124), which allowed periodic off-site discharge of clean stormwater runoff draining from capped areas of the site, including the P/S Landfill cap and the EE/CA cap areas.

6.4 Site-specific Persistence, Migration, and Transformation Potential by Media

The following sections provide a more detailed summary of the media where chemical constituents are encountered at the Casmalia site, and the physical, chemical, and biological processes that are potentially affecting the migration, persistence, and transformation of chemical classes in those media.

In the following section we discuss COPCs defined in the Baseline Ecological Risk Assessment. In some cases the list of COPCs has been revised based upon findings of Tier 2 Ecological Risk Assessment. The following sections discuss these chemicals as examples only, and it should

be recognized that not all chemicals discussed below have been carried forward as COPCs in the risk assessment process.

6.4.1 Surface Transport Pathways – COPC Fate & Transport

The migration of surface contaminants involves the fate and transport processes of chemicals associated with surface soil, sediment and surface water, and their impacts to potential receptors in the surrounding environmental setting. Surface soil chemicals and a discussion of surface soil contaminant migration are discussed in Sections 6.4.1.1 and 6.4.1.2, respectively. Sediment chemicals and a discussion of sediment contaminant migration are discussed in Sections 6.4.1.3 and 6.4.1.4 respectively. Surface water chemicals observed at the site and a discussion of surface water contaminant migration are discussed in Sections 6.4.1.5 and 6.4.1.6, respectively.

6.4.1.1 Surface Soil COPCs

Chemical constituents detected in surface soil in excess of screening levels (Section 5.3.1), by COPC class (Section 7.0), and include:

- VOCs – tetrachloroethene, trichloroethene;
- SVOCs – bis(2-ethylhexyl)phthalate;
- Pesticides and Herbicides – MCPP (2-(4-chloro-2-methylphenoxy)-propanoic acid), 4,4'-DDE, 4,4'-DDT, and Hexachlorobenzene;
- Dioxins/Furans – Dioxin TEQ;
- PCBs – PCB Aroclor 1260, and PCBs (total); and
- Metals – barium, cadmium, chromium, copper, lead, and zinc.

6.4.1.1.1 Migration and Persistence of Surface Soil COPCs

Although surface soil is a medium were many of the COPCs are detected, it is not a transport pathway itself; rather, surface soil serves as a medium that *may contribute* contaminants to other environmental pathways. Intermedia transport from surface soil to other environmental media is dependent upon a number of physical and chemical transport mechanisms. For example, soil erosion by rain or wind can entrain soil particles in water or into the atmosphere for redistribution and redeposition. Potential transport pathways for surface soils that may be carried and redeposited via surface water flow are discussed in Section 4.0, and historical drainage features are illustrated in Figures 4-1 through 4-6. Volatile chemicals that evaporate or de-sorb from surface soils would be emitted to the atmosphere. Leaching may occur when soil contaminants dissolve into soil pore water and migrate with water infiltration. Transport may also occur through entrainment in soil pore water of colloidal particles with adhered chemicals. The entrained particles follow the bulk fluid flow patterns in the soil.

VOCs

VOCs are organic compounds that exhibit relatively high vapor pressures, with typically limited solubility in water. Hence, a major transport process for VOCs from surface soil systems is volatilization. The most prevalent VOCs encountered in surface soil, trichloroethene and tetrachloroethene, are halogenated VOCs.
Halogenated VOCs (HVOCs) are not expected to selectively concentrate on or be sorbed by soils. If HVOC vapors migrate and partition to the atmosphere, HVOCs will be degraded by

photo-oxidation. Little biodegradation of HVOCs is expected to occur in surface soils, and processes other than volatilization do not appear to play a significant role in the removal of HVOCs from soil systems.

SVOCs

Semi-volatile organic compounds, such as bis(2-ethylhexyl)phthalate, are nonvolatile organic compounds that are relatively insoluble in water. Volatilization from either wet or dry soils is not expected to be an important fate process for this chemical class. Empirical data indicate that the degree of sorption of SVOCs is expected to increase as the natural organic carbon content of the soil matrix increases. The most important transport-controlling mechanism for SVOCs in surface soil appears to be adsorption to soil particles and potential redistribution by either wind or stormwater erosion.

Sorption or bioaccumulation appears to be a significant environmental fate-governing mechanism for SVOCs. Biotic and abiotic biodegradation or transformation processes may act as removal mechanisms for SVOCS, but at relatively slow rates.

Pesticides and Herbicides

MCPP is a selective 'broad-leaf' post-emergence herbicide. Its distribution in the environment is initially dependent on its application as an aerosol during spray application and removal from air by gravitational settling. When released to soil, the herbicide MCPP will readily leach, and may dissolve into and be transported with runoff water. Based upon is molecular weight, MCPP is not expected to volatilize. In addition, MCPP is not expected to strongly adsorb to soil.

MCPP's bioaccumulation potential appears to be low. Biodegradation in soil may be faster if soil microbes are acclimated to the presence of MCPP.

Dioxins and Furans

Dioxins/furans are generally nonvolatile organic compounds that are insoluble in water. If released to soil, dioxins/furans are expected to be readily adsorbed to soil based on their insoluble nature and as indicated by their relatively high K_{ow}. The degree of adsorption is expected to increase as the natural organic content in soil increases. The most important transport-controlling mechanism for dioxins/furans in surface soil appears to be adsorption to soil particles and redistribution by either wind or stormwater erosion.

Sorption or bioaccumulation appears to be a significant environmental fate-governing mechanism for dioxins/furans. Biotic and abiotic biodegradation or transformation processes have not been demonstrated to be significant removal mechanisms for dioxins and furans.

PCBs

PCBs are generally nonvolatile organic compounds that are insoluble in water. PCBs are expected to strongly adsorb to soils and sediment, and not readily leach because of their insoluble nature, and as indicated by their relatively high K_{ow}. The predominant environmental transport mechanism is believed to be via wind and rain erosion of soil particles. A secondary transport mechanism may be volatilization from impacted surface soils, and subsequent

removal from the atmosphere via wet/dry deposition. In general, the lesser-chlorinated PCBs volatilize from soils more readily.

In general, the persistence of PCBs increases with the degree of chlorination. Sorption or bioaccumulation appears to be the environmental fate-governing mechanism for PCBs. Limited data are available concerning the chemical degradation of PCBs in soil, but biotic and abiotic biodegradation or transformation processes have not been demonstrated to be significant removal mechanisms.

Metals

The measurement of anthropogenic metals contamination in environmental media is complicated by the presence of naturally-occurring metals. Dominant transport mechanisms for metals are surface water or wind erosion of surface soil and particulate transport. Significant downward transport of metals into soil is observed when the metal retention capacity of the soil is overloaded, or when metals are solubilized. The solubility of metals is often increased by reduced soil pH conditions. As soil concentrations of metals increase and the adsorptive capacity of the soil is exhausted, metals will migrate with infiltration water.

Metals are generally persistent in the environment indefinitely because metals do not degrade. Unlike organic compounds that can be destroyed, metals can only be changed in the oxidation state, chemical species, and physical form. However, biotic and abiotic transformations have been identified that, in some instances, may reduce the toxicity of the metal.

6.4.1.1.2 Site-specific Examples of Constituent Transport from Contaminated Surface Soils

Locations where elevated COPCs were detected in surface soil include:

- RCRA Canyon Area – a variety of inorganic constituents, with barium being most prevalent, were detected in the majority of sampling locations in the RCRA Canyon Area. Metals, such as barium, cadmium, chromium, cobalt, lead, mercury, nickel, selenium, tin, and zinc were detected above screening levels.
- West Canyon Spray Area - Metals, such as cadmium, chromium, cobalt, copper, iron, lead, nickel, tin, and zinc were detected above screening levels. Concentrations exceeded screening levels in locations primarily in the southern portion of the study area.
- Burial Trench Area – exceedences for inorganics in surface soils included lead, chromium, nickel and selenium, principally in the southern portion of the study area.
- Metals, including barium, cadmium, chromium, copper, manganese, molybdenum, nickel, selenium, tin, and zinc detected in the on-site stormwater ponds, including the RCF Pond, the A-series pond, and Pond 13.
- Inorganics, including barium, cadmium, copper, nickel, and selenium were detected at elevated levels in sediment samples from the treated liquids impoundments, including Pond A-5 and Pond 18.

It is believed that surface water runoff from other study areas transported these COPCs to the stormwater and treated liquids impoundments located on site. Sediment data suggests COPCs transported to these locations either precipitated from dissolved into solid phases, or if transported on particulate surfaces, settled due to gravity.

6.4.1.1.3 Actions Taken to Disrupt Surface Soil Environmental Transport Pathways

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Specific actions that have been taken to mitigate constituent transport in surface soil include:

- Landfill Capping – engineered landfill caps, such as the P/S Landfill cap and EE/CA cap, are designed to mitigate the erosive action of stormwater runoff and wind. Landfill cap design and construction prevent stormwater runoff contact with contaminated soils, and transport of contaminated soils. The vegetative cover prevents wind erosion of biotic cover soils.
- On-site stormwater runoff is captured and contained on-site to prevent off-site transport of COPCs via surface water. The RCF Pond, the A-series pond, and Pond 13 are designed to prevent off-site transport of untreated surface water.

6.4.1.2 Sediment COPCs

Chemical constituents detected in sediments in excess of screening levels (Section 5.3.3), by COPC class (Section 7.0), include:

- VOCs – 1,1-dichloroethane;
- Pesticides and Herbicides – MCPP (2-(4-chloro-2-methylphenoxy)- Propanoic acid);
- PCBs – PCB Congeners; and
- Metals – barium, cadmium and selenium.

6.4.1.2.1 Migration and Persistence of Sediment COPCs

Sediment is typically subjected to transport mechanisms similar to those that are active in surface soils. The primary process by which sediments are contaminated is the erosion of contaminated surface soil, particulate transport, and deposition of particulates in stream channels and ponds. Potential transport pathways for sediments that may be carried and redeposited via surface water flow are discussed in Section 4.0, and historical drainage features are illustrated in Figures 4-1 through 4-6. Stormwater erosion and contamination of sediments is particularly important for low-solubility contaminants that are bound or sorbed to soil particles, such as pesticides, herbicides, PCBs, and metals.

VOCs

VOCs are organic compounds that exhibit relatively high vapor pressures, with limited solubility in water. A major transport process for VOCs from surface soil systems is volatilization. The most prevalent VOC encountered in sediment, 1,1-dichloroethane, is a HVOC.

HVOCs are not expected to selectively concentrate on or be sorbed by soils or sediments. If a HVOC such as 1,1-dichloroethane volatilizes from sediment and partitions to the atmosphere, it will be degraded by photo-oxidation. Little biodegradation of HVOCs is expected to occur in soils or sediments, and processes other than volatilization do not appear to play a significant role in the removal of HVOCs from soil or sediment systems.

Pesticides / Herbicides

MCPP is a selective 'broad-leaf' post-emergence herbicide. Its distribution in the environment is initially dependent on its application as an aerosol during spray application and removal from air by gravitational settling. When released to soil, the herbicide MCPP will readily leach, and may be dissolved into and transported with runoff water, thus explaining the potential accumulation in sediment. MCPP's bioaccumulation potential appears to be low, and the compound can biodegrade in soil and sediment. Biodegradation in sediment may be faster if microbes have acclimated to the presence of MCPP.

PCBs

PCB compounds are nonvolatile organic compounds that are insoluble in water. PCBs are expected to strongly adsorb to soils and sediment, and not leach extensively because of their insoluble nature. The predominant environmental transport mechanism is believed to be soil particle transport via either wind- or rain-driven erosion. Therefore, accumulation of PCBs in sediment may be expected.

Sorption or bioaccumulation appears to be the environmental fate-governing mechanism for PCBs. Limited data are available concerning the chemical degradation of PCBs in soil, but biotic and abiotic biodegradation or transformation processes have not been demonstrated to be significant removal mechanisms.

Metals

The measurement of anthropogenic metals contamination in environmental media is complicated by the presence of naturally-occurring metals. Dominant transport mechanisms for metals are surface water or wind erosion of surface soil and particulate transport. Therefore, accumulation of metals in sediment may be expected.

Metals are generally persistent in the environment indefinitely because metals do not degrade. Unlike organic compounds that can be destroyed, metals can only be changed in the oxidation state, chemical species, and physical form.

6.4.1.2.2 Site-specific Examples of Constituent Transport in or to Sediments

Examples of Elevated COPCs detected in sediments include:

- Metals, including barium, cadmium, chromium, copper, manganese, molybdenum, nickel, selenium, tin, and zinc detected in the on-site stormwater ponds, including the RCF Pond, the A-series pond, and Pond 13.
- Metals, including barium, cadmium, copper, nickel, and selenium detected at elevated levels in sediment samples from the treated liquids impoundments identified as Pond A-5 and Pond 18.
- PCBs and pesticides alpha chlordane, DDD, DDT, dieldrin, and/or endrin detected above screening levels in sampling locations in the RCF Pond.

It is believed that surface water runoff from other site activities, such as the RCRA Canyon Area and the West Canyon Spray Area, transported dissolved or sediment-borne inorganics COPCs to the stormwater and treated liquids impoundments located on site. PCBs and pesticides alpha

chlordane, DDD, DDT, dieldrin, and/or endrin detected in sediments within the RCF Pond may have been transported there prior to capping the P/S Landfill.

6.4.1.2.3 Actions Taken to Disrupt Environmental Transport Pathways to or via Sediment

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Specific actions that have been taken to mitigate constituent transport to or via sediments include:

- On-site surface water runoff is captured and contained on-site to prevent off-site transport of COPCs via suspended particles or sediment. The RCF Pond, the A-series pond and Pond 13 are designed to prevent off-site transport of untreated surface water.
- Surface Impoundment Closure Activities – surface impoundments used during hazardous waste management operations have been closed. Closure activities removed contaminated liquids and bottom sludge removal, thus eliminated them as potential sources of contaminated sediment.
- Landfill Capping – engineered landfill caps, such as the P/S Landfill cap and EE/CA cap, are designed to mitigate the erosive action of surface water runoff. Landfill cap design and construction prevent stormwater runoff contact with contaminated soils, and transport of contaminated soils as suspended particles in stormwater. The landfill cap designs also mitigate the potential for wind erosion of contaminated soils, and subsequent redeposition as sediment in neighboring surface water bodies.

6.4.1.3 Surface Water COPCs

Chemical constituents detected in surface water in excess of screening levels (Section 5.3.4), by COPC class (Section 7.0), include:

- VOCs (acetone and acetonitrile);
- SVOCs (n-nitrosodipropylamine);
- PAHs;
- Dioxins / Furans; and
- Metals (arsenic, molybdenum, and selenium).

6.4.1.3.1 Migration and Persistence of Surface Water COPCs

Contaminant migration into surface waters at the Site may occur through surface water runoff and/or dust generation/redeposition. Upon reaching surface water, transport of chemicals can occur through advection and dispersion of solutes, suspended solids, and colloids. Intermedia transfer can occur if the surface water infiltrates into the subsurface, or through emission of volatile chemicals. Potential transport pathways for contaminated surface water are discussed in Section 4.0, and historical drainage features are illustrated in Figures 4-1 through 4-6.

VOCs

Volatile organic compounds tend to quickly volatilize into the atmosphere upon reaching surface water. Therefore, VOCs are rarely observed at detectable concentrations in surface water samples. However, those VOCs with relatively high solubilities or Henry's Law constant may tend to remain dissolved in surface water and persist longer.

SVOCs and PAHs

Major transport processes for SVOCs and PAHs in surface water include migration as solutes in water, or sorbed to suspended particulate material. As in natural water systems, solute transport is via surface water flow, and subsequently, either infiltration or deposition.

Dioxins/Furans

Dioxins/Furans can enter surface water by a number of different mechanisms including surface water runoff, deposition of particulates from combustion sources, deposition of particulates from wind erosion. Dioxins/Furans are expected to adsorb to suspended particulate material in the water column and be transported to the sediment. In fact, binding to particulates and sediments is considered a primary removal process of Dioxins/Furans from surface water. Low water solubilities and high K_{ow} coefficients indicate that Dioxins/Furans will strongly bind to organic matter. Dioxins/Furans are also expected to bioconcentrate in aquatic organisms, if present. However, as a result of their binding to organic matter, the actual uptake and transfer to aquatic organisms may be less than predicted.

Metals

Metals can enter surface water by a number of different mechanisms including surface water runoff and deposition of soil particulates from wind erosion. Once in surface water, major transport processes for metals are as solutes in surface water or sorbed to suspended particulate material, and subsequent dispersion via surface water flow.

A variety of natural reactions in surface water may occur that will influence the speciation and mobility of metals in surface water, including water pH, precipitation/dissolution, oxidation/reduction, sorption, or ion exchange. Precipitation, sorption, and ion exchange reactions would be expected to remove metals from the surface water column.

6.4.1.3.2 Site-specific Examples of Constituent Transport via Surface Water, or to Surface Water

Examples of Elevated COPCs detected in surface water include:

- Metals, including barium, cadmium, chromium, copper, manganese, molybdenum, nickel, selenium, tin, and zinc detected in the on-site stormwater ponds, including the RCF Pond, the A-series pond, and Pond 13. Of the surface water features sampled, Pond 13 has the highest concentrations of dissolved metals.
- Metals, including arsenic, nickel, and selenium have been detected at elevated levels in water samples from the treated liquids impoundments identified as Pond A-5 and Pond 18.

It is believed that surface water runoff from other study areas transported these COPCs to the stormwater and treated liquids impoundments located on site. Sediment data suggests COPCs transported to these locations either precipitated from dissolved to solid phases, or if transported on particulate surfaces, were deposited in sediments due to gravitational settling.

6.4.1.3.3 Actions Taken to Disrupt Environmental Transport Pathways to Surface Water

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Specific actions that have been taken to mitigate constituent transport to or via surface water include:

- On-site surface water runoff is captured and contained on-site to prevent off-site transport of COPCs via surface water. The RCF Pond, the A-series pond and Pond 13 are designed to prevent off-site transport of untreated surface water.
- Surface Impoundment Closure Activities – surface impoundments used during hazardous waste management operations have been closed. Closure activities removed contaminated liquids, thus eliminating them as a source for further surface and subsurface soil contamination via leaching.
- Landfill Capping – engineered landfill caps, such as the P/S Landfill cap and EE/CA cap, are designed to mitigate the erosive action of surface water runoff. Landfill cap design and construction prevent stormwater runoff contact with contaminated soils, and transport of contaminated soils.

6.4.2 Subsurface Transport Pathways – COPC Fate & Transport

The migration of subsurface contaminants involves the fate and transport of chemicals associated with subsurface soil, soil vapor, groundwater, and NAPL, and their impacts to potential receptors in the surrounding environmental setting. Subsurface soil COPCs observed at the site are discussed in Section 6.4.2.1 and 6.4.2.2. Soil Vapor chemical constituents, and contaminant transport processes are discussed in Sections 6.4.2.3 and 6.4.2.4, respectively. Groundwater chemicals and a discussion of groundwater contaminant migration are discussed in Sections 6.4.2.5 and 6.4.2.6, respectively. NAPL chemicals and a discussion of NAPL migration are discussed in Sections 6.4.2.7 and 6.4.2.8, respectively.

6.4.2.1 <u>Subsurface Soil COPCs</u>

Chemical constituents detected in subsurface soil in excess of screening levels (Section 5.3.1), by COPC class (Section 7.0), include:

- VOCs – tetrachloroethene, trichloroethene
- SVOCs – bis(2-ethylhexyl)phthalate
- Pesticides and Herbicides – MCPP (2-(4-chloro-2-methylphenoxy)- Propanoic acid), 4,4'-DDE, 4,4'-DDT, and Hexachlorobenzene
- Dioxins/Furans – Dioxin TEQ
- PCBs – PCB Aroclor 1260, and PCBs (total)
- Metals – barium, cadmium, chromium, copper, lead, and zinc.

6.4.2.1.1 Migration and Persistence of Subsurface Soil COPCs

Subsurface soil is a medium that, by itself, is not a transport pathway; rather, subsurface soil may contribute to groundwater and soil vapor as potential pathways for subsurface contaminant transport. COPC transport from subsurface soil to other environmental media is dependent upon physical, chemical, and biological mechanisms, such as dissolution, sorption/desorption processes. COPC transport can also be influenced by subsurface conduits that can potentially allow subsurface contaminant to reach the surface.

VOCs

VOCs are organic compounds that exhibit relatively high vapor pressures, with limited solubility in water. A major transport process for VOCs from subsurface soil systems is volatilization. The most prevalent VOCs encountered in subsurface soil are trichloroethene (TCE) and tetrachloroethene (PCE).

VOCs, particularly HVOCs like TCE and PCE, are not expected to selectively concentrate on or be sorbed by soils. If HVOC vapors migrate and partition to the atmosphere, HVOCs will be degraded by photo-oxidation. Little biodegradation of HVOCs is expected to occur in subsurface soils unless geochemical conditions are anaerobic or reduced. Processes other than volatilization do not appear to play a significant role in the removal of HVOC from soil systems.

SVOCs

A review of the physical, chemical, and biological data for SVOCs indicated that these compounds are generally nonvolatile organic compounds that are insoluble in water. SVOCs are expected to be readily adsorbed to subsurface soils because of their insoluble nature, and as indicated by their relatively high K_{ow}. Compounds with K_{ow} coefficients greater than 3 are considered to be relatively immobile in environmental media (Table 6-1).

Sorption or bioaccumulation appears to be the primary environmental fate-governing mechanism for SVOCs. Volatilization of SVOCs is not expected to be a significant removal factor. Limited data are available concerning the chemical degradation of SVOC in soil, but abiotic degradation has not been demonstrated to be a significant removal mechanism. Therefore, physical and biological transformation (e.g., intermedia transfers and biodegradation) of SVOCs is expected to be minimal.

Pesticides/Herbicides

A review of the physical, chemical, and biological data for pesticides detected at the Casmalia site indicate that most of these compounds are generally nonvolatile organic compounds that are insoluble in water. The detected pesticides are expected to be readily adsorbed to subsurface soils because of their insoluble nature, and as indicated by their relatively high K_{ow}. Removal of pesticides from soil via biodegradation or abiotic processes is expected to be quite slow at the Casmalia site. For example, pesticides such as endrin or DDT have observed half-lives in soil as great as 10 to 50 years. Sorption and/or bioaccumulation in plant and animal tissue appear to be the primary environmental fate-governing mechanism for most pesticides encountered at the Site.

The herbicides detected at the Casmalia site are generally nonvolatile organic compounds that are relatively insoluble in water. Release of these compounds to the environment may have occurred either by commercial use of these chemicals as herbicides, or by disposal of spray rinsate from herbicide drums or spray equipment. Once released to soil, the herbicides detected at the Casmalia site are expected to have a relatively high mobility based on lower K_{ow} coefficients, compared to pesticides, such as DDT. However, the biodegradation potential of herbicides appears to be much greater than pesticides such as DDT. Lastly, the potential for bioaccumulation in plant and animal tissue also appears to be less for herbicides than for pesticides such as DDT.

Dioxins/Furans

Dioxin/furan compounds are generally nonvolatile organic compounds that are insoluble in water. Dioxins/furans are expected to be readily adsorbed to subsurface soil based on their insoluble nature, and as indicated by their relatively high K_{ow} coefficients. Sorption or bioaccumulation appears to be a significant environmental fate-governing mechanism for dioxins/furans.

Available field data on biotic and abiotic degradation or transformation processes are insufficient to confirm their importance in reducing dioxin/furan concentrations in the environment.

PCBs

PCB compounds are generally nonvolatile organic compounds that are insoluble in water. PCBs are expected to strongly adsorb to subsurface soils, and not leach extensively because of their insoluble nature, and as indicated by their relatively high K_{ow}. In general, the persistence of PCBs increases with the degree of chlorination. Sorption or bioaccumulation appears to be the primary environmental fate-governing mechanism for PCBs.

Limited data are available concerning the chemical degradation of PCBs in soil, but biotic and abiotic biodegradation or transformation processes have not been demonstrated to be significant removal mechanisms.

Metals

A review of the physical, chemical, and biological data for metals indicates that persistence and migration of these constituents are impacted by the metal's chemical form, the matrix it is encountered in, soil type, and soil geochemistry. Unlike the organic constituents of concern, metals cannot be degraded. However, biotic and abiotic transformations have been identified that, in some instances, may reduce the toxicity of the metal. Significant downward transport of metals into soil is observed when the metal retention capacity of the soil is overloaded, or when metals are solubilized. The solubility of metals is often increased by reduced soil pH conditions. As soil concentrations of metals increase and the adsorptive capacity of the soil is exhausted, metals will migrate with infiltration water. Unlike organic compounds that can be destroyed, metals can only be changed in the oxidation state, chemical species, and physical form.

6.4.2.1.2 Site-specific Examples of Constituent Transport from Contaminated Subsurface Soils

Locations where elevated COPCs were detected in deep or subsurface soil include:

- Landfills Area – The waste deposits of both the capped and uncapped landfills.
- RCRA Canyon Area – The residual waste deposits former RCRA Landfill area. Drilling mud like materials with staining is present at RTTRRC-1.
- Burial Trench Area – available data indicate that shallow to deep soils, principally within the central portion of the Burial Trench Area; have been significantly impacted by a variety of inorganic and organic constituents. Deep soil impacts by VOCs are also present along the southern margin of the area.
- Central Drainage Area – Exceedances for organic constituents are limited almost exclusively to shallow to deep soils within the western portion of the study area,

principally in proximity to the toe of the P/S Landfill, Sump 9B and locations situated down slope of these areas toward the PSCT.

- Former Ponds & Pads Subarea – VOC concentrations in excess of screening levels (both TCE and PCE) are detected in medium depth soils in borings completed within the limits of former Pond A and Pond B, located in the north central portion of this area just south of the PSCT. Other borings completed within former Ponds A and B did not encounter similarly elevated organics, indicating that significant soil impacts related to these two former ponds are of limited lateral extent. Soil staining was present at the bottom of RITTRON-1 and -2 that evaluated the former drainage feature between Pond C and Pond M. No indications of significant soil impacts were encountered in deep borings and MIP investigations completed along historical drainage paths. Investigative findings indicate that prior soil cleanup activities conducted within the Former Ponds and Pads Subarea were very effective.
- Remaining On-Site Area – The most prevalent inorganics exceedances encountered in subsurface soils included nickel and zinc. Organics exceedances of PPOs and PAHs were detected in deep soil in four separate locations along the southern Site boundary. One location is associated with the former diesel fuel pump area south of former Pond A-1, and the others are in proximity to a former waste impoundment once located near the western end of the present RCF Pond that is visible on the 1974 and 1975 historical aerial photographs (RIBON-59 area – below)
- RISBON-59 Area – Available data, including analytical laboratory results, MIP measurements and field observations, indicate that the highest concentrations and greatest variety of contaminants within in this area are present at depths of between approximately 27 to 36 feet bgs in RISBON-59, and diminish both laterally and vertically away from this location. Contamination detected in the RISBON-59 area is coincident with the southern margin of former waste management Pond 2 as well as with a preceding former waste impoundment visible on historical aerial photographs from 1974 and 1975.

At any of these locations, there is the potential that contaminated subsurface soils may be contributing to impacts observed in other environmental media, such as groundwater and soil vapor. While historical information indicates otherwise, it is theoretically possible that subsurface soil impacts at these locations may originate from other sources such as NAPL, and/or leaching of surface contaminants via infiltration of stormwater, surface water runoff, or impoundment liquids.

6.4.2.1.3 Actions Taken to Disrupt Subsurface Soil Environmental Transport Pathways

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Specific actions that have been taken to mitigate constituent transport in subsurface soil include:

- Surface Impoundment Closure Activities – Removal of liquids, bottom sludge and contaminated sub-grade material removed potential sources of inorganic and organic contaminants that could impact subsurface soils underlying the former ponds and pads. Impacted materials were stabilized and emplaced in the now-capped landfills.
- Landfill Capping – engineered landfill caps, such as the P/S Landfill cap and EE/CA cap, are designed and constructed to mitigate stormwater infiltration into waste materials, and subsequent leaching of waste chemicals from subsurface soils into groundwater underlying the landfills.

6.4.2.2 Soil Vapor COPCs

Typically, soil vapor chemical constituents encompass VOCs exclusively. A total of 43 individual VOCs were detected at various soil vapor sampling locations around the perimeter of the landfills, the Burial Trench Area, and the Central Drainage Area, including chlorinated and aromatic hydrocarbons, acetone, methyl ethyl ketone, and freon gases. Chemicals detected in soil vapor that demonstrate some of the highest prevalence and reported concentrations, or that may potentially contribute to human health or ecological risks include acetone, methyl ethyl ketone, Freon 113, benzene, 1,3-butadiene, and tetrachloroethene.

6.4.2.2.1 Migration and Persistence of Soil Vapor COPCs

VOCs

VOCs encountered at the Site generally share similar volatility and water-solubility characteristics. When VOCs are released to soils, a significant fraction of the chemical rapidly partitions to the air by volatilization. VOCs are not expected to selectively concentrate on or be sorbed by soils or to be taken up and retained in biological tissues. However, VOCs with lower K_{ow} coefficients, such as acetone and methyl ethyl ketone, are expected to have very high mobility in soil, as their migration by advection and diffusion is not retarded by sorption to soil surfaces. Biodegradation of VOCs borne in soil vapor as interphase transfer from soil gas to soil moisture in soil takes place, although the rate is controlled by the presence (or lack) of available oxygen, or a secondary carbon substrate. Therefore, degradation byproducts or daughter products of VOCs would be expected to be observed in the environment surrounding source areas. For example, elevated levels of PCE/TCE degradation daughter products 1,1-dichloroethene, cis-1,2-dichloroethene, and vinyl chloride were detected in soil vapor samples collected along the southern boundary of the Central Drainage Area, and the central portion of the Burial Trench Area. Elevated levels of PCE and TCE were detected in soil vapor samples collected from both these areas. Maps illustrating the distribution of total VOCs in soil vapor are presented in Figures5-18, 5-19 and 5-20.

6.4.2.2.2 Site-specific Examples of Constituent Transport via Soil Vapor

The primary source areas at the Site where elevated soil vapor levels of VOCs were expected were areas where impacts to soil and groundwater were know to be significant. For example, primary source areas where elevated soil vapor concentrations have been detected include:

- The Capped Landfills Area;
- The PCB Landfill;
- The Liquids Treatment Area;
- The Central Drainage Area; and
- The Burial Trench Area.

Subsurface migration of chemicals in soil vapor is due to advection and diffusion. Typically, diffusion is the dominant mechanism for vapor transport within the vadose zone. An exception to this rule is the case for landfills that have large amounts of readily biodegradable material which will decompose and produce large amounts of methane as a byproduct. Generation of large amounts of methane can lead to advective soil vapor transport away from the landfill source area. Large quantities of methane generation are usually associated with landfills that

accept municipal and green waste. While Casmalia accepted organic hazardous waste materials, testing for methane gas has not been performed, but dissolved methane was detected in groundwater and indicative of biological activity in groundwater (Appendix O).

Conceptual soil vapor flow paths for migration of VOCs away from the primary source areas at the Site are shown on Conceptual Site Models, Figures 4-51 through 54. Soil vapors likely migrated away from these source areas northward offsite into the North Drainage, eastward offsite into the North Ridge, southward into the Former Ponds and Pads area, and westward towards the RCRA Canyon area. Prior to placement of the landfill caps VOC readily volatilized to the atmosphere, however since the placement of the landfill cap VOCs are likely retarded from direct off-gassing and may become trapped beneath portions of the caps. These trapped VOCs will migrate laterally in response to diffusion gradients from the higher VOCs underneath the capped area to the lower concentrations outside of the capped areas. For example, the highest concentration of two of the lighter and more mobile VOCs, acetone and 1,3-butadiene occurs along the north and eastern ridge area. These VOCs also extend northward into the North Drainage as described in Section 5. VOC off-gassing for the heavier DNAPL compounds is highest in and around the P/S landfill and along the PSCT trenches, typically the vapor density of VOCs is greater than air, and VOC gas tends to reside in open pore spaces close to the water table.

Relatively low concentrations of mostly petroleum hydrocarbon VOCs (and some chlorinated VOCs) were detected in the three samples collected furthest north and east of the site (RISBCL-03D, RISBCL-05D and RISBCL-08D). As further described in Appendix C, two of these three samples also contained a small concentration of the leak detection gas, isobutylene, indicative of a potential leak. The presence of the isobutylene indicates that background soil gas samples may contain a contribution from atmospheric sources.

The rate of any organic vapor mass flux from soil will be a function of the soil properties as well as the chemical's physical/chemical properties. Migrating soil vapors can cross contaminate groundwater that would otherwise not be contaminated sole due to groundwater contaminant transport. The soil vapor and potential groundwater impacts from migrating soil vapors are summarized below.

Soil Vapor Impacts

As presented in Table C-5 and shown in Figures 5-12 and 5-13, moderately elevated levels of acetone and methyl ethyl ketone were detected in soil vapor samples collected around the PCB landfill, Capped Landfills Area, Liquid Treatment Area, and within the Burial Trench Area. Moderately elevated concentrations of methyl ethyl ketone were also detected south of the Central Drainage Area. Low levels of 1,3-butadiene were also detected along the Capped Landfills Area northern boundary and step-out locations into the North Drainage, as well at the northwestern boundary of the PCB landfill (Figure 5-15). In general, acetone, methyl ethyl ketone, and 1,3-butadiene appear to exhibit greater mobility at the Site than other organic compounds detected in soil vapor. The apparent increased mobility of these compounds can be traced to common physical characteristics these compounds share. For example, acetone and methyl ethyl ketone have K_{ow} values that are less than 10 ml/gm, and both are very soluble in water. While 1,3-butadiene is not as soluble as acetone and methyl ethyl ketone, its vapor pressure properties indicate 1,3-butadiene will exist solely as a gas in the ambient atmosphere (Table 6-1).

Groundwater Impacts

The potential exists for soil vapor to impact groundwater via phase partitioning. Soil vapor in contact with groundwater (and soil moisture) will partition into the liquid phase in accordance with Henry's Law and Raoults' Law, where factors such as, the partial pressure exerted on the liquid by the gas, the specific compound solubility, and the compounds mole fraction in the mixture will determine the mass transfer rate. Areas where soil gas VOCs may impact groundwater occur in areas of NAPL product or at the peripheral edges of the groundwater plumes or containment structures.

6.4.2.2.3 Actions Taken to Disrupt Soil Vapor as an Environmental Transport Pathway

The P/S Landfill stopped receiving waste in 1986. The landfill was covered with stabilized materials from pond closure activities that were completed in the early 1990s. In the late 1990s, the CSC completed the design and construction of a landfill cap for the P/S Landfill.

According to the *P/S Landfill Revised Final Design Report* (Foster Wheeler and GeoSyntec, 1999), a series of gas flux measurements were performed at the P/S Landfill to direct the development of the final landfill cap design. The objectives of these pre-capping soil vapor flux measurements on the cover of the P/S Landfill included:

- Evaluating the potential for landfill gas emissions;
- Assessing whether a gas mitigation system would be needed to address VOC emission; and
- Providing data for a gas collection system or layer design in the event a gas mitigation system was deemed necessary.

Field testing for soil vapor emissions from the P/S Landfill was conducted by measuring the flux of VOCs, fixed gases (nitrogen, oxygen, carbon dioxide, carbon monoxide, and methane), and organochlorine pesticides through the existing, undisturbed soil cap of the P/S Landfill. Surface gas flux emission sampling was performed in November 1997.

In total, 10 VOC compounds were detected at levels at the method detection limit for the individual compounds. The highest flux of a VOC that was detected during the assessment was also PCE (1.9 ug/m^2-min). Assuming the landfill capped areas cover 41–acres and PCE is being emitted equally from all landfill cells, then approximately 1-pound of PCE would be emitted by volatilization per day prior to landfill capping. The lack of methane or other fixed gases at levels associated with waste decomposition was consistent with known site information that decomposable waste was not generally disposed in the P/S Landfill. These data demonstrated that landfill gas was not being produced at a significant rate prior to construction of the final P/S Landfill cap, and the rate of landfill gas production would not adversely impact a landfill cap. Based on these findings, it was concluded that the finalized landfill cap design constructed over the P/S Landfill would effectively eliminate the very low gas fluxes observed.

Based upon the cap liner system design employed for the P/S Landfill and EE/CA Landfill areas, the fate and transport of soil vapor from these potential source areas was significantly altered after capping. Installation of these engineered caps increased the soil column thickness, and thus the distance between the primary contaminant sources (i.e., landfill wastes) and their potential emission point to the ambient atmosphere. The construction materials selected for

emplacement for engineered caps included fine-grained soils and other materials (such as HDPE) exhibiting low air permeability characteristics, in order to mitigate both advective and diffusive transport of soil vapor.

6.4.2.3 Groundwater COPCs

As described in Section 5, VOCs are used to summarize the extent of organic compounds. VOCs are generally more mobile in groundwater relative to the other classes of organic compounds (SVOCs, herbicides, pesticides, PCBs, and dioxins/furans) and the extent of the other classes of organic compounds are generally contained within the extent of VOCs. Therefore, VOCs are used to illustrate the transport of organic contamination. Also as described in Section 5, arsenic is used to summarize the overall extent of elevated metals because it is the most broadly elevated metal within the Upper HSU, it exceeds primary MCLs where elevated, and the extent of the other elevated metals is generally contained within the extent of elevated arsenic.

Generally, VOCs that were detected in groundwater in the greatest number of wells and at relatively high concentrations (Appendix G; Section 3.3.2) include:

- PCE;
- TCE;
- cis-1,2-DCE;
- VC; and
- Benzene.

Inorganics that were detected in groundwater in the greatest number of wells and at relatively high concentrations included arsenic, nickel, cadmium, and selenium for metals that had primary MCL exceedances and iron and manganese for metals that had secondary MCL exceedance. .

Organic COCs. There appears to be no significant VOC contamination in groundwater underlying offsite areas (Zone 2), in either the Upper HSU or Lower HSU. Figures 5-18 through 5-20 show the distribution of Total VOCs within Zone 1, in the Upper HSU and Lower HSU.

Within Zone 1, the lateral extent of VOC impacts within the Upper HSU is defined by the following features:

- The area north of the PSCT contains the majority of the dissolved phase VOC contamination.
- The northern extent of the Upper HSU contamination, from east to west, is limited to the western portion of the Caustic/Cyanide Landfill, the western half of the Acids Landfill, the southern portion of the Metals Landfill, the northern portion the P/S Landfill and at the Burial Trench Area south of the PCB Landfill.
- The eastern extent of VOC contamination is delineated by several monitoring wells near the eastern extent of the PSCT and North Ridge wells.
- The western extent of the VOC contamination is delineated by RI monitoring wells on the North Ridge and west of the PSCT.
- The distribution of VOC contamination in the Upper HSU is consistent with groundwater flow directions.

There are also isolated locations of upper HSU groundwater impacts due to VOC contamination south of the PSCT. These impacts are highest south of PSCT-1 and PSCT-4. However, the contamination in these areas is typically one to two orders-of-magnitude lower than maximum concentrations observed north of the PSCT. The VOC contamination in this area may be associated with residual contamination extant before the PSCT was installed and related to the operation of the former waste disposal ponds.

VOC impacts in groundwater were observed in four areas of the Lower HSU:

- The North Ridge Area
- The Burial Trench Area;
- The Central Drainage Area; including the southern edge of the Acids Landfill; and
- Along the PSCT, including at extraction wells PSCT-1, PSCT-3, and PSCT-4.

The Central Drainage Area exhibits the greatest amount of VOC contamination in the Lower HSU, and is the only area in the Lower HSU where DNAPL is known to be present. The Lower HSU VOC contamination in the Central Drainage appears to be spatially related to overlying Upper HSU VOC groundwater contamination present between the P/S Landfill and PSCT.

Inorganic COCs. There appears to be no significant offsite inorganic contamination in groundwater underlying offsite areas (Zone 2) in either the Upper HSU or Lower HSU. Figures 5-45 and 5-46 show the distribution of arsenic within Zone 1, in the Upper HSU and Lower HSU. Within Zone 1, the general distribution of elevated metals is similar to the distribution of elevated VOCs in the Upper HSU, except for the ponds and PCTs, The higher concentrations of metals in the Upper HSU are generally located within the Central Drainage Area, similar to the higher concentrations of VOCs north of the PSCT. Elevated levels also occur south of the PSCT. Unlike the general absence of these VOCs in the ponds and PCTs, however, TDS (salts) and metals are significantly elevated within surface water in the five onsite ponds, groundwater extracted at the PCTs, and other groundwater monitored at other monitoring wells in the vicinity of the ponds and PCTs. Pond surface water is a recharge source to the PCTs. The concentrations of the salt and metals in the ponds that have been increasing due to evaporation since the 1997/98 El Nino winter are causing similar increases in metals and salts in the PCTs and area monitoring wells.

The highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the border between Zone 1 and Zone 2., and do not appear to coincide with the elevated Upper HSU concentrations. Metals concentrations in the Lower HSU are generally lower than in the Upper HSU.

6.4.2.3.1 Migration and Persistence of Groundwater COPCs

The primary physical processes that result in the movement of dissolved-phase COPCs in groundwater are advection and dispersion. Advection is the movement of COPCs with the bulk movement of groundwater. Advection is generally the primary transport mechanism at site with moderate to high groundwater flow rates. Mechanical dispersion is the mixing of COPCs with groundwater moving along the groundwater flow path. Dispersion will cause some COPC molecules to travel faster and some to travel slower than the average groundwater flow velocity. Dispersion will have the effect of spreading out (lowering) COPC concentrations as they adjectively move with groundwater.

Only highly "mobile" and "persistent" COPCs will move at the same or similar rate as groundwater flow. Most COPCs will move slower than groundwater due to natural attenuation mechanisms that include the following:

- Biodegradation (organics). Biodegradation is the process where microbes degrade and destroy organic COPCs by transforming them into other byproducts. This will reduce the concentration of the organic COPCs along the groundwater flow path. Organics may degrade aerobically or anaerobically. Metals are not subject to biodegradation.

- Sorption (organics and inorganics). Sorption is the process where organic and inorganic COPCs transfer from being dissolved in groundwater to the solid phase of the aquifer matrix. Sorption generally involves three primary mechanisms: adsorption onto the surface of the solid phase, precipitation onto the solid phase, and absorption (i.e., the diffusion into the solid phase).

- Dilution (organics and inorganics). Dilution is the process where recharge from another source (e.g., rainfall infiltration) dilutes the organic and inorganic COPC concentrations. Dilution also results from dispersion (mechanical mixing).

Hydraulic containment and chemical mass removal from groundwater also occurs via the onsite groundwater extraction and treatment facilities. This includes the current liquids extraction at the Gallery Well, Sump 9B, PSCT, and three PCTs as described in Section 4. Hydraulic containment will act to change the direction of groundwater and contaminant flow paths.

The migration and persistence of dissolved-phase COPCs based on their movement with groundwater movement, natural attenuation mechanisms, and hydraulic containment at the Site are evaluated below. The following figures were prepared based on the groundwater flow model particle tracking maps from Section 4 with the total VOC groundwater concentration contour maps from Section 5 to illustrate the potential movement of dissolved-phase COPCs with groundwater:

- *Figure 6-1, VOC – Groundwater Particle Flow Map, Upper HSU, 2004 (Dry)*
- *Figure 6-2,VOC – Groundwater Particle Flow Map, Upper HSU, 2001 (Wet)*
- *Figure 6-3, VOC – Groundwater Particle Flow Map, Lower HSU, 2004 (Dry)*
- *Figure 6-4, VOC – Groundwater Particle Flow Map, Lower HSU, 2004 (Dry)*

Figures 6-1 and 6-2 are a projection of the groundwater flow paths determined from MODFLOW modeling within the Upper HSU for the Dry (2004) and Wet (2001) model simulations, -2, respectively. The release point for these tracking particles was along the North Ridge. Additional particle tracks were provided for "reverse particle tracking" from PSCT-4 and the three PCTs to more fully show groundwater flow paths and capture by the extraction facilities. The modeling indicates that groundwater (and contaminant) flow within the Upper HSU is downhill to the south and converges towards the Central Drainage Area.

Figures 6-3 and 6-4 are a projection of the groundwater flow paths determined from MODFLOW modeling within the Lower HSU for the Dry (2004) model simulation. The release point for these tracking particles was north of the PSCT, to reflect contamination within the Lower HSU in this area. This includes the VOC's detected north of PSCT-4 at RIPZ-16 and also the VOC and DNAPL detected north of PSCT-1 at piezometers RGPZ-7C and RGPZ-7D. The modeling

indicates that groundwater (and contaminant) flow within the Lower HSU is south underneath the PSCT and continues southward toward the south part of the site.

The particle tracks represent the direction of groundwater flow and where dissolved-phase COPCs will potentially migrate. However, the actual rate and distance that COPCs will migrate along these groundwater flow paths will be influenced by the natural attenuation mechanisms and active hydraulic containment. The following EPA guidance documents provide additional information on the natural attenuation of organic and inorganic COPCs and technical protocol for data collection and analysis to evaluate the importance of these natural attenuation mechanisms on COPC migration:

- *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (EPA/600/R-98/128).

- *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater. Volume 1 – Technical Basis for Assessment (*EPA/600/R-07/139).

- *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater. Volume 2 – Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Leak, Nickel, Nitrate, Perchlorate, and Selenium* (EPA/600/R-07/140).

VOCs

VOCs encountered at the Site share similar volatility and water-solubility characteristics. When VOCs are released to soils or groundwater, a significant fraction of the chemical is expected to partition to the soil vapor by volatilization. VOCs are not expected to selectively concentrate on or be sorbed by soils or to be taken up and retained in biological tissues. Biodegradation of VOCs will occur in groundwater and soils, although the rate is controlled by the presence (or lack) of available oxygen, other electron donors or acceptors, or secondary carbon substrates. Therefore, degradation byproducts or daughter products would be expected to be observed in the environment surrounding source areas. Solute migration with groundwater flow or volatilization and soil vapor migration are expected to play a significant role in the transport and removal of VOC from the groundwater system.

A variety of potential corrective action options may be considered to remediate the upper and lower HSUs at the Site with respect to the mixture of chlorinated VOCs, their associated degradation products and petroleum hydrocarbons. One potential option is utilization of natural attenuation processes. Natural attenuation is often defined as naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, and/or concentration of contaminants in those media. Typically, three lines of evidence are evaluated to assess the effectiveness of natural attenuation processes:

- Historical groundwater and/or soil chemistry data that demonstrate and clear trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points (the concept of a stable or shrinking plume).
- Hydrogeologic and geochemical data that can be used to demonstrate indirectly that the appropriate natural attenuation processes are active at the site; and, the rate at which such processes will reduce contaminant concentrations to required levels.
- Data from field or laboratory microcosm studies. This third line of evidence is rarely, implemented, and is typically used to evaluate biodegradation processes only.

Typically, biodegradation is the one of most important destructive attenuation mechanisms for organic compounds, and is the primary process that was evaluated for groundwater at the Site (Appendix O of this RI Report). As summarized in Appendix O – *Monitored Natural Attenuation Evaluation*, an investigation was conducted to assess whether natural attenuation of both fuel hydrocarbon and chlorinated hydrocarbons is occurring at the site, particularly in locations proximal to the principal contaminant source areas, and in the vicinity of the PSCT.

Findings of the Monitored Natural Attenuation (MNA) assessment are summarized below for organic chemicals:

- The destruction process of aerobic and anaerobic biological degradation of organic chemicals in the source and plume areas is occurring.
- Non destructive process are also occurring, including sorption and dilution from rainfall recharge and dispersion,
- Organic chemical and geochemical analytical results support conclusion that a reductive dechlorination zone exists to the north of the PSCT trench. Reductive dechlorination may also be occurring south of the PSCT trench, but the evidence is less clear.
- Electron donors and acceptors – the relative concentrations of sulfate, nitrate, and dissolved manganese at locations within, up- and down-gradient of the source and plume areas are consistent with biological degradation and the use of these electron donors and/or acceptors.
- Presence of daughter or end-products – dissolved methane, ethane, and chloride – were observed at elevated levels within the source and plumes areas, indicating active biological degradation and complete dechlorination of chlorinated VOCs is occurring at the Site.
- General parameters – A decrease in oxidation reduction potential (ORP =< -100 millivolts, or mV) and an increase in alkalinity (greater than 2-times background locations) were observed in the source and plume areas. Reduced or negative mV ORP levels provide an indirect indication of anaerobic conditions supportive of reductive dechlorination, and elevated alkalinity levels indicate complete biodegradation of organic compounds, and the interaction between carbon dioxide and aquifer materials.

The MNA evaluation identified a number of key factors that qualitatively support the conclusion that natural attenuation processes are active at the Site, and these processes can play significant role in a final remedy for groundwater at the Site. However, ongoing MNA evaluation activities have yet to quantify the biodegradation rate of organic chemicals at the Site. The MNA evaluation concluded that the use of tracer chemicals to normalize the effects of dispersion, dilution, sorption, etc. was not practical at the site. For example, trimethylbenzene isomers were non-detect in a majority of the test or monitoring wells, and therefore, were not useful as tracers. Further, the use of chloride concentrations as an inorganic tracer was also inconclusive. Relatively high native levels of chloride in groundwater at the Site appear to result from infiltration of water bearing elevated TDS levels or high inorganic solute concentrations below various ponds where continued evaporation took place. Nevertheless, bulk changes in chemical concentrations over time in individual wells and chemical concentration trends over distance clearly show the importance of ongoing natural attenuation processes at the Site.

Other Synthetic Organic Compounds (PAHs, PCBs, Herbicides, Pesticides, Dioxin/ Furans and Others)

Synthetic organic compounds (excluding the VOCs), typically have less affinity for water (very

low solubility) and a greater affinity to absorb to soil. Because of their higher molecular weight, these compounds tend to be viscous and less volatile than VOCs. Synthetic organic compounds will persist in the environment for long periods of time, but have been demonstrated to be biodegradable by specialized bacteria or fungi under favorable conditions. Higher molecular weight organic compounds, such as, PAHs, PCBs, Herbicides, Pesticides, Dioxin/ Furans tend to be less mobile in groundwater, however, reduced and methanogenic groundwater conditions favor fermentation processes that support micro-organisms capable of breaking down these compounds.

Metals

The persistence and migration of metal constituents in groundwater are impacted by the metals' chemical form and the geochemistry of the local groundwater system. Unlike the organic constituents of concern, metals cannot be degraded. However, biotic and abiotic transformations have been identified that, in some instances, may reduce the toxicity and/or mobility of the metal in a groundwater system. The solubility of metals is often increased by reduced groundwater/soil pH conditions. As soil concentrations of metals increase and the adsorptive capacity of saturated soil is exhausted, metals will migrate with groundwater. Unlike organic compounds that can be destroyed, metals can only be changed in the oxidation state, chemical species, and physical form. The potential for metal precipitation exists in areas of reduced groundwater conditions which exist mostly with the Central Drainage area. Metals mobility generally increases under acidic groundwater conditions; in general, much of the groundwater across the site has relatively high alkalinity, which tends to buffer acidic groundwater conditions.

6.4.2.3.2 Site-specific Factors Controlling Constituent Transport via Groundwater

As summarized in Appendix F – *Groundwater Flow,* the following conclusions can be made regarding groundwater flow conditions at the Site:

- The dominant large scale feature influencing groundwater flow at the Site is a pervasive zone of weathering and enhanced secondary fracture conductivity in the Upper HSU.
- The Upper HSU is poorly transmissive, the Lower HSU even less so. Borehole hydraulic tests reported by the USEPA (1986) yielded a maximum hydraulic conductivity of 31 feet per year (ft/yr) in the Upper HSU. The HSCER Report (Woodward-Clyde Consultants, 1988) cites a geometric mean hydraulic conductivity of 70.4 ft/yr in the Upper HSU, and 1.04 ft/yr in the Lower HSU.
- The Upper/Lower HSU contact surface and associated permeability distribution influences flow conditions in the Upper HSU. Characterization of the contact surface includes recent borehole and geophysical data collected during summer and fall 2004 and 2006/2007 RI Investigations.
- A high degree of correlation exists between topographic elevation and water table elevation. This allows the topographic data to be used in guiding interpretation of water level data (Woodward-Clyde Consultants, 1988; ICF Kaiser, 1998).
- Groundwater flow through Zone 1 is generally to the south. Groundwater at the southern perimeter of the Site is intercepted by the PCTs, extracted, and discharged to onsite surface impoundments.
- Based on historical and recent groundwater elevation data from wells and piezometers, a groundwater flow divide that divides groundwater flow entering the Site is present along the north ridge, north of the landfills. The water table in this area receives recharge

from precipitation and inflow from the higher ground west of the Zone 1 boundary. The flow divide occurs as a result of ground surface and Upper/Lower HSU contact topography, with lateral flow to the north and south away from the topographic divide. The flow divide exists in roughly the same location in both Upper and Lower HSUs, and occurs in roughly the same location throughout the water year.

- Comparison of the elevation of the Upper/Lower HSU contact with groundwater elevations in Upper and Lower HSU wells and piezometers during 2006 and 2007 indicates the Upper HSU beneath the north ridge may be locally saturated after winter recharge events. The saturated thickness appears to vary in space and time with a maximum thickness of about 10 feet.
- Based on historical and recent groundwater elevation data from nested wells and piezometers, vertical gradients vary across the Site and change slightly during the water year. Downward vertical gradients are generally observed in the area between the north ridge and the PSCT, and neutral or upward gradients are indicated near the PCTs. The vertical gradients change over time, with maximum downward gradients generally observed during the summer or fall.
- Water budget analysis indicates the site as a whole exhibits a slight negative error, and more groundwater is being removed from the aquifer system than is recharging it.
- Groundwater flow modeling confirms the overall conclusions regarding groundwater flow paths and the state of the site water balance. MODPATH results indicate curvilinear flow paths downward from the North Ridge recharge area, through the Upper and Lower HSUs, and upward flow and discharge at the extraction features and Ponds.

6.4.2.3.3 Actions Taken to Disrupt Contaminant Transport via or to Groundwater

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Specific actions that have been taken to mitigate constituent transport in groundwater include:

- Surface Impoundment Closure Activities – liquids removal from surface impoundments eliminated a water column and hydraulic head that may have led to subsequent leaching and dissolved-phase contaminant infiltration to groundwater underlying the Site.
- Landfill Capping – The installation of engineered landfill caps, such as the P/S Landfill cap and EE/CA cap, served to mitigate stormwater infiltration into waste materials, and subsequent leaching of waste chemicals into groundwater underlying the landfills.
- Subsurface Site Liquids Management – operation of the Gallery Well, Sump 9B, the PSCT, and the PCTs (PCT-A, PCT-B, and PCT-C) all affect groundwater flow and the migration of contaminants. The Gallery Well captures groundwater originating from the north ridge area and P/S Landfill area. Sump 9B appears to capture groundwater originating from recharge within the Central Drainage Area north of sump 9B. Based on the distribution and concentrations north and south of the PSCT, the PSCT appears to contain VOC contamination in the northern areas, which helps limit the impact on areas south of the PSCT. The three PCTs were constructed to intercept groundwater at the downgradient Site boundary and prevent offsite migration of groundwater contaminants.

6.4.2.3.4 Observed Response to Implemented Groundwater Control Measures

The following provides a brief summary to the effectiveness of the Site groundwater control features implemented above:

Horizontal Groundwater Flow Analysis

Historical representation of groundwater elevation contour maps (as illustrated in Appendix F, Figures F-3 through F-17 for groundwater elevations observed in three periods i.e., March 2001, March 2004, and December 2006), indicate limited variability in the overall horizontal hydraulic gradient magnitudes and directions are observed between the different periods. Further, groundwater flow patterns depicted on the groundwater contour maps for these three periods are consistent with those previously observed in the 1980's, as documented by the USEPA (USEPA, 1986) and in the HSIR (Woodward Clyde Consultants and Canonie Environmental , 1989). Collectively, these data indicate that the implementation of current extraction system and landfill capping appears to have little impact on the lateral groundwater flow pattern in the site-wide scale; and thus the direction of groundwater across the Site is largely governed by surface topography and the HSU contact surface.

In particular, the area between the topographic ridge and the northern boundary of the landfill receives recharge from precipitation and inflow from the higher ground west of the Zone 1 boundary, and flows south through the landfills in the central area toward the low lying ponds, trenches, and Creek boundaries (i.e., axes of A-, B-, C- drainages). The location of the groundwater flow divide is conceptual along the North Ridge and its exact location is not quantified. As such, contaminant migration is generally unlikely for the groundwater originating from the major source area (as presented in Appendix G, Figure G-26) to flow northward to and/or across the North Ridge. The groundwater flow model incorporated this groundwater flow divide as a "no flow" boundary conditions, predefining that any particle tracks started south of this no flow boundary would move south. This simulation is provided in the groundwater modeling results (Appendix F, Attachment F-3) and particle tracking analysis (Appendix F, Figure F-50), which show flow paths from just south of the North Ridge groundwater divide generally toward the south. By definition, these particles do not indicate flow from Zone 1 to the north drainage.

As described above, a projection of the groundwater flow paths determined from MODFLOW modeling within the Upper HSU for the Dry (2004) and Wet (2001) simulations are presented in Figures 6-1 and 6-2, respectively. The modeling indicates that the PSCT and PCT are effective in capturing liquids moving southward across the Site within the Upper HSU. Notably the modeling indicates that for particles released on the North Ridge, groundwater flow will direct these particles to this Site containment features.

Groundwater flow across the southern perimeter of the site between the A-, B-, and C-Drainages appears to be prevented by a reversal in groundwater flow direction immediately south of the Site, associated with the prominent hills that rise just south of the Site boundary separating these three drainages. Groundwater in this southern area is channeled toward the heads of each of the three drainages, where the PCT liquid control features are located. MODPATH result indicates that the PCTs capture groundwater from the following areas:

- PCT-A captures groundwater originating from offsite areas to the north, onsite areas east and south of the PSCT, surface water from the RCF Pond, and the hills between the A- and B-Drainages.
- PCT-B captures groundwater originating from areas south of the PSCT, surface water from Pond 13 and the RCF Pond, B-Drainage, and the hills between the A-, B-, and C-Drainages.

- PCT-C captures groundwater originating from areas south of the PSCT and the A-Series Pond.

Although the site-wide groundwater horizontal flow pattern does not appear to be significantly affected by the implementation of current extraction system and landfill capping; observed data and model capture zone analyses (as presented in Appendix F) demonstrate the local influence of the existing facilities on the groundwater horizontal flow.

Although modeling and manual analysis of water level data do not show complete capture with certainty, the analysis does show that the PSCT likely captures the majority of groundwater flowing southward through the Upper HSU. For example, inward horizontal gradients toward the extraction wells at PSCT 1 and PSCT 4 was first observed immediately after these two wells were installed in 1998. Particle tracking analysis with MODFLOW and MODPATH (Appendix F, Attachment F-3) indicates that PSCT-1 captures most groundwater originating from the North Ridge areas north and east of the Metals, Caustics/Cyanide, and Acids Landfills, as well as groundwater recharged within the Central Drainage north of PSCT-1. PSCT-2 captures most groundwater recharged in the area of the PCB Landfill and Burial Trench Area, and areas between the Burial Trench Area and PSCT northwest of PSCT-2. This is consistent with the observed water table contour maps (Appendix F, Figures F-8 and F-13) which show the alignment of the contour lines roughly perpendicular to the PSCT trenches, indicating that the potential for groundwater flow across the PSCT (along the non pumping sections) is minimal. Groundwater horizontal gradients generally are steeper in the area north of the PSCT, and these steeper gradients coincide with the steeper topography. South of the PSCT, the groundwater horizontal gradients are more gradual, and further reduced by the presence of the onsite ponds.

As described above, a projection of the groundwater flow paths determined from MODFLOW modeling within the Lower HSU for the Wet (2001) simulations are presented in Figures 6-3 and 6-4, respectively. The modeling indicates that groundwater (and contaminant) flow within the Lower HSU is south and that flow beneath the bottom of the PSCT and PCT may occur.

Vertical Groundwater Flow Analysis

Based on historical and recent groundwater elevation data from nested wells and piezometers, vertical gradients vary across the Site and change slightly during the water year, with maximum downward gradients generally observed during the summer or fall. Comparative analyses on historical data of the vertical hydraulic gradients indicate the local influence of the existing extraction features and landfill capping on the groundwater flow and vertical transport.

Site-wide downward vertical gradients (between upper and lower HSUs) are generally observed, with largest values in the area approximated by the north ridge, which is consistent with a groundwater recharge area. However, neutral, slightly downward, or slightly upward gradients are indicated beneath the southern portions of the capped landfills and near the ponds, PSCT, and PCTs, most likely attributed to the implementation of extraction features and capped landfills. For example, an upward vertical hydraulic gradient at WP-8S/WP-8D (at the toe of the Metals Landfill) and RG-9B/RP-95 (at the toe of the Caustic/Cyanide Landfill) have been consistently observed since capping of these landfills occurred. Data do not exist to allow the determination of the vertical gradient at the toe of the P/S Landfill.

The local groundwater vertical flow change due to the implementation of existing control facilities is further illustrated through comparative data analyses on the historical vertical hydraulic gradients before and after the year 2001 when capping remedies for P/S landfill and Heavy Metal landfill were completed and the current groundwater extraction features were also put online. At the well pair RGPZ-7C/7D, located between Sump 9B and PSCT-1 (downgradient of the Gallery Well), the pre-2001 observed vertical hydraulic gradients (upward positive) had a range from -2.43 to 0.11 ft/ft with a median value of -1.852 ft/ft, statistically less than the post-2001 observed gradients (with a median value of 0.051 ft/ft). Similar observations (i.e., the pre-2001 observed vertical hydraulic gradients are generally less than the post-2001 observed vertical hydraulic gradients) have been also presented at the well pairs within 200-ft radii of PSCT-1 including RG-1B/1C, RGPZ-6B/6C and RGPZ-6C/6D. At the well pair of WP-8S and WP-8D, located at the toe of the Heavy Metals Landfill, the observed gradient is an example of an upward hydraulic gradient that develops without groundwater extraction but is significantly influenced by the recharge change associated with the 2001 capping over the Heavy Metal Landfill, as indicated by the fact that the pre-2001 observed vertical hydraulic gradients in a range of -0.182 and 0.165 ft/ft with a median value of 0.068 ft/ft, were statistically less than the post-2001 gradients ranging from 0.063 to 0.373 ft/ft with a median value of 0.230 ft/ft.

The emplacement of groundwater control features (i.e., interception trenches and capping of landfill cells) has not significantly affected the overall groundwater flow direction across the Site. However, changes to vertical gradients and a general decline in groundwater storage has been observed since control features were installed. The groundwater control features are fulfilling their design purpose in capturing and controlling the movement of contaminants within the Site's boundaries.

6.4.2.3.5 Potential Shut-down of PSCT and/or PCTs

The shut-down of containment features, i.e, pumps from the PSCT or PCTs would be contingent upon the demonstration of Monitored Natural Attenuation (MNA) processes being capable of breaking down or precipitation COCs to prevent offsite migration of COCs. As presented Appendix O, an evaluation for MNA processes was conducted by CSC in 2005, the assessment consisted of interpreting chemical trends in select wells to identify patterns that are indicative of MNA processes, and testing for select compounds (dissolved oxygen, nitrate manganese sulfate and sulfide) whose presence or absence provides information to the redox sate of groundwater.

With respect to organic compounds, the presence of daughter compounds for halogenated compounds (for example, cis-1,2-DCE and VC) suggests that in portions of the Site anaerobic microbial processes are active that facilitate the breakdown of halogenated compounds. While the petroleum hydrocarbons present may provide electron donor compounds to support reductive dechlorination for the halogenated compounds. However, due to difficulty in isolating a tracer compounds an estimate to the rate at which MNA processes may be active is not technically feasible.

With respect to metals compounds, the presence of reduced sulfide indicates that the potential for metals precipitation is viable. However, in general site-wide conditions do not appear favorable for MNA process with respect to metals.

While evidence and site conditions do appear favorable for MNA, further assessment would be required to quantify MNA processes before existing Site containment features of the PSCT and

PCTs could be taken off-line.

6.4.2.4 NAPL COPCs

Free phase LNAPL and/or DNAPL have both been detected in monitoring points in isolated locations north of the PSCT, including locations within the Central Drainage Area and the Capped Landfills Area (Section 5, Appendix G, and Appendix M). As described in Section 5, free phase LNAPL is currently present within the P/S Landfill and south of the P/S Landfill in the Central Drainage Area from the Gallery Well at the toe of the P/S Landfill to just north of PSCT-1. Free phase DNAPL is present within the southern end of the P/S Landfill and in the Lower HSU in an area between the P/S Landfill and PSCT-1. To date, neither LNAPL nor DNAPL have been measured as a separate phase in any other area. NAPL has not been detected in the recently installed RI wells and piezometers in the Burial Trench Area (although observations during drilling may suggest NAPL in this area), or in other site wells and piezometers near and downgradient of the other site landfills. The Upper HSU locations in the Central Drainage Area where LNAPL and DNAPL have been observed or inferred generally coincide with an historical site drainage that ran the length of the P/S Landfill and continued into the area that is now the RCF Pond. The findings of a UVIF/MIP survey conducted at the Site served to confirm that NAPL presence was limited to the areas specified above.

During the RI groundwater chemistry investigation activities (Appendix G – *Groundwater Chemistry*), LNAPL and DNAPL was collected and analyzed for chemical composition and physical properties from the following locations:

- LNAPL – Gallery Well, GW-PZ-W, and Sump 9B-PB
- DNAPL – Gallery Well, RGPZ-7C, and RGPZ-7D.

For chemistry, the NAPL samples were analyzed for VOCs, SVOCs, PCBs, PAHs, herbicides, pesticides, metals and cyanide. For physical properties, the NAPL samples were reanalyzed for density, viscosity, NAPL-water interfacial tension, and flash point. The LNAPL and DNAPL physical properties are summarized in Table 5-2. The LNAPL and DNAPL chemistry is provided in Appendix G.

Laboratory analyses indicated that the composition of each LNAPL and DNAPL sample was a mixture of cosolvated, primarily organic, compounds including VOCs, with lesser concentrations of SVOCs, PAHs, Herbicides, and a few metals. The predominant VOCs encountered in NAPL at the site include:

- Total xylenes;
- PCE;
- Toluene;
- Methylene Chloride;
- Ethylbenzene;
- 1,1,1-Trichloroethane;
- Freon-113; and
- TCE.

The NAPL densities were as follows for the 2004 samples:

- LNAPL – 0.9905 gm/cm^3 for the Gallery Well

- DNAPL – 1.0851 gm/cm^3 for the Gallery Well and 1.0184 gm/cm^3 for RGPZ-7C

The densities for both the LNAPL and DNAPL are relatively close to water, representing the mixture of both heavier and lighter components within each phase. The DNAPL densities are similar to 1994, 1998, and 2003 samples collected from the site (Table 5-2).

The DNAPL-water interfacial tension was 2.8 dynes/cm as measured with groundwater and 7.1 dynes/cm as measured with tap water for a 1998 DNAPL sample. This is a relatively low interfacial tension representing the solvent components in the DNAPL.

6.4.2.4.1 Migration and Persistence of NAPL COPCs

The LNAPL and DNAPL at the Site consist of a variety of organic and inorganic constituents. Organic compounds include VOCs, SVOCs, pesticides, herbicides, PCBs, and dioxins/furans. Metals include arsenic, nickel, cadmium, and selenium. The LNAP and DNAPL are a source of dissolved-phase organic and inorganic constituents to groundwater. VOCs are organic compounds that exhibit relatively high vapor pressures and will partition to the vadose zone as soil gas vapors. The fate and transport of dissolved phase organic and inorganic COPCs are described above.

6.4.2.4.2 Site-specific Factors Controlling Constituent Transport in NAPL

The primary potential primary sources of NAPLs at the site lie north of the PSCT, and include the P/S Landfill and the former ponds and pads located south of the P/S Landfill but within the Central Drainage Area. An additional potential source area of NAPLs is the Burial Trench Area, but no free-phase LNAPL or DNAPL has been found there as described in Section 5. It is reasonable to assume that the LNAPL and DNAPL in the gallery well represent a mixture of chemical liquids that were disposed of directly into the P/S landfill. The drummed wastes placed in the P/S landfill reportedly contained chemical mixtures in addition to single-compound spent solvents or other wastes. The P/S Landfill likely poses a continuing source of both LNAPLs and DNAPLs.

LNAPL

As described in Section 5, LNAPL has accumulated within the P/S Landfill behind the clay barrier in the vicinity of the Gallery Well (as illustrated in Figures 5-53 and 4-51. Due to its specific gravity of less than 1, LNAPL tends to float atop the water table, which is maintained at a level below the top of the clay barrier by liquids extraction from the PSCT. The distribution of LNAPL is known to occur from the north end of the P/S Landfill at RIPZ-14 southward to the area immediately surrounding the Gallery Well. Prior to installation of the P/S Landfill cap in 1999, no wells or piezometers existed to monitor for potential LNAPL accumulation.

The first piezometers (GW-PZ-E1 and GW-PZ-W) at the P/S Landfill were installed in August 1999, about the same time that the P/S Landfill cap was constructed in fall 1999. After placement of the cap in 1999, and installation of two additional piezometers along the Gallery Well Bench (GW-PZ-E2 and –E3) and placement of CPT borings along Bench One of the P/S Landfill in 2001, LNAPL accumulation was observed to occur upgradient of the clay barrier. LNAPL accumulation was first noted in Piezometer GW-P(E3), followed by GW-P(E2), GW-P(W), and then GW-P(E1). Additional piezometers were installed in 2004 for the RI on the top deck (RIPZ-14), on Bench 2 (RIPZ-39), on Bench 1 (RIPZ-13), and on Gallery Well Road (RIPZ-

38, RIPZ-23, RIPZ-24, and RIPZ-27). Since about 2004, the thickness of the LNAPL accumulation has been variable. The LNAPL thickness appeared to have largely declined through 2009. However, recent LNAPL thicknesses exceed 10 feet in some piezometers. Current maximum thicknesses are 20.30 feet in RIPPZ-27 and 33.59 feet in RIPZ-38 according to June 18, 2010 liquid level measurements. While fluctuations in LNAPL thickness are observed in wells over time, the LNAPL is below the top of the clay barrier and the Gallery Well appears to be capturing and removing LNAPL accumulating in this area.

LNAPL occurs within the Central Drainage Area from the P/S Landfill southward toward the PSCT. Due to its specific gravity of less than 1, LNAPL tends to float atop the water table. Measureable LNAPL occurs in the initially piezometers installed in near Sump 9B in 1999 (SUMP-9B-PA, -9B-PB, and -9B-PC) and additional wells and piezometers installed throughout the Central Drainage Area from 1998 through 2004. The thickness of LNAPL in all of the Central Drainage Area Wells has decreased from several feet to currently less than 1 foot. The LNAPL does not currently reach the PSCT. However, any southward LNAPL migration will be intercepted by the PSCT.

Movement of LNAPL in the subsurface is controlled by several processes. LNAPL will move downward through the unsaturated zone where a fraction of the LNAPL will be retained by capillary forces as residual globules in soil pores. If sufficient LNAPL occurs, it will continue to move downward under the force of gravity until it reaches a physical barrier (e.g., low permeability strata) or is affected by buoyancy forces near the water table. Once the capillary fringe is reached, the LNAPL may move laterally as a continuous, free-phase layer along the upper boundary of the water-saturated zone the water table. The principal migration direction will be in the direction of maximum decrease in water table elevation. The LNAPL mass may hydrostatically depress the capillary fringe and water table if a large enough mass of LNAPL is present. Infiltrating precipitation and passing groundwater in contact with residual or mobile LNAPL will dissolved soluble components and form an aqueous-phase contaminant plume.

Removal of free-phase LNAPL from the subsurface can feasibly be performed by primary pumping methods. Removal of free-phase LNAPL will leave behind residual phase LNAPL in the unsaturated zone and capillary fringe that is trapped by capillary forces as residual globules in the soil pores. Removal of residual LNAPL is much more energy intensive than removal of free phase LNAPL because of these capillary forces holding residual LNAPL in place.

DNAPL

As described in Section 5, free phase DNAPL is known to exist at the following locations:

- As a DNAPL pool overlying Lower HSU fractured claystone within the southern area of P/S Landfill. Free phase DNAPL occurs at the Gallery Well, RIPZ-27 immediately north of the Gallery Well, and RIPZ-13 approximately 150 feet north of the Gallery Well. The current measured DNAPL thicknesses are approximately 5 feet in RIPZ-27 and 14 feet RIPZ-13. DNAPL at the Gallery Well is kept pumped-down to a thickness of approximately 2 feet. The CSC measured a DNAPL thickness of 9 feet at the Gallery Well when initiating a DNAPL recovery test on July 9, 1997.

- Within fractures of the Lower HSU claystone in the Central Drainage Area between the P/S Landfill and the Perimeter Source Control Trench (PSCT). This free phase DNAPL occurs as measurable thicknesses of several feet within Lower HSU piezometers RGPZ-

7C and RGPZ-7D, approximately 500 feet south of the clay barrier and 150 feet north of the PSCT.

Pooled free phase DNAPL may also potentially be present, or historically have been present, overlying the Lower HSU of the Central Drainage Area in the area of former Pads 9A and 9B. However, the CSC has did not identify pooled DNAPL in this area during RI activities.

Free phase DNAPL has the potential to laterally migrate along the HSU contact in the P/S Landfill area. DNAPL also has the potential to migrate downward into and through the underlying fractured bedrock (i.e., Lower HSU) under certain conditions. Potential DNAPL penetration into the Lower HSU requires displacement of the water-saturated porous matrix or fractures. The driving force for DNAPL movement is the additional pressure buildup due to its higher density relative to water. Pore-scale capillary forces that retain water within pores or fractures counteract the additional pressure generated by the DNAPL pool. DNAPL is able to displace water only when the DNAPL pool height generates sufficient pressure to overcome the capillary pressures.

As noted above, the densities of the DNAPLs found within the P/S Landfill and within the Lower HSU in the Central Drainage area are relatively low (i.e., between 1 and 1.1 gm/cm^3). The low densities of these DNAPLs are due to the mixture of chemicals within them, which include many organic chemicals with individual densities less than water. The interfacial tension (i.e., the surface tension between two liquids) between the DNAPL and groundwater is also relatively low, apparently due to the presence of alcohols and/or inorganic surfactants that are present in the DNAPL (i.e., less than 10 dynes/cm). While the relatively low densities reduce the potential for DNAPL migration, the low interfacial tension produces the opposite effect, increasing the migration potential.

As detailed in Appendix F – *Groundwater Flow,* calculation in *Attachment F-4*, demonstrate that previous or current site conditions could have resulted in downward DNAPL migration based on reasonable assumptions for DNAPL properties (densities and interfacial tensions), DNAPL pooled heights, and fracture apertures. The observation of DNAPLs in piezometers RGPZ-7C and RGPZ-7D suggest that vertical migration of DNAPLs through the potentially interconnected fracture network in the Lower HSU has already occurred within the Central Drainage Area.

Subsurface conditions and DNAPL presence in the Upper and Lower HSUs between the P/S Landfill and PSCT are illustrated on Figures 4-51, 5-33 and 5-34. The presence of DNAPL in the Lower HSU (at piezometers RGPZ-7C and RGPZ-7D) could be attributable to a number of past conditions at the site and associated factors including but not limited to those listed below:

- DNAPL measured in piezometers RGPZ-7C and RGPZ-7D may have originated from the DNAPL in the P/S Landfill. Prior to the CSC's tenure at the site, when liquid extraction from the Gallery Well was limited and the action level in the well was significantly higher, the DNAPL pool height behind the clay barrier was reported to be as high as 9 feet, which exceeds the theoretical thickness required to effect DNAPL entry into underlying fractures. The DNAPL pool height could potentially be as high as 14 feet as measured in RIPZ-13.
- DNAPL measured in RGPZ-7C and RGPZ-7D may have originated from Upper HSU sources in the area other than the P/S Landfill, including former Pads 9A and 9B or Pond R. The DNAPL may have migrated through a limited fracture network below these historical sources to the depths of the piezometers. The CSC did not identify pooled

DNAPL in the Upper HSU at any other areas outside the P/S Landfill during RI activities, however the chemical and physical properties of the LNAPL identified in the Sump 9B area, with the exception of the 0.02 g/cm^3 difference in density, is similar to the DNAPL identified in wells RGPZ-7C and RGPZ-7D.

- The DNAPL noted in the Lower HSU may have entered the Lower HSU and migrated prior to the construction of the containment features of the P/S Landfill.

The potential for continued DNAPL migration into the Lower HSU is considered to be possible under current site conditions (i.e., with the current extraction systems operating in the P/S Landfill and the PSCT). Even though, the extent of DNAPL in the Lower HSU is not known, and a DNAPL pool with greater than 100,000 gallons of free DNAPL resides behind the clay barrier, the barrier acts to restrain the pool while the Gallery Well extraction acts to relieve hydrostatic pressure exerted by the buildup of liquids. Calculations have demonstrated that the greater than 10-feet of DNAPL present in the vicinity of RIPZ-13 is sufficient to penetrate underlying fractures within the unweathered claystone. Extraction by the Gallery Well will have limited hydraulic effect to prevent downward DNAPL migration in the vicinity of RIPZ-13. The vertical extent of fractures underlying the DNAPL is also unknown. Investigation findings elsewhere at the Site suggest that fracture density decreases with depth at some location while fractures occur throughout the ve4rtical depth drilled at other locations. Fracture interconnectivity is likely low on a site-wide scale but has been demonstrated to be interconnected on a local scale from dissolved-phase VOC contamination in the Lower HSU at the Burial Trench Area and free-phase DNAPL in the Lower HSU at the Central Drainage area. Based DNAPL observed during borehole video logging and fracture and bedding plane orientations measured during borehole optical televiewer logging, DNAPL movement along fractures and bedding plane from either the P/S Landfill and/or the Sump 9B area to RGPZ-7C and RGPZ-7D appears to have occurred. The DNAPL movement appears to be complex because at intermediate locations RGPZ-6C and RGPZ-6D only dissolved phase VOCs are present in these wells. It is possible the DNAPL migration bypassed the fractures screened in RGPZ-6C and RGPZ-6D in favor of surrounding wider fractures.

As detailed *Attachment F-4*, DNAPL density force analysis indicates the vertical hydraulic gradients in the southern Central Drainage area are approximately equal to the gradients required to counter-act DNAPL sinking. Since landfill capping occurred from 1999 through 2002, groundwater gradients have been sufficient in the south part of the Central Drainage Area and in the vicinity of PSCT-1 to prevent downward DNAPL movement. These upward gradients have likely been present since liquids extraction from the PSCT began in the early 1990s. However, data necessary to perform this assessment are not available to the north (i.e., under the P/S Landfill) to assess whether there are upward gradients that are sufficient to prevent the downward migration of DNAPL into the Lower HSU. The upward gradients likely become smaller in magnitude with increasing distance to the north away from the southern part of the Central Drainage Area, making it less likely that sufficient upward gradients occur under the P/S Landfill to prevent the downward migration of DNAPL into the Lower HSU.

6.4.2.4.3 Actions Taken to Disrupt Contaminant Transport as NAPL

As discussed elsewhere in the Remedial Investigation Report, numerous actions have been taken that affect the fate and transport of chemicals at the Casmalia site. Specific actions that have been taken to mitigate constituent transport in NAPL include the following:

- Subsurface Site Liquids Management - Note that presently LNAPL and DNAPL are both being recovered by liquid extraction conducted in the Gallery Well. The Gallery Well and associated clay barrier both serve to contain and collect DNAPL that may be migrating laterally along the contact with the Lower HSU under the P/S Landfill, as the containment feature is "keyed" approximately 5 feet into the underlying bedrock contact. The LNAPLs that exist in the P/S Landfill and Central Drainage Area are intercepted by a number of different physical containment features, including:

    - The Gallery Well/clay barrier at the toe of the P/S Landfill
    - Sump 9B
    - The PSCT (collected by extraction well PSCT-1)

Although significant DNAPL is currently being removed by liquids extraction at the Gallery Well (at a rate of approximately 4,000 gallons per year), the time required to drain the DNAPL pool contained by the clay barrier is difficult due to defining the configuration of the bottom of the P/S Landfill and the exact volume of the DNAPL pool.

As described in Section 5, once DNAPL has entered a fracture or fracture network, progressively smaller aperture fractures will be invaded if the pooled DNAPL source is allowed to extend itself vertically while remaining a continuous, interconnected phase. The DNAPL driving head is not only a function of the pool height in the overlying Upper HSU (or P/S Landfill) but also the height of DNAPL accumulated in the fractures beneath this pool. The potentially mobile DNAPL volume in the P/S Landfill does provide an ongoing source to allow the DNAPL to extend itself into fractures at depth.

Diffusion of contaminant mass from DNAPL contained within claystone fractures into pore water of the claystone matrix between fractures affects the persistence of DNAPL in the fractures. This diffusion causes a redistribution of contaminant mass from fractures to the claystone fractures that can slow the advance of DNAPL migration. If the DNAPL source is controlled, this diffusion can ultimately cause DNAPL migration to cease and DNAPL to disappear from fractures by dissolution and diffusion into the porous matrix. A series of chloride diffusion tests were performed on core samples from the Site (2 alluvium samples, 2 weathered claystone and 2 unweathered claystone samples); the diffusion rates into the unweathered claystone matrix ranged from 1-5 x 10^{-7} cm^2/s, which is similar to results for the weathered claystone and about an order of magnitude greater than for the alluvium core. Given the relatively low hydraulic conductivity (~$5X10^{-6}$ cm/s) of the unweathered claystone, chemical diffusion has the potential to attenuate both DNAPL and dissolved VOCs.

Removal of free-phase DNAPL from the P/S Landfill can feasibly be performed by primary pumping methods. Removal of free-phase DNAPL will leave behind residual phase DNAPL that is trapped by capillary forces as residual globules in the soil pores below the water table. Removal of residual DNAPL is much more energy intensive than removal of free phase DNAPL because of these capillary forces holding residual DNAPL in place.

Removal of free-phase DNAPL from Lower HSU fractures is likely not feasible because it is not possible to sufficiently characterize the site to identify all potential fractures that may contain DNAPL. Meeting this objective would require literally hundreds of deep borings and even then, the extent of mobile DNAPL in fractures would likely not be known. In addition, removing DANPL from select fractures that are found to contain mobile DNAPL would not be effective because of the very small storage capacity within fractures that would contain DNAPL. Any

DNAPL removed from fractures would be replaced until the DNAPL source is removed. The most feasible method of controlling free-phase DNAPL migration in the Lower HSU is to remove the mobile DNAPL source (i.e., from the P/S Landfill if that is the source). This would result in the mobile DNAPL in the fractures to stop being replenished, which would cause the DNAPL to stop advancing, and ultimately disappearing through matrix diffusion.

6.5 Summary and Conclusions

This section provides the summary and conclusions of the contaminant fate and transport discussion and evaluation. Contaminants evaluated for fate and transport include those constituents identified in the nature and extent of contamination sections for each medium (Section 5.0), and in Appendices that summarize media-specific remedial investigation activities. Sufficient data has been collected to evaluate the presence, nature, and extent of chemical constituents in the various environmental media encountered at the site. The findings of the fate and transport evaluation can be summarized as follows:

- The nature and distribution of chemicals present at the site with respect to the various environmental media is understood.
- The physical and chemical factors affecting the fate and mobility of these chemicals in the environment, and the operative transport pathways for these chemicals in the various media are understood.
- The location of principal contaminant sources at the site and how chemicals may migrate from these sources to other areas of the site within the various media is understood.
- Many measures have already been undertaken to mitigate (historical) contaminant sources at the site and disrupt potential migration of these chemicals within the various media
- Sufficient information is available to identify those areas, chemicals, and media still requiring mitigation in order to reduce the mobility and potential unacceptable exposures at the site.
- Surface water runoff from some study areas, such as the RCRA Canyon Area and the West Canyon Spray Area, has apparently transported surface soils containing elevated levels of COPCs, principally metals, into the stormwater and treated liquid impoundments, where they have accumulated in pond-bottom sediments.
- Discrete areas of contaminated subsurface soils have locally manifested in impacts to other environmental media, including soil vapor and groundwater. Such examples include subsurface conditions in the Burial Trenches Area, the Central Drainage area, the Capped Landfills Area, and to a limited extent the Former Pond and Pads Area just south of the PSCT.
- Elevated soil vapor levels are locally present in association with some former disposal areas, most notably the Capped Landfill Area and the Burial Trenches Area. Available data indicate these disposal areas to be the principal contaminant source areas at the site, and that lateral soil vapor migration from these source areas occurs. Elevated VOCs occur away from these source area offsite (to the north into the North Drainage and east into the North Ridge) and onsite (to the south across the PSCT into the former Ponds and Pads Area and to the west towards the RCRA Canyon area). Groundwater impacts are most pronounced in proximity to primary contaminant source areas, and impacts are generally greater north of the PSCT. Southerly migration of contaminated groundwater across the site is mitigated by continuing extraction from the PSCT, and potential migration into offsite areas is mitigated by the existing PCT groundwater

collection systems as well as active and ongoing natural attenuation and biodegradation mechanisms.

- Free phase LNAPL occurs within the P/S Landfill and Central Drainage Area between the landfill and PSCT-1. The Gallery Well and clay barrier appear to be effectively containing LNAPL within the P/S Landfill. LNAPL is not migrating to the south across the PSCT from primary source areas located north of this containment feature.
- Free phase DNAPL occurs within the P/S Landfill and in the Lower HSU between the landfill and PSCT-1. The volume of pooled DNAPL in the landfill may exceed 100,000 gallons. The vertical extent of DNAPL in the Lower HSU is not known, however, investigation data suggest that fracture pathways (which are predominantly steep) diminish with depth. The horizontal extent of DNAPL within the Lower HSU within the vicinity of the P/S landfill and Central Drainage Area is also not known, although the potential for DNAPL to occur beyond the site boundary is considered to be low. Potential sources to the Lower HSU DNAPL could be the large DNAPL volume within the P/S Landfill or an unidentified potential DNAPL within the former Pad 9A/B area of the Central Drainage Area. While active DNAPL recovery and hydraulic containment occurs in proximity to these sources. The combination of extraction features and local upward vertical groundwater gradients, acts to relieve pressure exerted by the DNAPL and inhibit further lateral and vertical DNAPL migration. Although extracting and locally upward vertical groundwater gradients occur, they may not be sufficient to prevent the continued potential for DNAPL migration.

6.6 References

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7.0 DATA EVALUATION

This section discusses the data evaluation steps that were conducted to develop a dataset and exposure point concentrations for evaluation in the Baseline Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA). The data evaluation was conducted in addition to the procedures for field sampling, chain-of-custody, laboratory analysis, reporting and data validation that were conducted in accordance to the QAPP, which was included as Appendix B of the RI/FS Work Plan (CSC, 2004). The data evaluation steps include:

(1) Risk Assessment Dataset Development
- Data Usability Assessment
- Data Processing
  - Evaluation of duplicate samples
  - Evaluation of chemicals analyzed by multiple methods
- Treatment of Dioxin and PCB congener data

(2) Background Analysis

(3) Chemicals of Potential Concern Selection

(4) Exposure Point Concentration Calculation

7.1 Risk Assessment Dataset Development

As discussed in earlier sections, the project database was constructed with several phases of RI sampling that have been conducted since 2004 in addition to limited historical data (background and West Canyon Spray area soil data). The database includes soil, sediment, surface water, soil vapor and groundwater data. To prepare a dataset for quantitative risk assessment purposes, the soil, sediment, surface water and soil vapor data were first evaluated for usability and then processed through several steps.

7.1.1 Data Usability Assessment

USEPA guidance presents six data usability criteria that should be considered in developing a dataset for risk assessment purposes (USEPA, 1992). These criteria were considered as a part of the DQO process and in developing the sampling and analysis program for the RI as presented in the SAP and QAPP in the RI/FS Work Plan (CSC, 2004). In addition, more recent guidance (USEPA 2006a) provides additional steps that can be conducted to determine if Site data meet the planning objectives for the project. This section discusses the usability of the RI data with respect to the conduct of the HHRA and ERA.

One of the primary uses of the data is to determine what chemicals are present, where they are located and at what concentrations. Other considerations include whether site concentrations are greater than background, whether exposure areas have been adequately characterized and if there is adequate data to calculate exposure point concentrations for use in the risk assessments. The data usability assessment can be used to evaluate if the minimum requirements have been met and to identify areas of uncertainty that should be considered in the risk assessments. The table below summarizes the assessment.

Data Usability Criterion	Minimum Requirements	RI/FS Outcome Summary
1 - Reports	Site description, sample design and sample locations, methods and detection limits, results on per sample basis and qualified if needed, sample quantitation limits and detection limits.	This information provided as a part of ongoing RI sampling program. Preliminary data reviewed at each phase of sampling to determine if additional data needs remained which were then included in next Phase.
2 - Documentation	Sample results can be related to geographic location through chain-of-custody, SOPS, field and analytical record).	Samples were collected and analyzed under chain-of custody per the methods and SOPs presented in the RI/FS Work Plan SAP and QAPP.
3 - Data Sources	Analytical sample data results for each medium within exposure area, broad spectrum of analysis for one sample per medium per exposure area, historical and current data.	Samples were collected from each medium and Study Area and analyzed for extensive list of analytes. Historical data used with current data for background samples, Site data from current sources.
4 – Analytical Method and Detection Limit	Established approved methods are used and detection limits are adequate.	Methods were performed as specified in the RI/FS Work Plan QAPP, MDLs were developed based on background and human health and ecological screening criteria, RI sample method detection limits (MDLs) were generally below Work Plan screening criteria for chemicals of potential concern (COPCs) with a few exceptions which will be noted in risk assessments.
5 – Data Review	Data reviewed according to specified plan and analytical errors or limitation noted for risk assessment.	90% of data underwent limited validation, 10% full (level IV) validation with qualifications added to database as necessary. Data were deemed useable for risk assessment with the exception of R-qualified, rejected data. Rejected data was not included in the risk assessment database but estimated (j-qualified) data was included.
6 – Data Quality Indicators	Data reviewed with respect to Completeness, Comparability, Representativeness, Precision; Data Qualification.	Appendix R presents the results of the Data Validation addressing these items. Appendix B presents the precision statistics for RCRA Canyon and FPP and ROS Study Areas; three of the largest Study Areas Sufficient data is available to calculate exposure point concentrations; used maximum concentration when sample size too small or not enough detected values per USEPA guidance.

Additional details are provided in the appendices for each media (Appendices A through D) and Appendix R – Data Validation. Appendix R also includes the identification of the major TICs for SVOCs and VOCs as specified in the RI/FS Work Plan. For the HHRA and ERA, TICs were not evaluated quantitatively. Further data quality assessment was conducted consistent with the Data Quality Assessment guidance (USEPA, 2006a) and is presented in Appendix B.

7.1.2 Data Processing

Measurements of contaminant concentrations in environmental media are recognized as being subject to variability, or "error" of varying degrees and magnitude. Factors that may contribute to variability include inherent small-scale spatial or temporal variability in the concentration or medium of interest; variability introduced by sampling, sample storage, or sample shipment; variability due to analysis by different instruments and/or laboratories; and inherent variability and stochasticity in analytical methods. Several types of quality control (QC) samples may be collected (e.g., field blanks, trip blanks, duplicates, split samples). QC samples provide quantitative measures of sample variability that can be compared with measurement quality objectives for precision established in a SAP for data used to calculate exposure point concentrations.

Field duplicates were collected to evaluate the quality of sample collection as well as sample analysis. Field duplicate samples are usually two samples collected simultaneously from the same sampling location and are used as measures of either the homogeneity of the medium sampled in a particular location or the precision in the sampling and sample handling (in transport and/or in the laboratory) (USEPA, 1989). Field duplicates typically have a unique sample ID, but share the same sample date and location identifiers as the corresponding parent or primary sample. Because the duplicate and parent samples both provide information regarding the measured concentration, the samples may be referred to as a "parent-duplicate pair". Also, sometimes more than one field duplicate is collected per parent sample as an additional quality control measure.

While Section 10 of the QAPP (CSC, 2004) specifies procedures for assessing data precision, accuracy, and completeness, it does not clearly specify the data processing steps for determining the single concentration value that represents a parent-duplicate sample pair. These procedures are described below and are generally consistent with USEPA's guidance regarding data verification, data validation, and data quality assessment (USEPA, 1992; 2002).

Another issue arises when a particular chemical is analyzed by multiple analytical methods within the same sample. While USEPA requires the use of standardized methods for the analysis of chemicals found in environmental samples, multiple analytical methods are available to measure a particular chemical of interest. For example, benzene can be analyzed as a VOC using USEPA method 8260 or 8020 or naphthalene can be analyzed as a SVOC using USEPA method 8270C or 8310 and as a VOC using USEPA method 8260. The various EPA methods have different accuracy in positive identification of the compound and determination of the concentration present in a particular media. Another issue can arise when a laboratory labels a nontarget analyte for a particular method as a TIC. This issue was addressed as the data were finalized and the TIC designation was removed in cases where the laboratory applied a TIC designation to a conventional (non-TIC) compound that was not on the target list for a given method.

For cases where a field duplicate sample is present or multiple analyses are present for the same chemical in a sample, a single representative concentration for the sample was selected as follows:

(1) If there was a detection in both samples the higher concentration was selected;
(2) If there was a detection in one sample but not the other, the detected concentration was selected; and

(3) If both samples were nondetect the lowest method detection limit was selected and appropriate techniques for handling nondetect data were applied in calculating statistics later in the data evaluation.

7.1.3 Treatment of Dioxin and Polychlorinated Biphenyl Congener Data

Dioxins/furans and polychlorinated biphenyls (PCB) are complex halogenated aromatic hydrocarbon mixtures made up of chemically-related chemicals. The 2,3,7,8-tetrachlorodibenzo-p-dioxin congener has been the most extensively studied of these halogenated aromatic hydrocarbons and is thought to be the most toxic chemical within the dioxin family. Because of their complex nature and the lack of specific toxicity information for each of the individual chemicals, dioxin/furans and some of the PCB congeners that exhibit dioxin-like behavior are evaluated in terms of their relative toxicity to that of 2,3,7,8-TCDD using Toxicity Equivalency Factors (TEFs). This approach is described below.

7.1.3.1 Dioxin Toxic Equivalent Calculations

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) comprise a group of 210 individual chemicals, all with a similar chemical structure. The individual chemicals are referred to as congeners. Of the 210 total PCDD/PCDF congeners, 75 congeners are PCDDs and 135 congeners are PCDFs. The toxicity of PCDD/PCDFs, collectively known as “dioxins”, is based on the teratogenic, mutagenic, and carcinogenic potential of these compounds. Only 17 congeners are considered to be of interest for evaluating environmental exposure and risk. These are the PCDD/PCDF congeners that have chlorines attached in at least the 2, 3, 7, and 8 positions. The 2,3,7,8-substituted congeners are believed to exhibit similar toxicity and act through the same toxic mechanism. Thus, these are usually the only individual congeners for which environmental samples are analyzed.

The ability of the 2,3,7,8-substituted congeners to cause toxic effects is mediated by their ability to bind the aryl hydrocarbon (Ah) receptor in vertebrates (ATSDR, 1998; Safe, 1986). Each congener has a different relative binding affinity, and thus a different relative toxicity. The most toxic congener to mammals is 2,3,7,8-TCDD. The other congeners are assigned a Toxicity Equivalency Factor (TEF), which is relative to 2,3,7,8-TCDD (Thus, the TEF for 2,3,7,8-TCDD is equal to one.). The World Health Organization (WHO) provides published and peer-reviewed TEF values, shown in the table at the end of this section (Van den Berg et al., 2005, Van den Berg et al., 1998). These TEFs are currently endorsed by the USEPA and most other regulatory agencies throughout the world. Individual congeners are assigned different TEFs for humans/mammalian species, avian species, and fish, due to differences in toxicity to these species. Concentrations of the individual 2,3,7,8-substituted congeners in environmental samples are then multiplied by their respective TEF, resulting in a congener concentration normalized to the toxicity of 2,3,7,8-TCDD for each species. Because the congeners all share the same mode of toxicity, the TEF-concentrations are summed for all 17 congeners. The resulting value is a total PCDD/PCDF toxic equivalent, or total dioxin TEQ concentration, given in terms of the toxicity of 2,3,7,8-TCDD. The total mammalian dioxin TEQ concentrations are used to assess exposure to humans and mammalian wildlife in the HHRA and ERA. The total avian dioxin TEQ concentrations are used to assess exposure to avian wildlife only.

In summary, the method to derive total TEQ concentrations is as follows:

Step 1. For each sample, select the detected concentrations of each of the 17 2,3,7,8-substituted PCDD/PCDFs;

Step 2. Multiply each congener concentration by the appropriate TEF for the specific congener from the table. For each receptor, use the appropriate set of TEF values (e.g., mammalian total TEQs should be calculated with mammalian TEFs); and

Step 3. Sum the resulting values from Step 2 to calculate total TEQ concentrations.

Although dioxins/furans were detected in surface water, the toxicity values for these compounds were not available for invertebrates and amphibians. Dioxins/furans bind to the aryl hydrocarbon (Ah) receptors in fish and wildlife causing change in gene expression which leads to carcinogenic or teratogenic effects. However, invertebrates lack the Ah receptor (Hahn et al., 1994, West et al., 1997) and therefore, it is considered inappropriate to use fish dioxin/furan screening values for the protection of invertebrates. A study by West et al., (1997), confirms previous investigations on the insensitivity of aquatic invertebrates to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) exposures. Although amphibians have the Ah receptor, the affinity to bind to TCDD has been found to be low and therefore, considered relatively insensitive to TCDD (Lavine et al., 1995). Therefore, risk to invertebrates and amphibians at the Site are unlikely to be underestimated. Please see Appendix U for more details.

7.1.3.2 Polychlorinated Biphenyl (PCB) Congener Calculations

Similar to PCDD/PCDFs, PCBs are a group of chemicals, each with a different chlorination substitution pattern on the basic biphenyl structure. There are 209 possible PCB congeners. Although production and use of PCBs has been banned in the United States since 1977, chemical manufacturing of PCBs occurred by a process that produced a PCB mixture containing many of the possible congeners in differing proportions. The mixtures were marketed as such, and sold by the total chlorine content of the mixture commonly referred to as Arochlors. Environmental PCB contamination reflects this process; samples with detectable PCBs contain many of the possible congeners but may differ from the original commercial mixture due to the effects of environmental processes such as partitioning or chemical transformations.

In addition, PCBs exhibit a wide range of toxicological effects, including immunosuppression, endocrine disruption, mutagenicity, teratogenicitity, and carcinogenicity (ATSDR, 2000; Safe, 1984). In most cases, toxicological studies have been conducted with the commercially-used PCBs mixtures; the effects of individual congeners are rarely known. Because environmental PCB contamination exists as a mixture of the congeners, and because toxicity data is based on PCB mixtures, congeners are typically summed together in order to assess risk to PCBs. For the ERA, the individual detected PCB congeners were summed for each sample and presented as total PCB congeners (in the ERA, they have also been referred to as total PCBs). The HHRA did not evaluate total PCB congeners. The HHRA and the ERA also evaluated PCBs by the Arochlor analysis.

In addition to the total PCB congener calculation, TEQs were calculated for the dioxin-like PCB congeners. These are a group of 12 PCB congeners that show structural similarity to PCDD/PCDF, bind to the aryl hydrocarbon receptor, elicit dioxin-specific biochemical and toxic responses and persist and accumulate in the food chain (USEPA, 1996, Van den Berg, 2006). Each of these PCB congeners has a TEF derived for it that relates its toxicity to 2,3,7,8-TCDD similar to the TEF scheme for PCDD and PCDF congeners. These TEF values are presented in table below. The total mammalian PCB TEQ concentrations are used to assess exposure to humans and mammalian wildlife in the HHRA and ERA. The total avian PCB TEQ concentrations are used to assess exposure to avian wildlife only.

The method to derive PCB TEQ concentrations followed the same steps as for dioxin TEQ concentrations as follows:

Step 1. For each sample, select the detected concentrations of each of the 12 dioxin-like PCB congeners;

Step 2. Multiply each congener concentration by the appropriate TEF for the specific congener from the table. For each receptor, use the appropriate set of TEF values (e.g., mammalian total TEQs should be calculated with mammalian TEFs); and

Step 3. Sum the resulting values from Step 2 to calculate total TEQ concentrations.

Dioxin, Furan and PCB Congener Toxicity Equivalency Factors

Congener	Mammalian TEF 2005[a]	Avian TEF 1998[b]	Fish TEF 1998[b]
Dioxins			
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PeCDD	1	1	1
1,2,3,4,7,8-HxCDD	0.1	0.05	0.5
1,2,3,6,7,8-HxCDD	0.1	0.01	0.01
1,2,3,7,8,9-HxCDD	0.1	0.1	0.01
1,2,3,4,6,7,8-HpCDD	0.01	0.001	0.001
OCDD	0.0003	0.0001	0.0001
Furans			
2,3,7,8-TCDF	0.1	1	0.05
1,2,3,7,8-PeCDF	0.03	0.1	0.05
2,3,4,7,8-PeCDF	0.3	1	0.5
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
OCDF	0.0003	0.0001	0.0001
PCB			
3,3',4,4'-TeCB-77	0.0001	0.05	0.0001
3,4,4',5-TeCB-81	0.0003	0.1	0.0005
3,3',4,4',5-PeCB-126	0.1	0.1	0.005
3,3',4,4',5,5'-HxCB-169	0.03	0.001	0.00005
2,3,3',4,4'-PeCB-105	0.00003	0.0001	--
2,3,4,4',5-PeCB-114	0.00003	0.0001	--
2,3',4,4',5-PeCB-118	0.00003	0.00001	--
2',3,4,4',5-PeCB-123	0.00003	0.00001	--
2,3,3',4,4',5-HxCB-156	0.00003	0.0001	--
2,3,3',4,4',5'-HxCB-157	0.00003	0.0001	--
2,3',4,4',5,5'-HxCB-167	0.00003	0.00001	--
2,3,3',4,4',5,5'-HpCB-189	0.00003	0.00001	--

a. Van den Berg et al. (2005)
b. Van den Berg et al. (1998) -- = Not Available

7.2 Background Analysis Summary

A statistical analysis was performed on RI and historical background data to calculate upper bound estimates of concentrations of metals and dioxins in background soils. These Upper Tolerance Limits (UTLs) were then used to compare Site data to determine what metals were within background levels. If a metal was determined to be within background it was not evaluated in the risk assessments. Dioxin UTLs were calculated to compare the Site data but were not used in the selection of COPCs.

Distribution analysis and UTL calculation for the background dataset involved consideration of several statistical descriptors and graphical evidence, consistent with principles in both CalEPA (1997) and USEPA (2002) background guidance and the RI/FS Work Plan. This analysis is presented in Appendix A.

Site data for a given Study Area were compared to the UTL and if the maximum concentration was below the UTL that chemical was not included as a COPC. The soil background data was also used to screen sediment samples since the sediment within the pond and drainages originates primarily from surrounding soils. For chromium, the data used in the Draft RI did not include all data (historical and RI) consistent with other metals. For the Draft Final RI all data has been included resulting in a UTL of 64 mg/kg. This revised UTL is used in Section 5 and in the final interpretation of risks but was not used in the COPC selection process. The initial UTL of 47 mg/kg was used on the COPC selection process which was completed for the Draft RI report submitted in 2008.

The UTL values are presented below.

Chemical	UTL Value	Units
Aluminum	18,000	mg/kg
Antimony	4	mg/kg
Arsenic	22	mg/kg
Avian Dioxin TEQ	16	pg/g
Barium	174	mg/kg
Beryllium	0.91	mg/kg
Cadmium	3.2	mg/kg
Chromium	47 (64)	mg/kg
Cobalt	20	mg/kg
Copper	19	mg/kg
Lead	11.9	mg/kg
Magnesium	5,500	mg/kg
Mammalian Dioxin TEQ	13	pg/g
Manganese	330	mg/kg
Mercury	0.026	mg/kg
Molybdenum	10	mg/kg
Nickel	49	mg/kg
Selenium	3.3	mg/kg
Thallium	0.64	mg/kg
Tin	65	mg/kg
Vanadium	81	mg/kg
Zinc	104	mg/kg

7.3 Selection of Chemicals of Potential Concern

Chemicals of potential concern (COPCs) were selected for each environmental media (soil, sediment, surface water and soil vapor) for inclusion in the risk assessment. COPCs are defined as chemicals clearly associated with the Site (e.g., chemicals that are prevalent) and present at concentrations higher than background levels. For the ecological risk assessment, COPCs are referred to as chemicals of potential ecological concern (CPECs).

Prior to selecting the COPCs, the chemical dataset was filtered based on media and depth as appropriate. For soil and sediment, samples taken from depths less than or approximately equal to 5 feet below ground surface were selected. The filtered dataset included all Study Areas (including offsite drainages), excluding background, historical West Canyon data, PCB landfills, and capped landfill areas. There was no division by depth for surface water and soil vapor. Study Areas include the following:

Terrestrial Uncapped Areas:

- RCRA Canyon;
- Liquid Treatment Area;
- West Canyon Spray Area;
- Burial Trench Area;
- Maintenance Shed Area;
- Central Drainage Area;
- Administration Building Area;
- Roadway Areas;
- Remaining Onsite Areas; and
- Former pond and pad areas south of the perimeter source control trench (PSCT).

Onsite Ponds:

- A-Series Pond
- RCF Ponds
- Pond A-5
- Pond 13; and
- Pond 18

Offsite Drainages:

- North Drainage
- A Drainage;
- B Drainage;
- Upper C Drainage; and
- Lower C Drainage

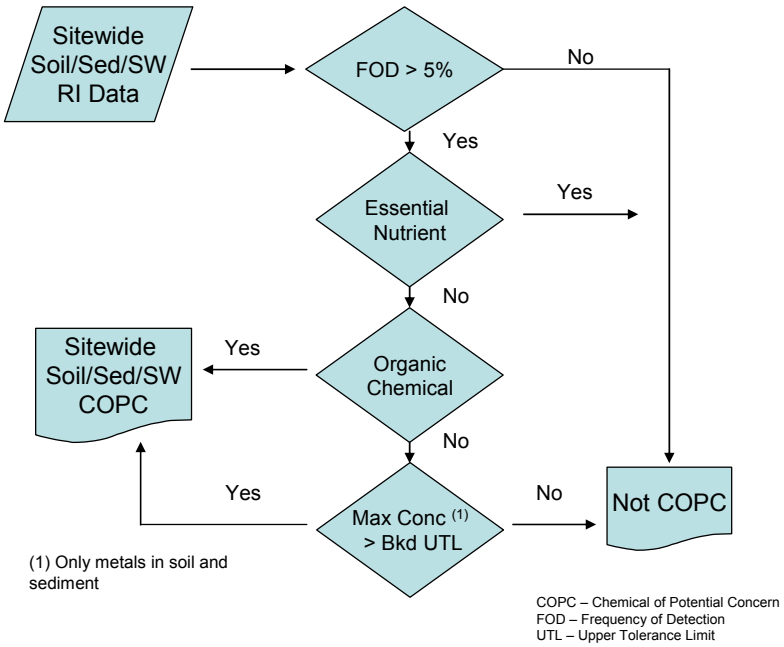
Additional areas such as seeps and RCRA Canyon runoff were also evaluated. However, as these areas were not identified as Study Areas in the Work Plan (CSC, 2004), they were evaluated separately and only for the ERA. Data for these areas are described in the ERA (Appendix U).

Sitewide prevalence tables were generated using the Sitewide dataset, which was analyzed on a parameter-by-parameter basis. These tables are presented in Appendix X – Attachment X-1. The results of the parameter-based analysis included the following:

- Number of total samples;
- Number of detections;
- Maximum and minimum results;
- Average of detected results;
- Frequency of Detection (number of detections / number of total samples);
- Frequency of Detection greater than 5 % (yes/no); and
- Maximum detected value exceeds the Background 95UTL (yes/no)

Based on the Sitewide prevalence tables, an analysis was performed to generate Sitewide COPCs. Chemicals were identified as a COPC on a per-matrix basis based on three criteria: (1) prevalence for organic and inorganic chemicals, (2) elimination of essential nutrients, and (3) comparison to background for inorganic chemicals. COPCs for soil and sediment were selected for the depth interval evaluated in the risk assessment, 0 to 5 feet below ground surface (bgs) from the Sitewide dataset; this also includes data from 5 to 5.5 feet bgs. The list of COPCs was then applied both Sitewide and on a Study Area-specific basis. The figure below presents an overview of the Sitewide COPC selection process. For soil vapor, all detected chemicals were included in the HHRA. In the ERA, soil vapor data was screened as described below.

COPC Selection Process



Chemicals were selected as COPCs if the percentage of positive detections exceeded a 5% prevalence screen (i.e., the chemical was positively detected in at least 5% or more of the samples). A chemical was eliminated form further analysis if it is considered an essential nutrient. The essential nutrients are calcium, magnesium, potassium, iron, and sodium and are generally excluded from risk assessments (USEPA, 1989). Following USEPA guidance (USEPA, 2003), aluminum is considered a COPC if soil pH is less than 5.5. However, as Site soil pH was greater than 5.5, aluminum was not considered a COPC. Aluminum was not detected in surface water and therefore not considered a COPC in surface water. Metals were then further evaluated with respect to background using the UTL derived from the background dataset. If the maximum concentration of a metal was greater than the background UTL value, the metal was included as a COPC for further evaluation.

Once the Sitewide COPCs were selected (Table 7-1), an additional analysis was conducted for each Study Area to determine if additional "Study Area"-specific COPCs should be added to the risk assessments. The purpose of this more detailed screening process was to address agency concerns that there may be localized detections of a chemical that should be evaluated in the risk assessments. Study Area-specific prevalence tables were developed to identify those chemicals with a prevalence of greater than 5% within th e Study Area. This list was then compared to the Sitewide COPC list to see if any new chemicals were identified as COPCs. This list was further screened to include only those chemicals with at least three detections in a Study Area. The minimum number of detections was used to screen out those chemicals that were more infrequently detected in Study Areas with smaller sample sizes, for example, a chemical detected in 2 out of 33 samples would be considered infrequently detected but still have a detection frequency of 6% which is slightly above 5%. The chemicals that were not carried forward into the risk assessments for the particular Study-Area based on this step are presented in Table 7-1a.

At the request of EPA, a review of the chemicals that were eliminated in this step was conducted. It was found that an additional 46 chemicals that were not on the sitewide COPC list fell in this category. A review of the concentration data for these 46 chemicals indicate only one chemical, 1,2,4-trichlorobenzene, had a concentration greater than 1 mg/kg (1.1 mg/kg) which was detected in the Central Drainage Area. Thirteen chemicals were detected at concentrations between 0.1 and 1 mg/kg and the remaining chemicals were detected at lower concentrations (less than 0.1 mg/kg). Nine of the 13 chemicals that were detected at concentrations greater than 0.1 mg/kg were detected in the Burial Trench Area, Central Drainage Area and Liquid Treatment Area. As these areas will be considered further in the Feasibility Study, not considering these COPCS in the risk assessments does not have a significant impact on the RI/FS. The remaining four chemicals with concentrations greater than 0.1 mg/kg included: 1-Butanol detected in one of eight samples from the Administration Building Area at a maximum concentration of 0.12 mg/kg; di-n-butylphthalate detected in 2 of 31 samples from the West Canyon Spray Area at a maximum concentration of 0.23 mg/kg, N-nitrosodi-n-butylamine detected in 2 of 22 samples from the Remaining On-site Area at a maximum concentration of 0.33 mg/kg, and malathion detected in 1 of 15 samples from the Remaining On-site Area at a maximum concentration of 0.16 mg/kg. Due to the relatively low detection frequency and concentrations, the exclusion of these chemicals would not be expected to have a significant impact on the risk characterization of the Study Areas. Finally, since many of the chemicals were detected at relatively low concentrations, the list was further screened against the residential PRGs for the HHRA. For the ERA, VOCs in soil were further screened out as this chemical class is known to be relatively low in toxicity for ecological receptors and therefore did not warrant inclusion in the ingestion (soil or diet) pathway for wildlife receptors in the ERA. The

inhalation pathway for VOCs in soil gas was quantitatively evaluated in the ERA (see Appendix U). The Study Area-specific COPCs are presented in Appendix X – Attachment X-2.

Any chemical retained after this additional screening process was included as a COPC only in the Study Area in which it was selected.

Table 7-1 presents a summary of the results of the COPC selection.

7.4 Exposure Point Concentration Calculation

Exposure point concentrations (EPCs) are the concentrations of chemicals in environmental media to which receptors may be exposed through defined exposure pathways. EPCs were estimated for each of the environmental media associated with complete and potentially complete pathways identified in the CSMs for the HHRA and ERA. The media evaluated in the risk assessments include:

- Surface (0 to 6 inches bgs) and shallow soil (0 to approximately 5 feet bgs; this also includes data from 5 – 5.5 feet bgs)
- Surface (0 to 6 inches bgs) and shallow sediment (0 to approximately 5 feet bgs)
- Soil vapor; and
- Surface water

In addition, a separate evaluation for soil from 0 to approximately 10 feet bgs is presented in the ERA for deep burrowing mammals.

EPCs represent an estimate of the average chemical concentrations across an exposure domain to which a potential receptor is likely to be exposed under current and reasonably foreseeable future Site activities and uses. The average concentration is the best estimate of exposure provided that sampling is representative of Site concentrations and exposure is random across the entire exposure area. Because of uncertainty in both of these assumptions, conservative estimates using statistical methods or maximum reported concentrations are typically used as EPCs for risk calculations.

7.4.1 Exposure Area Definition

A consideration in developing the EPCs is the definition of the exposure area the EPC will represent. The exposure area can be defined as the minimum area that will sustain an assumed exposure. All of the data within an exposure area is considered in the EPC calculation.

The Casmalia Site has historically been subdivided in two broad areas or zones. Zone 1 (onsite) and Zone 2 (offsite) which encompasses the extent of Site-related contamination or potential contamination outside the Zone 1 boundary. In addition, several Study Areas have been defined that consider similar past and current waste management practices, geographic boundaries and potential for exposure. For example, the Burial Trench Area is a defined area that accepted buried waste, which is currently still present. The Liquid Treatment Area is currently in operation and frequented by Site workers. The Former Ponds and Pads Area south

of the PSCT, while originally may have accepted various wastes, has undergone significant soil removal and grading. In addition, Site workers do not frequent specific areas within this Former Ponds and Pads Area and have equal chance of contacting soil within the area. This is also true for ecological receptors. Therefore, to evaluate potential exposures, the Former Ponds and Pads area can be considered as one exposure area. In the risk assessments, each of these Study Areas was evaluated separately to assist in the remedial planning for the Site.

In addition to the Study Area designation, presumptive remedies have been accounted for in the exposure area designation and EPC calculation. As discussed in the RI/FS Work Plan (CSC, 2004), the CSC has already constructed RCRA caps over some of the Site landfills and anticipates that all five Site landfills will be capped as part of the final Site remedy. The CSC capped the P/S Landfill in 1999, the Heavy Metals Landfill in 2001, and the Caustics/Cyanides and Acids Landfill in 2002. These caps cover approximately 50 acres and include interstitial areas between the landfills. The PCB Landfill (located west of the P/S Landfill) will receive a RCRA cap during final remedy implementation.

All the freshwater aquatic areas were evaluated in the ERA for exposure to aquatic receptors. The CSC and USEPA have agreed that the two treated liquid impoundments, Pond A-5 and Pond 18, will have presumptive remedies in place and the stormwater ponds (Pond 13, Pond A-5, and RCF Pond) may have presumptive remedies as part of the USEPA-approved closure plan for the Site. These ponds will be backfilled/graded to prevent accumulation of water and thus will be unavailable as a pathway for the aquatic ecological community, thereby eliminating the potential for adverse effects to these receptor populations. Presumptive remedies for the ponds will be further detailed as part of the FS process. Based on the proposed remedies for the ponds, the ponds were also evaluated as terrestrial areas (e.g., soil).

Therefore, for the baseline condition for the Site, it is assumed that caps on the P/S, Heavy Metals, Caustics/Cyanides, Acids and PCB Landfills are in place, and Ponds A-5 and 18 are drained. Additional exposure areas other than the Study Areas were evaluated to address this baseline condition. For example, for the ERA, Sitewide soils with and without the sediment data from Ponds A-5 and 18 were evaluated.

Figure 7-1 presents the exposure areas and Study Area boundaries evaluated in the risk assessments. Additional evaluations were conducted in the ERA in specific offsite drainages and onsite seeps and runoff locations. These are discussed in more detail in the ERA (Appendix U). The following exposure areas and media were evaluated in the risk assessments and were included in the EPC calculation process discussed in the next section.

Exposure Area/Media	Included in HHRA	Included in ERA
Study Areas - Soil		
Administration Building	X	X
Burial Trenches	X	X
Central Drainage	X	X
Former Ponds and Pads	X	X
Liquid Treatment	X	X
Maintenance Shed	X	X
RCRA Canyon	X	X
Roadways	X	X
Remaining Onsite	X	X

Exposure Area/Media	Included in HHRA	Included in ERA
West Canyon Spray Area	X	X
Other Exposure Areas/Media		
Sitewide Soil with Ponds 18 and A-5		X
Sitewide Soil without Ponds		X
B-Drainage Offsite Soils	X	X
Onsite Pond Sediments (all 5 ponds)	X	X
Stormwater Impoundments Sediment (A-Series pond, RCF pond, and Pond 13)		X
Offsite Drainage Sediments (all 4 drainages)	X	X
Onsite Surface Water (all 5 ponds)		X
Stormwater Impoundments Surface Water (A-Series pond, RCF pond, and Pond 13)	X	X
Offsite Surface Water (all 4 drainages; B Drainage was dry)		X
Onsite Soil Vapor	X	X
Offsite Soil Vapor	X	X

7.4.2 Derivation of Exposure Point Concentrations

EPCs were derived for the Site using two primary approaches. For all exposure areas, EPCs were derived as point estimates, represented by the 95% Upper Confidence Limit (95% UCL) or data maximum, using ProUCL version 4.0 and the methodology outlined in the USEPA guidance for calculating EPCs (USEPA 2006, 2007a, and 2007b). In addition, for the ERA, spatial EPCs were derived for a subset of chemicals.

Where possible, the 95% UCL was selected over the data maximum per USEPA guidance. Since the EPC term represents the average exposure contacted by an individual over an exposure area during a long period of time; EPCs should be estimated by using an average value (such as an appropriate 95% UCL of the mean) and not by the maximum observed concentration. This is because it is unlikely that an individual will visit the location of the maximum detected value all of the time.

Consistent with USEPA guidance (2007a; 2007b), in the HHRA and ERA the EPC is represented by a 95% UCL when the data consists of at least 8 observations and 5 detects. If either condition is not satisfied, there is insufficient coverage of the exposure area and the EPC is represented by the maximum detected concentration.

Data were grouped into exposure areas as presented in Section 7.4.1 prior to calculation of the EPCs using ProUCL 4.0. For Phase 1 data (the majority of the data collected during the RI sampling), data were assigned specific Study Area designations as defined above. However, 11 of the 39 Phase 2 locations were assigned as Remaining Onsite Soils in the initial database and were evaluated in the risk assessments as such. These samples were step-out samples from Phase 1 locations within the Former Ponds and Pads Study Area. These locations have been reassigned in the database and will be reassigned in the risk assessments in the Final RI.

The incorrect assignment only affects the nonspatial EPCS; spatial EPCs used in the ERA were not affected. Observed concentrations in the step-out samples are generally similar to that seen in the Phase 1 samples and therefore do not significantly affect the outcome of the risk assessments.

7.4.2.1 EPCs Derived using ProUCL

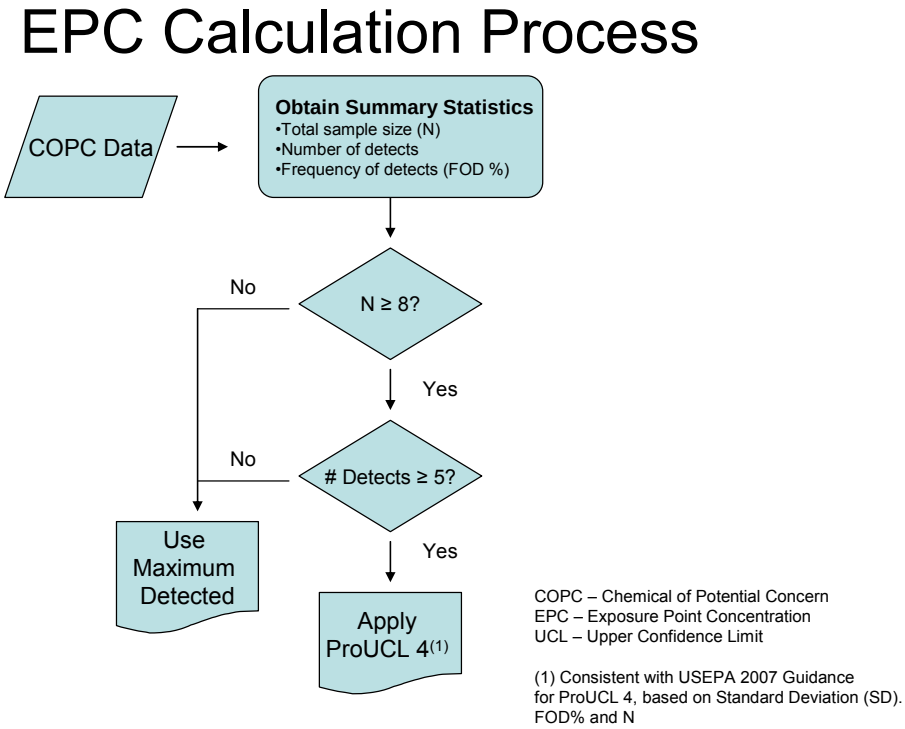
In early 2007, USEPA released statistical software called ProUCL Version 4.0 (ProUCL 4.0) to facilitate the calculation of 95% UCLs (USEPA, 2007a and 2007b). ProUCL 4.0 is an upgrade of ProUCL Version 3.0 and contains statistical methods to evaluate both full environmental data sets without nondetect values and data sets with nondetect values (also known as left-censored data sets).

Prior to calculating 95% UCLs for each exposure area with ProUCL, the data were screened with respect to sample size and number of detects as follows:

1. If a chemical was not detected in any sample for a given exposure area and media, it was assumed to not be present, so an EPC was not calculated.
2. If the number of samples in an exposure area was less than 8, then the maximum detected concentration was used as the EPC.
3. If the number of detects was less than 5, then the maximum detected concentration was used as the EPC.

If a sufficient number of samples and detections were present for a chemical, ProUCL 4.0 was used to calculate the 95% UCL. ProUCL 4.0 can calculate UCLs using up to 15 different parametric and nonparametric statistical methods. Some of the methods (e.g., Kaplan-Meier method, regression on order (ROS) methods) are applicable to left-censored data sets having multiple detection limits. The optimal method(s) for a particular data are identified by the software based on USEPA's numerical experiments with hypothetical data sets with a wide range of statistical properties, such as distribution shape, sample size, percent non-detects, and skewness (USEPA, 2006b). In the HHRA and ERA, if multiple UCLs were identified as being equally plausible, the relative percent difference (RPD) in 95% UCLs was evaluated. If the RPD was less than 5%, the EPC was determined by the method that yields the highest value. If the RPD was greater than 5%, then professional judgment was used to select the method that generally exhibits the most consistent performance according to USEPA guidance (USEPA, 2007a). EPCs were derived using the same methodology for soil, sediment, soil vapor and surface water. For soil vapor, the maximum detected concentrations were used in the HHRA; for the ERA, both the maximum detected and 95% UCL concentrations were used. A summary of the EPCs by exposure area and media is presented in Tables 7-2 through 7-9.

The figure below presents an overview of the EPC calculation process. Appendix X – Attachment X-2 presents detailed decision trees for final EPC selection based on the USEPA ProUCL guidance.



7.4.2.2 EPCs Derived using Spatial Analysis

For the ERA, area-weighted or spatial EPCs for soil were also calculated for a subset of chemicals with hazard quotients (HQs) greater than 1 (see Appendix U for details). USEPA's guidance on probabilistic risk assessment (USEPA, 2001) discusses the importance of accounting for spatial autocorrelation in environmental data. The main benefit of applying spatial statistics is that a more explicit consideration of spatial relationships may lead to a more accurate estimate of the confidence limits for the arithmetic mean concentration (USEPA, 2001). The tradeoff with some spatial statistics approaches (e.g., kriging) is that additional effort is required to evaluate underlying modeling assumptions, and the analysis may be less transparent for readers that are either unfamiliar with the method or do not have access to software that can be used to reproduce the results. In this ERA, Thiessen Polygons were applied to decluster the samples that may be grouped in close proximity. The size and shape of each polygon is determined by the spatial arrangement of sample locations. Samples located closer together are enclosed by relatively small polygons, whereas areas with less dense sampling will be divided into larger polygons. The size of the polygon divided by the size of the exposure area determines the probability weighting factor for each observation. Thiessen Polygons require minimal assumptions, are intuitive, are relatively straightforwared to implement, and can accommodate left-censored data.

The main challenge with the polygon method is that most statistics software, including ProUCL 4, are designed to calculate 95% UCLs for data sets with equal sample weights. For this ERA, a bootstrap resampling approach was used to resample the original data set (with replacement)

in order to generate B=250 data sets with the sample size as the original data set. ProUCL 4.0 was then used to calculate a unique 95% UCL for each bootstrapped sample. An unbiased estimate of the EPC was determined by the arithmetic mean of the 95% UCLs. Numerical experiments with a variety of data sets suggests that B=250 bootstrap samples is sufficient to achieve stability in the mean 95% UCL.

The methods used to calculate the spatial EPCs and the spatial EPC values are presented in detail in the ERA (Appendix U).

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8.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

8.1 Introduction

The objective of the baseline human health risk assessment (HHRA) was to evaluate potential baseline health risks associated with chemicals detected at the Site. The results of the HHRA in conjunction with the ecological risk assessment findings can be used to identify chemicals and exposure media that may pose an unacceptable risk to current and/or future receptors at the Site and to provide information for remedial planning. This risk assessment was prepared as part of this RI to evaluate potential exposures and "define risks to public health and the environment" related to soil, sediment, soil vapor, and surface water, and to subsequently provide information for the FS.

The overall approach used in the HHRA was based on United States Environmental Protection Agency (USEPA, 1989; 1991ab; 1997a; 2002; 2004; 2006a,b,c) and Cal-EPA guidance documents (2000; 2003). The risk assessment consists of five major components organized in the following manner:

- **Data Review and Evaluation:** A review of available data to characterize the Site and identify data gaps; to define the nature and extent of environmental contamination identified at the Site; and to identify Site-related chemicals of potential concern (COPCs) (defined as potentially hazardous chemicals associated with the Site that are present at concentrations higher than background levels).
- **Exposure Assessment:** An assessment of the magnitude, frequency, duration, and routes of potential human exposure to Site-related COPCs. The exposure assessment considers both current and likely future Site uses and is based on complete exposure pathways to actual or probable human receptors (i.e., general groups that could come in contact with Site-related COPCs). The exposure scenarios are summarized in the Conceptual Site Model (CSM), which includes the sources, affected media, release mechanisms, and exposure pathways for each identified receptor population.
- **Toxicity Assessment:** A presentation of available information to identify the nature and degree of toxicity and to characterize the dose-response relationship (the relationship between magnitude of exposure and magnitude of potential adverse health effects on each receptor) for each COPC.
- **Risk Characterization:** A synthesis of exposure and toxicity information to yield quantitative estimates of potential cancer risks and noncancer hazards to defined receptor populations.
- **Uncertainty Analysis:** A discussion of the uncertainties associated with each of the four previous steps to assist decision-makers in evaluating the risk assessment results in the context of the assumptions and variability in the data used.

For purposes of the HHRA, the Site includes both Zone 1 and Zone 2, as depicted on Figure 7-1 Zone 1 (the Site) includes the inactive Class I hazardous waste management facility and comprises approximately 252 acres. Zone 2 (offsite) includes the area encompassing the extent of Site-related contamination or potential contamination outside the Zone 1 boundary.

Because potential human health effects from exposure to Site-related chemicals are evaluated based on current and potential future land use scenarios, an important step in developing the risk assessment approach was to define baseline conditions. As discussed in Section 7-1, the HHRA was developed assuming that certain remedies are already in place. In this way, any pathways of exposure considered incomplete, because of the existing or presumptive remedies, were not evaluated in the HHRA. The following areas of the site have been capped: (1) the P/S Landfill, and (2) the EE/CA Area, which includes the Heavy Metals, Caustics/Cyanides and the Acids Landfill and the areas between these landfills. As discussed earlier in this RI report, the PCB Landfill located adjacent to the P/S Landfill will also be capped.

In addition, the CSC and USEPA have agreed that the two treated liquids impoundments, Pond A-5 and Pond 18, will be drained as part of Site remediation. As a result, potential exposures to treated liquid impoundment waters were not considered in the HHRA. However, impoundment sediments were evaluated as exposed surface soils, since the impoundments will be drained. As a part of this assumption, it is assumed that once drained, the treated liquid impoundment area will be graded as appropriate to minimize future collection of water.

8.2 Data Review and Evaluation

The data evaluation steps that were conducted to develop a risk assessment dataset, identify media-specific chemicals of potential concern (COPCs), and calculate exposure point concentrations (EPCs) for evaluation in the HHRA and BERA were previously discussed in Section 7. The data evaluation was conducted in addition to the procedures for field sampling, chain-of-custody, laboratory analysis, reporting and data validation that were conducted in accordance to the QAPP. The data evaluation was consistent with guidance provided by USEPA in *Risk Assessment Guidance for Superfund* (RAGS) (USEPA, 1989), *Guidance for Data Usability in Risk Assessments* (USEPA, 1992), *Data Quality Assessment: Statistical Methods for Practitioners (USEPA, 2006a)* and guidance for calculating EPCs (USEPA, 2007 a,b).

All data determined to be of sufficient quality were carried forward into the COPC selection process, which was discussed in detail in Section 7.3. COPCs were selected on a sitewide basis for soil, sediment, soil vapor and surface water. Onsite Soil COPCs were additionally evaluated with respect to each Study Area. Table 7-1 presents the list of COPCs by media that were evaluated in the HHRA.

8.3 Exposure Assessment

The objectives of an exposure assessment are to identify receptors (populations) that may be exposed to chemicals in impacted media, the exposure pathways, and the route of potential intake. In addition, for pathways considered complete, the chemical concentrations to which the receptors are potentially exposed (EPCs) and the frequency, magnitude, and duration of these potential exposures (exposure parameters) must be estimated.

The following steps are considered in the exposure assessment:

- Identification of potentially exposed receptor populations;
- Identification of complete exposure pathways;
- Estimation of exposure point concentrations for specific pathways; and

- Estimation of chemical intakes for receptor populations associated with each complete exposure pathway.

The end product of the exposure assessment is a measure of chemical intake as an average daily dose (ADD) that integrates the exposure parameters for the receptors of concern (e.g., contact rates, exposure frequency, and duration) with the EPC for the media of concern. These ADDs are then used in conjunction with chemical-specific toxicity values (e.g., reference doses and cancer slope factors) to arrive at an estimate of potential health risks for the receptors of concern.

This section describes the steps that were followed in the exposure assessment.

8.3.1 Conceptual Site Model

The Conceptual Site Model (CSM) identifies potential chemical sources, release mechanisms, transport media, routes of chemical migration through the environment, exposure media, and potential receptors. Receptors that may be potentially exposed to Site-related chemicals are identified and the likelihood of their potential exposures assessed through consideration of the current and the anticipated future use of the Site.

The CSM represents the understanding of the sources of chemicals of potential concern, the means by which they are released and transported within and among media, and the exposure pathways and routes by which both human and ecological receptors may contact them. For potential human health exposures, the CSC formulated three specific CSMs for Zones 1 and 2 based on a review of previous and additional information that has been collected for the Site (see Figures 6-1 through 6-3 of the Workplan). Figures 8-1 and 8-2 present the revised CSMs for the HHRA. The major components of the CSMs are discussed below and in more detail in Appendix T.

8.3.2 Exposure Pathways and Receptors

Given the characteristics of the COPCs and conditions at the Site and adjacent areas, several exposure pathways may be potentially complete. Exposure pathways and receptors were selected based on current and future use of the Site.

Based on current, available information, the following exposure pathways were considered potentially complete for human receptors at the Site:

- Incidental ingestion of COPCs in soil, sediment, or surface water;
- Contact with soil, sediment, or surface water and absorption of COPCs through the skin;
- Inhalation of COPCs in windborne dust generated from soil or sediment;
- Inhalation of vapors emanating from soil, sediment, or surface water into outdoor air;
- Inhalation of vapors emanating from soil vapor into outdoor air;
- Inhalation of vapors emanating from onsite soil into indoor air;
- Inhalation of vapors emanating from offsite soil vapor into indoor air; and
- Ingestion of beef.

The current land-use of Zone 1 is a hazardous waste management facility. Land-use surrounding the Site includes open-space, cattle grazing and oil-field development. The majority of land that adjoins the Site (Zone 2) is owned and controlled by the CSC. There are privately

held land(s) that currently adjoin the site on the southwest border of the Site. These lands are being used for cattle-grazing.

The CSC is in the process of working with EPA to place deed restrictions on both the parcels of land that the Site occupies and approximately 1,000 acres that surround the site (i.e. in Zone 2). Future residential development is unlikely based on current zoning and the deed restrictions that will be in place. Nevertheless, a hypothetical future residential exposure scenario for Zone 2 was included in this HHRA as the deed restriction process has not been completed. Residential exposure pathways are indicated as only potentially complete in the CSM due to the hypothetical nature of this pathway.

Based on the well survey information, the groundwater beneath and in the immediate vicinity of the Site is not currently being used for potable water. In addition, groundwater extraction for purposes of potable water will not be allowed in the future. Therefore, this exposure pathway was not considered complete and was not evaluated in the HHRA.

The following receptors may be potentially exposed to Site-related chemicals within Zone 1:

- Onsite workers maintaining the liquids treatment area, surface impoundments, and landfill covers and drainage structures;
- Trespassers; and
- Ranchers using the NTU road to access their lands.

The following receptors were also evaluated in the HHRA since they are potentially exposed to Site-related chemicals within Zone 2:

- Ranchers working the fields along the southwest border of Zone 1;
- Consumers of beef raised in the fields near Zone 1;
- Recreational users of the drainage areas; and
- Hypothetical residents living near the Site.

Middle school- and high school-aged children (11-17 year olds) were included as part of the evaluation for the recreational scenario. Based on professional judgment, recreational use of the surrounding area of the Site, within Zone 2, is not expected. Access to this area is considered limited, no trails have been observed, and the area is used primarily for cattle grazing. Although the area surrounding the Site does not appear to be used for recreational purposes, this scenario was evaluated in this HHRA as a conservative approach. Moreover, an assumption of once per month as the exposure frequency is considered conservative for this particular receptor given that person has a low potential for recreating within Zone 2.

The following table summarizes the receptor groups, exposure medium and exposure pathways under current and potential future land use conditions that were quantitatively evaluated in the HHRA.

Receptor Population	Exposure Medium	Study Area	Exposure Pathways
Commercial/ Industrial Worker	Onsite Soil/Sediment SS = 0-6 inches bgs SB = 0-5 feet bgs	**Onsite Soil =** • Administration Building • Burial Trench • Central Drainage • FPP • Liquid Treatment • Maintenance Shed • RCRA Canyon • Roadways • Remaining Onsite • West Canyon Spray **Onsite Sediment =** • Pond 18 • Pond A-5	• Incidental Ingestion • Dermal Contact • Outdoor Fugitive Dust/Vapor Inhalation
	Onsite Surface Water	• A-Series Pond • Pond 13 • RCF Pond	• Incidental Ingestion • Dermal Contact • Outdoor Inhalation
	Onsite Soil Vapor	• Onsite Soil Vapor	• Outdoor Vapor Inhalation
	Onsite Soil SB = 0-5 feet bgs	• Administration Building	• Indoor Air Vapor Inhalation
Trespasser	Onsite Soil/Sediment SS = 0-6 inches bgs SB = 0-5 feet bgs	**Onsite Soil =** • Administration Building • Burial Trench • Central Drainage • FPP • Liquid Treatment • Maintenance Shed • RCRA Canyon • Roadways • Remaining Onsite • West Canyon Spray **Onsite Sediment =** • Pond 18 • Pond A-5	• Incidental Ingestion • Dermal Contact • Outdoor Fugitive Dust/Vapor Inhalation
	Onsite Surface Water	• A-Series Pond • Pond 13 • RCF Pond	• Incidental Ingestion • Dermal Contact

Receptor Population	Exposure Medium	Study Area	Exposure Pathways
Recreator	Offsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Offsite Sediment SS = 0-6 inches bgs	**Offsite Soil =** • B Drainage **Offsite Sediment =** • North Drainage • A Drainage • Lower Drainage • Upper C Drainage	• Incidental Ingestion • Dermal Contact • Outdoor Fugitive Dust/Vapor Inhalation
Rancher	Offsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Offsite Sediment SS = 0-6 inches bgs	**Offsite Soil =** • B Drainage **Offsite Sediment =** • North Drainage • A Drainage • Lower Drainage • Upper C Drainage	• Incidental Ingestion • Dermal Contact • Outdoor Fugitive Dust/Vapor Inhalation • Ingestion of Beef
	Onsite Roadway Soil SS = 0-6 inches bgs SB = 0-5 feet bgs	• Roadways	• Incidental Ingestion • Dermal Contact • Outdoor Fugitive Dust/Vapor Inhalation
Hypothetical Offsite Resident	Offsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Offsite Sediment SS = 0-6 inches bgs	**Offsite Soil =** • B Drainage **Offsite Sediment =** • North Drainage • A Drainage • Lower Drainage • Upper C Drainage	• Incidental Ingestion • Dermal Contact • Outdoor Fugitive Dust/Vapor Inhalation
	Offsite Soil Vapor	• Offsite Soil Vapor	• Indoor Air Vapor Inhalation
	Onsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs	**Onsite Soil =** • Administration Building • Burial Trench • Central Drainage • FPP • Liquid Treatment • Maintenance Shed • RCRA Canyon • Roadways • Remaining Onsite • West Canyon Spray	• Outdoor Fugitive Dust/Vapor Inhalation

Notes: SS = refers to surface soil; SB = refers to shallow soil

8.3.3 Exposure Point Concentrations

Exposure point concentrations (EPCs) are the concentrations of chemicals in environmental media to which receptors may be exposed through defined exposure pathways. EPCs were estimated for each of the environmental media associated with complete and potentially complete pathways identified in the CSM. These media and pathways include the following:

- Surface (0 to 6 inches bgs) and shallow soil (0 to approximately 5 feet bgs; this also includes data from 5 – 5.5 feet bgs) considered for incidental ingestion, dermal contact, and inhalation of fugitive dust and vapor pathways, as well as ingestion of beef;
- Surface (0 to 6 inches bgs) and shallow sediment (0 to approximately 5 feet bgs) considered for incidental ingestion, dermal contact, and inhalation of fugitive dust and vapor pathways;
- Soil vapor considered for the vapor inhalation pathway; and
- Surface water considered for incidental ingestion, dermal contact and inhalation pathways.

Evaluating data collected from shallow soils (0 to approximately 5 feet bgs) accounts for potential future exposure to the subsurface soils if the Site and adjacent areas become reconfigured and deeper soils are brought to the surface and made available for direct contact exposures (e.g., via incidental ingestion, dermal contact) and outdoor air inhalation of fugitive dust and vapors. While individuals are unlikely to have direct contact with impacted soil at depths greater than 5 feet bgs, the potential does exist for VOCs to migrate from beneath the subsurface. Therefore, onsite and offsite soil vapor samples collected at depths of greater than 5 feet bgs were used to evaluate the the vapor pathways for a commercial/industrial worker (outdoor air) and a hypothetical resident (indoor air) living near the Site, respectively. In addition, onsite soil data from samples in close proximity to the Administration Building were used to evaluate the indoor air pathway for onsite commercial/industrial workers.

Derivation of EPCs is discussed in more detail in Section 7.4. EPCs were derived using the same statistical methodology for soil, sediment, and surface water. EPCs for the outdoor and indoor air exposure pathways in the HHRA were further developed using fate and transport modeling as described in Appendix T.

8.3.4 Estimating Chemical Intake

The exposure assessment quantifies the magnitude, frequency, and duration of chemical intake (daily intake) by receptor populations. ADD or “Lifetime Average Daily Dose” (LADD) of COPCs for each exposure pathway was estimated. ADDs and LADDs were calculated using guidelines in the Risk Assessment Guidance for Superfund (USEPA, 1989), Site-specific information, and professional judgment, as appropriate.

The ADD or LADD is estimated by multiplying an intake factor by the selected EPC (COPC concentration). The intake factor combines the Site-specific and receptor-specific assumptions for a given exposure pathway and is expressed as the amount of media (e.g., soil) taken into the body per unit concentration of chemical in the media. Multiplying the intake factor by the selected EPC yields the ADD or LADD (mg/kg-day) for that receptor population and exposure pathway. The following is a generic equation used to estimate the daily dose:

$$\text{ADD/LADD (mg/kg - day)} = \text{Selected EPC x Summary Intake Factor}$$

Separate intake factors are estimated for each exposure pathway. The values and assumptions used to estimate each intake factor are dependent on the exposure pathway and receptor population being evaluated. A more detailed description of the values used for the intake calculations are presented in Appendix T.

8.4 Toxicity Assessment

The toxicity assessment 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. For purposes of calculating exposure criteria to be used in HHRAs, adverse health effects are classified into two broad categories: noncarcinogens and carcinogens. Toxicity criteria are generally developed based on the threshold approach for noncancer effects and the non-threshold approach for cancer effects.

Potential cancer effects resulting from human exposure to carcinogens are generally estimated quantitatively using oral cancer slope factors (CSFs) or inhalation unit risk factors (URFs). Oral CSFs are expressed in units of $(\text{mg/kg-day})^{-1}$. To characterize potential cancer risks from inhalation, URFs were converted when needed from units of $(\text{ug/m}^3)^{-1}$ to units of $(\text{mg/kg-day})^{-1}$ by assuming that an individual inhales at a rate of 20 cubic meter per day, and has an average body weight of 70 kg and this absorption is equivalent by either route (USEPA, 1989).

Potential noncancer effects resulting from human exposure to noncarcinogens are estimated quantitatively using chronic reference doses (RfDs) for ingested chemicals and reference concentrations (RfCs) for inhaled chemicals.

These toxicity values are developed by the USEPA RfD/RfC workgroup on the basis of a wide array of noncancer health effects. The RfD, expressed in units of milligrams of chemical intake per kilogram of body weight per day (mg/kg-day), is an estimate of the maximum human exposure level that can be present without an appreciable risk of deleterious effects during a designated time. The RfC is expressed in units of milligrams of chemical per cubic meter of air (mg/m^3) and is an estimate of the maximum air concentration that can be present without an appreciable risk of deleterious effects. RfCs assume a human body weight of 70 kilograms and an inhalation rate of 20 m^3/day. In addition, Cal-EPA has developed chronic Reference Exposure Levels for the Air Toxics Hot Spots program, which were used if they were more conservative than the RfCs.

As is the case for the CSFs, RfDs and RfCs are only available for oral and inhalation exposures. In the absence of criteria specific to the dermal exposure pathway, the oral RfDs were used to evaluate the dermal route of exposure.

In the HHRA, chronic toxicity criteria were selected (in order of preference) from the following sources: 1) Cal-EPA Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database, online (2007a); 2) USEPA's (2007) Integrated Risk Information System (IRIS) as referenced in USEPA Region IX Preliminary Remedial Goals (PRG) table (USEPA, 2004b); 3) USEPA (1997) Health Effects Assessment Summary Tables (HEAST), as referenced in the Region IX PRG table (USEPA, 2004b); or 4) USEPA NCEA Superfund Health Risk Technical Support Center, as referenced in the USEPA PRG table (2004b).

The traditional RfD approach to the evaluation of chemicals is not applied to lead because most human health effects data are based on blood lead concentrations, rather than external dose (Cal-EPA, 1992). The Centers for Disease Control has identified the Lowest Observed Affect Level for lead of 10 micrograms of lead per deciliter (μg/dl) and 30 μg/dl for children and adults, respectively. Consistent with the Centers for Disease Control, Cal-EPA DTSC previously considered exceedances over 10 μg/dl of whole blood (μg/dl) as levels that could indicate potential adverse effects. However, more recently, the Cal-EPA OEHHA has developed a 1 μg/dL benchmark for source-specific incremental change in blood lead levels for protection of school children and fetuses (Cal-EPA, 2007b). This value is now being used by Cal-EPA for evaluating potential lead exposures.

8.5 Risk Characterization

Risk characterization integrates the results of the toxicity assessment (Section 8.4) and the exposure assessment (Section 8.3) to estimate potential cancer risks and adverse noncancer health effects associated with exposure to chemicals detected at the Site. This integration provides quantitative estimates of risk and noncancer hazard that are then compared to acceptable standards.

The process of risk assessment is an iterative process where Site, receptor, and chemical-specific data are used when available. When Site-specific data are not available, conservative (i.e., health protective) assumptions are utilized. The use of repeated, conservative assumptions can lead to overly conservative estimations of risk but certainly provides an upper-bound estimate of the actual risk. Thus, for any site, the estimated risk level reflects an upper-bound estimate of the most probable risk. The most probable risk is likely to be much less, perhaps as low as zero, and probably not measurable in the potentially exposed population.

8.5.1 Introduction to Risk Characterization

Various demarcations of acceptable risk have been established by regulatory agencies. For example, the USEPA has established an acceptable risk range for Superfund sites. The National Contingency Plan (NCP; 40 CFR 300) indicates that lifetime incremental cancer risks posed by a site should not exceed a range of one in one million (1×10^{-6}) to one hundred in one million (1×10^{-4}) and noncarcinogenic chemicals should not be present at levels expected to cause adverse health effects (i.e., a hazard index [HI] greater than 1). Other relevant guidance (USEPA, 1991b) additionally states that sites posing a cumulative cancer risk of less than 10^{-4} and hazard indices less than unity (1.0) for noncancer endpoints are generally not considered to pose a significant risk warranting remediation. The California Hazardous Substances Account Act (HSAA) incorporates the NCP by reference, and thus also incorporates the acceptable risk range set forth in the NCP. The Resource Conservation and Recovery Act (RCRA) Corrective Action program incorporates this same range of potential health risks as the “acceptable risk range” for determining whether corrective action is warranted at RCRA facilities and for closure purposes. Finally, The Safe Drinking Water and Toxic Enforcement Act of 1986 (California Proposition 65) regulates chemical exposures to the general population and is based on an acceptable risk level of 1×10^{-5}.

The maximum acceptable risk level for a site is between 10^{-4} and 10^{-6}, and is selected on a case-by-case basis by USEPA. The risk range between 10^{-4} and 10^{-6} is commonly called the “discretionary risk range.”

For the purposes of this section, a cumulative risk of 1 x 10^{-5} and noncancer hazard index of 1 is used to compare industrial/commercial worker risk estimates. For all other potential exposures a risk level of 1 x 10^{-6} and noncancer hazard index of 1 is used. These risk levels are used to provide context to the risk results and to support the following discussion which focuses on those pathways and chemicals that contribute the majority to the risk estimates. It is acknowledged that additional risk management considerations such as technical feasibility, economic, social, political, and legal factors may be part of the final risk management decision. The results of the risk characterization are really the starting point for risk management considerations for a site (USEPA, 1995).

8.5.2 Risk Characterization Results

Excess cancer risks are expressed as the upper-bound, increased likelihood of an individual developing cancer as a result of exposure to a particular chemical. For example, a cancer risk of 1 x 10^{-4} refers to an upper-bound increased chance of one in ten thousand of developing cancer over a lifetime.

In the risk characterization step of the HHRA, excess cancer risk was estimated by multiplying the LADD by the chemical-specific cancer slope factor (CSF). The following equation was used to estimate the excess cancer risk per each COPC:

$$\text{Excess Cancer Risk} = \text{LADD x CSF}$$

The chemical-specific excess cancer risks were then summed to yield a cumulative cancer risk, which is typically compared to the USEPA acceptable risk range of 10^{-6} to 10^{-4}.

The potential for noncancer effects due to exposure to a particular chemical is expressed as the hazard quotient (HQ). Chemical-specific hazard quotients were estimated by calculating the ratio of the ADD to the corresponding chronic reference dose (RfD) for noncancer effects. The following equation was used to estimate the noncancer hazard quotient:

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

The chemical-specific hazard quotients were then summed to form a cumulative hazard index (HI), which was compared to an acceptable hazard level of one (1). For multiple chemical exposures, the total HI might exceed 1 even if no single chemical intake exceeds its RfD. If the cumulative HI is less than the benchmark level of one (1), cumulative exposures to the COPCs at the Site are judged unlikely to result in adverse noncancer health effects. If the sum is greater than 1, a more detailed and critical evaluation of potential noncancer health hazards may be warranted. Such additional evaluation considers the specific target organ(s) affected and mechanism(s) of action of the COPCs.

The chemical-specific potential cancer risk and hazard index estimates are presented in Tables 8-1 through 8-7 for each of the receptor groups, media, and exposure pathways discussed above. The detailed HHRA is presented in Appendix T. The table below summarizes the receptor groups and exposure medium evaluated in this HHRA.

Receptor Population	Exposure Medium	Corresponding Table
Commercial/Industrial Worker	Onsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Onsite Sediment SS = 0-6 inches bgs SB = 0-5 feet bgs	**Table 8-1** **Table 8-3**
	Onsite Surface Water	**Table 8-4**
	Onsite Soil Vapor	**Table 8-5**
	Administration Building Soil	**Table 8-6**
Trespasser	Onsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Onsite Sediment SS = 0-6 inches bgs SB = 0-5 feet bgs	**Table 8-1** **Table 8-3**
	Onsite Surface Water	**Table 8-4**
Recreator	Offsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Offsite Sediment SS = 0-6 inches bgs	**Table 8-2**
Rancher	Offsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Offsite Sediment SS = 0-6 inches bgs	**Table 8-2**
	Onsite Roadway Soil SS = 0-6 inches bgs SB = 0-5 feet bgs	**Table 8-1**
Hypothetical Offsite Resident	Offsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs Offsite Sediment SS = 0-6 inches bgs	**Table 8-7**
	Offsite Soil Vapor	
	Onsite Soil SS = 0-6 inches bgs SB = 0-5 feet bgs	

Notes: SS = refers to surface soil; SB = refers to shallow soil

For potential exposures to onsite soils and sediments via direct contact (ingestion and dermal contact) and outdoor inhalation (Tables 8-1 and 8-3, respectively), only the FPP and Liquid Treatment Study Areas exhibited elevated risk for commercial/industrial worker exposures with a cumulative risk of 5 x 10^{-5} and a noncancer HI of 2, respectively. PCE in shallow soil was the primary risk driver for the FPP Study Area and MCPP was the primary risk driver for both surface and shallow soils at the Liquid Treatment Study Area. In addition, risk estimates for trespasser exposures to FPP soils were slightly elevated (2 x 10^{-6}) due to the presence of PCE in subsurface soils. The sample locations that contributed the majority to these risk estimates were RISBON-37, RISBON-41 and RISBON-63 in the FPP Study Area just south of the PSCT and RISBLT-02 in the Liquid Treatment Study Area.

For offsite soils/sediments (Table 8-2), cancer risk and noncancer hazard estimates for recreational and rancher exposures were below a cancer risk level of 1 x 10^{-6} and a noncancer hazard of 1.

For onsite surface water, Ponds A-Series (Table 8-4), 13 and RCF cancer risk estimates were elevated for commercial/industrial worker exposures (maximum cumulative risk of 8 x 10^{-5}) and trespassers (maximum cumulative risk of 3 x 10^{-6}) with arsenic being the primary risk driver. All noncancer HIs were below 1.

For the hypothetical offsite resident (Table 8-7), the Burial Trench, Central Drainage, and FPP Study Areas exhibited elevated risk due to exposures from the transport of onsite vapors to offsite locations, with a maximum cumulative risk estimate for the Burial Trench Study Area of 1 x 10^{-5}. The primary risk drivers were tetrachloroethene and trichloroethene. The sample locations that contributed the majority to these risk estimates were RISBON-37, RISBON-41 and RISBON-63 in the FPP Study Area just south of the PSCT, RISBCD-07 in the Central Drainage Study Area and RISSBC-05 in the Burial Trench Study Area. It should be noted that the hypothetical offsite resident evaluation is overly conservative in that the modeling assumes the resident is located adjacent to the Study Area being evaluated. In reality, the resident would be located some distance from the Study Area boundary thereby resulting in lower estimates of exposure.

For other hypothetical offsite residential exposures (Table 8-7), only the vapor intrusion pathway resulted in a marginally elevated risk estimate with a cumulative risk estimate of 2 x 10^{-6}. The primary risk driver for this pathway was 1,3-butadiene. When considering more recent soil vapor sampling, this risk estimate would be even lower and similar to the target risk level of 1 x 10^{-6}.

Adverse health effects associated with exposure to lead have been correlated with concentrations of lead in whole blood and not with intake of lead by an individual. Because lead was selected as a COPC, the health effects of lead were evaluated by using the DTSC LeadSpread version 7.0 model to predict the percentile blood lead level for adults and children with an age range of 11 to 17 years old. Because this model provides blood lead predictions for adults and 1-2 year old children, the default exposure parameters (e.g., skin surface area, soil adherence factor, soil ingestion rate, etc.) were revised to reflect age-specific exposure assumptions for 11 to 17 year-old children.

The DTSC previously considered exceedances over 10 μg/dl of whole blood as levels that could indicate potential adverse effects consistent with the Centers for Disease Control Lowest Observed Affect Level for lead of 10 μg/dl and 30 μg/dl for children and adults, respectively. More recently, the Cal-EPA OEHHA has developed a 1 μg/dL benchmark for source-specific

incremental change in blood lead levels for protection of school children and fetuses (Cal-EPA, 2007b). This value is now being used by Cal-EPA for evaluating potential lead exposures. Based on the revised target blood lead level OEHHA derived California Human Health Screening Levels (CHHSLs) of 80 mg/kg and 320 mg/kg for residential and occupational exposures, respectively (Cal-EPA 2009). Lead EPCs in onsite soils for the Study Areas ranged in concentrations from 9.8 mg/kg to 498 mg/kg with a Site-Wide 95UCL of 17.3 mg/kg. The highest lead EPC (498 mg/kg) was from surface soil at the Maintenance Shed Study Area, with the next highest lead EPC (295 mg/kg) from the same Study Area but in shallow soil. All other lead EPCs were less than or equal to 61 mg/kg. The results of the lead evaluation indicated that no predicted blood lead levels (neither 95th nor 99th percentiles) exceeded the previous DTSC threshold of 10 μg/dl. In addition, all Study Area lead EPCs, with the exception of the Maintenance Shed Area, as well as the Site-Wide lead EPC were below the most conservative lead CHSSL of 80 mg/kg. For the Maintenance Shed Area, the surface soil EPC was above the industrial CHHSL of 320 mg/kg; however the EPC is being driven by one sample, RISBMS-11 in which the lead concentration is 970 mg/kg. The next highest concentration is 160 mg/kg well below the industrial CHHSL. The LeadSpread worksheets are presented in Appendix T.

8.6 Uncertainty Analysis

The methodology used in the HHRA is consistent with USEPA and Cal-EPA risk assessment guidance. However, the procedures used in any quantitative RA are conditional estimates given the many assumptions that must be made about exposure and toxicity. Major sources of uncertainty in risk assessment include (1) natural variability (e.g., differences in body weight or sensitivity in a group of people); (2) incomplete knowledge of basic physical, chemical and biological processes (e.g., the affinity of a chemical for soil, degradation rates); (3) model assumptions used to estimate key inputs (e.g., exposure, dose response models, fate and transport models); and (4) measurement error primarily with respect to sampling and laboratory analysis.

Site-specific factors, which this HHRA incorporated, decrease uncertainty, although uncertainty may persist in even the most site-specific RAs due to the inherent uncertainty in the process. However, because the assumptions used tend to be health-protective and conservative in nature, the estimated risks are likely to exceed the most probable risk posed to potential receptors at the Site and actual risks would be much lower.

In addition to the factors mentioned above, at the request of the EPA additional information is included in this section including (1) a qualitative evaluation of the PCB Landfill, (2) a qualitative evaluation of soil samples collected for the RISBON-59 area and (3) an evaluation of a 100 percent ingestion rate for home-grown beef.

Some of the most significant elements affecting uncertainty for this HHRA include:

- It was assumed that chemical concentrations remain constant over the duration of exposure. No abiotic or biotic degradation mechanisms, which reduce the concentrations of COPCs over time, are assumed to occur. This general assumption of steady-state conditions also applies to sources and chemical release mechanisms and may result in a conservative estimation of long-term exposure concentrations.
- The exposure assumptions used for the RME approach are considered conservative and likely lead to overstating the most probable estimate of potential risk. For example, the RME exposure scenario assumes a hypothetical offsite resident will remain at the same

location from birth through age 30 years for 350 days per year, or a commercial worker will work at the site for 25 years.

- Intake parameters for the various exposure pathways (soil ingestion, dermal contact, inhalation) were conservatively assumed to be upper bound estimates (e.g., 3300 cm^2 of exposed skin exposed every day–regardless of the weather conditions–or ingestion of 100 mg of soil each day over the exposure period for adults, etc.) for the RME approach.
- For exposures via outdoor air inhalation, the outdoor air flux model assumes that the VOC is present at the surface and that the receptors will come into contact via outdoor air inhalation. When chemicals are present at depths below 6 inches, the flux would be lower resulting in lower estimates of potential risk.
- Soil samples were collected as part of the Phase III RI where step-out borings were completed in the RISBON-59 area (located along NTU road, south west of the west end of RCF pond). However data from this round of sampling were not included in the risk evaluation. The Phase III data relevant for exposure from 0 to 5 feet bgs (samples collected at 0.5 feet bgs and 6 feet bgs) were compared to metals background UTLs and/or human health screening levels. This screening indicated marginal potential risks from the N-nitroso compounds in two samples. These samples represent a small potential exposure given that they represent a localized area of primarily subsurface impacts and site-workers would not be in the area on a frequent basis. While there is some uncertainty in not including these samples, due to the localized nature of impact and infrequent exposure potential, the results and conclusions reached in this HHRA are not significantly impacted.
- This HHRA assumed that the PCB Landfill has been capped as discussed in the conceptual site model earlier in the report. The PCB Landfill has an interim soil (claystone) cover of unknown thickness placed in the 1980's with the northern part of the landfill currently used as a temporary storage area for the CSC's investigation-derived waste. According to existing information (RCRA Part B Permit Application, Modernization Plan Final EIR), the interim cover soil generally came from the area in which the landfill was constructed and was placed at a minimum 1-foot thickness. The presence of a 1-foot minimum thickness of cover does provide a barrier for human contact. In addition, due to the nature of the area being a landfill, worker exposure would not be expected due to intrusive activities beneath the cover. As a result potential human health risk to PCB Landfill contents is considered insignificant.
- Revising the assumption that ranchers consume only 10% of beef from their own lots to assuming that they consume 100% of their own beef resulted in risk and hazard estimates that were also significantly less than the target risk levels of 1×10^{-6} and 1, respectively. Therefore the results and conclusions reached in the HHRA for this pathway are not significantly impacted.
- The risk assessment focused on soil from surface to approximately 5 feet bgs as this is considered the most likely depth interval that may be contacted. If significant concentrations were present at depths below that interval and the soil was brought to the surface then exposures may have been underestimated. To evaluate this issue, the data from greater than 5 feet to 10 feet bgs were reviewed. There was one area where deeper concentrations were significantly higher in RISBON-37. However, this location has already been identified in the risk assessment as posing a potential health risk and will likely be targeted for remediation.

- Default soil physical properties were used for the soil type, silty clay (SIC). Lack of Site-specific values may introduce some uncertainty into the vapor modeling and may result in an over-prediction or under-prediction of vapor inhalation exposures from beneath the surface.
- A hypothetical resident was evaluated assuming locations near the Site (offsite) would be developed as residential land use. This land use is highly unlikely given the nature of the Site and the planned use of institutional controls such as deed restriction to preclude this type of land use.
- For modeling of onsite impacts to offsite locations via the windblown particulate and vapor pathways for soil, it was assumed that the hypothetical resident was located adjacent to the Study Area being evaluated. This is a conservative assumption as the actual offsite location would likely be much farther from the Study Area boundary resulting in decreased exposures.

8.7 Summary and Conclusions

This HHRA was prepared to evaluate potential baseline health risks associated with chemicals present in soil, sediment, soil vapor, and surface water at the Site. The results of the HHRA can be used to identify chemicals and exposure media that may pose an unacceptable risk to current and/or future receptors at the Site and to provide information for remedial planning. This risk assessment was prepared as part of the RI to evaluate potential exposures and "define risks to public health and the environment" related to soil, sediment, soil vapor, and surface water, and to subsequently provide information for the FS.

The chemicals of potential concern evaluated include inorganics, PCBs, dioxins, herbicides/pesticides, PAHs, SVOCs, and VOCs. Potential exposure scenarios that were considered include inhalation of indoor air and outdoor air vapors, inhalation of particulates, dermal contact with surface water, and exposure via direct contact to soils and sediment.

The results of the HHRA indicate that the following COPCs are primary risk drivers: MCPP, tetrachloroethene, trichloroethene in onsite soils and arsenic in onsite surface water.

For onsite soils, only the FPP and Liquid Treatment Study Areas exhibited elevated risk estimates for commercial/industrial worker exposures. PCE in shallow soil was the primary risk driver for the FPP Study Area and MCPP was the primary risk driver for both surface and shallow soils at the Liquid Treatment Study Area. Both of these chemicals are present at elevated concentrations in localized areas within the Study Areas as shown in the figures for these chemicals presented in Section 5 of the RI Report.

For the hypothetical offsite resident, only the Burial Trench, Central Drainage, and FPP Study Areas exhibited elevated risk estimates from potential exposures from the transport of onsite soil contamination via windborne vapors. The primary risk drivers were tetrachloroethene and trichloroethene which are both present at elevated concentrations in localized areas within the Study Areas. It should be noted that the hypothetical offsite resident evaluation is overly conservative in that the modeling assumes the resident is located adjacent to the Study Area being evaluated. In reality, the resident would be located some distance from the Study Area boundary thereby resulting in lower estimates of exposure. For hypothetical offsite residential exposures to offsite soil, sediment and soil vapor, only the vapor intrusion pathway results in a marginally elevated risk estimate. The primary risk driver for this pathway was 1,3-butadiene.

When considering more recent soil vapor sampling, this risk estimate would be even lower and similar to the target risk level of 1×10^{-6}.

For offsite soils/sediments cancer risk and noncancer hazard estimates for recreational and rancher exposures were below a cancer risk level of 1×10^{-6} and a noncancer hazard of 1.

Potential cumulative cancer risk and noncancer hazard estimates exceeded target health levels due to a few locations within a few Study Areas. The sample locations that contributed the majority to the risk estimates were RISBON-37, RISBON-41 and RISBON-63 in the FPP Study Area just south of the PSCT, RISBLT-02 in the Liquid Treatment Study Area, RISBCD-07 in the Central Drainage Study Area and RISSBC-05 in the Burial Trench Study Area. The results indicate that Site cleanup, engineering controls and/or institutional controls may be necessary to mitigate potential risks associated with these localized areas.

8.8 References

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9.0 ECOLOGICAL RISK ASSESSMENT

This section presents the Ecological Risk Assessment (ERA) prepared by ARCADIS (formerly Blasland, Bouck & Lee, Inc. [BBL]) for the Site. This ERA is consistent with the Work Plan prepared by the CSC (2004) and describes the most current approach and methodologies used to conduct an ERA, including modifications to some extent based on input from the agencies in spring and summer 2007, and incorporating comments from agencies received on October 15, 2008. This section provides a summarized version of the ERA, which is presented in detail in Appendix U of this RI Report.

The objective of this ERA was to conduct a sitewide assessment using a tiered approach that provides information for the RI. To achieve this objective, the CSC assessed whether Site-related chemicals in onsite media have adversely affected resident flora (plants) and migratory or resident fauna (animals). The findings and conclusions of the ERA will be further refined and utilized in the feasibility study (FS) portion of the environmental program to develop and evaluate remedial alternatives protective of these biota. Ultimately, the conclusions reached from conducting the ERA, along with other information, will be utilized in establishing an overall Site risk management strategy. These objectives are consistent with the U.S. Environmental Protection Agency's (USEPA's) defined functions of an ERA (USEPA, 1997):

- Document whether actual or potential ecological risks exist at the Site;
- Identify which contaminants present at the Site pose an ecological risk; and
- Generate data to be used in evaluating cleanup options.

Details of this ERA are presented in Appendix U and include:

- A description of the approach for the tiered (Screening-Level, Tier 1, and Tier 2), risk-based process;
- A description of the results of biological surveys conducted at the Site;
- A definition of baseline conditions;
- A conceptual site model including habitats, receptors, and complete exposure pathways;
- An overview of the technical approach discussing the exposure scenarios, models necessary to conduct the exposure assessments, and ecological benchmarks;
- A description of the effects assessment including development of toxicity values protective of ecological receptors;
- A description of the Screening-Level and Tier 1 risk characterization process;
- A description of the uncertainties associated with the Screening-Level and Tier 1 ERA process;
- A summary of the Screening-Level and Tier 1 ERA with conclusions and recommendations;
- A description of the approach for a Tier 2 ERA;
- An overview of the technical approach discussing the exposure scenarios, models necessary to conduct the Tier 2 exposure assessments using Site-specific parameters, and summary of Site-specific biota studies conducted;
- An overview of the development of tissue toxicity values protective of ecological receptors;
- A description of the Tier 2 risk characterization process;
- A description of the uncertainties associated with the Tier 2 ERA process;

- A summary of the Tier 1 and 2 ERA with conclusions and recommendations.

9.1 Overview of Approach

The overall approach for this risk assessment followed all applicable guidance documents and regulations to identify those locations, receptors, and pathways that are drivers for risk management decisions. An ERA is the process of estimating and characterizing the likelihood that adverse ecological effects may be occurring or have occurred as a result of exposure to one or more chemical stressors (USEPA, 1997), and the process consists of the four main phases: (1) Problem Formulation, (2) Analysis, (3) Risk Characterization, and (4) Uncertainty Analysis (USEPA, 1992a, 1997, 1998; CalEPA, 1996). USEPA and the California Environmental Protection Agency (CalEPA) recommend that an ERA be conducted in an iterative, or tiered manner, as described below. Although the same basic components are found within each tier of analysis, greater detail and refinement are characteristic of each successive tier. The components of the ERA are summarized in this section; details are presented in Appendix U. The tiers evaluated are as follows:

- In the Screening-Level ERA, components, such as use of maximum exposure estimates and conservative ecological benchmarks based on no-observed adverse effects levels (NOAELs), were incorporated and risks were estimated for all the chemicals of potential ecological concern (CPECs).
- In the Tier 1 ERA, components, such as use of upper-bound exposure estimates and ecological benchmarks based on lowest-observed adverse effects levels (LOAELs), were incorporated and risks were estimated for all the CPECs.
- In the Tier 2 ERA, components, such as use of upper-bound exposure estimates, use of Site-specific biota uptake values, and ecological benchmarks based on LOAELs, were incorporated and risks were estimated for all the “risk drivers” or chemicals of interest (COIs) identified in the Tier 1 ERA.

9.2 Problem Formulation

The first step of an ERA addresses elements of Problem Formulation and includes (1) description of environmental setting; (2) delineation of exposure areas; (3) development of conceptual site models (CSMs), which includes identification of exposure pathways and identification of ecological and indicator receptors; and (4) identification of assessment and measurement endpoints.

9.2.1 Environmental Setting

The location and description of the Site is discussed in Section 2.0, and detailed information on habitats and biota are provided in detail in the Biological Species and Habitat Survey (BSHS) report (Appendix P). For the purposes of this ERA, the 252-acre Site was divided into the following types of habitat: (i) terrestrial capped areas, (ii) terrestrial uncapped areas, and (iii) freshwater aquatic areas.

A considerable area of the Site is currently capped (approximately 47 acres) or planned to be capped (approximately 5 acres); exposures to ecological receptors from these areas of the Site can be considered minimal to unlikely once all capping is complete and as long as the landfill caps are adequately maintained. Habitats and receptors present in the capped areas of the Site are expected to be the same as those described as terrestrial uncapped areas. Terrestrial

habitats and receptors in the offsite areas are also expected to be similar to those onsite. The terrestrial uncapped areas of the Site are generally characterized as disturbed, sparsely vegetated, annual/grazed grassland area.

The freshwater aquatic areas include large impoundments for the collection of surface water runoff onsite. These include the RCF Pond, the A-Series Pond, Pond 13, Pond 18, Pond A-5. Allr ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the Site. Weedy grasses and forbs may be present along the borders of the ponds. However, the pond borders also contain gravel, debris, and unvegetated soil. Although these ponds are highly degraded, use by birds, mammals, and aquatic life is likely. These waters could be inhabited by aquatic invertebrates and amphibians and also used for foraging by mammals and birds. In addition, freshwater aquatic areas include RCRA Canyon runoff and offsite drainages. Onsite seeps no longer exist; however, potential risk based on historical seep data are discussed qualitatively in the risk characterization section.

9.2.2 Biological Surveys

In cooperation with the California Central Coast Regional Water Quality Control Board (RWQCB), California Department of Fish and Game (CDFG), U.S. Fish and Wildlife Service (USFWS), and USEPA, the CSC developed a list of 39 known or potentially occurring species of concern within or proximate to the Site. The list of species is presented in Appendix U (Table U-1). Generally, this list of potentially occurring special-status species was developed by consulting the California Native Diversity Database (CNDDB) maintained by the CDFG (2007) and by seeking the observations of regional experts.

Surveys were conducted onsite between fall 2000 and spring 2005 to assess the presence/absence of the special-status plants, amphibians, reptiles, birds, and/or mammals identified in Appendix U (Table U2-1). In addition to surveying specifically for special-status species, the surveys also generated species lists that would assist in understanding the communities and populations of plants, amphibians, reptiles, birds, and mammals that utilize the Site annually, seasonally, or as transients. Results of the surveys conducted from fall 2000 to spring 2005 are presented in Appendix P. The presence/absence type surveys that have been conducted provide sufficient information for this ERA, which only requires the identification of representative species and functional groups present or likely to be present onsite.

9.2.3 Conceptual Site Model

The CSM relates the sources of Site-related chemicals to the receptor populations by depicting the potential pathways for transport of the stressor and the routes of entry into the receptor. The CSM also facilitates development of exposure models and ecological benchmarks in the analysis phase of the assessment. The CSM identifies potentially complete exposure pathways and potential receptors by group (e.g., mammals, birds).

The CSMs were developed on the basis of existing information regarding the nature and extent of chemical contamination, habitat types, and flora and fauna at the Site (Figures 9-1 through 9-3). The exposure media evaluated included soils, sediment, surface water, and soil gas. The ecological receptors evaluated included terrestrial ecological communities (plants and soil invertebrates), freshwater ecological communities (sediment-dwelling invertebrates, aquatic life, and aquatic plants), terrestrial wildlife (reptiles, amphibians, mammals, birds, and deep burrowing mammals), and freshwater wildlife (amphibians, mammals, and birds).

9.2.3.1 Identification of Exposure Pathways

An exposure pathway consists of sources and release mechanisms, retention and transport media, exposure points, and exposure routes (USEPA, 1989). In accordance with USEPA guidance (1992a, 1997), only the complete and significant pathways were evaluated in this ERA.

As discussed previously, certain areas of the Site are capped, and although the capped areas can provide habitat that is utilized by receptors (i.e., exposure pathways may exist), these areas were not quantitatively evaluated because the vegetated soils that overlie the "cap" or high density polyethylene (HDPE) geomembrane cap are "clean" and consequently do not pose a risk to ecological receptors. The "clean" vegetated soils were obtained from areas that are representative of background soil conditions; the cap prevents burrowing animals from coming into contact with contaminated soils; therefore, the cap effectively blocks complete exposure pathways between contaminated soils and ecological receptors. The exposures to ecological receptors from these capped areas of the Site can be considered minimal to unlikely once all capping is complete and as long as the landfill caps are adequately maintained. The presumptive remedies planned for the aquatic areas will eventually result in these areas becoming terrestrial. Therefore, three general exposure areas present onsite were identified: terrestrial capped areas, terrestrial uncapped areas, and freshwater areas. Onsite areas (Zone 1) are the focus of the sections below. Data collected in offsite areas (Zone 2; e.g., offsite drainages) were also evaluated.

The following exposure pathways were identified as complete and significant and, therefore, were quantitatively evaluated in this ERA:

Terrestrial Uncapped Areas (Zone 1):

- Direct contact or uptake of soil by plants and soil invertebrates;
- Inhalation of burrow air by mammals (this also accounts for volatiles from groundwater);
- Incidental ingestion of soil by mammals and birds;
- Ingestion of surface water by mammals and birds from RCRA Canyon, West Canyon Spray Area (WCSA), and A-Series Pond; and
- Ingestion of contaminated prey tissue by mammals and birds.

The incidental ingestion of soil, surface water, and prey tissue pathways are complete and significant for reptiles and amphibians in the terrestrial areas; however, due to limited toxicity data, potential risks to reptiles and amphibians in the terrestrial areas could not be estimated. Uncertainties associated with risks to reptiles and amphibians are discussed in Appendix U.

Freshwater Aquatic Areas (Zones 1 and 2):

- Direct contact or uptake of surface water by aquatic plants, aquatic invertebrates, and amphibians;
- Direct contact or uptake of sediment by aquatic plants, aquatic invertebrates, and amphibians;
- Incidental ingestion of sediment by birds and mammals;
- Ingestion of surface water by birds and mammals; and
- Ingestion of contaminated prey tissue (aquatic invertebrates) by birds and mammals.

The incidental ingestion of sediment, ingestion of surface water, and ingestion of prey tissue pathways are complete and significant for amphibians. Due to limited toxicity data, potential risks to amphibians could not be estimated via these pathways. However, the direct contact pathway is considered to be the most significant pathway and thus, protective of all exposure pathways for amphibians. Uncertainties associated with risks to reptiles are discussed in Appendix U.

The following exposure pathway was identified as complete and potentially significant but was not quantitatively evaluated in this ERA:

- Inhalation of volatiles in burrow air by reptiles and birds

Inhalation of volatiles by birds and reptiles is considered complete and significant; however, the tools to evaluate exposure and risk are lacking or highly limited and, therefore, were not quantitatively evaluated in this ERA.

The following exposure pathways were identified as complete but not significant and, therefore, were qualitatively evaluated in this ERA:

- Dermal contact with media (soil, sediment, surface water, and seeps) by reptiles, birds, and mammals; and
- Inhalation of particulates and volatiles in ambient air by reptiles, amphibians, birds, and mammals.

The following exposure pathways were identified as incomplete and, therefore, were not evaluated in this ERA:

- Uptake or direct contact with groundwater by all receptors;
- Ingestion of groundwater by reptiles, amphibians, birds, and mammals; and
- Inhalation of volatiles from groundwater by all receptors except burrowing mammals.

Ingestion of surface water (i.e., seep water) by reptiles, amphibians, terrestrial mammals, and terrestrial birds was also considered incomplete, as the seeps no longer exist at the Site; however, potential risks based on historical data are discussed qualitatively in Section 9.6.

9.2.3.2 Identification of Ecological Receptors and Indicator Species

To characterize potential ecological risks associated with the Site, general classes of ecological receptors, or functional groups that may be exposed to CPECs, were identified to represent different trophic levels. Representative species were used to represent a wide range of receptors within each functional group.

Terrestrial Habitats

The terrestrial portions of the Site include the terrestrial uncapped areas onsite.

Terrestrial Ecological Communities:

- Terrestrial Plants: general category (not species-specific) and
- Soil Invertebrates: general category (not species-specific).

Terrestrial Wildlife:

- Amphibians: general category (not species-specific)
- Reptiles: western fence lizard (*Sceloporus occidentalis*)
- Mammals:
    - Herbivorous small mammals: California vole (*Microtus californicus*);
    - Invertivorous small mammals: ornate shrew (*Sorex ornatus*); and
    - Carnivorous mammals: striped skunk (*Mephitis mephitis*).
- Birds:
    - Invertivorous ground-feeding birds: western meadowlark (*Sturnella neglecta*) (breeding)
    - Herbivorous ground-feeding birds: western meadowlark (*Sturnella neglecta*) (non-breeding); and
    - Carnivorous birds (raptors): American kestrel (*Falco sparverius*).
- Deep Burrowing Mammals: represented by the American badger (*Taxidea taxus*)

Freshwater Aquatic Habitats

The aquatic portions of the Site include the freshwater ponds, the surface water runoff in RCRA Canyon, and the drainages offsite.

Freshwater Aquatic Ecological Communities:

- Sediment-dwelling Invertebrates: general (not species-specific);
- Aquatic Life: general (not species-specific); and
- Aquatic Plants: general (not species-specific).

Freshwater Aquatic Wildlife:

- Amphibians: general (not species-specific).
- Mammals:
-
    - Omnivorous/Invertivorous small mammals: raccoon (*Procyon lotor*)

- Birds:

    - Invertivorous Wading Birds: killdeer (*Charadrius vociferus*) and
    - Invertivorous (breeding) diving birds (ducks): mallard duck (*Anas platyrhynchos*).

9.2.3.3 Identification of Assessment and Measurement Endpoints

Assessment endpoints (AEs) are formal expressions of the actual environmental value to be protected from risk (Suter et al., 1993). AEs are typically tied directly to specific ecological values needing protection. Further, AEs provide a clear logical connection between regulatory policy goals and anticipated ecotoxicological investigations. They are selected based on the ecosystems, communities, and/or species that are of particular concern at a site. For example, an AE may be “protective of the population viability of small mammals.”

Generally, AEs cannot be directly measured; rather, a measurement endpoint related to the AE is evaluated. Measurement endpoints are quantitative expressions of an observed or

measurable effect and must correspond or predict assessment endpoints. General AEs were selected for the Site, and the associated measurement endpoints are presented in Appendix U.

9.3 Data Evaluation

The RI sampling approach was implemented to investigate the nature and extent of contamination at the Site. The approach and methodologies employed during sampling activities are described in Section 3.0. Data evaluated for this ERA were based on the exposure pathways as described in Section 9.2.3.1 and summarized in this section. A complete description of the data analysis is presented in Section 7.0.

For estimating exposures to ecological receptors at the Site, the following Site media data were evaluated:

- Surface soil (0 to 6 inches below ground surface [bgs]) will be henceforth referred to as surface soil;
- Surface and shallow soil (0 to 5 feet bgs; this also includes data from 5 to 5.5 feet bgs) will be henceforth referred to as shallow soil;
- Surface and deep soil (0 to 10 feet bgs; only for the deep burrowing receptor) will be henceforth referred to as deep soil;
- Sediment (0 to 6 inches bgs);
- Surface water (from ponds and runoff); and
- Soil gas.

The exposure depths were selected following guidance provided by CalEPA (1998). Exposures to terrestrial receptors are primarily via ingestion of prey items, although ingestion of soil, surface water, and inhalation of burrow air are also important pathways and were evaluated as appropriate. Burrow air was evaluated using soil vapor data collected at depths of between 5 to 10 feet bgs. Ingestion of prey items generally occurs at the surface, and prey items reside and take up chemicals from surface soils (and sediments), not from the bottom of the burrows. Therefore, surface soil (and sediments) was used to estimate uptake into prey items except for plant tissue, where the greater exposure point concentration (EPC) of the surface and shallow soil was used to model uptake. Soil (and sediment) ingestion generally is associated with foraging for prey items, although some soil ingestion may occur during grooming/preening that could include soils from deeper burrows. CalEPA guidance indicates that characterization of soil to 6 feet bgs is sufficient for the majority of ecological receptors (CalEPA, 1998). For the burrowing receptors likely to be onsite, a maximum depth of 5 feet bgs was considered sufficient to capture the range of burrow depths of the majority of small mammals present onsite (i.e., ranging from 6 inches for moles to 4 feet for squirrels, skunk, and fox).

For mammals that can burrow deeper than 6 feet bgs (the badger), deep soil data were evaluated separately, as the list of CPECs could be different for surface and shallow soils. The selection of CPECs in deep soil is described in Appendix U.
Groundwater data have been collected for the Site, but are not considered relevant for the purposes of the ERA because no complete exposure pathway exists between Site receptors and groundwater. The depth to groundwater is generally much deeper than 6 feet bgs, and plants are not expected to significantly uptake groundwater from the site. Please see Appendix F (Groundwater Flow) and the Routine Groundwater Monitoring Element of Work (RGMEW; groundwater monitoring) reports.

Additional sediment samples were collected to refine estimates of toxicity of specific metals in sediments to sediment-dwelling invertebrates at the Site. An equilibrium partitioning (EqP) approach, commonly referred to as the Acid Volatile Sulfide - Simultaneously-Extracted Metals (AVS-SEM) method, promulgated by USEPA (2005), was used. This method is summarized in Appendix U.

Data evaluated for each exposure medium, the datasets generated, calculation of dioxin and polychlorinated biphenyl (PCB) toxicity equivalent (TEQ), and selection of CPECs for further risk evaluation are presented in Section 7.0 and Appendix X and summarized in Appendix U.

9.4 Exposure Assessment

The methods that were used to estimate exposures for the ecological receptors for this ERA are described in Appendix U. Consistent with USEPA and CalEPA guidance (see Section 1.2 in Appendix U), this assessment was conducted using upper-bound assumptions, thus providing a high level of protection for the receptors represented by the evaluated functional groups. Chemicals, receptors, and pathways showing unacceptable risks (i.e., where exposures exceed effects-based screening values) were further evaluated in Tier 2.

9.4.1 Exposure Point Concentrations

An EPC is the representative concentration of a constituent in an environmental medium that is potentially contacted by the receptor (USEPA, 1997). USEPA (1989) defines the EPC as “the arithmetic average of the concentration that is contacted over the exposure period.” CalEPA (1996) and USEPA (1989, 1992b) recommend using the 95 percent upper confidence limit (95%UCL) on the mean as an estimate for the EPC so that the estimate of the average (or mean) is conservative and will not be underestimated. Following CalEPA guidance (CalEPA, 1996), risks were estimated using both the maximum detected concentrations (Screening-Level) and the EPCs (i.e., 95%UCL) on the mean (Tier 1 and Tier 2) for each CPEC/COI in each Site medium. Data distributions and 95%UCLs for CPEC in Site media were determined using USEPA’s ProUCL (V 4.0). These EPCs were referred to as “non-spatial” EPCs. A complete description of statistical methods used is provided in Section 7.0 and Appendix X.

For terrestrial receptors, a tiered approach was used to evaluate for potential risks. As mentioned above, risks were estimated using both maximum detected concentrations (Screening-Level) and non-spatial EPCs (Tier 1 and Tier 2). The CPECs that indicate potential adverse risks (i.e., hazard quotients [HQs] greater than 1) identified in the risk estimates, based on non-spatial EPCs, were further evaluated using a spatial approach (also part of Tier 1). Soil EPCs were calculated on an area-weighted basis according to USEPA guidance (USEPA, 2006). These EPCs were referred to as “spatial” EPCs. A complete description of the methods used to calculate spatial EPCs is provided in Attachment 4 of Appendix U.

Soil gas exposures (maximum detected concentrations and non-spatial EPCs only) were calculated in milligrams per cubic meter (mg/m^3) for burrowing mammals and presented in Attachment 3 of Appendix U.

Other evaluations included the RCRA runoff (maximum detected concentrations only).

9.4.2 Exposure Scenarios

Exposure scenarios were developed based on the CSMs and potential exposure areas. Each study area was referred to as an "exposure unit" in this ERA. The receptors described above in each of these exposure units are exposed to contaminants in different ways. The exposure scenarios evaluated for the ecological receptors are presented in Appendix U and summarized below. This subsection discusses the exposure pathways evaluated for the Screening-Level and Tier 1 ERA. The refined exposure scenarios evaluated in Tier 2 are summarized in Section 9.11.2.

As mentioned earlier, two other exposure areas not defined in the Work Plan (CSC, 2004) were also evaluated. These included the RCRA Canyon runoff (quantitatively) and the seeps (qualitatively; A-Series Seep, CA Seep, Caustic LF Seep, and Seep 9B).

9.4.2.1 Terrestrial Uncapped Areas

The terrestrial uncapped areas evaluated included the following exposure units:

- RCRA Canyon;
- Liquid Treatment Area;
- WCSA;
- Burial Trench Area;
- Maintenance Shed Area;
- Central Drainage Area;
- Administration Building Area;
- Roadway Areas;
- Remaining Onsite Areas;
- Former Pond and Pad Areas
- A-Series Pond;
- RCF Ponds;
- Pond A-5;
- Pond 13; and
- Pond 18

The treated liquid impoundments (Pond A-5 and Pond 18) have presumptive closure remedies, and the stormwater ponds (A-Series Pond, RCF Pond, and Pond 13) are also planned for closure as part of the USEPA-approved closure plan for the Site; this will be further detailed as part of the FS process. Therefore, the treated liquid impoundments and the stormwater ponds were evaluated similar to terrestrial areas.

For terrestrial receptors, exposures were estimated for each of the units listed above and also for the two following sitewide scenarios:

- Sitewide (i.e., all terrestrial uncapped units) with Pond A-5 and Pond 18 and
- Sitewide without ponds (i.e., all terrestrial uncapped units only).

9.4.2.2 Freshwater Aquatic Areas

The freshwater aquatic areas evaluated included the following exposure units:

- Onsite freshwater aquatic areas:
  - A-Series Pond;
  - RCF Ponds;
  - Pond A-5;
  - Pond 13; and
  - Pond 18.

- Offsite freshwater aquatic areas:
  - North Drainage;
  - A Drainage;
  - B Drainage;
  - Upper C Drainage; and
  - Lower C Drainage.

- Onsite runoff sample collected in RCRA Canyon; and

- Onsite freshwater seeps (qualitatively only):
  - A-Series Seep
  - CA Seep
  - Caustic LF Seep; and
  - Seep 9B.

For onsite freshwater aquatic receptors, exposures were estimated for each of the units listed above and also for the following two sitewide scenarios:

- Pondwide (i.e., all onsite ponds) and
- Stormwater Impoundments (A-Series pond, RCF pond, and Pond 13).

9.4.3 Exposure Assumptions

Ecological community exposures are expressed in terms of Site media concentrations, whereas wildlife exposures are expressed in terms of dose. For wildlife receptors, numerous exposure assumptions, such as contact rates, body weights, and absorption factors, are defined in this ERA for estimation of exposure dose. Exposure assumptions used in all tiers of the ERA, including estimation of intakes (or dose), are described in detail in Appendix U.

The area use factor (AUF) is the ratio of the Site area to the home range for receptors with home ranges larger than the Site area. AUFs based on home ranges were considered in the next tier assessments where primary literature sources were reviewed and home range/foraging range estimates were refined, as appropriate. Consistent with guidance for a Screening-Level and Tier 1 approach, the AUFs were set at 1 for all receptors in this ERA.

9.4.4 Bioaccumulation Factors

Bioaccumulation factors (BAFs) are multipliers used to estimate concentrations of chemicals that can accumulate in tissues through any route of exposure (USEPA, 2000). In this report, BAFs were used to estimate concentrations of CPECs in biota and food item tissue (i.e., prey) from Site media. Chemicals with low octanol-water partitioning coefficient (log K_{ow}) values generally do no bioaccumulate (CalEPA, 1996; USEPA, 2000). Only CPECs with the potential to bioaccumulate were evaluated for the food ingestion pathway; namely, some metals and organics with log K_{ow} values greater than 3.5 (USEPA, 2000). All CPECs were evaluated for ingestion of soil, sediment, and surface water.

BAFs for the Screening-Level and Tier 1 ERA were primarily obtained from guidance documents or other commonly used sources, as described in detail in Attachment 1 of Appendix U. The following media-to-biota BAFs were developed:

- Soil-to-Plant;
- Soil-to-Soil Invertebrate;
- Soil-to-Mammal;
- Sediment-to- Aquatic Invertebrate; and
- Surface Water-to-Aquatic Invertebrate.

For Tier 2 ERA, site-specific BAFs were developed as summarized in Section 9.11.4 and discussed in detail in Appendix U.

9.4.5 Bioavailability of Metals in Sediment

USEPA (2005) states that "[Equilibrium Partitioning Sediment Benchmarks] ESBs may be useful as a complement to existing sediment assessment tools, to help assess the extent of sediment contamination, to help identify chemicals causing toxicity, and to serve as targets for pollutant loading control measures." For this ERA, ESBs were not used to screen out CPECs in sediment. All CPECs were carried through the Screening-Level and Tier 1 ERA, and the ESBs were used as a weight-of-evidence in the risk characterization process. Note that ESBs are only applicable to sediment-dwelling invertebrates, and comparisons to ESBs did not affect evaluation of risks to wildlife receptors.

All the pond sediment samples contained very high AVS concentrations, with ΣSEM-AVS values were less than zero (ranging from -197 to -27 micromole per gram [µmol/g]). For all samples, the organic carbon normalized excess SEM-AVS ([ΣSEM-AVS]/f_{oc}) was negative, indicating that toxicity due to copper, cadmium, lead, nickel, and zinc may not be observed because the metals are bound as insoluble sulfides, which are not biologically available to benthic receptors in the ponds.

9.5 Effects Assessment

The effects assessment includes the identification and development of toxicity values for ecological receptors. Following CalEPA guidance (CalEPA, 1996), toxicity values were based on “no-effect” levels. The “no-effect” level is the concentration or dose at or below which no adverse effects on the test organism are observed. However, to evaluate a range of risk estimates for ecological receptors in all the tiers of the ERA, “lowest observable effects” data or other alternate “upper bound” toxicity values were also developed.

For ecological communities and amphibians, effects are assessed using toxicity values referred to as “screening values.” Screening values are threshold concentrations expressed in milligrams per kilogram (mg/kg) or milligrams per liter (mg/L) that are effect levels or benchmarks for organisms inhabiting/exposed to that matrix (soil, sediment, surface water). For terrestrial plants, soil invertebrate ecological communities, and amphibians, single screening values were developed; for sediment-dwelling invertebrates and aquatic life, low and high screening values were developed; and for aquatic plant ecological communities and amphibians, single screening values were developed.

For wildlife (mammals and birds), effects are assessed using toxicity values referred to as “toxicity reference values” (TRVs). A TRV is defined as a daily dose of a chemical expressed in milligrams of chemical per kilogram of body weight per day (mg/kg bw-day) and represents a dose associated with no-effect, lowest-effect, or mid-range effects for ecologically relevant endpoints. For wildlife, a range of low and high TRVs were developed. Low TRVs were based

on no-observed adverse effects levels (NOAELs) and high TRVs were based on lowest-observed adverse effects (LOAELs). TRVs could not be developed for reptiles due to limited toxicity data. Both NOAELs and LOAELs represent doses affecting receptors at the individual level. If risks (i.e., HQs over 1) are predicted at this level (i.e., when the estimated exposure dose exceeds the LOAEL) effects may be evident at the population level. Because there is a higher level of concern, NOAEL-based TRVs are considered when making risk management decisions for protected (threatened and endangered) species.

Screening values protective of ecological communities and TRVs protective of wildlife were developed for CPECs identified onsite. Screening values and TRVs were selected or developed from literature sources based on specific guidelines provided by CalEPA (1996) and USEPA (1997; 1998; 1999a,b; 2007). The approach, guidelines, and hierarchy used to develop screening values for ecological communities and TRVs for wildlife are described in detail in Attachment 2 of Appendix U.

In Tier 2, tissue TRVs were developed for the COIs and are summarized in Section 9.11.4 and discussed in detail in Attachment 7 in Appendix U.

9.6 Screening-Level and Tier 1 Risk Characterization

The risk characterization phase consists of two steps: risk estimation and risk description. Risk estimation is the quantitative evaluation that integrates the exposure and effects data to evaluate the potential for adverse ecological effects in terms of HQs. Risk description is an interpretation of the risk estimates and includes other non-quantitative lines of evidence, such as habitat quality and area, as well as a spatial evaluation of potential risk drivers.

For plants and soil invertebrate ecological communities, exceedances of the screening values which are conservative in general are uncertain, and it is not clear whether an adverse effect would result. For sediment-dwelling invertebrates, Screening-Level and Tier 1 HQs were estimated on both low and high screening values. For aquatic life and aquatic plants ecological communities, as well as amphibians, Screening-Level and Tier 1 HQs were based on single screening values. However, to provide a range of Screening-Level and Tier 1 risks for aquatic life, the acute screening value was also used. For mammals and birds, a range of Screening-Level and Tier 1 HQs were calculated; low HQs based on high TRVs (LOAELs) and high HQs based on low TRVs (NOAELs).

Proper interpretation of HQs is critical to the risk assessment process and risk management decision-making. The purpose of considering the LOAEL-based values for wildlife was to provide context to the NOAEL-based evaluation. Because the low TRVs are based on NOAELs, an exceedance of these values does not necessarily indicate risk. The low toxicity values represent a toxicological threshold below which there is high confidence in a finding of no unacceptable risk (i.e., risk is considered *de minimis*). LOAEL-based or “high” toxicity values represent a value above which risk is possible and further evaluation may be needed. In between these two values, the exact concentration at which toxicological effects might be observed is uncertain and therefore, risk can be considered possible. However, for most receptors, exceedance of a LOAEL-based or high TRV, especially in the Screening-Level and Tier 1 evaluation such as this one that utilizes conservative assumptions, is considered more likely to result in a significant adverse effect than exceedance of a NOAEL-based or low TRV. HQs greater than 1 when compared to high benchmarks or LOAEL-based TRVs (designated as LOAEL/high TRV-based HQs) provide stronger evidence that there is potential for significant

adverse effects. In this Screening-Level and Tier 1 ERA, CPECs with NOAEL/low TRV-based HQs greater than 10 and/or LOAEL/high TRV-based HQs greater than 1 were considered potential "risk drivers" or COIs, which were evaluated further in Tier 2.

Toxicity data were insufficient to develop LOAEL-based or high benchmarks for plants, soil invertebrates, aquatic plants, and amphibians. However, risks interpreted based on the exceedance of the benchmarks developed using NOAEL-based or low toxicity values, can be highly uncertain (e.g., those for inorganic chemicals that fall below background). Screening values could not be developed for reptiles and amphibians in terrestrial areas due to limited available toxicity data; therefore, Screening-Level and Tier 1 HQs could not be estimated for these receptors. However, potential risks to reptiles and amphibians in terrestrial areas are described qualitatively in Section 9.9.

HQs were calculated as described above for all CPECs and receptors identified in the CSMs (Figures 9-1 through 9-3) for each exposure scenario (described in Section 9.6.2) based on the tiered approach described earlier in Section 9.6.1:

- HQs based on background data (95 upper tolerance limit [UTL]);
- HQs based on maximum detected concentrations for all CPECs – Screening-Level;
- HQs based on non-spatial EPCs for all CPECs – Tier 1; and
- HQs for terrestrial receptors based on spatial EPCs only for the CPECs with HQs greater than 1 based on the non-spatial EPCs – Tier 1.

Additionally, wildlife Screening-Level and Tier 1 HQs based on non-spatial EPCs were also calculated using Biological Technical Advisory Group (BTAG) TRVs (henceforth referred to as BTAG HQs). This comparison table is presented in Section 6 and 7 of Appendix U, but is not discussed in this section.

CPECs with Tier 1 LOAEL-based HQs greater than 1 may require further evaluation (Tier 2 assessment). Hazard indices (HIs) were calculated (i.e., sum of HQs) for some chemical classes. These include total DDT (sum of DDD, DDE, and DDT), total low molecular weight polycyclic aromatic hydrocarbons (LMW PAHs; i.e., sum of all individual LMW PAHs), total high molecular weight polycyclic aromatic hydrocarbons (HMW PAHs; i.e., sum of all individual HMW PAHs), and total TEQ (i.e., sum of dioxin TEQ and PCB TEQ). In this section, HIs for these groups of chemicals are not discussed separately but together with HQs. In some cases, when the HI exceeds 1, because the HQ of one chemical in the group is driving that value, then HIs are denoted in parentheses. Where no HQs exceed 1 but the HI exceeds 1, chemicals contributing to the HI exceedance were identified and may require further evaluation. As discussed previously, the Tier 1 assessment used conservative assumptions that ensure protection of all potential receptors in each functional group, including special-status species, which are afforded a higher level of protection.

9.6.1 Screening-Level and Tier 1 Risk Estimation

For exposure units, HQs were calculated for sitewide CPECs (i.e., selected based on sitewide data evaluation) and for exposure unit-specific CPECs (i.e., selected based on exposure unit data evaluation) for terrestrial uncapped areas only (not ponds). This section provides a summary of CPECs with HQs greater than 1 only. The full sets of risk estimates are described in detail in Appendix U.

9.6.1.1 Risk Estimates Based on Background

HQs were calculated for ecological communities and wildlife receptors based on background soil/sediment (95UTLs) for metals and dioxins (for wildlife only). For sediment-dwelling invertebrates, all background LOAEL/high TRV-based and NOAEL/low TRV-based HQs are less than 1. Those chemicals with background HQs greater than 1 are provided below.

Terrestrial Ecological Community Background Risk Estimates			
Chemical	**Plant HQ**	**Soil Invertebrate HQ**	**Sediment-Dwelling Invertebrates[1]**
Cadmium	<1	<1	**3**
Chromium	**47**	**118**	**1**
Cobalt	**2**	<1	<1
Manganese	**2**	<1	<1
Molybdenum	**5**	<1	<1
Nickel	**1**	<1	**2**
Selenium	**3**	<1	**1**
Tin	**1**	**1**	NA
Vanadium	**41**	**51**	<1
Zinc	**2**	**1**	<1

[1] Based on soil background values.

Note that, because their HQs (based on background) are greater than 10, HQs estimated herein for chromium and vanadium for plants and chromium for soil invertebrates are considered highly uncertain.

	Terrestrial Wildlife Background Risk Estimates											
	Ornate Shrew		**California Vole**		**Striped Skunk**		**Western Meadowlark (Invertivore)**		**Western Meadowlark (Herbivore)**		**American Kestrel**	
CPEC	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**
Cadmium	<1	**8**	<1	<1	<1	<1	**1**	**5**	<1	<1	<1	<1
Chromium	<1	**3**	<1	<1	<1	<1	**3**	**3**	**1**	**1**	<1	<1
Lead	<1	<1	<1	<1	<1	<1	<1	**1**	<1	<1	<1	<1
Mercury	<1	<1	<1	<1	<1	<1	<1	**2**	<1	<1	<1	<1
Molybdenum	<1	**3**	**3**	**27**	<1	**2**	<1	<1	<1	**4**	<1	<1
Nickel	<1	**1**	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	<1	**15**	<1	**6**	<1	<1	<1	**4**	<1	**3**	<1	<1
Vanadium	<1	<1	<1	<1	<1	<1	**5**	**11**	**4**	**8**	<1	**1**
Zinc	<1	**12**	<1	**1**	<1	<1	<1	**8**	<1	**1**	<1	**1**
Mammalian Dioxin TEQ	**2**	**17**	<1	<1	<1	<1	--	--	--	--	--	--
Avian Dioxin TEQ	--	--	--	--	--	--	<1	**2**	<1	<1	<1	<1

High HQ = NOAEL/low TRV-based
Low HQ = LOAEL/high TRV-based
-- Not applicable

CPEC	Aquatic Wildlife Background Risk Estimates					
	Raccoon		Killdeer		Mallard Duck	
	Low HQ	High HQ	Low HQ	High HQ	Low HQ	High HQ
Barium	<1	<1	**1**	**2**	<1	<1
Cadmium	<1	<1	<1	**1**	<1	<1
Copper	<1	<1	<1	**2**	<1	<1
Chromium	<1	<1	**3**	**4**	<1	<1
Molybdenum	<1	**2**	<1	<1	<1	<1
Selenium	<1	**3**	**1**	**4**	<1	**1**
Tin	<1	<1	**1**	**3**	<1	<1
Vanadium	<1	<1	**7**	**14**	<1	<1
Zinc	<1	<1	<1	**2**	<1	<1
Mammalian Dioxin TEQ	<1	**1**	--	--	--	--

High HQ = NOAEL/low TRV-based
Low HQ = LOAEL/high TRV-based
-- Not applicable

In summary, for several CPECs, background levels show HQs greater than 1. The results of the Site-related risk estimates are compared to those for background levels in the risk description section to provide additional context to the risk estimates. Chemicals with HQs similar to background HQs are not considered risk drivers.

9.6.1.2 Risk Estimates Based on Maximum Detected Concentrations (Screening-Level)

For the Screening-Level ERA, HQs were calculated for ecological communities and wildlife receptors based on maximum detected concentrations of CPECs in terrestrial areas (exposure areas listed in Section 9.4.2.1 above), onsite ponds (exposure areas listed in Section 9.4.2.2 above), and offsite drainages (exposure areas listed in Section 9.4.2.2 above). The risk summaries are presented in Appendix U. The results of the Screening-Level ERA were not used to screen out any chemicals, receptors, or areas for evaluation. Risks based on maximum concentrations are most useful when evaluating a special-status species that might be exposed in a single area (e.g., plant species), which are not present on this Site. Additionally, the Screening-Level ERA is the most conservative screen; thus, exclusions of risk for chemicals, receptors, or areas based on this evaluation have the highest confidence of no unacceptable risk. Details of the Screening-Level risks are presented in Appendix U.

Risk estimates based on dissolved concentrations for receptors exposed to RCRA Canyon runoff are presented in Table U-24 in Appendix U. To summarize:

- Most of the organic chemicals and a few of the metals were not detected in any of the samples.
- HQs based on the selected screening levels for aquatic life are less than 1 for most of the CPECs except some metals and two organic chemicals. For arsenic, barium, cadmium, selenium, vanadium, benzo(b)fluoranthene, and ethylene glycol, HQs range from 2 to 6; for selenium, the HQ is 200.

- HQs based on the upper-bound surface water screening levels are less than 1 for all the metals except cadmium and selenium; upper-bound surface water screening levels are not available for other CPECs.
- HQs for amphibians are less than 1 for all the organic CPECs, but greater than 1 for most of the metals except antimony, barium, and thallium. Metal HQs for amphibians range from 2 for silver, lead, and beryllium to greater than 1,100 for selenium.
- HQs for aquatic plants are less than 1 for all the CPECs except arsenic, cadmium, nickel, and selenium, with an HQs ranging from 2 to 20.

9.6.1.3 Risk Estimates Based on Non-Spatial Exposure Point Concentrations (Tier 1)

For the Tier 1 ERA, HQs were calculated for ecological communities and wildlife receptors based on non-spatial EPCs. Due to the volume of information, only the CPECs with HQs greater than 1 are summarized in this section; risk estimates for all other CPECs and exposure scenarios are described in detail in Appendix U. The risk description section below provides a more concise discussion of risk drivers/COIs that takes into account background HQs discussed above and the range of HQs.

Risk Estimates for Terrestrial Ecological Community:

Terrestrial Ecological Community: CPECs with HQs > 1			
Terrestrial Plants		**Soil Invertebrates**	
Metals	**Organic Chemicals**	**Metals**	**Organic Chemicals**
Barium	HMW PAHs	Barium	DDT (and total DDT)
Chromium	DDT (total DDT)	Chromium	Trichloroetheylene (TCE)
Cobalt	--	Cobalt	Tetrachloroethylene (PCE)
Copper	--	Copper	Endrin[1]
Lead	--	Total Cyanide	Heptachlor Epoxide[1]
Manganese	--	Manganese	Aroclor 1260
Molybdenum	--	Mercury	PCB Congeners
	--	Tin	Hexachlorbenzene
Nickel	--	Vanadium	--
Selenium	--	Zinc	--
Tin	--	--	--
Vanadium	--	--	--
Zinc	--	--	--

[1] Exposure unit-specific CPECs only (not sitewide CPECs).
-- Not applicable for CPEC/receptor.

Risk Estimates for Aquatic Ecological Community:

Aquatic Ecological Community: CPECs with HQs > 1			
Sediment-Dwelling Invertebrates		**Aquatic Plants**	
Metals	**Organic Chemicals**	**Metals**	**Organic Chemicals**
Cadmium	DDD	Arsenic	Acetone[1]
Copper	DDT	Copper	MIBK[1]
Chromium	total DDT	Nickel	--
Manganese[1]	MCPP	Selenium	--

Nickel	Aroclor 1260	Zinc	--
Selenium	total PCBs[2]	Cadmium[1]	--
--	Endosulfan Sulfate	--	--
--	1,1-Dichloroethane	--	--
--	Acetone	--	--
--	Carbon Disulfide	--	--

[1] HQ > 1 in one offsite drainage only.
[2] Sum of PCB congeners are referred to as total PCBs in this ERA.
-- Not applicable for CPEC/receptor.

Aquatic Ecological Community: CPECs with HQs > 1			
Aquatic Life		**Amphibians**	
Metals	**Organic Chemicals**	**Metals**	**Organic Chemicals**
Arsenic	Bis(2-ethylhexyl) Phthalate	Arsenic	Acetone[1]
Barium	Benzo(b)fluoranthene (and Total HMW PAHs)[1]	Barium	Acetonitrile[1]
Beryllium[1]	Acetonitrile[1]	Beryllium	Ethylene Glycol[1]
Copper	Ethylene Glycol[1]	Cadmium	1,1-Dichloroethane
Lead	MIBK[1]	Chromium	--
Manganese	Carbon Disulfide[1]	Cobalt[1]	--
Nickel	--	Copper	--
Selenium	--	Lead	--
Silver[1]	--	Manganese	--
Vanadium	--	Molybdenum	--
--	--	Mercury	--
--	--	Nickel	--
--	--	Selenium	--
--	--	Silver	--
--	--	Vanadium	--
--	--	Zinc	--

[1] HQ > 1 in offsite drainages only.
-- Not applicable for CPEC/receptor.

Risk Estimates for Terrestrial Wildlife:

Terrestrial Wildlife: CPECs with HQs > 1			
Mammals		**Birds**	
Metals	**Organic Chemicals**	**Metals**	**Organic Chemicals**
Barium	Dioxin TEQ	Barium	Dioxin TEQ
Cadmium	Aroclor 1260	Cadmium	Aroclor 1260
Chromium	total PCBs	Chromium	total PCBs
Copper	PCB TEQ	Copper	PCB TEQ
Lead	total TEQ	Total Cyanide	total TEQ
Molybdenum	MCPA	Lead	MCPP
Nickel	MCPP	Mercury	DDE
Selenium	DDE	Molybdenum	DDT
Zinc	DDT	Selenium	total DDT
--	total DDT	Vanadium	Hexachlorobenzene
--	Hexachlorobenzene	Zinc	Aldrin[1]

--	Endrin[1]	--	Endrin[1]
--	TCE	--	Bis(2-ethylhexyl) Phthalate
--	PCE	--	--
--	Dieldrin[1]	--	--
--	Mirex[1]	--	--
--	Heptachlor Epoxide[1]	--	--

[1] Exposure unit-specific CPECs only (not sitewide CPECs).

Risk Estimates for Aquatic Wildlife:

Aquatic Wildlife: CPECs with HQs > 1			
Mammals		**Birds**	
Metals	**Organic Chemicals**	**Metals**	**Organic Chemicals**
Barium	PCB TEQ (and total TEQ)	Arsenic	PCB TEQ (and total TEQ)
Cadmium	--	Barium	Aroclor 1260
Manganese[1]	--	Cadmium	total PCBs
Molybdenum	--	Chromium	--
Selenium	--	Copper	--
Zinc[1]	--	Manganese	--
--	--	Mercury	--
--	--	Molybdenum	--
--	--	Nickel	--
--	--	Selenium	--
--	--	Tin	--
--	--	Vanadium	--
--	--	Zinc	--

[1] HQ > 1 in offsite drainages only.
-- Not applicable for CPEC/receptor.

9.6.1.4 Risk Estimates for Deep Burrowing Mammals (Screening-Level)

Risks for the deep burrowing mammals were evaluated based on the maximum detected concentrations at depths of deep soil for the exposure units only (no sitewide risks were estimated). Only chemicals with deep soil maximum concentrations that were greater than shallow soil maximum concentrations were evaluated for the badger.

Deep Burrowing Mammal HQs based on Maximum Detected Concentrations	
Metals	**Organics**
Molybdenum	Dioxin TEQ (total TEQ)
Selenium	MCPA
Vanadium	DDT (and total DDT)
--	Hexachlorobenzene
--	Mirex
--	PCE
--	TCE

-- Not applicable for CPEC/receptor.

9.6.1.5 Soil Gas Evaluation

Risks were estimated for burrowing mammals via inhalation of burrow air as presented in Attachment 3 of Appendix U. Based on the non-spatial EPCs, only two volatile organic compounds (VOCs) exceed the NOAEL/low TRV-based HQ of 1, and these include:

- 1,1-dichloroethene (HQ = 7) and
- PCE (HQ = 9).

All other VOCs have NOAEL/low TRV-based HQs less than 1. Based on the non-spatial EPCs, none of the VOCs exceed an LOAEL/high TRV-based HQ of 1. The offsite NOAEL/low TRV-based and LOAEL/high TRV-based HQs for all VOCs are well below 1.

9.6.1.6 Risk Estimates Based on Spatial Exposure Point Concentrations (Tier 1)

HQs were calculated for terrestrial ecological communities and terrestrial wildlife receptors based on spatial EPCs. The exposure areas evaluated spatially included only the terrestrial uncapped areas (i.e., Sitewide [with and without ponds] and the terrestrial exposure units). The Roadway Area was not evaluated spatially because, unlike other areas on the Site, the Roadway Area does not conform to an exposure unit that is typically defined for a receptor (i.e., thin/narrow strips). The ponds were also not evaluated spatially. As mentioned earlier, risks based on spatial EPCs were estimated only for the CPECs with LOAEL/high TRV-based HQs greater than 1 based on the non-spatial evaluations. A sitewide CPEC with a LOAEL/high TRV-based HQ of greater than 1 for any of the terrestrial receptors was spatially evaluated for all the terrestrial receptors. These CPECs included most of the metals, dioxin TEQ, two herbicides (MCPA and MCPP), PCBs (Aroclor 1260, total PCBs, and PCB TEQ), four pesticides (DDE, DDT, total DDT, and hexachlorobenzene), one semivolatile organic compound (SVOC; bis[2-ethylhexyl]phthalate), and two VOCs (TCE and PCE). The risk summaries are presented in Appendix U.

Spatial analyses indicated results similar to the non-spatial analyses. Comparisons of the spatial and non-spatial based risk estimates are presented in Attachment 5 of Appendix U.

9.6.2 Risk Description

Risk description is used to bound the threshold for adverse effects and provide information to the risk managers regarding the likelihood and ecological significance of estimated risks. This section integrates the risk estimates and non-spatial and spatial analyses described above, as well as key uncertainties that may impact overall risk conclusions. As stated above, risks associated with CPECs and receptors with NOAEL/low TRV-based HQs less than or equal to 1 are considered to be unlikely to none (*de minimis*), and no further evaluation is warranted. When a NOAEL/low TRV-based HQ was greater than 1, a spatial risk evaluations was considered along with additional weight of evidence and key uncertainties to draw risk conclusions. The following sections provide the risk description for the assessment endpoints and representative receptors identified for the Site.

Risk description for each receptor is provided in detail in Appendix U. The following general “criteria” based on the non-spatial and spatial risk evaluations were used in determining whether a chemical is Site-related and a significant risk driver and, therefore, warrants further evaluation or whether a chemical does not warrant further evaluation based on guidance and weight of evidence (i.e., comparison to background, spatial risk evaluation, and uncertainties):

- For ecological communities and amphibians, chemicals with low screening level-based HQs less than 1 indicate that risk to receptor populations is expected to be *de minimis*; these chemicals were not further evaluated.
- For ecological communities and amphibians, chemicals with low screening level-based HQs greater than 1 but less than or equal to 2 indicate that risk to receptor populations is possible but not likely given the low magnitude of the risk; these chemicals were not further evaluated (i.e., only chemicals with HQs > 2 and meeting other criteria listed here were further evaluated).
- For wildlife, chemicals with LOAEL/high TRV-based HQs less than 1 indicate that risk to receptor populations is expected to be *de minimis*; these chemicals were not further evaluated.
- For wildlife, chemicals with LOAEL/high TRV-based HQs greater than 1 but less than 2 indicate that risk to receptor populations is possible but not likely given the low magnitude of the risk; these chemicals were not further evaluated.
- For ecological communities and wildlife, chemicals with HQs greater than 1 but less than background HQs were not further evaluated as it was assumed risk from the site was similar to risk from background for that chemical.
- For ecological communities and wildlife, chemicals with HQs greater than 1
- For study areas that have a presumed remedy were not further evaluated.
- For ecological communities and wildlife, chemicals with HQs greater than 1 based on low in confidence toxicity values, and that were infrequently detected were not further evaluated, however, risks in such cases are discussed below.
- For wildlife, chemicals with NOAEL/low TRV-based HQs greater than or equal to 10 or LOAEL/high TRV-based HQs greater than 1 were identified for further evaluation.

As part of the USEPA-approved closure plan for the site, a potential remedy for Pond A-5, Pond 18, A-Series Pond, the stormwater ponds or impoundments (RCF pond and Pond 13), Central Drainage Area, Liquid Treatment Area, Burial Trench Area, and Maintenance Shed Area are planned and will be further detailed as part of the FS process. However, for documentation purposes, risk to receptors in these exposure areas were estimated and discussed in Appendix U.

For documentation purposes, risk to aquatic ecological communities from the North Drainage, Upper C Drainage, and Lower C Drainage were estimated and discussed in Section 6.1 of Appendix U. However, these offsite drainages do not receive any stormwater runoff from the Site. As discussed in Section 4.3.1, and depicted in Figures 4-2 through 4-6, surface runoff within the developed Site area has historically been controlled and contained within the limits of the active disposal areas, either by natural topographic divides or by constructed embankments and containment systems. The containment of surface water runoff within the Site boundaries has effectively prohibited the offsite release of CPEC-bearing stormwater from disposal areas into offsite areas. Therefore, any potential risks to aquatic communities from these drainages are not considered Site-related and are not recommended for further evaluation.

Based on the above general criteria, risk drivers were identified for the Site and are summarized in this section. Chemicals that did not warrant further evaluation are discussed in detail in Appendix U. Uncertainties associated with the lack of toxicity values for some chemicals are also discussed in detail in Appendix U.

9.6.2.1 Tier 1 Risk Description for Terrestrial Communities

Based on the weight of evidence criteria above, chemicals that indicate potential risk and that may require further evaluation include:

Chemical	Terrestrial Plants	Soil Invertebrates
Barium	RCRA Canyon Area	RCRA Canyon Area
Chromium[1]	RCRA Canyon Area, Roadway Area, and WCSA	RCRA Canyon Area, Roadway Area, and WCSA
Copper	WCSA	WCSA

-- Not applicable for receptor/chemical.
[1] Note that the toxicity value for chromium is uncertain.

9.6.2.2 Tier 1 Risk Description for Aquatic Communities

Sediment-Dwelling Invertebrates

Based on the weight-of-evidence criteria above, chemicals that indicate potential risk and that could require further evaluation include:

- Barium in the A-Series Pond, Pond 18, Pond A-5, Pondwide, and Stormwater Impoundments;
- Nickel and selenium in all the ponds, Pondwide, and Stormwater Impoundments;
- MCPP in Pond 18, Pond A-5, Pondwide, RCF Pond, Pondwide, and Stormwater Impoundments;
- Total PCBs, total DDT, endosulfan sulfate, and acetone in RCF Pond;
- 1,1-Dichloroethane in Pond A-5 and RCF Pond; and
- Carbon disulfide in Pond 13

Aquatic Life

Based on the criteria listed above in Section 6.2 for ecological communities, chemicals that were identified as potential risk drivers and could warrant further evaluation include:

- Arsenic in Pond 13, RCF Pond, Pondwide, and Stormwater Impoundments;
- Barium in all the ponds, Pondwide, and Stormwater Impoundments;
- Manganese in A-Series Pond, Pond 13, Pond A-5, Pondwide, and Stormwater Impoundments;
- Nickel and selenium in all the ponds, Pondwide, and Stormwater Impoundments;
- Zinc in A-Series Pond, Pond A-5, Pondwide, and Stormwater Impoundments;
- Total HMW PAHs in Pondwide; and
- Bis(2-ethylhexyl)phthalate in Pond A-5 and Pondwide.

Aquatic Plants

Based on the criteria listed above in Section 6.2 for ecological communities, chemicals that were identified as potential risk drivers and could warrant further evaluation include:

- Arsenic in all the ponds, Pondwide, and Stormwater Impoundments;
- Copper and zinc in A-Series Pond, Pond 18, Pond A-5, Pondwide, and Stormwater Impoundments; and

- Nickel and selenium in all the ponds, Pondwide, and Stormwater Impoundments.

However, all of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the site and will be backfilled/graded to prevent accumulation of water. Therefore, they will be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all onsite ponds will be further detailed as part of the FS process. Thus, none of the chemicals in the ponds with HQs greater than 1 were identified for further evaluation.

Risks to aquatic communities for the RCRA Canyon runoff were estimated based on a conservative scenario by comparing the maximum concentration detected in three surface water samples to toxicity values that have been approved for use in the ERA. This scenario evaluated the potential risk to aquatic receptors under the hypothetical scenario that water pools in RCRA Canyon, which based on site observations, does not occur under current site conditions. Additional evaluations of RCRA Canyon runoff and the potential for pooling once a remedy is in place for A-Series Pond will be evaluated in the FS. The seeps are currently dry and, therefore, are not expected to be sources of exposure to aquatic life or aquatic plants.

9.6.2.3 Risk Description for Amphibians

Assessment of amphibian populations in the ponds indicate potential risk, mostly from metals, because of HQs significantly greater than 1. High conductivity/salinity conditions in many of the ponds make them unsuitable for amphibians in their current state.

However, as all of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the site and will be backfilled/graded to prevent accumulation of water, they will be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all onsite ponds will be further detailed as part of the FS process. Therefore, none of the chemicals in the ponds with HQs greater than 1 for aquatic ecological communities and amphibians were identified for further evaluation.

Risks to amphibians for the RCRA Canyon runoff were estimated based on a conservative scenario by comparing the maximum concentration detected in three surface water samples to toxicity values that have been approved for use in the ERA. This scenario evaluated the potential risk to aquatic receptors under the hypothetical scenario that water pools in RCRA Canyon, which based on site observations, does not occur under current site conditions. Additional evaluations of RCRA Canyon runoff and the potential for pooling once a remedy is in place for A-Series Pond will be evaluated in the FS. The seeps are currently dry and, therefore, are not expected to be sources of exposure to amphibians.

9.6.2.4 Risk Description for Terrestrial Mammals

Risk estimates indicate that potential risk to terrestrial mammal populations is expected to be *de minimis* from exposure to most of the organic CPECs. No further evaluation is warranted for chemicals with LOAEL/high TRV-based HQs less than 1 and/or NOAEL/low TRV-based HQs less than 10, and/or those with HQs similar to background. Based on the weight-of-evidence criteria, chemicals that indicate potential risk and warrant further evaluation include metals and a few organic chemicals as summarized below.

Chemical	Ornate Shrew	California Vole	Striped Skunk
Barium	RCRA Canyon Area	RCRA Canyon Area	--
Cadmium	RCRA Canyon Area and WCSA	--	--
Chromium	RCRA Canyon Area and WCSA	--	--
Copper	RCRA Canyon Area and WCSA	--	--
Zinc	Roadway Area, Former Ponds and Pads, RCRA Canyon Area, and WCSA	--	--

-- Not applicable for receptor/chemical.
[1] Exposure unit-specific CPECs only (not sitewide CPECs).

Risk to the ornate shrew from selenium in A-Series Pond and Pond A-5 and MCPP and mirex in the Liquid Treatment Area and risk to the California vole from selenium in the A-Series Pond and Pond A-5 may have been overestimated, as they were based on the maximum detected concentrations. Further evaluation may be required for these chemicals in these exposure areas.

9.6.2.5 Risk Description for Terrestrial Birds

No further evaluation is warranted for chemicals with LOAEL/high TRV-based HQs less than 1, and/or NOAEL/low TRV-based HQs less than 10, and/or those with HQs similar to background. Based on the weight-of-evidence criteria, chemicals that indicate potential risk and warrant further evaluation include metals and a few organic chemicals, as summarized below.

Chemical	Western Meadowlark (Invertivore)	Western Meadowlark (Herbivore)	American Kestrel
Barium	RCRA Canyon Area	Former Ponds and Pads Area and RCRA Canyon Area	--
Cadmium	RCRA Canyon Area and WCSA	--	--
Chromium	RCRA Canyon Area, Roadway Area, and WCSA,	RCRA Canyon Area, Roadway Area, and WCSA	WCSA
Copper	WCSA	WCSA	--
Lead	Roadway Area and RCRA Canyon Area	--	--
Zinc	RCRA Canyon Area and WCSA	--	--

-- Not applicable for receptor/chemical.
[1] Exposure unit-specific CPECs only (not sitewide CPECs).

9.6.2.6 Risk Description for Aquatic Mammals and Birds

Based on the weight-of-evidence criteria, chemicals that indicate potential risk and that could warrant further evaluation include metals and a few organic chemicals as summarized below.

Chemical	Raccoon	Killdeer	Mallard
Arsenic	--	A-Series Pond	--
Barium	Pond A-5	Pond A-5 and RCF Pond	Pond A-5
Cadmium	--	Pond A-5	--
Chromium	--	A-Series Pond, RCF Pond, Pond 18, and Pond A-5	A-Series Pond
Manganese	--	A-Series Pond	--
Mercury	--	A-Series Pond	A-Series Pond
Molybdenum	--	A-Series Pond	--
Selenium	A-Series Pond and Pond 18	A-series Pond, Pond A-5, and Pond 18	A-Series Pond
Zinc	--	A-Series Pond	--
PCB TEQ (and total TEQ)	--	RCF Pond	--

-- Not applicable for receptor/chemical.

Risk to the raccoon from barium in Pond A-5 and selenium in A-Series Pond and Pond 18; risk to the killdeer from barium, cadmium, selenium, and PCB TEQ (and total TEQ) in all the exposure units listed above; and risk to the mallard from barium in Pond A-5 may have been overestimated, as they were based on the maximum detected concentrations. Further evaluation may be required for these chemicals in these exposure areas.

However, as all of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the site and will be backfilled/graded to prevent accumulation of water, they will be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all onsite ponds will be further detailed as part of the FS process. Therefore, none of the chemicals in the ponds with HQs greater than 1 were identified for further evaluation.

9.6.2.7 Screening-Level Risk Description for Deep Burrowing Mammals

One assessment endpoint was identified for deep burrowing mammals at the Site and included protection of mammals that burrow deep (up to 10 feet bgs). For this trophic group, the American badger was selected as the indicator species for quantitative evaluation and was considered representative and protective of populations of all mammals within that trophic group. Note that the American badger is considered a top predator, is a special-status species that was observed onsite, and burrows deeper than the gopher (i.e., to depths with the greatest contamination at the Site). Based on the weight of evidence, no chemicals indicate potential risk for deep burrowing mammals considering the LOAEL/high TRV-based HQs; therefore, no further evaluation of this receptor is warranted. To further assess risk to the badger itself, the uncertainty analysis in Appendix U discussed the exceedances of the NOAEL/low TRVs. Screening-Level and Tier 1 Risk Description for Burrowing Receptors based on Soil Gas Evaluation

One assessment endpoint was identified for burrowing mammals at the Site and included protection at the population level of mammals that inhale burrow air. No specific receptor was identified for the quantitative evaluation of soil gas; instead, conservative risk-based concentrations were developed for mammals in general and screened against soil gas data. The maximum detected concentrations were used in the Screening-Level risk estimates. Details

are presented in Attachment 1 of Appendix U. Tier 1 risk estimates indicate that potential risk is expected to be *de minimis* from most of the VOCs, except for 1,2-dichloroethene and PCE. However, based on the Tier 1 risk estimates and conservative methodology used to estimate HQs, the risks from these VOCs are not considered significant. Risk estimates for offsite locations indicate that potential risk is expected to be *de minimis* from most of the VOCs. Based on the soil gas evaluation, no further evaluation is warranted.

9.6.2.8 Risk Description for Receptors Exposed to Historical Seeps

Several seeps were once present onsite, and historical data were reviewed for risk to aquatic life and amphibians. Only a few surface water samples were collected (historically) from the four seeps located on the Site. Seep data were mainly collected in 1997 and 1998 (and not as part of the RI data) and were not validated to the same level as the rest of the RI data. The reporting limits for many of the metals are higher than the screening values for amphibians, indicating uncertainties associated with potential risks. Based on the historical data, risks were estimated for aquatic life and amphibians; however, based on the quality of the data, the risks were likely overestimated. Historical seep data were not evaluated for wildlife receptors, as seeps are seasonal and probably not a significant exposure pathway for wildlife receptors. All the seeps at the Site are currently dry; therefore, no exposure pathways exist from this source for ecological receptors.

9.7 Screening-Level and Tier 1 Uncertainty Analysis

The approach used in the ERA was designed to mitigate sources of uncertainties that could result in underestimation of risks. Uncertainties may result from both the use of assumptions or models in lieu of actual data and from the error inherent in the estimation of exposure parameters. These uncertainties may result in the potential overestimation or underestimation of risks. However, because direct measurements are not available for many of the components upon which the risk estimates depend, conservative assumptions and methodologies were employed to minimize the possibility of underestimating risk.

The following steps were taken to minimize the potential for underestimation of risks:

- Estimates of CPEC concentrations in media were based on samples collected from known or suspected impacted locations within each study area and also from locations with much lower concentrations (including step-out samples) to limit overestimation of actual exposures.
- Wildlife representative species were intentionally selected based on attributes (e.g., small foraging areas) that provide conservative estimates of exposure for other members of the guild. Exposure parameters for the selected representative species from approved sources (e.g., USEPA's Wildlife Exposure Factor Handbook [USEPA,1993]) were preferred sources of wildlife exposure information to reduce the uncertainty for the species living at this specific Site.
- Estimates of exposure and risk do not necessarily account for avoidance behavior of wildlife (e.g., avoiding or not avoiding contaminated areas or foods).
- Reproductive or developmental effects, among the most ecologically relevant endpoints, were the preferred endpoints when identifying toxicity studies used in the selection of TRVs.
-

Because of these approaches and other protective assumptions made throughout the ERA, risks are expected to overestimate rather than underestimate the true risk associated with the Site. A detailed analysis of the major sources of uncertainties associated with the ERA methodology, specifically, uncertainties associated with the problem formulation, the data evaluation, the exposure assessment, the effects assessment, and risk characterization is described in detail in Appendix U.

9.8 Screening-Level and Tier 1 ERA Summary and Conclusions

The objective of the Screening-Level and Tier 1 ERA was to provide information in the RI phase on potential risks to ecological receptors that could be exposed to Site-related chemicals in selected onsite and offsite environmental media characterized as part of the RI. Ultimately, the findings and conclusions of this Screening-Level and Tier 1 ERA will be incorporated with other information in the FS portion of the environmental program to develop and evaluate remedial alternatives. The conclusions reached in this Screening-Level and Tier 1 ERA, along with other information, will be used to establish an overall Site risk management strategy.

Overall, risk to terrestrial birds at the Site is driven mainly by:

- Barium in the RCRA Canyon Area and the Former Ponds and Pads Areas
- Cadmium in the RCRA Canyon Area and WCSA
- Chromium in the RCRA Canyon Area, Roadway Area, and WCSA
- Copper in the WCSA
- Lead in the RCRA Canyon Area and Roadway Area
- Zinc in the RCRA Canyon Area and WCSA

Based on the results of the Tier 1 ERA, the invertivorous bird (based on the invertivorous meadowlark) is predicted to be the terrestrial bird most sensitive to potential adverse effects from exposure to these chemicals in soil 0 to 0.5 feet bgs except for the herbivorous bird (based on the herbivorous meadowlark) from barium Ingestion of surface water pathway was included for terrestrial wildlife in the RCRA Canyon and WCSA, where water data from the RCRA Canyon runoff were used, and terrestrial wildlife in the A-Series Pond, where water data from the A-Series Pond were used. The RCRA Canyon runoff and most of the A-Series EPCs are based on the maximum detected concentrations and, therefore, could potentially be contributing significantly to the overall risk to terrestrial birds in these exposure areas. Further evaluation may be required for these chemicals in the exposure areas listed above, for which no presumptive remedies are planned.

Risk to terrestrial mammals at the Site is driven mainly by:

- Barium in the RCRA Canyon Area
- Cadmium in the RCRA Canyon Area and WCSA
- Chromium in the RCRA Canyon Area and WCSA
- Copper in the RCRA Canyon Area and WCSA
- Zinc in the Roadway Area, Former Ponds and Pads Areas, RCRA Canyon Area and WCSA

Based on the Tier 1 ERA, the invertivorous mammal (based on the shrew) is predicted to be the terrestrial mammal most sensitive to potential adverse effects from exposure to metals in soil 0 to 5 feet bgs. The carnivorous mammal (based on the skunk) is predicted to be the

terrestrial mammal most sensitive to potential adverse effects from exposure to organics in soil 0 to 5 feet bgs. Potential adverse risk to deep burrowing mammals (0 to 10 feet bgs) via inhalation of burrow air or by ingestion of soil is expected to be unlikely from exposure to chemicals at the Site. Ingestion of surface water pathway was included for terrestrial wildlife in the RCRA Canyon and WCSA, where water data from the RCRA Canyon runoff were used, and terrestrial wildlife in the A-Series Pond, where water data from the A-Series Pond were used. The RCRA Canyon runoff and most of the A-Series EPCs are based on the maximum detected concentrations and, therefore, could potentially be contributing significantly to the overall risk to terrestrial mammals in these exposure areas, Further evaluation may be required for these chemicals in the exposure areas listed above, for which no presumptive remedies are planned.

Risks to terrestrial ecological communities at the site are driven mainly by:

- Barium in the RCRA Canyon Area
- Chromium in the RCRA Canyon Area, Roadway Area, and WCSA
- Copper in the WCSA

Risk to aquatic wildlife at the Site is driven mainly by:

- Arsenic, chromium, manganese, mercury, molybdenum, selenium, vanadium, and zinc in A-Series Pond;
- Barium, cadmium, chromium, and selenium in Pond A-5;
- Chromium and selenium in Pond 18; and
- Barium, chromium, chromium, and avian total PCB TEQ (and avian total TEQ) in RCF Pond.

Based on the Tier 1 ERA, the invertivorous bird (based on the killdeer) is predicted to be the aquatic bird most sensitive to potential adverse effects from exposure to these chemicals in surface sediment. However, all of these risk drivers are based on the maximum detected concentrations and may be overestimating potential risk to aquatic wildlife. Additionally, the diet for aquatic wildlife was based on a mixture of sediment invertebrates and aquatic invertebrates, assuming 50 percent of each, and this general assumption could potentially introduce uncertainty to the risk estimates. Further evaluation may be required for these chemicals in the exposure areas listed above, for which no presumptive remedies are planned.

Risk to sediment-dwelling invertebrates is mainly from:

- Barium, Nickel, and Selenium in A-Series Pond
- Barium and MCPP in Pond 18
- Barium, MCPP, and 1,1-dichloroethane in Pond 18
- MCPP, total PCBs, total DDT, acetone, and 1,1-dichloroethane in RCF Pond
- Carbon disulfide in Pond 13

Based on the Tier 1 ERA, risks to aquatic life, aquatic plants, and amphibians are mainly from metals in the onsite ponds. Potential risk to aquatic life, aquatic plants, and amphibians from chemicals in the offsite drainages were probably overestimated, as they were based on the maximum detected concentrations. Risks to amphibians for the RCRA Canyon runoff were estimated based on a conservative scenario. This scenario evaluated the potential risk to aquatic receptors under the hypothetical scenario that water pools in RCRA Canyon, which based on site observations, does not occur under current site conditions. Additional evaluations

of RCRA Canyon runoff and the potential for pooling once a remedy is in place for A-Series Pond will be evaluated in the FS. The seeps are currently dry and, therefore, are not expected to be sources of exposure to amphibians, aquatic life, or aquatic plants.

As mentioned earlier, all of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the site and will be backfilled/graded to prevent accumulation of water, they will be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all onsite ponds will be further detailed as part of the FS process. Therefore, none of the chemicals in the ponds with HQs greater than 1 were identified for further evaluation.

9.9 Screening-Level and Tier 1 ERA Recommendations for Tier 2 ERA

Based on the results of the Screening-Level and Tier 1 ERA, a Tier 2 assessment was recommended to further evaluate pathways, receptors, and CPECs requiring further evaluation (risk drivers/COIs), which can include additional studies and evaluations designed to make the assessment more Site-specific and less generic.

Data collection and further evaluation efforts recommended to further refine the risks included:

- Tissue sampling, specifically, plant, soil invertebrate, and/or mammal tissue sampling (tissue data collected collocated with existing soil data in areas of the Site that showed elevated risks), would be appropriate to refine risks for metals, pesticides, and PCBs.
- Bioassay tests (aquatic and/or terrestrial) were considered but not recommended due to limited usefulness given the chemicals that are risk drivers and the fact that the ponds will likely have presumptive remedies in place (also, bioassays using pond water would be challenging, given the high salt content of the pond water).
- Refinement of exposure assumptions (e.g., use of average or median concentrations), Site-specific life history information (e.g., dietary habits), and AUFs less than 1 were also recommended for consideration.
- Refinement of ecological benchmarks, including developing tissue TRVs to use as additional weight-of-evidence in the risk characterization, were recommended. Bioavailability tests were also recommended.

The areas that show unacceptable risks should be evaluated further in the FS and can also be used to narrow the areas of concern. For example, if an area is determined to need remediation based on both the assessment of human and ecological risks (e.g., a significant hot spot), further evaluation of that area and the risk-driving chemicals associated with it will not be necessary. Management of these key risk-driving areas will focus efforts on the more significant risks at the Site and will, consequently, reduce the overall Site risks, likely to within acceptable levels.

Presumptive remedies will be in place as part of the USEPA-approved closure plan for the Site for the treated liquid impoundments (Pond 18 and Pond A-5). Also, as part of the USEPA-approved closure plan for the Site, potential remedies for the stormwater ponds or impoundments (A-Series pond, RCF pond, and Pond 13), Central Drainage Area, Liquid Treatment Area, Burial Trench, and Maintenance Shed areas are also planned which will be further detailed as part of the FS process. These areas were not further evaluated in Tier 2.

The focus of any additional studies or evaluations (i.e., Tier 2) and the FS should involve the evaluation of the significant risk drivers listed above and the collection of data that provide a clearer understanding of the environmental benefit of reducing concentrations at the Site.

9.10 Tier 2 ERA Objectives and Approach

A Tier 2 assessment was conducted to further evaluate pathways, receptors, and COIs identified in the Tier 1 assessment as requiring further evaluation (i.e., risk drivers). Based on Tier 1 ERA results reported in th Draft RI Report and the Next Steps Memorandum (ARCADIS, 2008), a list of COIs were identified for Tier 2 assessment. The Tier 2 assessment was conducted by building on the results of the Tier 1 assessment and incorporating Site-specific tissue and bioaccumulation data. The Tier 1 ERA used modeled/assumed bioaccumulation factors for uptake of chemicals into prey items. Such assumptions and models are often conservative and overestimate risk.

The objectives of Tier 2 were to provide valuable information for refining risks, reduce the overall uncertainty in the risk estimates by incorporating Site-specific information into exposure estimates, and to provide additional lines of evidence to support a clearer understanding of the environmental benefit of reducing concentrations at the Site.

The Tier 2 ERA focused on the COIs, receptors, and exposure areas for which there is no presumptive remedy in place or contemplated. The Tier 1 ERA predicted that invertivorous bird and mammal populations were the most sensitive terrestrial wildlife, and their risks were driven by exposure to chemicals in surface soil. The aquatic invertivorous bird (based on the killdeer) was generally predicted to be the most sensitive aquatic bird, exposed to chemicals in surface sediment. The risks to aquatic birds are similar yo those for terrestrial birds when the Tier 1 ERA was conducted assuming the ponds would be drained. The pathway that generally contributed most to the risk estimate for all wildlife was food ingestion.

As discussed above, presumptive remedies will be in place as part of the USEPA-approved closure plan for the Site for the treated liquid impoundments (Pond 18 and Pond A-5). Also, as part of the USEPA-approved closure plan for the Site, a potential remedy for the stormwater ponds or impoundments (A-Series Pond, RCF pond, and Pond 13), Central Drainage Area, Liquid Treatment Area, Burial Trench, and Maintenance Shed areas are also likely to be implemented and will be further detailed as part of the FS process. Therefore, the Tier 2 ERA focused on the remaining exposure areas which included:

- RCRA Canyon;
- WCSA;
- Administration Building Area;
- Roadway Areas;
- Remaining Onsite Areas; and
- Former pond and pad areas.

The approach for Tier 2 assessment was discussed in the Next Steps Memorandum (ARCADIS, 2008) submitted to the USEPA in November 2008 and the Sampling and Analysis Plan (CSC, 2009) submitted to the USEPA in November April 2009, both of which were approved by the USEPA.

COIs, receptors, and pathways showing unacceptable risks in the Tier 2 ERA will be further evaluated in the FS.

9.11 Tier 2 Exposure Assessment

The methods used to estimate exposures for the ecological receptors for Tier 2 are similar to those used in Tier 1, which are summarized is Section 9.4 and described in detail in Appendix U. Similar to Tier 1, and consistent with USEPA and CalEPA guidance, the Tier 2 assessment was conducted using upper-bound assumptions, thus providing a high level of protection for the receptors represented by the evaluated functional groups. The methodology that was specific to Tier 2 is summarized below.

9.11.1 Tier 2 Exposure Point Concentrations

The non-spatial EPCs (95%UCLs) for soil, sediment, and surface water used for the Tier 1 assessment were also used for the Tier 2 assessment. Methods used to estimate non-spatial EPCs are summarized in Section 9.4.1.

Based on the COIs and exposure areas for Tier 2, EPCs for the following COIs/COI groups were used:

- Metals - RCRA Canyon;
- Metals - WCSA;
- Total PCBs - Roadway Areas;
- Total DDT - Remaining Onsite Areas;
- Total PCBs - Former Ponds and Pads; and

9.11.2 Tier 2 Exposure Scenarios

The Tier 2 exposure scenarios were developed based on the CSMs for Tier 1 but refined based on the results of the Tier 1 ERA. These are summarized below.

9.11.2.1 <u>Terrestrial Uncapped Areas</u>

The terrestrial uncapped areas for which no presumptive remedy is in place or contemplated included the following units:

- RCRA Canyon;
- WCSA;
- Roadway Areas;
- Administration Building Area;
- Remaining On-site Areas;
- Former ponds and pads; and

The receptors (indicator species) evaluated for the terrestrial uncapped exposure areas include:

- Mammals:
  - Herbivores (California vole)

  - Invertivores (ornate shrew)
  - Carnivore (striped skunk).

- Birds:
  - Invertivores (western meadowlark)
  - Herbivores (western meadowlark)
  - Carnivores (American kestrel).

The Tier 2 focused on the following COIs (i.e., risk drivers identified in Tier 1 ERA):

- Terrestrial Areas:
- Metals:
  - Barium
  - Cadmium
  - Chromium
  - Copper
  - Lead
  - Zinc.

The Tier 2 focused on the following additional chemicals, although they were not identified as risk drivers identified in Tier 1 ERA:

- Terrestrial Areas:
- Metals:
  - Molybdenum
  - Selenium
  - Vanadium

- Organics:
  - Total PCBs
  - Mammalian and avian PCB TEQs
  - Total DDT.

As mentioned above, freshwater aquatic areas were not quantitatively evaluated in the Tier 2 ERA because presumptive remedies are in place for all aquatic areas. Surface water ingestion by terrestrial wildlife was considered a completed and potentially significant pathway and were evaluated for RCRA Canyon and WCSA.

9.11.3 Tier 2 Exposure Assumptions

Exposure assumptions used in Tier 1 were also used in Tier 2 and described in detail in Appendix U.

Exposure assumptions, such as dietary composition and AUFs based on home ranges, were considered in the Tier 2 and discussed in the uncertainty analysis in Appendix U; however, no changes were made to the Tier 2 risk estimates, as Tier 1 assumptions provide a conservative but reasonable approximation of actual Site conditions.

9.11.4 Tier 2 Site-Specific Bioaccumulation Factors/Regressions

In Tier 1, literature-derived BAFs were used to estimate concentrations of CPECs in biota and food item tissue (i.e., prey) from Site media. Such assumptions and models are more uncertain in predicting site-specific bioaccumulation given differences in chemical form, exposure duration, and other Site-specific factors. Measurement of tissue concentrations in organisms at this Site addresses these factors and reduces the uncertainty in the resulting risk estimates. Site-specific tissue samples were collected in April 2009, and these data were paired with collocated soil/sediment data to evaluate uptake relationships between soil/sediment and tissue. These relationships developed using Site-specific data were used to estimate tissue concentrations rather than relying on BAFs derived from the scientific literature. Preliminary Site-specific BAFs were reviewed by USEPA in August 2009. Additional details on Site-specific BAF and regression development are provided in Attachment 6 of Appendix U.

9.11.5 Tier 2 Intakes/Dose Estimates

Tier 2 intake/dose estimates were calculated using the same approach described in Tier 1 (Appendix U). However, as mentioned above, Site-specific uptake regressions or BAFs were used instead of literature derived BAFs or regressions in Tier 2. Tier 2 intake/dose calculations and food/prey EPCs were calculated only for the exposure areas listed in Sections 9.11.2.

9.12 Tier 2 Effects Assessment

The NOAEL/low TRVs and the LOAEL/high TRVs used to estimate risks in the Tier 1 ERA (see Section 9.5) were used to estimate risks for the Tier 2 ERA. The approach, guidelines, and hierarchy used to develop screening values for ecological communities and TRVs for wildlife are described in detail in Attachment 2 of Appendix U.

9.12.1 Tier 2 Tissue Toxicity Reference Values for Wildlife

Mammalian tissue TRVs were developed for liver and kidney tissue, which were collected during the sampling effort described in Section 9.11.4 as additional weight of evidence to interpret and refine the Tier 1 risk estimates. Tissue TRVs were developed using methods similar to those presented in the Ecological Soil screening Level (EcoSSL) Guidance (USEPA, 2007; Attachment 4-5). The TRV development procedure consisted of three primary steps: (1) mode of action review, (2) a detailed literature search, and (3) TRV selection. A total of 348 results from 212 studies were reviewed during the tissue TRV development process. Target tissue TRVs were developed for kidney and liver tissue for cadmium, chromium, copper, lead, and zinc. Tissue TRVs were not derived for barium because kidney and liver tissue are not target tissue for barium toxicity. The approach and results of the tissue TRV process are described in Attachment 7 of Appendix U. A memorandum of the tissue TRVs was reviewed by the USEPA in July and August 2009.

9.13 Tier 2 Risk Characterization

Following CalEPA and USEPA guidance, and similar to Tier 1, the Tier 2 risk characterization phase consists of two steps: risk estimation and risk description. A Tier 2 spatial analysis was also conducted and the objective was to evaluate the distribution of elevated COI concentrations across exposure units to facilitate risk management for the site.

HQs were calculated for all COIs and receptors identifed in the CSMs for each exposure scenario (describe in Section 9.12.2):

- HQs based on background data (95 UTL), Site-specific bioaccumulation data, and literature derived TRVs for all COIs;
- HQs based on non-spatial EPCs, Site-specific bioaccumulation data, , and literature derived TRVs for all COIs; and
- HQs for mammalian receptors based on kidney and liver tissue concentrations and tissue TRVs for COIs that exhibit toxic effect on target tissues.

9.13.1 Tier 2 Risk Estimation

This section provides a summary of the risk estimations for the Tier 2 assessment.

9.13.1.1 Tier 2 Risk Estimates Based on Background

HQs were calculated for wildlife receptors based on background soil (95 UTLs) for metals. Those chemicals with background HQs greater than 1 are provided below.

	Tier 2 Terrestrial Wildlife Background Risk Estimates											
	Ornate Shrew		**California Vole**		**Striped Skunk**		**Western Meadowlark (Invertivore)**		**Western Meadowlark (Herbivore)**		**American Kestrel**	
COI	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**
Barium	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium	< 1	**1**	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Copper	< 1	**1**	< 1	< 1	< 1	< 1	< 1	**2**	< 1	< 1	< 1	**1**
Lead	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Molybdenum	< 1	**12**	< 1	**4**	< 1	**1**	< 1	**1**	< 1	< 1	< 1	< 1
Selenium	1	**15**	< 1	**6**	< 1	< 1	< 1	**14**	< 1	**3**	< 1	< 1
Vanadium	< 1	< 1	< 1	< 1	< 1	< 1	**4**	**9**	**4**	**8**	< 1	< 1
Zinc	< 1	**8**	< 1	< 1	< 1	< 1	< 1	**5**	< 1	**2**	< 1	**3**

High HQ = NOAEL/low TRV-based
Low HQ = LOAEL/high TRV-based

9.13.1.2 Tier 2 Risk Estimates Based on Site-Specific Tissue Data

NOAEL/low TRV and LOAEL/high TRV-based HQs were calculated for wildlife receptors based on non-spatial EPCs and Site-specific bioaccumulation data. Only COIs with NOAEL/low TRV and LOAEL/high TRV-based HQs greater than 1 are summarized in this section; risk estimates for all COIs are described in detail in Appendix U.

Terrestrial Wildlife: COIs with Tier 2 HQs > 1							
RCRA Canyon		WCSA		Administration Building Area		Roadway Area	
Birds	**Mammals**	**Birds**	**Mammals**	**Birds**	**Mammals**	**Birds**	**Mammals**
Barium	Barium	Chromium	Chromium	Copper	Molybdenum	Chromium	Chromium
Chromium	Chromium	Copper	Copper	Selenium	Selenium	Copper	Copper
Cadmium	Copper	Selenium	Molybdenum	Vanadium	Zinc	Lead	Molybdenum
Chromium	Molybdenum	Vanadium	Selenium	Zinc	--	Selenium	Selenium
Copper	Selenium	Zinc	Zinc	--	--	Vanadium	Zinc
Selenium	Zinc	--	--	--	--	Zinc	PCB TEQ
Vanadium	--	--	--	--	--	PCB TEQ	Total DDT
Zinc	--	--	--	--	--	Total DDT	--

Terrestrial Wildlife: COIs with Tier 2 HQs > 1			
Remaining Onsite Area		Former Ponds and Pads Areas	
Birds	**Mammals**	**Birds**	**Mammals**
Copper	Copper	Barium	Copper
Selenium	Molybdenum	Copper	Molybdenum
Vanadium	Selenium	Selenium	Selenium
Zinc	Zinc	Vanadium	Zinc
Total DDT	PCB TEQ	Zinc	PCB TEQ
--	Total DDT	PCB TEQ	--

■ Not applicable for receptor/chemical/exposure area.

HQs were also calculated on a sample-specific basis for kidney and liver tissue. The kidney and liver LOAEL/high TRV-based HQs were less than the 1 for cadmium, chromium, copper, lead, and zinc. The kidney tissue NOAEL/low TRV-based HQ was greater than 1 for copper in one sample (RC-05SM) only.

	Tier 2 Kidney Tissue Risk Estimates									
Sample	**RC-02SM**		**RC-03SM**		**RC-04SM1**		**RC-04SM2**		**RC-05SM**	
COI	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**	**Low HQ**	**High HQ**
Copper	< 1	**1**	< 1	**1**	< 1	**1**	< 1	**1**	< 1	**2**

9.13.2 Tier 2 Risk Description

This section provides a summary of the risk description for the Tier 2 assessment.

9.13.2.1 Tier 2 Risk Description for Terrestrial Mammals

Risk estimates indicate that potential risk to terrestrial mammal populations is expected to be *de minimis* from exposure to the organic COIs. Similar to the Tier 1 ERA, no further evaluation is warranted for chemicals with LOAEL/high TRV-based HQs less than 1 and/or NOAEL/low TRV-based HQs less than 10, and/or those with HQs similar to background. Based on the weight of evidence, chemicals that indicate potential risk and warrant further evaluation include metals as described below.

Chemical	Ornate Shrew	California Vole	Striped Skunk
Barium	RCRA Canyon	--	--

-- Not applicable for receptor/chemical/exposure area.

9.13.2.2 Tier 2 Risk Description for Terrestrial Birds

No further evaluation is warranted for chemicals with LOAEL/high TRV-based HQs less than 1, and/or NOAEL/low TRV-based HQs less than 10, and/or those with HQs similar to background. Based on the weight of evidence, chemicals that indicated potential risk and warrant further evaluations include metals as described below.

Chemical	Western Meadowlark (Invertivore)	Western Meadowlark (Herbivore)	American Kestrel
Barium	RCRA Canyon	RCRA Canyon	RCRA Canyon
Chromium	RCRA Canyon Area, WCSA, and Roadway Areas	RCRA Canyon and WCSA	--
Copper	RCRA Canyon, WCSA, and Roadway Areas	RCRA Canyon and WCSA	RCRA Canyon and WCSA
Zinc	RCRA Canyon and WCSA	--	--

-- Not applicable for receptor/chemical/exposure area.

9.14 Spatial Analysis

A spatial analysis was conducted for those COIs and receptors where the potential for risk was identified. The objective of the spatial analysis was to evaluate the distribution of elevated COI concentrations across exposure units to facilitate risk management for the Site. For ecological communities (soil invertebrates and terrestrial plants), COIs included those chemicals identified as risk drivers in Tier 1. Spatial risks for wildlife receptors were evaluated for those COIs described above in Tier 2 for terrestrial mammals and birds. To eliminate redundancy and to provide information to focus the FS, the spatial analysis was limited to the most sensitive wildlife species for both soil depth intervals (surface and shallow), which included the western meadowlark (invertivore) for the surface interval and the ornate shrew for the shallow soil interval.

The spatial analysis provides a tool for a more detailed interpretation of potential risk at the Site. Specifically, this analysis provides a clear understanding of where specific soil locations that could result in potential unacceptable Site-related risk to ecological receptors are found. This analysis also clarifies where elevated concentrations are localized (i.e., potential unacceptable risk identified in the risk estimate is driven by exposure estimates that are skewed and do not represent general conditions) or are more widespread and where potential unacceptable risks are low or high in magnitude. The results of the spatial analysis are discussed in detail in Appendix U.

9.15 Tier 2 Uncertainty Analysis

The approach used in the Tier 2 ERA was designed to reduce uncertainties that were inherent in the Screening-level and Tier 1 ERA in an effort to avoid the underestimation of risks. This

was accomplished in the Tier 2 ERA by incorporating Site-specific data rather than relying on modeled/estimated accumulation estimates, and relying on 95% UCLs on the mean to estimate exposure rather than maximum concentrations. Although Tier 2 represents a more refined and Site-specific ERA, protective assumptions inherent to the ERA process were retained, and Tier 2 risks are expected to overestimate rather underestimate the true risk associated with the Site. A detailed analysis of the major sources of uncertainties associated with the Tier 2 ERA is provided in Appendix U.

9.16 Tier 2 Summary and Conclusions

The objective of the Tier 2 ERA was to further evaluate pathways, receptors, and COIs identified in the Tier 1 ERA as requiring further evaluation (i.e., risk drivers). Ultimately, the findings and conclusions of this Tier 2 ERA will be incorporated with other information in the FS portion of the environmental program to develop and evaluate remedial alternatives. The conclusions reached in this Tier 2 ERA, along with other information, will be used to establish an overall Site risk management strategy.

Overall, risk to terrestrial birds at the Site is driven mainly by:

- Barium, chromium, copper, and zinc in the RCRA Canyon Area;
- Chromium, copper, and zinc in the WCSA;
- Chromium and copper in the Roadway Areas;

The invertivorous bird (based on the invertivorous meadowlark) is predicted to be the terrestrial bird most sensitive to potential adverse effects from exposure to these chemicals in soil 0 to 0.5 feet bgs except for the herbivorous bird (based on the herbivorous meadowlark) from barium. The ingestion of surface water pathway was included for terrestrial wildlife in the RCRA Canyon and WCSA, where water data from the RCRA Canyon runoff were used. The RCRA Canyon runoff and most of the A-Series EPCs are based on the maximum detected concentrations and, therefore, could potentially be contributing significantly to the overall risk to terrestrial birds in these exposure areas.

For terrestrial mammals, a comparison of Site-specific tissue data to tissue-based TRVs developed for kidney and liver tissue indicates that cadmium, chromium, copper, lead, and zinc are not expected to accumulate in target tissues at levels that would result in potential risks to terrestrial mammals.
Risk to terrestrial mammals at the Site is driven mainly by:

- Barium in the RCRA Canyon Area;

The invertivorous mammal (based on the shrew) is predicted to be the terrestrial mammal most sensitive to potential adverse effects from exposure to metals in soil 0 to 5 feet bgs. Ingestion of the surface water pathway was included for terrestrial wildlife in the RCRA Canyon and WCSA, where water data from the RCRA Canyon runoff were used. The RCRA Canyon runoff and most of the A-Series EPCs are based on the maximum detected concentrations and, therefore, could potentially be contributing significantly to the overall risk to terrestrial mammals in these exposure areas.

9.17 Summary of Tier 1 and Tier 2 Risk Drivers

Based on the Tier 1 ERA and Tier 2 ERA for the Site, the following risk drivers were identified for surface soil and shallow soil:

Exposure Area	Risk Drivers[1] in Surface Soil (based on Terrestrial Birds, Soil Invertebrates, and Plants)	
	Tier 1 ERA	Tier 2 ERA[2]
RCRA Canyon Area	Barium, Cadmium, Chromium, Lead, and Zinc	Barium, Chromium, Copper, and Zinc
WCSA	Cadmium, Chromium, Copper, and Zinc	Chromium, Copper, and Zinc
Administration Building Area	None	None
Roadway Area	Chromium	Chromium and Copper
Remaining Onsite Area	None	None
Former Ponds and Pads	Barium	None
Liquid Treatment Area[3]	Cadmium, Chromium, Vanadium, MCPP, DDT, total DDT, and Hexachlorobenzene	--
Burial Trench Area[3]	Chromium, Vanadium, and TCE	--
Maintenance Shed Area[3]	Cadmium, Chromium, Lead, Vanadium, and DDE, and Total DDT	--
Central Drainage Area[3]	Chromium, Vanadium, Dioxin TEQ, Total TEQ, Bis (2-ethylhexyl)phthalate, and Endrin[3]	--
A-Series Pond[3]	Cadmium, and Selenium	--
RCF Pond[3]	Barium and Chromium	--
Pond A-5[3]	Barium, Cadmium, Chromium, and Selenium	--
Pond 13[3]	Cadmium and Selenium	--
Pond 18[3]	Cadmium and Chromium, and Selenium	--

-- Exposure area not evaluated in Tier 2
[1] = Risk drivers selected based on the criteria described in Section 6.2 and 12.2 of Appendix U.
[2] = Risk drivers based on terrestrial birds only.
[3] = Exposure area has a presumptive remedy in place and was not evaluated in Tier 2.

Exposure Area	Risk Drivers[1] in Shallow Soil (based on Terrestrial Mammals, Soil Invertebrates, and Plants)	
	Tier 1 ERA	Tier 2 ERA[2]
RCRA Canyon Area	Barium, Cadmium, Chromium, Copper, and Zinc	Barium
WCSA	Cadmium, Chromium, Copper, and Zinc	None
Administration Building Area	None	None
Roadway Area	Chromium and Zinc	None
Remaining Onsite Area	None	None

Exposure Area	Risk Drivers[1] in Shallow Soil (based on Terrestrial Mammals, Soil Invertebrates, and Plants)	
	Tier 1 ERA	Tier 2 ERA[2]
Former Ponds and Pads	Zinc	None
Liquid Treatment Area[3]	Cadmium, Molybdenum Selenium, Zinc, DDT, Total DDT, MCPP, Hexachlorobenzene, and Mirex[3]	--
Burial Trench Area[3]	Molybdenum, Selenium, and Zinc	--
Maintenance Shed Area[3]	Cadmium, Chromium, Lead, Zinc, Dioxin TEQ, and Total TEQ	--
Central Drainage Area[3]	Molybdenum, Zinc, Dioxin TEQ, and Total TEQ	--
A-Series Pond[3]	Cadmium, Molybdenum, Selenium, and Zinc	--
RCF Pond[3]	Molybdenum, Selenium, and Zinc	--
Pond A-5[3]	Barium, Cadmium, Molybdenum, Selenium, and Zinc	--
Pond 13[3]	Cadmium, Selenium, and Zinc	--
Pond 18[3]	Cadmium, Molybdenum, Selenium, and Zinc	--

-- Exposure area not evaluated in Tier 2
[1] = Risk drivers selected based on the criteria described in Section 6.2 and 12.2 of Appendix U.
[2] = Risk drivers based on terrestrial mammals only.
[3] = Exposure area has a presumptive remedy in place and was not evaluated in Tier 2.

Based on the Tier 1 ERA and Tier 2 ERA for the Site, no risk drivers were identified for sediment:

Exposure Area	Risk Drivers[1] in Sediment (based on Aquatic Wildlife and Sediment Invertebrates)	
	Tier 1 ERA	Tier 2 ERA
A-Series Pond	Arsenic, Chromium, Manganese, Mercury, Molybdenum, Selenium, Vanadium, and Zinc	--
RCF Pond	Barium, Chromium, Avian PCB TEQ, total TEQ, and MCPP	--
Pond A-5	Barium, Cadmium, Chromium, Selenium, and MCPP	--
Pond 13	None	--
Pond 18	Chromium, Selenium, and MCPP	--

[1] = No risk drivers were identified for sediment as all of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the site and will be backfilled/graded to prevent accumulation of water, they will

be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all onsite ponds will be further detailed as part of the FS process.

9.18 References

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10.0 PRELIMINARY TECHNICAL IMPRACTICABILITY EVALUATION

As part of the feasibility study, the CSC plans to evaluate and consider proposing a TI waiver zone for groundwater restoration as provided in Section 2.9.2.2(K) of the Site Consent Decree. This section of the Consent Decree provides the following performance standard:

> *Perform an analysis, substantiated by data and other evaluation information, consistent with 300.430(f)(ii)(C) of the NCP and the Guidance for Evaluating the Technical Impracticability for Groundwater Restoration. EPA Directive 9234.2-25, of the technical impracticability of restoring the groundwater in the Zone 1 area.*

EPA has not approved any TI waiver for the Site. EPA will review and consider the CSC's planned TI waiver zone evaluation for groundwater restoration based on information provided in the RI Report, the FS Report, and any other information deemed necessary by EPA. EPA will make an evaluation of whether a TI waiver is appropriate for the Site only after all necessary information has been provided and reviewed.

The restoration of contaminated groundwater, especially for a designated drinking water aquifer, is one of the objectives of the CERCLA or Superfund program. The NCP, which provides the regulatory framework for the CERCLA program, states that the USEPA "expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site" [NCP section 300.430(a)(l)(iii)(F)]. Generally, restoration cleanup levels are established by ARARs, such as the use of federal or state standards for drinking water quality (USEPA, 1993).

Experience has shown, however, that restoration to drinking water quality may not always be achievable due to the limitations of available remediation technologies and the inherent limitations of the subsurface physical characteristics and contaminant properties. USEPA, therefore, must evaluate whether groundwater restoration at Superfund sites is attainable from an engineering perspective. As discussed in EPA's "*Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration, Interim Final*, USEPA OSWER Directive 9234.2-25, September 1993" there are a number of factors that can inhibit groundwater restoration which include hydrogeologic and contaminant-related factors, such as the presence of DNAPLs. This is particularly relevant to the Site, where the LNAPLs and DNAPLs that are found at the Site are primarily from the disposal of billions of pounds of liquid wastes within capped landfills that cannot be removed. We have discussed the factors that affect groundwater restoration, and their specific relevance to the Site, in Table 10-1 and in Section 10.2, below.

As provided for by USEPA guidance, groundwater ARARs may be waived or modified in cases where compliance with the requirements is technically impracticable from an engineering perspective. Where groundwater ARARs are waived at a Superfund site due to technical impracticability, the USEPA's general expectations are to prevent further migration of the contaminated groundwater plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction measures as appropriate [NCP section 300.430(a)(l)(iii)(F)].

As stated in the RI/FS Work Plan, the preliminary remedial action objectives for the Site include restoring groundwater quality to applicable standards, where technically practicable. As discussed in the performance standards for the RI/FS (see RI/FS Work Plan; CSC, 2004), the CSC will evaluate the practicability of restoring groundwater quality to applicable media

standards per the NCP. Because EPA recognized that restoring groundwater under the Site posed some specific challenges, the Consent Decree (and attached Statement of Work) with the CSC provided that the CSC was required to complete a preliminary TI Evaluation as part of the RI process. This requirement is discussed in more detail in Section 10.1 below.

Per the TI Evaluation Guidance (USEPA, 1993), groundwater restoration can be technically impracticable based on: (1) geologic and hydrogeologic constraints; (2) chemical-specific conditions (such as the presence of DNAPLs); and/or (3) treatment technology limitations. As provided for in the TI Evaluation Guidance, decisions regarding the technical practicability of groundwater restoration must be based on a thorough characterization of the physical and chemical aspects of the Site. All reasonable efforts must be made to identify the location of source areas through historical information searches and Site characterization efforts. The TI Evaluation Guidance notes "the presence of known remediation constraints, such as DNAPL, fractured bedrock, or other Site conditions, are by themselves not sufficient to make a TI determination. Adequate Site characterization data must be presented to demonstrate not only that the constraint exists, but that the effect of the constraint or contaminant distribution and recovery potential poses a critical limitation to the effectiveness of available technologies."

This section of the RI Report presents a preliminary Technical Impracticability Evaluation (TIE) for the Site. This section first presents the basis for the preliminary TIE (Section 10.1) and then provides a discussion of the factors affecting groundwater restoration (Section 10.2). This preliminary TIE then provides an evaluation of the first three components of a complete TI evaluation, and includes:

- Component 1 – Identifying specific ARARs or media cleanup standards for which TI determinations are sought (Section 10.3);
- Component 2 – Evaluating the spatial area over which the TI decision may apply (Section 10.4); and
- Component 3 – Developing a conceptual model that describes the geology, hydrogeology, groundwater contaminant sources, transport, and fate (Section 10.5).

As we noted above, the Statement of Work for the Consent Decree between USEPA and the CSC (USEPA, 1997) provides that the CSC will complete the TIE in two steps and in this first step evaluate whether we have gathered the data needed to provide an evaluation of the first three of the six components. The technical engineering and cost evaluations associated with the TI evaluation will be completed within the upcoming FS (i.e., the second three of the six steps). The FS will therefore include the following TIE components, which will complete the overall TI evaluation:

- Component 4 – An evaluation of the restoration potential of the Site, including data and analyses that support any assertion that attainment of ARARs or media cleanup standards is technically impracticable from an engineering perspective;
- Component 5 – Estimates of the cost of the existing or proposed remedy options, including construction, operation, and maintenance costs; and
- Component 6 – Any additional information or analyses that the USEPA deems necessary for the TI evaluation.

The FS will also update the evaluation of the first three components presented in this preliminary TIE to (1) incorporate additional ARAR or media-specific standards that are identified and would be appropriate for a TI Waiver, (2) revise the spatial area over which a

potential TI decision would apply based on the full analysis of all six components of the TI evaluation, and (3) update the conceptual Site model based on any additional data or analysis that would update or change the understanding of the geology, hydrogeology, groundwater contaminant sources, transport, and fate.

10.1 Basis for Preliminary TI Evaluation

It is premature to conclude whether a waiver of ARARs for groundwater restoration due to technical impracticability (a TI waiver) will be necessary or not for the Site. The inclusion of this preliminary TIE within the RI Report is required as part of an approved work plan for the RI/FS that in turn relies on the requirements of the September 1997 Consent Decree. The RI/FS Work Plan describes how the TI evaluation would be integrated into the RI/FS to be consistent with the Consent Decree SOW. As defined in the Performance Standards for the RI/FS (see Table 1-1 of the RI/FS Work Plan), the RI/FS will "perform an analysis, substantiated by data and other evaluative information, consistent with §300.430(f)(ii)(C) of the NCP and the *Guidance for Evaluating the Technical Impracticability of Groundwater Restoration*, *EPA Directive 9234.2-25,* of the technical impracticability of restoring groundwater in Zone 1 of the Site." The CSC therefore integrated the TI evaluation into the RI/FS Work Plan so that the data needed to determine if a TI waiver is warranted could be collected as part of the RI; and the technical, engineering, and cost evaluations associated with the TI evaluation will be considered during the FS.

The CSC will complete the final TI evaluation in concert with the FS, such that appropriate alternate remedial strategies (such as source control and containment) can be developed, in the event that groundwater restoration is not technically practicable. Pairing the TI evaluation with the FS also ensures that a consistent technology performance and cost basis is being used to make remedial decisions for the Site.

The groundwork for certain aspects of the TI evaluation (such as defining Site hydrogeologic characteristics, the nature and extent of dissolved-phase groundwater contaminants, and the distribution and fate and transport of NAPL in the subsurface) are discussed in this section of the RI Report.

10.2 Factors Affecting Groundwater Restoration

As described in Section 10.1, the CSC has not concluded at this time whether a TI waiver will be necessary for the Site, however, as described in Sections 1 through 7 of this RI Report, there are many Site conditions that are considered unfavorable for implementing a groundwater restoration remedy that would return groundwater to its beneficial uses within a timeframe that is reasonable, as required by the NCP §300.430(a)(1)(iii)(C). As described in the TI Evaluation Guidance, certain Site characteristics may limit the effectiveness of subsurface remediation. Table 10-1 describes these factors and provides a generalized remediation difficulty scale. Site-specific information (along with references to specific sections of this RI Report that more thoroughly describe these characteristics) are also provided in Table 10-1 to provide perspective on how these factors might affect groundwater restoration at the Site.

As shown in Figure 1 of USEPA's TI Waiver Guidance (OSWER Directive 9234.2-25, September 1993), there are many characteristics that affect groundwater restoration, including, but not limited to:

- Site Use (e.g., volumes, durations, types of chemical releases);
- Chemical Properties (e.g., decay potential, volatility, retardation potential);
- Contaminant Distribution (e.g., phase, volume of impacted media, depth);
- Geology (e.g., stratigraphic complexity, grain size, heterogeneity); and
- Hydraulics/Flow (e.g., conductivity, temporal variations, vertical flow).

Table 10-1 describes how many of these factors, when reviewed individually and applied to the Site conditions, tend to fall along the "increasing difficulty" end of the remediation difficulty scale as defined by USEPA in the TI Evaluation Guidance. In some cases, limitations on remedial effectiveness based on individual factors like the ones described above could be addressed by selecting more aggressive treatment technologies. For example, solvent DNAPLs are generally considered more difficult to remediate than dissolved phased solvents in groundwater. If all other conditions were generally favorable for groundwater restoration potential (e.g., it was a small release in a shallow homogenous sandy aquifer overlying competent unfractured bedrock), then an aggressive treatment technology could be selected to address the presence of recalcitrant DNAPLs that could possibly be effective within a reasonable timeframe. However, at the Site, there are combinations of many factors that are unfavorable for groundwater restoration. For example:

- There are LNAPLs and DNAPLs *in* fractured bedrock.
- There are mixed wastes in groundwater (hydrocarbons, solvents, PCBs, metals, etc,) that are not likely to be treatable by a single technology.
- Many of the contaminants are relatively immobile and sorption within the aquifer matrix appears to be the primary environmental fate-governing mechanism.
- The geology is complex; the overburden geology has low permeability and the basement rock is fractured.
- There are ongoing sources of contaminants that cannot be physically removed (e.g., pesticides and solvents within the capped P/S Landfill).

In addition to the regulatory framework that dictates the evaluation of factors related to Technical Impracticability (as described in Section 10.1), the data collected during the RI have demonstrated a set of conditions that, when evaluated individually or combined with each other, are consistent with the types of conditions that may ultimately require a TI waiver for the Site. This preliminary TIE has therefore been developed to provide a contextual framework for Site data as they apply to a potential TI waiver application. This section does not include detailed engineering evaluations or cost analyses (those components of the evaluation will be presented in the forthcoming Feasibility Study).

10.3 Site-specific Applicable or Relevant and Appropriate Requirements

The NCP requires that remedial actions at CERCLA sites meet ARARs unless there are reasons for invoking a waiver. ARARs consist of federal and state environmental requirements that may affect implementation of remedial alternatives. CERCLA, as amended by SARA in 1986, and implemented by the NCP, requires identification of all potential ARARs that must be addressed by the USEPA or parties undertaking the remedial action. Determination of ARARs is Site-specific and depends on the chemical contaminants, Site/location characteristics, and remedial actions being investigated for Site cleanup. As discussed in the TI Waiver Guidance, the USEPA may determine that groundwater restoration is technically impracticable when groundwater cannot be restored with available remediation technologies within a reasonable timeframe. In a case where groundwater may be used for drinking water, "restoration" refers to

federal or state standards for drinking water quality or risk-based levels for compounds where no ARARs exist.

Hydrogeologic limitations, such as complex sedimentary deposits, low permeability aquifers, and types of fractured bedrock, and contaminant-related factors, such as the presence of NAPLs, are among the factors that can inhibit groundwater restoration. DNAPL is present at most sites where the USEPA has determined that groundwater restoration is technically impracticable (USEPA, 1993). The Site includes many of the elements supporting technical impracticability, including the presence of large quantities of drummed wastes within capped landfills, wastes that were directly disposed of into the subsurface (e.g., in the Burial Trench Area), and DNAPLs associated with these sources that have migrated into deep fractured bedrock.

ARARs are promulgated, enforceable federal and more stringent state environmental or public health requirements. There are two categories of requirements: “applicable” and “relevant and appropriate.” A requirement may be either applicable or relevant and appropriate, but not both. These categories are defined below:

- Applicable Requirements – The NCP defines applicable requirements as “those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.”
- Relevant and Appropriate Requirements – The NCP defines relevant and appropriate requirements as “those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to a particular site.”
- To Be Considered – TBC guidelines are non-promulgated criteria, advisories, and guidance issued by the federal or state governments. Along with ARARs, TBCs may be used to develop the interim action limits necessary to protect human health and the environment.

ARARs and TBCs are divided into three categories: chemical-specific, location-specific, and action-specific. These categories are briefly described for Casmalia groundwater in the paragraphs that follow. The ARARs provided herein are specific to TI evaluation for groundwater impacts, and do not necessarily represent a complete list of ARARs that will be presented in the upcoming FS for Site-wide remedial alternative evaluations, and represent only a portion of the ARARs identified in the 2004 RI/FS Work Plan.

As noted above, the FS will incorporate additional ARAR or media-specific standards that are identified and would be appropriate for a TI Waiver.

10.3.1 Chemical-specific ARARs

Chemical-specific ARARs are usually health-based or risk-based numerical values or methodologies that establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment. In general, chemical-specific requirements

are set for a single chemical or a closely related group of chemicals. These requirements do not consider mixtures of chemicals. Chemical-specific ARARs for groundwater at the Site include:

- State and federal MCLs, which are chemical-specific ARARs that govern the quality of drinking water provided by a public water supply. MCLs may be used as relevant and appropriate requirements in establishing groundwater remediation goals for private wells and surface water remediation goals at the Site;
- PRGs, which may be used for general risk screening purposes or to set initial cleanup goals; and
- Public Health Goals (PHGs), which are chemical-specific water quality goals based on current health risk assessment methods.

As described below in this preliminary TIE, restoration of groundwater quality to drinking water standards may be technically impracticable at the Site. The compounds and their respective ARARs for which a technical impracticability waiver may be requested are presented in Table 10-2. The compounds include all chlorinated solvents released at the Site and related compounds, such as daughter compounds, as well as other co-located compounds dissolved in groundwater such as petroleum hydrocarbons, pesticides, herbicides, and heavy metals. At Casmalia, chlorinated compounds are the most widespread. These and other co-located compounds are generally recalcitrant and may limit the ability to restore groundwater at the Site. There are multiple chemicals of concern that commingle with the chlorinated solvents at the Site, and there is little perceived benefit to attempting to remediate the co-located compounds (i.e., not seeking to apply an ARAR waiver) while applying an ARAR waiver to chlorinated compounds. Therefore, a TI waiver would likely apply to all dissolved contaminants found at the Site. The maximum reported groundwater concentrations for each of the compounds exceeding MCLs are listed in Table 10-3 for reference.

10.3.2 Location-specific ARARs

Location-specific ARARs are restrictions placed on the concentrations of hazardous substances, or the conduct of activities solely because they are in specific areas. The general types of location-specific ARARs that may be applied to the Site are summarized on Table 10-4 and briefly described below.

- Location standards for construction of any new treatment, storage, or disposal facilities based on seismic considerations;
- Air quality standards for storage of VOCs on site; and
- Water quality criteria based on the Central Coast RWQCB Basin Plan.

No waiver of location-specific ARARs would likely be sought for the Site if a TI waiver is implemented. It is assumed that any remedial activities at the Site will be designed to meet location-specific ARARs.

10.3.3 Action-specific ARARs

Action-specific ARARs are usually technology-based or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are generally focused on actions taken to remediate, handle, treat, transport, or dispose of hazardous wastes. These action-specific requirements do not in themselves determine the

remedial alternative; rather, they indicate how a selected alternative must be implemented. The general types of action-specific ARARs that may be applied to the Site are summarized on Table 10-5 and are briefly described below:

- Air quality. Ambient air quality standards may be applied to actions that could result in air emissions of specific VOCs. Air Quality Management District Regulations and a number of RCRA regulations govern emissions from process vents, equipment, tanks, and containers. These requirements may be considered depending on the response actions selected;
- Water quality. The potential for off-site migration of chemicals will be monitored at a selected POC. A POC is a vertical surface, located at the hydraulically downgradient limit of the waste management units, extending through the uppermost aquifer underlying the regulated unit. Water quality goals must be met based on beneficial uses that have been established by RWQCB; and
- Hazardous waste management. Various California state regulations establish standards for identification, treatment, storage, and disposal of hazardous waste, in addition to establishing standards for closure, post closure, and groundwater monitoring.

No waiver of action-specific ARARs would likely be sought for the Site if a TI waiver is implemented. It is assumed that any remedial activities at the Site will be designed to meet action-specific ARARs.

10.4 Spatial Extent of TI Decisions

As described in the TI Waiver Guidance, where the USEPA determines that groundwater restoration is technically impracticable, the area over which the decision applies (the “TI zone”) may include a portion of, or all portions of the contaminated groundwater that do not meet the required cleanup levels. However, delineation of a TI zone based on the location of a particular mapped concentration contour interval (e.g., the MCL for a particular VOC) should generally be avoided because the location of mapped contours is often highly interpretive and their position may change over time.

For the Site, the area over which the CSC believes that the area over which a potential TI zone may apply could vary by hydrostratigraphic unit as follows:

- Upper HSU – The potential TI zone for the Upper HSU may encompass the entire footprint of the Site; and
- Lower HSU – The potential TI zone for the Lower HSU may encompass the area north of the PSCT. The depth of this TI zone would correspond to the deepest impacted well within the Site boundaries.

The spatial extent of these potential TI Zone areas is shown in Figure 10-1. These areas are currently impacted by contamination emanating from the Site or we anticipate that they may become impacted in the foreseeable future.

The CSC’s basis for proposing this TI zone is described in more detail in Section 10.5, but is generally due to the following conditions at the Site:

- For the area north of the PSCT (included in both the Upper HSU and Lower HSU TI zones) – this area represents non-removable contaminant sources – primarily drummed

wastes within capped landfills, wastes that were directly disposed of into the subsurface (e.g., in the Burial Trench Area), and DNAPLs associated with these sources that have migrated into deep fractured bedrock; and

- For the area south of the PSCT and north of the Site's southern boundary (applies to the Upper HSU TI zone only) – this area already contains groundwater concentrations above drinking water standards for organic and/or inorganic chemicals of concern (MCLs are the presumed cleanup goals for groundwater) and may be impacted by residual chemicals from former waste disposal ponds and pads that were not completely excavated during previous remedial actions.

As noted above, the FS will update the evaluation of the spatial area over which a potential TI decision would apply based on the full analysis of all six components of the TI evaluation.

10.5 Conceptual Site Model

This section of the RI Report presents a summary of information related to the Site's physical characteristics, nature and extent of groundwater contamination (including the presence of NAPLs), and the fate and transport of contamination as it relates to the practicability of groundwater restoration at the Site. These items are presented in the form of a conceptual Site model (CSM). Development of a CSM for the Site is a dynamic process; the CSC has been developed the CSM over time following numerous investigations and the CSM has been presented in many forms in existing documents for the Site. The foundations of the CSM are provided in previous sections of this RI Report. A detailed discussion of the Site-specific geology and hydrogeology is presented in Section 4. The nature and extent of contamination in the various environmental media are described in Section 5. Contaminant fate and transport is summarized in Section 6.

The CSM, as summarized below, includes the most important geologic and hydrogeologic conditions at the Site to support the TIE. This section includes general summaries of the following:

- Regional and Site Geologic and Hydrogeologic Setting – This section references other specific sections and appendices of this RI Report wherein detailed discussions of regional and local geologic and hydrogeologic conditions may be found. Information presented in these other sections and appendices include descriptions of geologic formations, topography, drainage features, and regional groundwater quality, as well as descriptions of hydrostratigraphic units, the degree of fracturing in the subsurface, groundwater movement and hydraulic properties, solute transport, groundwater elevations, flow divides, vertical gradients, annual fluctuations in response to recharge, and liquid control features operating at the Site. (Section 10.5.1);
- Contaminant Distribution in Groundwater – The discussion in this section will identify primary Site groundwater contaminant source areas, present the lateral and vertical extent of aqueous phase contamination, and describe the location and extent of NAPL contamination. (Sections 10.5.2 and 10.5.3); and
- Contaminant Fate and Transport – The CSC will identify major groundwater contaminant transport pathways at the Site, summarize relevant flow model findings, and provide information on the potential for natural attenuation or degradation of groundwater contaminants. (Section 10.5.4).

To the extent practical, the subsections below are abbreviated because more detailed descriptions are provided elsewhere in this RI Report. To avoid duplication of illustrative figures, the following sections will reference figures found elsewhere in this RI Report.

As noted above, the FS will also update the CSM based on any additional data or analysis that would update or change the understanding of the geology, hydrogeology, groundwater contaminant sources, transport, and fate.

10.5.1 Regional and Site Geologic and Hydrogeologic Setting

To avoid redundancy with information presented elsewhere, please refer to Sections 4.4 and 4.5 of this RI Report for a complete discussion of regional and local geologic and hydrogeologic conditions. In addition to the above-referenced sections, further details regarding Site-specific hydrogeologic conditions are presented in Appendices E, F, and G of this RI Report.

For the purposes of the TIE, it is important to understand the local hydrostratigraphic units that have been the focus of investigation at the Site. The Upper HSU consists of localized alluvium, colluvium, and fill and the weathered and highly fractured claystone, as described in Sections 4.4.2.1 and 4.4.2.2, respectively. The thin, approximately 2- to 5-foot transition zone between the weathered and unweathered claystone is included in the Upper HSU. The Upper HSU is found beneath 90 percent of the Site and ranges in thickness from approximately 30 to 60 feet. The Upper HSU is generally thicker in the higher topographic areas, although the unit is mostly to completely unsaturated in some of the topographically higher areas of the Site. The Upper HSU is poorly transmissive. The Lower HSU consists of the unweathered claystone at the Site. The top of the unit generally follows the surface topography. The unit is estimated to be approximately 900 to 1,300 feet thick and is underlain by Monterey shale. The Lower HSU has a much lower fracture density compared to that of the Upper HSU, as discussed in Section 4.4.2.2. Although groundwater flow occurs through fractures, most groundwater in this unit is in the matrix porosity. The Lower HSU is expected to approximate a porous medium on a large scale (hundreds of feet or more). This unit is less transmissive than the Upper HSU. The Upper HSU/Lower HSU contact is one of the boundaries that may be included in a potential Technical Impracticability zone, described later in this section.

It is also important to understand the fractured nature of the hydrostratigraphic units at the Site. As described in Section 4.4.4.5, geologic investigations concluded the following:

- The weathered claystone is more pervasively fractured than the unweathered claystone.
- The fractures in the weathered claystone display highly variable dip within boreholes, with the dip generally less than 30°.
- Within the unweathered claystone, there is a wide range of fracture orientation and no discernible predominant orientation of fractures.
- Some common fracture orientations occur in both the weathered and unweathered claystone, typically northeast- to east-northeast striking high angle to near vertical fractures.
- The density and degree of fracturing within the unweathered claystone varies between both distant and adjacent sampling locations.
- Fractures within the unweathered claystone are observed to display primarily relatively steep dips (predominantly between 50° and 90°) with a significant population of fractures also displaying less steep dips (predominantly between 0° and 20°). Fractures dips between these two populations also occur (between 20° and 50°).

- Fracture dip directions within the unweathered claystone are also variable, but predominant dip-directions occur to the northwest, northeast, and southeast for the more steeply dipping fractures (greater than 20°) and occur to the northeast and east for the less steeply dipping fractures(less than 20°). The dip direction of the more steeply dipping fractures is variable and not uniformly consistent with the regional strike indicating that the steeper fractures observed at the Site are secondary features.
- Bedding plane dip directions within the unweathered claystone are generally observed at less than 20°, which is consistent with surface observations.
- Fractures in the unweathered claystone are observed to decrease with depth in some boreholes while they are present throughout the depth of other boreholes. Therefore, the depth to which DNAPL migration occurs within these fractures is not known. At depth, it is likely that fractures ultimately lead to dead-ends.
- The continuity between fractures in the unweathered claystone may limit the extent of potential fluid pathways on a Site-wide scale while the continuity on a local scale appears to be sufficient to transmit groundwater and DNAPL.
- Clay constitutes the dominant mineral type of fracture infilling at depths 40 feet below the weathered/unweathered claystone contact.

This interconnectivity of fractures within the unweathered claystone is important because, as described below, DNAPL may be pooled in dead-end fractures or remains as residual in the fractures where diffusive losses to the porous matrix may dissipate DNAPL over time. These fracture characteristics, coupled with the low permeability of the Upper HSU, limit the hydraulic accessibility of DNAPLs, which is one of the important justifications for creating a TI zone for portions of the Site.

10.5.2 Dissolved Phase Contaminant Distribution

The CSC has used the groundwater chemistry data collected both during the RGMEW and RI monitoring programs to assess groundwater contamination at the Site and to evaluate areas of the Site that have the potential to contain NAPL (see Section 5 and Appendix M for a complete summary of the available data). Groundwater contamination is predominantly located within the boundary of Zone 1 with significantly less contamination in Zone 2.

10.5.2.1 Organic Compounds

VOCs are used to summarize the extent of organic compounds. VOCs are generally more mobile in groundwater relative to the other classes of organic compounds (SVOCs, herbicides, pesticides, PCBs, and dioxins/furans) and the extent of the other classes of organic compounds are generally contained within the extent of VOCs. Therefore, to illustrate the extent of contamination, Figures 5-20 through 5-22 present maps of Total VOC iso-concentration contours with time-concentration graphs of select VOCs posted next to wells for the Upper HSU and Lower HSU. Additional figures in Appendix G post organic chemistry data next to individual wells for these VOCs, other VOCs, other organic compounds (SVOCs, pesticides, PCBs, herbicides, and dioxins and furans) for wells in the Upper HSU and Lower HSU.

In the Upper HSU, VOC contamination zones are separated by the PSCT. The Zone 1 area is north of the PSCT in the area of the primary source areas and contains the majority of the dissolved phase VOC contamination and all of the known NAPL contamination. As further described below, free-phase LNAPL occurs within the P/S Landfill and in the Central Drainage Area and free-phase DNAPL occurs within the P/S Landfill. The areas with the highest

concentrations of VOCs are located within the P/S Landfill, the Central Drainage, the Burial Trench Area (BTA), and near the toe of the Metals, Caustic/Cyanide, and Acids Landfills (Figure 5-20). The concentrations for VOC compounds in the Upper HSU north of the PSCT ranged from below laboratory reporting levels to in excess of 1,000,000 ppb.

In the Lower HSU, the majority of the samples collected did not contain VOC concentrations in excess of MCL/PRGs. However, low concentrations of VOCs occur within the Lower HSU at the following areas: The Central Drainage Area; the Burial Trench Area; the southern edge of the Acids Landfill; along the PSCT; along the North Ridge; and northeast of the Caustic/Cyanide Landfill (Figure 5-22). The elevated concentrations in the Burial Trench Area and along the North Ridge are in areas with strong downward hydraulic gradients. The elevated concentrations along the PSCT are laterally downgradient of the higher dissolved-phase concentrations in the Burial Trench Area (RIPZ-16) and DNAPL present in the Central Drainage Area (RGPZ-7C/D).

In Zone 2, VOC concentrations in Upper HSU wells in the North Ridge, North Drainage, and the A-, B-, and C-Drainages have only infrequently exceeded their respective MCL/PRGs.

10.5.2.2 Metals

Dissolved concentrations of arsenic and other metals are elevated within the Zone 1 boundary but are generally not elevated in Zone 2. Arsenic is used to summarize the overall extent of elevated metals because it is the most broadly elevated metal within the Upper HSU, it exceeds primary MCLs where elevated, and the extent of the other elevated metals is generally contained within the extent of elevated arsenic. Figures 5-24 and 5-25 present arsenic iso-concentration contours for the Upper HSU and Lower HSU. Similar iso-concentration contours are provided in Figures 5-26 through 5-31 for nickel, cadmium, and selenium because they also are broadly elevated within the Upper HSU and exceed primary MCLs where elevated.

The general distribution of elevated metals is similar to the distribution of elevated VOCs in the Upper HSU. The higher concentrations of metals in the Upper HSU are generally located within the Central Drainage Area, similar to the higher concentrations of VOCs north of the PSCT. Elevated levels also occur south of the PSCT. Metals concentrations in the Lower HSU are generally lower than in the Upper HSU. The highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the borders of Zone 1 and Zone 2. The elevated metals concentrations in the Lower HSU do not appear to coincide spatially with the elevated VOC concentrations in the Lower HSU to the degree that the distributions of elevated metals and elevated VOCs coincide for the Upper HSU.

10.5.2.3 Evaluation of Areas Potentially Containing NAPL

The CSC compared concentrations of known Site NAPL COCs with each chemical's aqueous solubility to determine if dissolved chemical concentrations greater than 1 percent and 10 percent of their solubility concentration are present in Site groundwater. Dissolved concentrations greater than 1 percent or 10 percent of NAPL compounds solubilities are often an indicator of NAPL presence (USEPA, 2004). The solubilities used in this analysis were compiled from the Risk Assessment Information System (www.risk.lsd.ornl.gov) (USDOE, 2006). Figures 5-32, 5-33, and 5-34 show the areas where dissolved chemical concentrations are greater than 1 and 10 percent aqueous solubility and also where free-phase NAPL has been

measured for LNAPL in the Upper HSU, DNAPL in the Upper HSU, and DNAPL in the Lower HSU, respectively.

As described by USEPA (USEPA, 1992), for DNAPLs comprising a mixture of chemicals, the "effective solubility" should be calculated for comparison to groundwater concentrations. The effective solubility is the theoretical aqueous solubility of an organic constituent in groundwater that is in chemical equilibrium with a mixed DNAPL (a DNAPL containing several organic chemicals). The effective solubility of a particular organic chemical can be estimated by multiplying its mole fraction in the DNAPL mixture (obtained via analysis of the DNAPL sample or estimated from waste characterization data) by its pure-phase solubility. For example, if a laboratory analysis indicates that the mole fraction of TCE in DNAPL is 10 percent, then the effective solubility would be 110 mg/L [pure-phase solubility of TCE, multiplied by the mole fraction of TCE (1,100 mg/L)*(0.10) = 110 mg/L].

The use of this approach at the Site is problematic because of the large number of chemicals detected in Site DNAPL (the Gallery Well DNAPL contained over 40 different VOCs). Using this approach, the calculated effective solubilities of any individual constituent are significantly lower than the pure-phase aqueous solubilities. For example, the mole fraction of TCE in the Gallery Well DNAPL was approximately 3 percent, which results in an effective solubility of 31 mg/L [(1,100 mg/L)*(0.03) = 31 mg/L]. As discussed below, it is likely not appropriate to employ the 1 percent rule of thumb for inferring the presence of a DNAPL phase based on this calculated effective solubility. The CSC has documented that numerous wells at the Site containing concentrations of constituents greater than 1 percent of these calculated effective solubilities do not contain DNAPLs. Feenstra and Cherry (Feenstra and Cherry, 1996) noted that use of a 1 percent rule of thumb in any assessment of the spatial distribution of DNAPL zones must be performed cautiously, particularly in the downgradient direction, as the dissolved plume emitted by the DNAPL could migrate a substantial distance from the source zone. The CSC has found that the 1 percent rule of thumb is generally consistent when comparing dissolved-phase chemical concentrations with pure-phase aqueous solubilities, rather than effective solubilities (i.e., DNAPL observations in wells are generally found in locations where the dissolved chemistry exhibits concentrations greater than 1 percent of the pure-phase solubilities).

The CSC compared COC concentrations to aqueous solubilities of the following chemicals: 1,1-DCA, 1,1,1-TCA, 1,2-DCB, 1,2,4-TMB, benzene, carbon tetrachloride, chloroform, ethylbenzene, Freon 113, methylene chloride, MEK, MIBK, n-Nitrosopyrrolidine, PCE, toluene, TCE, VC, and xylenes (see Table 10-6). These chemicals were chosen because they were detected at the highest concentrations in the speciation analysis of the NAPL collected from Gallery Well, GW-P(W), SUMP 9B-PB, RGPZ-7C, and RGPZ-7D. The Site wells and piezometers that are known to contain NAPL or are potentially impacted by NAPL (based on dissolved chemical concentrations) are listed in Table 10-6 and shown on Figures 5-32, 5-33, and 5-34.

For the fall 2004 and spring 2005 RI sampling events, ethylbenzene, toluene, and xylenes were detected in the groundwater samples at concentrations greater than 1 percent and 10 percent of their aqueous solubilities (see Table 10-6). The dissolved concentrations greater than 1 percent and 10 percent of the aqueous solubility for the Upper HSU are primarily located in the Central Drainage Area between the Gallery Well and PSCT-1 (see Figure 5-32). However, dissolved concentrations of LNAPL greater than 1 percent and 10 percent of the aqueous solubility for these two sampling events have not been detected in PSCT-1 or in any sampling locations south of the PSCT. In the Burial Trench Area, RIMW-7 had dissolved concentrations of xylenes

greater than 1 percent of the aqueous solubility. Lower HSU piezometer RGPZ-6D, had dissolved concentrations of xylenes greater than 1 percent of the aqueous solubility.

For the chlorinated VOCs, 1,1,1-TCA, 1,2-DCB, 1,2,4-TMB, Freon 113, methylene chloride, MIBK, PCE, and TCE were detected at dissolved concentrations greater than 1 percent of the aqueous solubility, and 1,2-DCB, 1,2,4-TMB, and PCE were detected at dissolved concentrations greater than 10 percent of the aqueous solubility (see Table 10-6). Dissolved concentrations greater than 1 percent of the aqueous solubility in the Upper HSU were primarily located in the Central Drainage Area (see Figure 5-33). One well at the toe of the Metals Landfill (WP-8S) and one at the toe of the Caustic/Cyanide Landfill (RG-9B) had detections of Freon 113 greater than 1 percent of the aqueous solubility, although concentrations of other COCs including PCE, TCE, cis-1,2-DCE, and VC were much lower in these wells. Wells RIMW-7 and RIMW-8, which are located downgradient of the burial trenches, have detections of Freon 113, PCE, and TCE greater than 1 percent solubility (see Figure 5-33). RIMW-8 had dissolved concentrations of Freon 113 greater than 10 percent of the aqueous solubility.

10.5.3 NAPL Observations

The CSC has directly measured and/or observed LNAPL and DNAPL in the Central Drainage Area of the Site. Detailed descriptions of the distributions of LNAPL and DNAPL are included in Section 5. Figures 5-32, 5-33, and 5-34 show the areas where dissolved chemical concentrations are greater than 1 and 10 percent aqueous solubility and also where free-phase NAPL has been measured for LNAPL in the Upper HSU, DNAPL in the Upper HSU, and DNAPL in the Lower HSU, respectively.

Currently, LNAPL is present as a separate (free) phase in 12 Upper HSU wells and piezometers in an area from RIPZ-14 at the top of the P/S Landfill to just north of PSCT-1. In the Upper HSU, DNAPL is present as measurable amounts in P/S Landfill Piezometers RIPZ-13 and RIPZ-27, and the Gallery Well. In the Lower HSU, DNAPL is present as measurable amounts in piezometers RGPZ-7C and RGPZ-7D between the P/S Landfill and PSCT-1. LNAPL and DNAPL depths and thicknesses are routinely measured in these wells and piezometers, and a summary of historical NAPL levels is presented in Section 5. The source of DNAPL to the Lower HSU piezometers is uncertain. The two potential source areas are the approximately 100,000 gallons of free-phase DNAPL in the P/S Landfill (located 500 feet to the north of the Lower HSU piezometers) or an unknown (current or former) body of free-phase DNAPL in the former Pad 9A/B area located between the P/S Landfill and the two Lower HSU piezometers.

Some uncertainty regarding the distribution of DNAPLs in the subsurface will always remain, because it is impossible to collect data from every potential geologic fracture. However, other than the above-listed locations, to date, neither LNAPL nor DNAPL has been measured as a free phase in any other Site wells or piezometers outside the boundary of the P/S Landfill and Central Drainage Area. Free-phase NAPL has not been detected in the recently installed RI wells and piezometers in the Burial Trench Area (although observations during drilling may suggest some NAPL in this area), or in other Site wells and piezometers near and downgradient of the other Site landfills. Groundwater samples from some monitoring wells in the Central Drainage Area that do contain free-phase NAPL also have relatively high concentrations of dissolved LNAPL and DNAPL constituents. Relatively high concentrations may indicate the presence of LNAPL or DNAPL near these wells, and the CSC reviewed the aqueous groundwater chemistry as evidence of NAPL presence (see Section 10.5.2). The CSC also reviewed the RI drilling investigation data with respect to NAPL observations in core samples.

All of these lines of evidence were evaluated to delineate the likely lateral and vertical extent of NAPL. Table 10-7 summarizes this information with respect to potential NAPL locations at the Site. Figures 5-32, F-33, and 5-34 show the locations of known or inferred NAPLs in the Upper and Lower HSU. Based on these data, discrete Site areas potentially impacted by NAPL have been identified, as discussed below.

10.5.3.1 P/S Landfill and Central Drainage Area

The Upper HSU locations in the Central Drainage Area where LNAPL and DNAPL have been observed or inferred generally coincide with a historical Site drainage that ran along the length of the P/S Landfill and continued into the area that is now the RCF Pond (see Figures 5-32 and 5-33). A brief discussion of potential NAPL sources based on information contained in Sections 2.2.3 through 2.2.5 of this report (specifically Tables 2-2 through 2-6, and Figure 2-6) follows.

The potential source(s) of NAPLs in the Central Drainage Area include:

- The P/S Landfill, where billions of pounds of pesticides and solvents were disposed of from 1979 through 1989. As described in Section 2.2.3.1.1, waste disposal in the P/S Landfill began at the toe of an existing canyon (or surface drainage), and waste placement continued to the north. The landfill is unlined and the landfill operators excavated Upper HSU and alluvial deposits to the approximate contact with the Lower HSU claystone to create landfill volume. As shown on Figures 4-1 through 4-3, a former surface-water drainage feature ran the entire length of the P/S Landfill.
- Former ponds and pads in the NAPL area downgradient of the P/S Landfill. These include Pond R and Pads 9A and 9B, which were all designated as “Landfill Runoff/Leachate Control” units. Pond R held liquids from 1977 through 1987 and Pads 9A and 9B contained liquids from 1985 through 1987. Note that Pond 7 (which held waste liquids from 1979 through 1984) was converted into Pads 9A and 9B in 1985. Neither Pond R nor Pads 9A and 9B were completely closed during pond closure activities and these three units were recommended for landfill closure (presumably a capping remedy as recommended for the Site landfills).
- Former ponds (Ponds 6 and 19) just west of the NAPL area, which held Site runoff and other liquids from about 1980 though 1987. These ponds are considered possible NAPL sources because (1) they were designated to receive landfill runoff or leachate, (2) they are located along former Site drainages where NAPL may more easily migrate, and (3) they were not completely closed during pond closure activities. Notations made during closure of Pond 6 indicated that the western third of the pond was possibly impacted by leachate from the P/S Landfill. Pond 19 was recommended for closure, with the exception of the south dike and adjacent fill materials. The western third of Pond 6 and the southern portion of Pond 19 were recommended for closure as landfills.

10.5.3.1.1 P/S Landfill and Central Drainage Area LNAPL

LNAPL is currently detected in the following Upper HSU wells and piezometers within the P/S Landfill and Central Drainage Area (Figure 5-32):

P/S Landfill (from north to south)

- RIPZ-14 located on top of the landfill, 700 feet north of the Gallery Well;
- RIPZ-39, located on Bench 2 Road, 300 feet north of the Gallery Well;
- RIPZ-13 located on Bench 1 Road, 150 feet north of the Gallery Well; and

- Gallery Well, and adjacent piezometers GW-PZ-W, GWPZ-E1, GW-PZ-E2, GW-PZ-E3, RIPZ-23, RIPZ-24, and RIPZ-38 (these wells are all located at the toe of the P/S Landfill).

Central Drainage Area

- Sump 9B piezometers Sump 9B-PB, Sump 9B-PC, Sump 9B-CW, RIMW-3, RIPZ-25, and RIPZ-31 (all located in the former Pad 9B area); and
- RGPZ-5B and RIPZ-8 (located on the former Pond R bench).

10.5.3.1.1.1 LNAPL in the P/S Landfill

The LNAPL zone in the P/S Landfill extends from the top of the landfill at RIPZ-14 southward to the Gallery Well. The extent of the LNAPL zone does not imply that the LNAPL is contiguous throughout this area; LNAPL is probably located in discrete zones as influenced by available flow paths and soil properties. Several of the piezometers along the clay barrier (Figure 5-35) and north of the clay barrier within the landfill interior (Figure 5-36) are constructed with the top of the screen below LNAPL and therefore, some of the LNAPL thickness shown in the cross sections in Figures 5-35 and 5-36 may not represent actual thicknesses. LNAPL in these wells may be trapped in the blank casing above the screen. The top of LNAPL in the piezometers along the clay barrier is approximately 10 feet or more below the top of the barrier (Figure 5-35).

The Gallery Well was the only well in the P/S Landfill prior to 1999 to assess liquid levels, including LNAPL. The Gallery Well is screened at the bottom 20 feet of the well. The current action level implemented in 2000 (63 feet BTOC) maintains the pumping liquid level at approximately the mid-point of the screen. The liquid level prior to 2000 (30 feet BTOC) was above the screen. Although the current liquid level is maintained within the screened interval, the extraction pump is near the bottom of the Gallery Well so LNAPL may not be effectively recovered at the Gallery Well.

Along the clay barrier, the CSC installed piezometers GW-PZ-W and GWPZ-E1 in 1999 to assess whether the liquid levels were below the top of the clay barrier (25 feet west and east of the Gallery Well). The CSC installed GW-PZ-E2 and GW-PZ-E3 in 2003 to further assess LNAPL thicknesses and the liquid levels in relation to the clay barrier (50 and 75 feet east of the Gallery Well). In 2001, the maximum LNAPL thickness in these piezometers was approximately 9 feet in GW-PZ-E3 (Figure F-40). The CSC installed RIPZ-23 and RIPZ-24 next to GW-PZ-W and GW-PZ-E1 in 2004 because the screen elevations for GW-PZ-W and GW-PZ-E1 were below the LNAPL. The CSC installed RIPZ-27 and RIPZ-38 in 2007 to follow-up from the Phase 2 seismic refraction survey in the P/S Landfill to delineate the bottom of the landfill where pooled DNAPL potentially exists. The LNAPL thicknesses have fluctuated over time in these piezometers along the clay barrier (Figure F-40, Table F-6). Current maximum thicknesses are 20.30 feet in RIPZ-27 and 33.59 feet in RIPZ-38 according to June 18, 2010 liquid level measurements (Table F-3).

North of the clay barrier, the CSC installed piezometer RIPZ-14 in 2006 to assess liquid levels at the top of the P/S Landfill and RIPZ-13 in 2007 to follow-up from the Phase 2 seismic refraction survey in the P/S Landfill to delineate the bottom of the landfill where pooled DNAPL potentially exists. The LNAPL thickness in RIPZ-14 has been several tenths of a foot since the piezometer was installed (Figure F-40). However, RIPZ-14 is screened significantly below the water table so this may not represent the true LNAPL thickness (the objective of this piezometer was not to assess LNAPL). The LNAPL thickness in RIPZ-13 was initially 8.88 feet after

installation and is currently 4.03 feet according to June 18, 2010 liquid level measurements (Figure F-40; Tables F-3 and F-6).

10.5.3.1.1.2 LNAPL in the Central Drainage Area

Based on the LNAPL elevation monitoring, dissolved chemistry analyses, and sample observations, the LNAPL zone in the Central Drainage Area likely extends from the Gallery Well to a location near RG-3B, approximately 200 feet north of PSCT-1. LNAPL was not observed in wells, piezometers, or deep soil borings drilled downgradient of RG-3B during the 2000, 2004, or 2006 drilling programs, and has not been observed during subsequent water level measurements. The extent of the LNAPL zone does not imply that the LNAPL is contiguous throughout this area; LNAPL is probably located in discrete zones as influenced by available flow paths and soil properties. The lateral extent of the LNAPL zone may be 300 to 400 feet wide from near piezometer RIPZ-8 to near RGPZ-5B, and possibly narrows to the south.

In the Sump 9B area, the early piezometers and wells installed by the CSC were screened below the water table and potential LNAPL. CSC installed piezometers SUMP-9B-PA, -9B-PB, and -9B-PC in 1999 to assess the hydraulic effect of liquids extraction from Sump 9B. The liquid levels in these piezometers were above the top of the screens in this area. RGPZ-5B was installed between Sump 9B and the Gallery Well in 2000 and is screened below the water table. Piezometer SUMP-9B-CW was installed in 2001 as a “companion well” next to Sump 9B. SUMP-9B-CW was screened at the bottom of the Upper HSU to assess for the potential presence of pooled DNAPL in the Sump 9B area, since the bottom of Sump 9B is above the HSU contact. The liquid level is above the screen in SUMP-9B-CW. RG-3B was installed in 1998 to generally assess the liquid level in the Central Drainage Area. The liquid levels were above the screen in RG-3B.

Recent wells installed as part of the RI were intentionally screened above the water table to assess the potential presence and thickness of LNAPL. These included RIPZ-8, RIPZ-25, RIPZ-26, and RIPZ-31. The thickness of LNAPL in all of the Central Drainage Area Wells (including the early wells screened below the water table and the RI piezometers screened across the water table) has decreased over time and is currently less than 1 foot (Figure F-40; Tables F-3 and F-6).

10.5.3.1.2 P/S Landfill and Central Drainage Area DNAPL

DNAPL is currently detected in the following P/S Landfill and Central Drainage Area wells (Figures 5-33 and 5-34):

P/S Landfill (from north to south)

- RIPZ-13 located on Bench 1 Road, 150 feet north of the Gallery Well;
- RIPZ-27 located on Gallery Well Road, 10 feet north of the Gallery Well; and
- Gallery Well (Upper HSU).

Central Drainage Area

- RG-PZ-7C (Lower HSU); and
- RG-PZ-7D (Lower HSU).

Figures F5-1, F5-2, and F5-3 in Attachment F-5 provide DNAPL hydrographs for RIPZ-13 in the P/S Landfill and RGPPZ-7C and RGPZ-7D in the Lower HSU. These hydrographs are further referenced below.

10.5.3.1.2.1 DNAPL in the P/S Landfill

There is a potentially large volume of free-phase DNAPL in the P/S Landfill based on (1) past and current DNAPL extraction rates at the Gallery Well and (2) volumetric estimates from thicknesses of DNAPL measured in the Gallery Well and piezometers within the landfill. This volume is estimated to potentially be approximately 100,000 gallons.

The CSC continued EPA's liquids extraction from the Gallery Well when the CSC began Site work in 1996. The long term average DNAPL recovery rate measured since 2003 was approximately 7 gallons per day, or 2,500 gallons per year and the recent DNAPL recovery rate during 2008 and 2009 was approximately 4,000 gallons per year based on the CSC's tank fill gauging data (Figure F-46).

The initial DNAPL thickness in the Gallery Well at the time the CSC continued EPA's liquids extraction from the Gallery Well in 1996 is not known. The first known measured DNAPL thickness was 9.2 feet prior the CSC performing a DNAPL recovery test in 1997. The DNAPL thickness was approximately 7 to 8 feet during normal operations in 1998 and 1999 (Figure F-42). Beginning in November 1999 the CSC lowered the pump intake to near well bottom and subsequently the DNAPL thickness has been less than 2 to 3 feet.

The CSC installed the following four piezometers in the P/S Landfill in August 2007 to follow up from the Phase 2 seismic refraction survey to delineate the bottom of the P/S Landfill where pooled DNAPL might potentially exist:

- RIPZ-27 located on Gallery Well Road, 8 feet north of the Gallery Well;
- RIPZ-38 located on Gallery Well Road, 50 feet west of the Gallery Well;
- RIPZ-13 located on Bench 1 Road, 150 feet north of the Gallery Well; and
- RIPZ-39 located on Bench 2 Road, 300 feet north of the Gallery Well.

Since installation, DNAPL has accumulated in RIPZ-13 and RIPZ-27, but not RIPZ-38 and RIPZ-39 (Figure F-42). DNAPL entered RIPZ-13 and RIPZ-27 slowly after installation before reaching current steady-state thickness of approximately 14 feet and 6 feet, respectively. The CSC performed a DNAPL recovery test at RIPZ-13 in 2009 to determine the rate and amount of DNAPL recharge in the immediate vicinity of the well (Figure F5-2). Approximately 42 gallons of DNAPL were pumped from the well during the eight pumping tests. The CSC is in continuing discussions with EPA about any appropriate next steps to develop more information to test whether the DNAPL present in RIPZ-13 originated from a discreet release of a relatively small volume of DNAPL from drums pierced during CPT or piezometer installation activities, or is instead a larger in situ pool of DNAPL at the base of the P/S Landfill.

10.5.3.1.2.2 DNAPL in the Central Drainage Area

In the Lower HSU, the following drilling and monitoring well data indicate DNAPL in the Central Drainage Area:

- RGPZ-7C and RGPZ-7D – DNAPL observed in Lower HSU fractures during drilling/coring for piezometer installation in 2000 and DNAPL measured during routine groundwater monitoring from 2003 through 2010;
- RGPZ-6C and RGPZ-6D – DNAPL observed in Lower HSU fractures during drilling/coring for piezometer installation in 2000 and high dissolved-phase concentration of VOCs in groundwater measured during the two RI groundwater monitoring events in 2004 and 2005; and
- RISB-02 – DNAPL in Lower HSU fractures during drilling/coring, accumulated DNAPL measured in the bottom of the borehole, and free-phase DNAPL "blobs" actively entering the borehole liquid column during down-hole video logging in 2006.

These four piezometers, boring RISB-02, and the fracture intervals within the five borings where DNAPL was observed during drilling/coring are shown in Figure 5-38. The DNAPL observed in the Lower HSU fractures was sometimes noted as a "chemical sheen", "product sheen", or as an actual NAPL. At RISB-02, DNAPL was observed to actively enter the borehole water column from Lower HSU fractures during downhole video logging and accumulate at the bottom of the 253-foot deep boring to a thickness of approximately 15 feet.

The horizontal DNAPL extent in the Lower HSU fractures likely encompasses the southern portion of the P/S Landfill to the north and the Central Drainage Area to the south (Figure 5-34).

10.5.3.2 Burial Trench Area

Neither LNAPL nor DNAPL have been directly measured in the Burial Trench Area, but NAPL may be present based on observations made during drilling and groundwater sampling, and the dissolved chemistry analyses. At RIMW-7, LNAPL was inferred during drilling and DNAPL could be present based on the dissolved-phase chemistry analysis. Only one DNAPL compound (Freon 113) was noted as a possible DNAPL indicator in the Upper HSU at RIMW-8. Because only one compound exceeded 10 percent of its solubility at that location, the likelihood of DNAPL there is low (the CSC would expect more chemicals indicating DNAPL). Piezometers RIPZ-15 and RIPZ-16 were installed downgradient (south) of the Burial Trench Area and were constructed (screened) to intercept potential DNAPL present at the base of the Upper HSU and upper portions of the Lower HSU. To date, no free-phase LNAPL or DNAPL has been observed in Piezometers RIPZ-15 and RIPZ-16.

The former burial trenches themselves are the most likely source of any potential NAPLs in this area. Seven trenches (approximately 15 feet deep) were sequentially excavated into the subsurface and wastes were placed in the trenches from 1974 to 1979 before the landfills were constructed. Waste disposal in that area also included disposal into 11 injection wells (approximately 30 to 40 feet deep) that operated from 1978 to 1982 (records indicate that one well was reportedly never placed into service). The trenches reportedly received between 6,000 and 80,000 pounds of waste and approximately 1.3 million pounds of waste were disposed via injection wells.

Pond 23 (located over the former burial trenches) was constructed in 1984 to provide runoff control in the area and held liquids until 1987. Although the pond was designated as an alternate alkaline pond (or designated to receive bulk liquid wastes), it is not clear that the pond was used for those purposes. Based on the waste disposal history, it appears that the most significant sources of potential NAPLs in the Burial Trench Area are the trenches and wells themselves.

10.5.3.3 Other Site Areas

NAPLs have not been detected in any Site wells or piezometers outside the boundary of the P/S Landfill beyond those noted in the Central Drainage Area. Also, the results of the UVIF/MIP work completed across the Site (targeted at former ponds where NAPL constituents may have been disposed of, and along the former Site drainages) indicated only one potential NAPL location at the southern perimeter of the Site (sample RISBON-59), but a subsequent focused study of that area later determined that no NAPLs were present.

Although Figure G-71 indicates potential DNAPL (based on dissolved concentrations) at the toe of the Metals and Caustics/Cyanides Landfills, the CSC does not consider these locations to contain potential NAPL. Only one chemical (Freon 113) exceeded 1 percent solubility in both of these locations and dissolved concentrations of other NAPL-indicator VOCs were much lower.

10.5.4 Aqueous-Phase Contaminant Fate and Transport

Site-specific characteristics influencing aqueous-phase contaminant migration are presented in Section 6. This evaluation includes analyses of the following potential migration pathways for aqueous phase contamination in groundwater:

- Potential migration toward the North Drainage Area;
- Potential migration from the Landfills and Burial Trench Area;
- Potential migration across or beneath the PSCT;
- Potential migration across or beneath the PCTs; and
- Potential migration within the Lower HSU.

The primary physical processes that result in the movement of dissolved-phase COPCs in groundwater are advection and dispersion. Advection is the movement of COPCs with the bulk movement of groundwater. Advection is generally the primary transport mechanism at Site with moderate to high groundwater flow rates. Mechanical dispersion is the mixing of COPCs with groundwater moving along the groundwater flow path. Dispersion will cause some COPC molecules to travel faster and some to travel slower than the average groundwater flow velocity. Dispersion will have the effect of spreading out (lowering) COPC concentrations as they adjectively move with groundwater.

Only highly “mobile” and “persistent” COPCs will move at the same or similar rate as groundwater flow. Most COPCs will move slower than groundwater due to natural attenuation mechanisms that include the following:

- Biodegradation (organics). Biodegradation is the process where microbes degrade and destroy organic COPCs by transforming them into other byproducts. This will reduce the concentration of the organic COPCs along the groundwater flow path. Organics may degrade aerobically or anaerobically. Metals are not subject to biodegradation.
- Sorption (organics and inorganics). Sorption is the process where organic and inorganic COPCs transfer from being dissolved in groundwater to the solid phase of the aquifer matrix. Sorption generally involves three primary mechanisms: adsorption onto the surface of the solid phase, precipitation onto the solid phase, and absorption (i.e., diffusion into the solid phase).

- Dilution (organics and inorganics). Dilution is the process where recharge from another source (e.g., rainfall infiltration) dilutes the organic and inorganic COPC concentrations. Dilution also results from dispersion (mechanical mixing).

Hydraulic containment and chemical mass removal from groundwater also occurs via the on-site groundwater extraction and treatment facilities. This includes the current liquids extraction at the Gallery Well, Sump 9B, PSCT, and three PCTs as described in Section 4. Hydraulic containment will act to change the direction of groundwater and contaminant flow paths.

The migration and persistence of dissolved-phase COPCs based on their movement with groundwater movement, natural attenuation mechanisms, and hydraulic containment at the Site are summarized below. As described in Section 6, the following figures were prepared based on the MODFLOW groundwater flow model particle tracking maps from Section 4 with the total VOC groundwater concentration contour maps from Section 5 to illustrate the potential movement of dissolved-phase COPCs with groundwater:

- *Figure 6-1, VOC – Groundwater Particle Flow Map, Upper HSU, 2004 (Dry)*
- *Figure 6-2,VOC – Groundwater Particle Flow Map, Upper HSU, 2001 (Wet)*
- *Figure 6-3, VOC – Groundwater Particle Flow Map, Lower HSU, 2004 (Dry) – PSCT-4*
- *Figure 6-4, VOC – Groundwater Particle Flow Map, Lower HSU, 2004 (Dry) – RGPZ-6 & 7*

The particle tracks represent the direction of groundwater flow and where dissolved-phase COPCs will potentially migrate. However, the actual rate and distance that COPCs will migrate along these groundwater flow paths will be influenced by the natural attenuation mechanisms and active hydraulic containment.

10.5.4.1 Potential Migration toward the North Drainage Area

The CSC evaluated the potential for aqueous-phase contaminant migration into the North Drainage area using the interpreted Upper HSU water level data, the RGMEW chemistry data, and the MODFLOW groundwater modeling results. The interpreted water table contour maps created from Site-wide monitoring results consistently indicate a groundwater divide approximately coincident with the ridgeline along the northern Site boundary. The presence of the groundwater divide (that generally coincides directly with the topographic divide on the North Ridge) indicates that groundwater and potential aqueous-phase contaminants occurring along the southern side of the groundwater divide will flow to the south in a direction away from the North Drainage area. Groundwater monitoring data collected during RGMEW from wells completed along the groundwater divide and in the North Drainage indicate that aqueous-phase contaminants are not migrating into the North Drainage. Groundwater modeling results (Figures 6-1 through 6-2) also indicate flow paths from just south of the North Ridge groundwater divide are to the south, and do not indicate flow from Zone 1 to the North Drainage.

10.5.4.2 Potential Migration from the Landfills and Burial Trench Area

The interpreted water table contour maps created from Site-wide monitoring results consistently indicate that groundwater flows in a southerly direction from the landfills toward the PSCT. Groundwater flow south of the PSCT occurs towards the A-Series Pond and RCF Ponds.

Monitoring results indicate that groundwater downgradient of the P/S Landfill has been impacted by organic compounds, primarily from the P/S Landfill, extending from the Gallery Well down to the vicinity of PSCT-1. The distribution of contamination appears to follow the groundwater gradient from the source areas towards the PSCT indicating migration of aqueous-phase contaminants. Chemistry data indicate that additional sources between the P/S Landfill and the PSCT may also have contributed aqueous-phase contaminants to groundwater, particularly in the area of Sump 9B and RG-3B. Sump 9B is within the area of the former Pad 9B, while Well RG-3B and the Road Sump are within the area of the former Pad 9A.

Chemical sampling results suggest that the Heavy Metals, Caustics/Cyanides, and Acids Landfills may be source areas for aqueous-phase contaminants resulting in aqueous-phase migration downgradient from the toes of the landfills. The groundwater flow paths interpreted from the water level data suggest that aqueous-phase migration of contaminants from the vicinity of these three landfill areas is occurring toward the PSCT.

Chemical sampling results from SW-17, which is on the downgradient side of the Burial Trench Area, suggest that this area is a source for aqueous-phase contaminant migration. Contaminants, presumably from the Burial Trench Area, appear to migrate southward to the PSCT, approximately 100 feet downgradient. The chemicals detected at SW-17 appear to be among the main contaminants detected along the PSCT, including those from PSCT-1.

There is a potential for NAPL presence (both LNAPL and DNAPL) in and around the Burial Trench Area. This is a likely area for NAPL occurrence because of the significant quantities of containerized liquids (including solvents) that were deposited in the burial trenches and other various products that were injected into the injection wells. This is supported by the high VOC concentrations in groundwater from SW-17, (where cis-1,2-DCE significantly exceeds 1 percent of its solubility). In addition, downward gradients (up to about 0.5 ft/ft) are present at the northern part of this area. The downward vertical gradient increases to the north (in area of PCB Landfill) and lessens toward the south (in area of PSCT-4). The potential therefore exists for contaminant migration into the Lower HSU from potential Burial Trench sources.

10.5.4.3 Potential Migration Across or Beneath the PSCT

The design and operation of the PSCT should prevent the potential migration of aqueous-phase contamination across or beneath this liquid control feature. Water-level data collected to date support the interpretation that the PSCT captures groundwater approaching from the upgradient side and captures groundwater within the vicinity of the downgradient side of the PSCT. Groundwater modeling results (Appendix F) indicate the PSCT effectively captures groundwater in the Upper HSU with limited underflow beneath the PSCT through the Lower HSU.

A projection of the groundwater flow paths determined from MODFLOW modeling within the Upper HSU for the Dry (2004) and Wet (2001) simulations indicate the PSCT is effective in capturing liquids moving southward across the Site within the Upper HSU (Figures 6-1 and 6-2, respectively). The 2004 (dry) model simulated particle tracks pass through the trench in the PSCT-1 area indicating some uncertainty during drier conditions when a recharge mound from precipitation may not be present to the south of PSCT-1. The bypass of the trench may be an artifact of the model.

Organic compounds have been detected in some areas south of the PSCT. On the basis of the specific compounds detected and their concentrations relative to the wells within and upgradient

of the PSCT, these compounds appear to potentially be related either to previously existing ponds and pads or to contaminants that were present in these areas prior to construction of the PSCT. On the basis of the evaluation of the water levels from within the PSCT and nearby piezometers and wells, the wells immediately south (within approximately 75 feet) of the PSCT are likely within the capture zones of the PSCT extraction wells. In addition, the measured gradient between Well Pair RG-2B and -4B (respectively located approximately 30 and 100 feet downslope of PSCT-4), typically shows a southward horizontal gradient at this location.

10.5.4.4 Potential Migration Across or Beneath the PCTs

Concentrations of organic compounds in the area between the PSCT and the PCTs appear to potentially be related to contaminants present prior to construction of the PSCT. Closer to the PCTs, organic compound detections are generally sporadic and at relatively low concentrations (<10 µg/L). Higher concentrations have been detected on occasion (e.g., Well RP-100A in October 1998); however, such concentrations have not been confirmed by subsequent results.

Groundwater flow at the southeastern perimeter of the Site is directed into the A-Drainage due to the presence of a prominent hill south of the Zone 1 boundary. Groundwater recharge through this hill causes a reversal of the flow gradient immediately south of the Site boundary. This topographically induced groundwater barrier is complemented by the presence of the PCT-A, which extends eastward across the head of the A-Drainage.

Water levels in all three PCT-A extraction wells are generally maintained between 10 to 30 feet lower than the prevailing water levels immediately downgradient of the PCT. These data appear to demonstrate the reversal in groundwater gradients by the operation of PCT-A, and the effective prevention of groundwater movement from the Site into the A-Drainage.

Groundwater flow at the south-central perimeter of the Site is directed into the B-Drainage due to presence of two prominent hills, which define the B-Drainage. The PCT-B perimeter trench contains an extraction well (RAP-1B), which is directly south of Pond 13 in the B-Drainage. Groundwater elevation in RAP-1B was approximately 9 feet lower than the stage elevation of Pond 13, and 4 feet lower than the groundwater elevation in Well B-5. The lower water level in PCT-B suggests that the facility is effective in preventing off-site groundwater flow. Groundwater flow in the vicinity of PCT-B is further impeded by the reversal in groundwater gradients that occur immediately south of the Site. The two prominent hills on either side of the B-Drainage just south of the southern Site border result in corresponding increases in groundwater elevation on either side of the B-Drainage. The net result is that groundwater gradients are oriented northward toward the Zone 1 Site boundary, or are directed into the B-Drainage. Thus, the head of the B-Drainage serves as a groundwater divide, preventing groundwater from flowing past PCT-B. The eastern and western edges of PCT-B terminate within the adjoining hills.

Water levels in PCT-C and adjacent observation wells indicate that, under normal operations, a significant capture zone exists south of PCT-C and gradients are oriented northward from the nearby off-site (Zone 2) wells. At the southeastern end of the clay barrier, groundwater is impeded by a reversal in the groundwater gradient due to the hill between the B- and C-Drainages. Groundwater flow past the western end of the clay barrier is prevented by groundwater extraction from the PCT-C trench. Thus, PCT-C appears to be effectively preventing off-site migration of groundwater in this vicinity.

The water level data, the ground surface topography, and the inward groundwater gradients along the southern perimeter of the Site suggest that there is a low probability that aqueous-phase contaminants are migrating across or beneath the PCTs. A projection of the groundwater flow paths determined from MODFLOW modeling within the Upper HSU for the Dry (2004) and Wet (2001) simulations indicate the PCTs are effective in capturing liquids moving southward across the Site within the Upper HSU (Figures 6-1 and 6-2, respectively).

10.5.4.5 Potential Migration within the Lower HSU

As summarized above, the majority of the samples collected from the Lower HSU did not contain VOC and metals concentrations in excess of MCL/PRGs. However, low concentrations of VOCs occur within the Lower HSU at the following areas: the Central Drainage Area; the Burial Trench Area; the southern edge of the Acids Landfill; along the PSCT; along the North Ridge; and northeast of the Caustic/Cyanide Landfill (Figure 5-22).

Overall, the potential for aqueous-phase contaminant migration in Lower HSU is considered to be low due to a relatively large (order of magnitude) difference in estimated hydraulic conductivity between the Upper and Lower HSUs. The hydraulic conductivity contrast should preferentially direct groundwater flow from the less transmissive material (Lower HSU) toward the Upper HSU during horizontal groundwater flow conditions. However, dissolved-phase contaminant movement does occur where higher groundwater gradients occur. For example, the elevated concentrations of dissolved-phase VOCs in the Burial Trench Area and along the North Ridge are in areas where there are strong downward hydraulic gradients, which are sufficient to move dissolved-phase contaminants downward from source areas through interconnected fractures in the Lower HSU. Dissolved-phase contaminants along the PSCT are likely from horizontal movement of dissolved-phase contaminants towards the south from higher concentrations in the Burial Trench Area (RIPZ-16) and the DNAPL present in the Central Drainage Area (RGPZ-7C/D).

A projection of the groundwater flow paths determined from MODFLOW modeling within the Lower HSU for the Dry (2004) simulations indicates that groundwater (and contaminant) flow within the Lower HSU is south and that flow beneath the bottom of the PSCT may occur (Figures 6-3 and 6-4). Although groundwater flow may occur beneath the bottom of the PSCT, natural attenuation mechanisms will act to limit the actual downgradient transport of dissolved-phase contaminants.

10.5.5 Potential NAPL Mobility/Migration

Site-specific characteristics influencing NAPL movement are summarized in Section 6. The subsections below summarize the following:

- Potential NAPL migration mechanisms within the P/S Landfill and Central Drainage Area which are the primary areas with free-phase NAPL contamination; and
- Potential for migration in the Burial Trench Area, even though free-phase NAPL contamination has not been identified in this area.

10.5.5.1 Mobility/Migration of NAPLs between the P/S Landfill and PSCT-1

The primary potential sources of free-phase NAPLs within the eastern portion of the Site are the P/S Landfill and the former ponds and pads located south of the P/S Landfill but within the

Central Drainage Area. The P/S Landfill may be a continuing source of both LNAPLs and DNAPLs. Note that presently LNAPL and DNAPL are both being recovered by liquid extraction conducted in the Gallery Well.

The Gallery Well and associated clay barrier contain and collect DNAPL that migrates laterally along the contact with the Lower HSU under the P/S Landfill, as the containment feature is "keyed" approximately 5 feet into the underlying bedrock contact. The LNAPLs that exist in the P/S Landfill and Central Drainage Area are intercepted by a number of different physical containment features, including:

- The Gallery Well/clay barrier at the toe of the P/S Landfill;
- Sump 9B; and
- The PSCT (collected by extraction well PSCT-1).

In addition to the potential lateral migration along the HSU contact in this area, DNAPLs could migrate downward into the underlying fractured bedrock (i.e., Lower HSU) under certain conditions. Potential DNAPL penetration into the Lower HSU requires displacement of the water-saturated porous matrix or fractures. The driving force for DNAPL movement is the additional pressure buildup due to its higher density relative to water. Pore-scale capillary forces that retain water within pores or fractures counteract the additional pressure generated by the DNAPL pool. DNAPL is able to displace water only when the DNAPL pool height generates sufficient pressure to overcome the capillary pressures.

The densities of the DNAPLs found in this area are relatively low (the Gallery Well DNAPL density has been measured at approximately 1.08 g/cm^3, and Piezometer RGPZ-7C DNAPL density is only 1.02 g/cm^3). The low densities of these DNAPLs are due to the mixture of chemicals within them, which include many organic chemicals with individual densities less than water. The interfacial tension (i.e., the surface tension between two liquids) between the DNAPL and groundwater is also relatively low, apparently due to the presence of alcohols and/or inorganic surfactants that are present in the DNAPL. While the relatively low densities reduce the potential for DNAPL migration, the low interfacial tension produces the opposite effect, greatly increasing the migration potential.

As described in Section 6, previous Site conditions have resulted in downward DNAPL migration based on reasonable assumptions for DNAPL properties (densities and interfacial tensions), DNAPL pooled heights, and fracture apertures. The observation of DNAPLs in piezometers RGPZ-7C and RGPZ-7D suggest that vertical migration of DNAPLs through the limited but potentially interconnected fracture network in the Lower HSU has already occurred within the Central Drainage Area.

Subsurface conditions and DNAPL presence within the P/S Landfill and in the Upper and Lower HSUs between the P/S Landfill and PSCT are illustrated on Figures 4-51, 5-33, and 5-34. The presence of DNAPL in the Lower HSU (at RGPZ-7C and RGPZ-7D) could be attributable to a number of past conditions at the Site and associated factors including, but not limited to, those listed below:

- Prior to the CSC's tenure at the Site, when liquid extraction from the Gallery Well was limited and the action level in the well was significantly higher, the DNAPL pool height behind the clay barrier was reported to be as high as 9 feet, which exceeds the required thickness to effect DNAPL entry into underlying fractures.

- DNAPL reported in RGPZ-7C and RGPZ-7D may have originated from sources in the area other than the P/S Landfill, including Pads 9A and 9B or Pond R. The DNAPL may have migrated through a limited fracture network below these historical sources to the depths of the piezometers.
- The DNAPL noted in the Lower HSU may have entered the Lower HSU and migrated prior to the construction of the containment features of the P/S Landfill.

Although groundwater and NAPL observation data from this area are abundant, there are many geologic and hydraulic uncertainties regarding NAPL migration pathways that will always remain. However, based on the data collected to date, the potential for continued and significant DNAPL migration deep into the Lower HSU continues due to potential large volume (approximately 100,000 gallons) of free-phase DNAPL pooled in the P/S Landfill. Although the current extraction systems operating in the P/S Landfill limit the build-up of liquids behind the clay barrier, the hydraulic effect will not inhibit the downward driving force of DNAPL north of the Gallery Well in the vicinity of RIPZ-13. Extraction at the PSCT creates localized upward gradients, but these upward gradients do not extend northward into the Central Drainage Area consistently enough to prevent downward DNAPL migration.

The vertical extent of free-phase DNAPL in the Lower HSU is not known with certainty. Once DNAPL has entered a fracture or fracture network, progressively smaller aperture fractures will be invaded if the pooled DNAPL source is allowed to extend itself vertically while remaining a continuous, interconnected phase. The DNAPL driving head is not only a function of the pool height in the overlying Upper HSU (or P/S Landfill) but also the height of DNAPL accumulated in the fractures beneath this pool. The potentially mobile DNAPL volume in the P/S Landfill provides an ongoing source to allow the DNAPL to extend itself into fractures at depth, where those fractures are interconnected.

The localized horizontal extent of free-phase DNAPL in the Lower HSU is uncertain in the area of the P/S Landfill and Central Drainage Area, although the horizontal extent of free-phase DNAPL is not believed to extend off site. Of the 408 boreholes that explored the Lower HSU, fracture interconnectivity between boreholes is difficult to demonstrate. The degree of interconnectivity of the fracture network is considered to decrease on a Site-wide scale. On a localized scale, sufficient fracture interconnectivity has allowed DNAPL movement within the Lower HSU in the Central Drainage Area as evidenced by (1) free-phase DNAPL observed in Lower HSU fractures while drilling borehole RISB-2 and (2) measurable DNAPL accumulation in piezometers RGPZ-7C/D. The potential source of this DNAPL is from known free-phase DNAPL from the P/S landfill and/or potential former free-phase DNAPL from the former Pad 9A/B area. Both of these areas are to the north of RISB-2 and RGPZ-7C/D.

Diffusion of contaminant mass from DNAPL contained within claystone fractures into pore water of the claystone matrix between fractures affects the persistence of DNAPL in the fractures. This diffusion causes a redistribution of contaminant mass from fractures to the claystone matrix that can slow the advance of DNAPL migration. If the DNAPL source is controlled, this diffusion can ultimately cause DNAPL migration to cease and DNAPL to disappear from fractures by dissolution and diffusion into the porous matrix.

It may be possible to remove free-phase DNAPL from the P/S Landfill by primary pumping methods. However, removal of free-phase DNAPL will leave behind residual phase DNAPL that is trapped by capillary forces as residual globules in the soil pores below the water table.

Removal of residual DNAPL is much more energy intensive than removal of free-phase DNAPL because of these capillary forces holding residual DNAPL in place.

Removal of free-phase DNAPL from Lower HSU fractures is likely not feasible because it is not possible to sufficiently characterize the Site to identify all potential fractures that may contain DNAPL. Meeting this objective would require literally hundreds of deep borings and even then, the extent of mobile DNAPL in fractures would likely not be known. In addition, removing DNAPL from select fractures that are found to contain mobile DNAPL would not be effective because of the very small storage capacity within fractures that would contain DNAPL. Any DNAPL removed from fractures would be replaced until the DNAPL source is removed. The most feasible method of controlling free-phase DNAPL migration in the Lower HSU is to remove the mobile DNAPL source. This would result in the mobile DNAPL in the fractures to stop being replenished, which would cause the DNAPL to stop advancing, and ultimately disappearing through matrix diffusion.

10.5.5.2 Mobility/Migration of NAPLs between the Burial Trench Area and PSCT-4

Three new RI monitoring wells (RIMW-6, RIMW-7, and RIMW-8) were installed within the Burial Trench Area to evaluate groundwater chemistry and to identify NAPL presence in that area. Although observations made during the drilling of well RIMW-7 indicated the potential presence of LNAPL, none of the newly installed RI monitoring wells in this area has contained measurable amounts of NAPLs. It should be noted, however, that these wells were intentionally installed outside of the former burial cells, and the CSC has assumed that NAPLs could be present within any of these former waste disposal features. The absence of NAPLs in the new wells is therefore not definitive evidence that NAPLs do not exist within the study area; rather, it indicates that the NAPLs that may be present are not found outside their original trench locations. Subsurface conditions between the Burial Trench Area and PSCT-4 are illustrated on a cross-section diagram in Figure 4-52.

Piezometers RIPZ-15 and RIPZ-16 were installed within and downgradient (south) of the burial trenches in the Lower HSU. To date, no free-phase DNAPL has been observed in either piezometer, although higher concentrations are present in RIPZ-16, the piezometer between the Burial Trench Area and PSCT-4.

There are some potentially significant differences between the potential mobility of NAPLs observed within the Central Drainage Area and those NAPLs present within the Burial Trench Area. These potential differences include:

- The volume of wastes within the presumed sources can affect lateral and vertical migration of the NAPLs (e.g., increased DNAPL pool heights can increase the potential for downward migration within fractures), and the magnitude of the NAPL sources is likely significantly greater in the Central Drainage Area compared with the Burial Trench Area. The CSC currently believes that the primary source of the NAPLs in the Central Drainage Area is the P/S Landfill, which contains billions of pounds of waste pesticides and solvents. The quantity of wastes within the Burial Trench Area is not as great as that of the P/S Landfill.
- NAPL migration in the Central Drainage Area is likely influenced by the geologic properties of an alluvial canyon. This includes the presence of high hydraulic conductivity alluvium and weathered claystone. The former drainage channel could also act as a geologic depression where DNAPLs could accumulate and migrate down slope.

In contrast, the Burial Trench Area was carved out of a ridge of bedrock. No obvious preferential flow paths or low points are known to exist in this area.

Similar to the Central Drainage Area where the CSC extracts DNAPL using the existing well network, the CSC extracts liquids from an extraction point within the PSCT located immediately downgradient from the Burial Trench Area. To date, NAPLs have not been observed within PSCT-4, which is the closest extraction well to the Burial Trench Area. The data collected to date indicate that the NAPLs (if present) beneath the Burial Trench Area have not migrated significantly since they were originally emplaced.

10.6 Conceptual Groundwater Remedies

In Section 3.10.3 of the RI/FS Work Plan, the CSC presented some preliminary groundwater remedial alternatives. These broad-brush alternatives provide a basis for formulating more detailed alternatives in the forthcoming Feasibility Study; however, they are important for consideration within the context of this preliminary TIE.

In the RI/FS Work Plan, conceptual remedial options were formulated for the Northern Groundwater Area (i.e., the contaminated plume north of the PSCT), Southern Groundwater Area, and Off-Site Groundwater Area.

The groundwater concentration maps presented in Section 5.4.5 indicate that the primary chemicals found in DNAPL are present in the dissolved-phase Upper HSU plume at concentrations exceeding MCLs some distance south of the PSCT. Therefore, the PSCT may not be a logical boundary for remedial planning because contaminants above MCLs are present well beyond that boundary. The contaminants may have come from groundwater contamination north of the PSCT, or may be the result of former ponds and pads in this area and could have contributed to the dissolved-phase plume beyond the PSCT. Based on the numerous and compounding factors that affect remedial effectiveness as described in Section 10.5, the CSC expects to evaluate whether the existing contamination and the presence of the Site NAPLs preclude groundwater restoration to MCLs (which are, at present, the presumed remediation standards for the Site) for the entire Site in the Upper HSU. In this section, the CSC has described the conceptual remedies presented in the RI/FS Work Plan but does not segregate the Site plume into “northern” and “southern” areas.

Please note that defining a TI zone that extends past the PSCT over the entire Site in the Upper HSU would be consistent with the point-of-compliance ARAR (22 CCR §66264.95), which would locate the groundwater point of compliance at the Site boundary. The point of compliance for groundwater is the location at which a facility evaluates compliance with groundwater cleanup standards. The point of compliance is to be located at the hydraulically downgradient limit of the waste management area, although where the facility contains more than one regulated unit, the waste management area is described by using an imaginary line along the outer boundary of the regulated units. (See also NCP Preamble, 55 FR 8666, 8753.) At the Site, the regulated units have been located throughout the Site, including throughout the southern portion, south of the PSCT. Thus, the appropriate boundary for the point of compliance may encompass all of the Site’s waste management areas and be located at the Site boundary.

As described in the RI/FS Work Plan, the CSC plans to develop groundwater remediation alternatives that include elements such as NAPL removal, source control and/or containment, passive groundwater treatment, and institutional controls. The CSC will evaluate in situ

treatment alternatives (e.g., biosparging, vacuum extraction) and whether they are potentially effective in the technology-screening phase of the Feasibility Study. These in situ treatment alternatives may not be effective because technologies to treat the wide variety of chemicals on site are limited, and because the low permeability of the weathered and unweathered fractured bedrock may limit the effectiveness of these types of in situ treatment technologies. At the present time, the CSC expects to consider remedial alternatives for the Upper HSU Site groundwater that may include, but not be limited to, the following elements implemented alone or in combination:

- NAPL Removal – This scenario includes removal of NAPL from selected existing extraction points and from any new extraction points identified during the Feasibility Study process. The scope of source removal actions will be based on the degree of risk reduction expected and any other potential benefits that would result from source removal. The option of NAPL removal will include off-site disposal for extracted NAPL.
- Source Control – This option includes extraction of groundwater from the Gallery Well, Sump 9B, the Road Sump, and the PSCT to maintain hydraulic control of the dissolved-phase plume. The option includes on-site treatment of extracted liquids from the PSCT followed by on-site storage of the effluent.
- Physical Containment – This scenario includes extending the engineered cap from the base of the former landfills south to the PSCT, thereby reducing infiltration and groundwater flow through the contaminated water bearing zone within the Upper HSU. Other possible containment features could include constructing subsurface barrier walls downgradient of PSCT-1 and PSCT-4 to impede lateral migration of NAPL and aqueous-phase contamination.
- Passive Treatment – This includes installing passive treatment walls in lieu of subsurface barriers downgradient of PSCT-1 and PSCT-4. The in situ passive treatment walls are designed to reduce organic and metal concentrations in the aqueous plume. The passive treatment walls could be combined with subsurface barriers to achieve a funnel and gate scenario.
- Monitored Natural Attenuation – This option includes continued groundwater quality monitoring to indicate stable or declining contaminant concentrations in the leading edge of the plume. This option may be considered as a source control and/or containment option if further assessment indicates that the plume has (or will) reach equilibrium.
- Perimeter Control – This includes continued extraction of groundwater from the RAP and PCT wells at the Site perimeter. The option may include treatment of the extracted liquids, and the effluent will be routed to an on-site pond for evaporation.
- Perimeter Containment/Treatment – This option includes installing barrier walls and/or in situ passive treatment walls downgradient and in lieu of the three PCTs. The in situ passive treatment walls are designed to reduce organic and metal concentrations in the aqueous plume. The passive treatment walls could be combined with subsurface barriers to achieve a funnel and gate scenario.
- Institutional Controls – This includes instituting Site access and deed restrictions to mitigate potential exposure to contaminants in Site groundwater. Ongoing groundwater quality monitoring is also included in this option.

The remedial options discussed in the above paragraphs generally apply to the Upper HSU groundwater. Remedial options for the Lower HSU groundwater will be very limited primarily because of the reduced permeability in this claystone, which makes it almost impossible to extract groundwater or DNAPL at these depths. Table 10-8 describes potentially applicable remedial technologies and process options for DNAPL contamination and/or contaminated

fractured bedrock. This table is not intended to be a comprehensive screening of all potential alternatives (which will be provided in the FS), but it does describe the anticipated effectiveness, implementability, and relative costs for some of the more commonly applied technologies and process options.

The CSC expects that removal of DNAPL from within the Lower HSU and hydraulic containment alternatives for dissolved-phase contaminants or DNAPL within the Lower HSU may be eliminated in the screening phase based on physical limitations imposed due to contaminant depth and because of the uncertainties associated with designing an effective remedy when the precise mechanism for the deeper DNAPL contamination is unknown. Source removal from the Lower HSU would be infeasible not only based on depth considerations but also because the DNAPL migration pathway cannot be defined. It is commonly accepted that if there is residual DNAPL in the pore spaces and fractures in the Lower HSU, these DNAPL zones (of unknown location) will continue to provide a source for ongoing aqueous-phase groundwater contamination. The locations of adsorbed DNAPL in the Central Drainage Area of the Site (which cannot physically be removed) cannot reasonably be defined because of the complex geology of the fractured claystone matrix. In situ technologies will likely be eliminated from consideration in the Feasibility Study based on the depth and variety of chemicals present in groundwater, and because of the complex geologic and hydrogeologic Site conditions. The USEPA's Technology Innovation Program and the United Kingdom's Environmental Agency have both assembled information on efforts to identify and remediate DNAPLs in fractured rock sites, which can be reviewed on the USEPA's CLU-IN website: http://clu-in.org/fracrock/ and http://www.clu-in.org/conf/itrc/dnaplpa/dnapl_handbook_final.pdf.

The remedial options for Lower HSU groundwater may, therefore, include monitored natural attenuation and institutional controls. Regardless of the final remedy selected, continued groundwater quality monitoring in the Lower HSU will be required to assess the effectiveness of the proposed remedy and to assess future groundwater quality trends.

10.7 Conclusions

The purpose of this preliminary TIE is to preliminarily evaluate the practicability of returning groundwater to its beneficial use, as established by ARARs, or by risk-based goals where no ARARs exist, and to evaluate whether we have collected sufficient data as part of the RI to complete a TI Evaluation as part of the FS. As required by the RI/FS Work Plan and the SOW of the Consent Decree, the TI Evaluation (for the first three of the six steps of the full evaluation) the CSC has included in the RI Report is preliminary and does not include detailed engineering evaluations or cost analyses of possible remedy alternatives for restoring groundwater at the Site (these components of the evaluation will be presented in the forthcoming Feasibility Study). We believe based on this preliminary TI Evaluation that sufficient data exists or have been collected during the RI to evaluate the types of conditions that may ultimately require a TI waiver for the Site. In addition to including detailed engineering evaluations and cost analyses of possible remedy alternatives (the last three of the six steps for the full evaluation), the FS will also update the evaluation of the first three components presented in this preliminary TIE to (1) incorporate additional ARAR or media-specific standards that are identified and would be appropriate for a TI Waiver; (2) revise the spatial area over which a potential TI decision would apply based on the full analysis of all six components of the TI evaluation; and (3) update the conceptual Site model based on any additional data or analysis that would update or change the understanding of the geology, hydrogeology, groundwater contaminant sources, transport, and fate.

The USEPA TI Waiver Guidance identifies three general categories of factors that may inhibit groundwater restoration:

- Hydrogeologic limitations such as complex sedimentary deposits, aquifers of very low permeability, fractured bedrock aquifers, and other factors that make in situ treatment of contaminated groundwater extremely difficult;
- Contaminant-related factors that may limit the success of an extraction or in situ treatment process (such as DNAPLs); and
- Remediation system design inadequacies. This factor is not considered by the USEPA to be sufficient justification for a determination of technical impracticability.

As summarized below, we have sufficient information to evaluate these limitations for the Site:

- There are large quantities of wastes that were disposed into landfills, ponds, evaporation pads, burial trenches, and injection wells at the Site between the late 1970s and late 1980s. Much of that waste remains on site and it would not be practical to consider removal. The previous disposal practices resulted in releases of LNAPLs and DNAPLs into a hydrogeologically complex environment where low permeability and fractured overburden and bedrock exist. NAPL data, Site hydrology, and fractures were evaluated in the RI process and we have sufficient information to fully evaluate Site conditions.
- Although hydraulic containment features (such as the Gallery Well and the PSCT) are currently in place to limit horizontal migration of contaminants within the Upper HSU, the presence of contaminants in deep fractured bedrock in the Lower HSU demonstrates that there may be a pathway of aqueous phase chlorinated solvent contamination and DNAPL contamination between the P/S Landfill and potentially other source areas to the deeper bedrock (Lower HSU) aquifer.
- The RI has identified chlorinated solvent contamination in the Central Drainage Area that is located several hundred feet from the P/S Landfill, and demonstrated widespread Upper and Lower HSU contamination in this area. Similarly, there are groundwater impacts from the Burial Trench Area that extend well south of the PSCT into the former ponds and pads subarea.
- The RI has identified that the bedrock under the Site is sedimentary in nature and is fractured. Once DNAPL reaches the bedrock, it will migrate downward until it cannot overcome the entry pressure of the fracture due either to the small aperture width or limitations in pool height. The DNAPL may also enter dead-end fractures and cause diffusion of aqueous contaminants into the rock matrix. Removal of DNAPL from fractured bedrock and restoration of groundwater to background concentrations in DNAPL zones within a reasonable timeframe is extremely difficult due to limited natural or induced flushing within bedrock fractures, particularly dead-end fractures. Also, as discussed in the literature and guidance documents, back diffusion from the matrix could cause concentrations to persist above groundwater standards for decades. While this will be further and completely evaluated in the FS, current remedial technologies are not effective in restoring DNAPL zones in low permeability (weathered claystone) and fractured media (unweathered claystone), particularly in complex settings such as the Site.
- The overburden aquifer is a low-permeability, weathered claystone formation. LNAPLs and DNAPLs have been identified at several wells/piezometers within the Upper HSU, and it is likely that NAPLs may exist at other locations within the Upper HSU based on current groundwater chemistry data. DNAPL may be pooled in dead-end fractures or

remain as residual in the fractures where diffusive losses to the porous matrix may dissipate DNAPL over time. These characteristics limit the hydraulic accessibility of DNAPL and, coupled with the low permeability of the Upper HSU, make removal of DNAPL and restoration of groundwater to background levels within a reasonable timeframe unlikely.

- There are currently no available technologies that are known to be effective in restoring DNAPL zones in complex heterogeneous geologic environments to drinking water quality in a reasonable timeframe.

The CSC will carry the analysis forward to the FS regarding whether a TI waiver of selected groundwater ARARs is warranted for the Site under NCP Section 300.430(f)(l)(ii)(C)(3) and the USEPA's TI Waiver Guidance for groundwater restoration. Based on the CSC's preliminary evaluation, the CSC believes the groundwater zone over which the TI zone would apply could encompass all areas in the overburden (Upper HSU) and bedrock (Lower HSU) aquifers north of the PSCT and the overburden (Upper HSU) aquifer south of the PSCT. These areas are currently, or conceivably could be, impacted by contamination emanating from sources at the Site. As shown in Figure 10-1, the potential lateral boundaries of a TI waiver zone could extend to the Site boundaries. The depth of the TI waiver zone is considered to be at least the depth of the deepest impacted well within the Site boundaries. This is consistent with the point-of-compliance ARAR, pursuant to which the point of compliance boundary would encompass the Site's waste management areas and therefore be located at the Site boundary.

The compounds and their respective list of preliminary ARARs for which a TI waiver will be considered are presented in Table 10-2. This list of preliminary ARARs will be updated in the FS. The chlorinated organic compounds are the most widespread and recalcitrant compounds at the Site and will dictate the ability to restore groundwater. However, the previous disposal operations at the Site accepted a variety of mixed liquid wastes and, as such, groundwater beneath the Site is commonly impacted by numerous contaminants. For example, waste solvents that were used as degreasers can produce groundwater impacted by both VOCs and petroleum hydrocarbons; because these were disposed of in a mixed pesticide/solvent landfill, liquids that have historically discharged from that landfill can contain pesticides, VOCs, and hydrocarbon constituents. In addition, concentrations of inorganic contaminants (e.g., arsenic and nickel) above drinking water standards are present throughout the Site. Based on this, there is little perceived benefit to remediating the co-located (non-chlorinated) compounds (i.e., not apply an ARAR waiver), while applying an ARAR waiver to the chlorinated compounds. Therefore, if implemented, a TI waiver would likely apply to all dissolved contaminants found in Site groundwater, which include VOCs, SVOCs, pesticides, herbicides, and metals.

As noted above, the final TIE will be completed in the Feasibility Study for the Site. In addition to the first three TIE components evaluated above, the Feasibility Study will also include the following components, which will complete the overall TIE:

- An evaluation of the restoration potential of the Site, including data and analyses that support any assertion that attainment of ARARs or media cleanup standards is technically impracticable from an engineering perspective;
- Estimates of the cost of the existing or proposed remedy options, including construction, operation, and maintenance costs; and
- Any additional information or analyses that the USEPA deems necessary for the TIE based on comments provided on this preliminary TIE.

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11.0 SUMMARY AND CONCLUSIONS

In this section, the CSC summarizes the findings and conclusions of the investigations and studies for the various media completed as part of the RI at the site. The discussions presented in this section are summaries of the information presented in earlier sections of the RI Report which are also detailed in the various appendices to the RI Report.

We have summarized our conclusions regarding the nature and extent of contamination detected in the various environmental media, including soils, sediments, soil vapor, surface drainage water, groundwater, and NAPL, reviewed the conclusions of the human health and ecological risk assessments, and provided recommendations for any additional investigations or studies that may be merited. Please note that the CSC sent EPA a separate memorandum dated August 21, 2009 that reviewed the preliminary remedial action objectives (RAOs) for the upcoming Feasibility Study (FS) for the site. That memorandum also discussed the preliminary list of remedy alternatives that we suggest we include in the FS. The RI Report references and attaches that August memorandum.

11.1 Contaminant Distribution

11.1.1 Soils

The sampling results from the various phases of RI soil sampling discussed earlier in this RI Report indicate that the majority of the study areas of the Site have some level of soil contamination attributable to former Site operations or facilities. The soil impacts are primarily associated with former disposal areas or previous Site facilities. The soils impacts are typically inorganic and/or organic contaminants and have been documented in the following study areas:

- Administration Building Area;
- Capped Landfills Area;
- RCRA Canyon Area;
- West Canyon Spray Area;
- Burial Trench Area;
- Central Drainage Area;
- Liquids Treatment Area;
- Maintenance Shed Area;
- Roadways Area; and
- Remaining On-site Area, including the Former Ponds and Pads Subarea.

The RI sampling program indicated there are no soil impacts of significance in off-site soils directly adjoining the Site. While high concentrations of organic constituents were detected in one location from within the Capped Landfills Area, these were encountered in a sample collected from depths in excess of 70 feet below ground surface, lying within waste and beneath the engineered cap of P/S landfill.

The locations where constituents were found to exceed Site-specific Human Health and/or Ecological risk-bases concentrations in soil (HH RBCs and Eco RBCs, respectively) are much more widely distributed across a larger number of study areas for inorganic constituents than for organic constituents. Inorganic constituents found to exceed Eco RBCs in surface and shallow soil at the Site are limited to barium, chromium, copper, and zinc. No inorganics were found to

exceed their respective HH RBCs. Barium and copper are widely present in excess of their respective Eco RBCs in surface and to a lesser extent shallow subsurface soils in both the RCRA Canyon Area and the West Canyon Spray Area. Such exceedances for chromium and zinc are less frequent and widespread. Other study areas found to have one or more of these inorganic constituents in exceedance of their respective Eco RBCs include the Burial Trench Area, Liquids Treatment Area, Central Drainage Area, Maintenance Shed Area, Roadways Area, and Remaining On-Site Area (including Former Ponds and Pads Sub Area). Significantly, however, in comparison to those in the RCRA Canyon Area and the West Canyon Spray Area, Eco RBC exceedances in these other study areas are typically more localized, occurring in only one to several discrete sampling locations, or clusters of sampling locations.

The number and distribution of surface and/or shallow soil sampling locations with organic constituents in excess of Site-specific RBCs is much more limited that that for inorganics. RBC exceedances for organics were limited to portions of six study areas, including the Burial Trench Area, Liquids Treatment Area, Central Drainage Area, Maintenance Shed Area, Roadways Area, and Remaining On-Site Area (including Former Ponds and Pads Sub Area). In strong contrast to inorganics, no organic constituents were encountered in excess of their respective HH RBCs or Eco RBCs in either the RCRA Canyon Area or the West Canyon Spray Area. Organic constituents found to exceed RBCs include total DDT, dioxin toxicity equivalent (TEQ) (Mammalian), MCPP, total PCB congeners, and trichloroethylene, tetrachloroethylene (PCE). Each of these organic constituents were found to exceed their respective Eco RBC in one or more locations within the above-listed study areas, whereas HH RBCs exceedances were limited to dioxin TEQ, MCPP, and PCE in only discrete single sample locations within the Central Drainage Area, Liquids Treatment Area, Maintenance Shed Area, and the Remaining On-Site Area (including Former Ponds and Pads Sub-area). With the exception of total DDT which has a more broad and scattered distribution of exceedances, the majority of organics RBC exceedances occur within the central portion of the Site in proximity to the toe of the P/S Landfill or former waste management units within the Central Drainage area and Former Ponds and Pads Subarea proximal to the PSCT. In general, organics RBC exceedances occur in isolated single or several clustered sampling locations.

With a few noted exceptions, the depth and lateral extent of soil impacts in excess of RBCs has been adequately defined across the Site. Elevated inorganic constituents are mostly restricted to surface or shallow to medium depth soils (i.e., 0 to 10 feet below ground surface [bgs]), and typically demonstrate diminishing concentrations with increased depth. Exceptions to this general condition include high barium concentrations to depths of at least 24 feet bgs in the northern portion of the RCRA Canyon Area, localized occurrences of other elevated inorganics at depths of at least 20 feet bgs in several borings completed in the Maintenance Shed Area and the Administration Building Area, and inorganics impacts in excess of 10 feet bgs in portions of the Central Drainage Area. Elevated concentrations of inorganic and organic constituents are also present in medium to deep soil in the vicinity of location RISBON-59, where soil impacts are locally found to extend to depths of at least 30 feet bgs (inorganics) and 55 feet bgs (organics). Elevated inorganics concentrations were also locally encountered at depths of at least 49 feet bgs along the southeastern margin of the Site, along NTU Road south of the RCF Pond.

High concentrations of organic constituents, principally VOC, polycyclic aromatic hydrocarbons (PAHs) and/or PCBs, also locally present to the maximum depths explored in several borings completed in proximity to former waste management facilities within the Central Drainage Area, the Former Ponds and Pads Sub-area and the Burial Trench Area. High organics concentrations are present to depths of at least 20 feet bgs near former Ponds A and B just

south of the PSCT, to depths of at least 5 feet bgs in a cluster of shallow borings completed north of the western end of the RCF Pond, to depths of at least 5 feet bgs in a cluster several shallow soil borings just south of PSCT-1, and to depths of at least 48 feet bgs in the area between the toe of the P/S Landfill south to the PSCT. High VOC concentrations extending to depths of greater than 40 feet bgs in the Liquids Treatment Area are attributable to collection of these soil samples below the local water table, and likely reflect influences of contaminated groundwater present in the area.

Maximum VOC concentrations were encountered in a boring completed within the approximate limits of former Pond B, followed by several deep borings completed in the Burial Trench Area. The maximum depth of soil impacts on Site was encountered in the Burial Trench Area where former deep waste disposal operations have resulted in elevated inorganics concentrations in soil at depths of up to 44.75 feet bgs, and elevated organics concentrations at depths of up to 77.5 feet bgs.

It should be noted that while there may be a few individual samples in a Study Area that exceed a RBC, the Study Area as a whole may not pose a significant risk due to the use of the 95-percent upper confidence limit (95UCL) concentration in the ERA and HHRA. Moreover, it is important to note that elevated constituent concentrations encountered at depths in excess of 10 feet bgs are not pertinent to human health or ecological risks, as there are no complete exposure pathways to potential receptors. However, elevated concentrations encountered both in shallow and deeper subsurface soils may pose a threat to groundwater.

The lateral extent of soil impacts in these above-listed areas is adequately defined by soil samples from surrounding borings that do not indicate significant contaminant concentrations. While the maximum depth of soil impacts has not been demonstrated in all these locations, with few exceptions, field observations and analytical results for the majority of borings completed across the Site indicate that soil impacts typically diminish with increased depth beneath the surface in the areas south of the PSCT and west of the PCB Landfill and Burial Trench Area. These areas include the RCRA Canyon/West Canyon Spray Area and most areas of the Former Ponds and Pads Area. Not including the landfills, high concentrations of organic constituents, principally VOC, PAHs, and/or PCBs, are locally present to the maximum depths explored at locations near former waste management facilities within the Central Drainage Area, select areas the Former Pond and Pad Subarea, and the Burial Trench Area. Drilling and sampling for chemical analysis was not performed below the contact.

The CSC has reviewed the soil data collected during the RI and considers this data sufficient to characterize the nature, and the extent, of impacts to this media. As described in this report, the review of available inorganics data for background locations, as well as for off-site and on-site areas, indicate that there are more than sufficient numbers of samples (i.e., high power) and adequate spatial distribution of samples to perform the necessary additional statistical evaluations (e.g., calculate UCLs) that factor into the human health and ecological risk assessments to be conducted as part of the RI. Lithologic conditions across the Site have been adequately defined, and in conjunction with soil physical property data and the chemical data developed to date, provide the information needed to evaluate fate and transport of the contaminants present in the various study areas, and provide sufficient data with which to complete the forthcoming Feasibility Study.

Results of surface soil samples collected in the Off-site Area indicate these materials have not been significantly affected by historical Site operations or existing on-site conditions. Soil

conditions in the Off-site Area have been adequately characterized, and no additional data are necessary.

11.1.2 Sediments

While inorganic constituents were present in sediment samples collected from the various on-site ponds and off-site drainages, none were identified to be risk-driving chemicals, thus no RBCs were established for inorganics in sediment. Only one organic constituent – MCPP – was detected in on-site sediments at concentrations in excess of its Eco RBC. No HH RBCs were exceeded for any on-site or off-site sediment samples tested. MCPP is present above its Eco RBC in surface to shallow sediments (i.e., 0 to 5 feet bgs) in the following on-site ponds:

- RCF Pond;
- Pond A-5; and
- Pond 18.

Organics RBC exceedances for on-site sediments are limited to single, isolated sample locations in the above-listed ponds. No organic constituents were detected above their respective RBCs in the A-Series Pond, Pond 13, nor in sediment samples collected from within off-site drainages.

While inorganic constituents, and to a lesser extent organic constituents, were locally detected in some off-site drainage sediment samples, none were reported at levels in excess of established RBCs. Moreover, the positions of these off-site sediment samples in locations situated either upstream or distal from the Site, indicate these occurrences are likely not Site-related.

The depth of chemical impacts in excess of Site-specific RBCs has been adequately defined in all on-site and off-site sediment sampling locations. Sediment data collected during the RI are considered sufficient to characterize the nature and extent of impacts to this media, and no further sediment data are judged to be necessary. Sediment conditions within across the Site and in off-site areas have been adequately defined, and in conjunction with sediment physical property data and the chemical data developed to date, provide the information needed to evaluate fate and transport of the contaminants present in sediment, and provide sufficient data with which to complete the Feasibility Study.

11.1.3 Soil Vapor

VOC concentrations above sample quantitation limits were reported at all soil vapor sample locations, including both on-site and off-site step-out locations. A total of 43 individual VOCs were detected at the various sampling locations around the perimeter of the landfills, the Burial Trench Area, and Central Drainage Area, including chlorinated and aromatic hydrocarbons, acetone, methyl ethyl ketone and Freon gases. With only few exceptions, those VOCs detected in off-site step-out locations were also reported to be present in on-site sampling locations. Chemicals detected in soil vapor that demonstrate some the highest prevalence and reported concentrations, or that may contribute to human health or ecological risk, include acetone, methyl ethyl ketone, Freon 113, benzene, 1,3-butadiene, and tetrachloroehtylene. Maximum concentrations of these chemicals were encountered along the eastern and northeastern limits of the Capped Landfills Area (acetone and 1,3-butadiene), south of the PSCT below the Maintenance Shed Area (1,3-butadiene and benzene), the western limit of the Central Drainage Area and eastern margin of the Burial Trench Area (Freon 113), the southern and western

Central Drainage Area (tetrachloroethylene), as well as west of the Burial Trench Area, the northwestern limit of the Capped Landfills Area, and two locations along the PSCT south of the Central Drainage Area and Burial Trench Area (methyl ethyl ketone). The locations of the samples with elevated concentrations on site are consistent with previously identified source areas at the site, including the existing capped landfills, Burial Trench Area, former Pond R where waste was not removed, and the PSCT which has historically contained free product.

The presence of detectable levels of these chemicals in soil vapor at the site does not pose unacceptable risks to on-site human receptors. Soil vapor concentrations in adjacent off-site locations could result in marginally elevated risks to hypothetical off-site residents via the vapor intrusion pathway. Soil vapor concentrations in adjacent off-site locations could result in marginally elevated risks to hypothetical off-site residents via the vapor intrusion pathway, however this exposure is unlikely due to restrictions in residential development that will be put in place. Soil vapor conditions are not considered to cause adverse effects on on-site or off-site ecological receptors.

The soil vapor sampling conducted at several different times at the same offsite locations. However, these were discrete, one-time soil vapor samples collected from temporary (non-permanent) probes, so temporal concentration trends could not be evaluated. In addition, samples were collected at two depths (7.5 ft and 20 ft bgs) at three near the northern Zone 1 boundary in the Capped Landfills Area. No general concentration trend with respect to depth was observed. Conceptually, elevated soil vapor concentrations are interpreted to occur from near ground surface down to the water table in the landfill areas. The CSC has begun a long-term soil vapor monitoring program at the three locations near the northern Zone 1 boundary to continue to track the slightly elevated chemical concentrations discussed above. That soil vapor sampling will look for any temporal trends and confirm the concentrations do not pose unacceptable risk.

11.1.4 Surface Water

A total of 16 out of 27 inorganic constituents tested were reported in benchmark sampling locations in the North Drainage and upper C-Drainage at dissolved concentrations in excess of one or more screening levels. With few exceptions, for a given sampling period reported values for these constituents in benchmark locations indicate concentrations in the North Drainage are typically elevated relative to those in upper C-Drainage. Noted differences in dissolved inorganics concentrations between these two benchmark locations are likely attributable to soil and hydrologic conditions unique to the North Drainage, and are affected by seasonal factors relating to rainfall and stormwater runoff. Detections of organic compounds in the benchmark locations were mainly limited to several SVOCs and dioxins reported at levels slightly in excess screening levels.

Available data generally indicate that surface water samples collected in the North Drainage contain a larger variety of constituents at overall higher concentrations than comparable samples collected from other off-site and on-site drainages. The notable exceptions to this general condition include the presence of arsenic, molybdenum, nickel, selenium and N-Nitrosodipropylamine at maximum reported concentrations within surface water from the RCRA Canyon drainage, and the unique presence of acetone and acetonitrile in the RCRA canyon drainage relative to all other surface-water sampling locations.

Surface water within the on-site ponds contains relatively low levels of organic compounds, though some VOCs, SVOCs, and PAHs are commonly detected at elevated concentrations.

Concentrations of chlorinated VOCs are generally low to non-detect. Of the inorganic analytes, arsenic, nickel, chromium and selenium are commonly detected at elevated concentrations. Of the ponds sampled, Pond 13 has the highest concentrations of dissolved metals. Total dissolved solids (TDS) concentrations within the ponds have historically been higher than those observed in the off-site drainages and RCRA Canyon, due to the concentration of salts within the ponds that occurs as the water within them evaporates. With few exceptions, inorganic constituents in surface water within on-site ponds are reported to be elevated relative to those present in on-site of off-site drainages. TDS concentrations in on-site ponds are uniformly and consistently higher that corresponding concentrations reported for on-site and off-site drainages. In general, concentrations of inorganic constituents in the on-site ponds have gradually increased over time since the 1997/1998 El Nino winter, with annual fluctuations corresponding to seasonal conditions.

11.1.5 Groundwater and Nonaqueous Phase Liquids

The distribution of groundwater contamination is predominantly located within Zone 1 boundary with little to no contamination in Zone 2. In the Upper HSU, VOC contamination is separated by the PSCT within Zone 1 by the PCTs between Zone 1 and Zone 2. The Zone 1 area north of the PSCT contains the majority of the dissolved phased VOC contamination and all of the known NAPL contamination. VOCs that originate in the northern uphill portions of the Site migrate and converge downhill towards the Central Drainage Area and into the PSCT in the PSCT-1 area. The VOC plume in the Upper HSU in the Burial Trench Area flows south into the PSCT in the PSCT-4 area. In perimeter areas, within Upper HSU groundwater, VOCs are sporadically detected at low concentrations for the in the North Ridge, North Drainage, A-, B- and C- drainage areas. Following operational closure of the facility, VOC movement within the Upper HSU is consistent with groundwater flow patterns.

The P/S Landfill and Central Drainage are the only areas of the site where both DNAPL and LNAPL in the Upper HSU were observed during drilling, gauged in routine liquid level monitoring, and observed based on dissolved chemistry. The Central Drainage is the only area of the site where DNAPL was gauged in routine liquid level sampling and observed based on dissolved chemistry. LNAPL occurs in piezometers within both the P/S Landfill and Central Drainage Area. The P/S Landfill contains a DNAPL pool with an estimated volume of approximately 100,000 gallons of free DNAPL. This pool may be an ongoing source for mobile DNAPL in the Lower HSU that exists in the Central Drainage Area between the P/S Landfill and the PSCT. However, potential fracture pathways are steep, and to –date no DNAP{l has been observed to daylight at surface fracture or seeps. Outside of the P/S landfill Lower HSU DNAPL occurs in RGPZ-7C and RGPZ-7D. The horizontal and vertical extent of mobile DNAPL in the Lower HSU in the vicinity of the P/S Landfill and Central Drainage Area is not known with certainty due to the difficulty in determining or predicting fracture interconnectivity.

There is also a significant area of contamination located in the Burial Trench Area that extends from the upgradient reach at the southern toe portion of the PCB Landfill, and flows downgradient into the PSCT. The Burial Trench Area was investigated for the presence of DNAPL and LNAPL, and although dissolved VOC concentrations are relatively high in this area, no wells or piezometers were observed to contain NAPL during liquids level monitoring.

Historical trends of VOCs at well indicates that the PSCT in combination with natural attenuation mechanisms appears to contain and capture the VOC contamination north of the PSCT; over time VOC trends in wells south of the PSCT appear to be stable to declining.

Upper HSU VOC contamination in groundwater south of the PSCT is the highest south of PSCT-1 and PSCT-4, and is typically one to two orders of magnitude lower in concentration than the concentrations observed in the Burial Trench Area and the Central Drainage Area. The VOC contamination may be residual contamination that existed in-place prior to the PSCT being installed. The VOC contamination sharply declines north of the current Ponds, and is generally not detected south of the five open ponds.

The majority of the samples collected from the Lower HSU did not contain VOC concentrations in excess of the cleanup levels. However, areas of VOC presence in the Lower HSU primarily include: The Central Drainage Area; the Burial Trench Area; the southern edge of the Acids Landfill; along the PSCT; along the North Ridge; and northeast of the Caustic/Cyanide Landfill. The Central Drainage Area contains the greatest amount of VOC contamination in the Lower HSU, and this contamination appears directly related to overlying Upper HSU VOC contamination present between the P/S Landfill and PSCT. The greatest number of VOC cleanup level exceedances in the Central Drainage Area Lower HSU was detected in piezometer RGPZ-6D, which may be related to the Lower HSU DNAPL detected in nearby RGPZ-7C and RGPZ-7D. The Lower HSU location with the second greatest number of VOC exceedances is piezometer RIPZ-16, located in the Burial Trench Area. The remainder of Lower HSU wells with infrequent to few VOC exceedances occur along the PSCT, along the North Ridge, and northeast of the Caustic/Cyanide Landfill.

Dissolved concentrations of arsenic and other metals are elevated within the Zone 1 boundary but are generally not elevated in Zone 2. Similar to VOCs, the higher concentrations of metals in the Upper HSU are located north of the PSCT. Elevated levels also occur south of the PSCT. Unlike the general absence of these VOCs in the ponds and PCTs, however, TDS (salts) and metals are elevated within surface water in the five onsite ponds, groundwater extracted at the PCTs, and other groundwater monitored at other monitoring wells in the vicinity of the ponds and PCTs. Pond surface water is a recharge source to the PCTs. The concentrations of the salt and metals in the ponds that have been increasing due to evaporation since the 1997/98 El Nino winter are causing similar increases in metals and salts in the PCTs and area monitoring wells.

Metals concentrations in the Lower HSU are generally lower than in the Upper HSU; the highest dissolved metals concentrations in the Lower HSU are predominantly located along the North Ridge on the border of Zone 1 and Zone 2. The metal concentrations in the Lower HSU do not appear to coincide with the potentially elevated Upper HSU concentrations.

11.2 Risk Assessments

11.2.1 Human Health Risks

The COPCs evaluated in the Human Health Risk Assessment (HHRA) include inorganics, PCBs, dioxins, herbicides/pesticides, PAHs, SVOCs, and VOCs. The HHRA considered potential exposure scenarios that included inhalation of indoor air and outdoor air vapors, inhalation of particulates, dermal contact with surface water, and exposure via direct contact to soils and sediment.

The results of the HHRA indicate that the following COPCs are primary risk drivers:

- On-site Soils:

- MCPP;
- Tetrachloroethene; and
- Trichloroethene.

- Surface Water (On-site Ponds):
  - Arsenic.

For on-site soils, only the FPP and Liquid Treatment Study Areas exhibited elevated risk estimates for commercial/industrial worker exposures. PCE in shallow soil was the primary risk driver for the FPP Study Area and MCPP was the primary risk driver for both surface and shallow soils at the Liquids Treatment Study Area. Both of these chemicals are present at elevated concentrations in localized areas within these Study Areas.

For the hypothetical off-site resident, only the Burial Trench, Central Drainage, and FPP Study Areas exhibited elevated risk estimates from potential exposures from the transport of on-site soil contamination via windborne vapors. The primary risk drivers were tetrachloroethene and trichloroethene which are both present at elevated concentrations in localized areas within the Study Areas. It should be noted that as discussed in the Uncertainty Sections of the HHRA, the hypothetical off-site resident evaluation is overly conservative as the calculations assume the resident is located adjacent to the Study Area being evaluated. For hypothetical off-site residential exposures to off-site soil, sediment and soil vapor, only the vapor intrusion pathway resulted in a marginally elevated risk estimate. The primary risk driver for this pathway was 1,3-butadiene.

For off-site soils/sediments cancer risk and noncancer hazard estimates for recreational and rancher exposures were below a cancer risk level of 1×10^{-6} and a noncancer hazard of 1.

Potential cumulative cancer risk and noncancer hazard estimates exceeded target health levels because of a few locations within a few Study Areas at the site. The sample locations that contributed the majority to the risk estimates were RISBON-37, RISBON-41 and RISBON-63 in the FPP Study Area just south of the PSCT, RISBLT-02 in the Liquids Treatment Study Area, RISBCD-07 in the Central Drainage Study Area and RISSBC-05 in the Burial Trench Study Area. These results indicate that site cleanup, engineering controls and/or institutional controls should mitigate potential risks associated with these localized areas.

Arsenic concentrations detected in several on-site surface-water impoundments, including the A-Series Pond, Pond 13 and the RCF, are estimated to pose a potentially unacceptable risk to on-site commercial/industrial workers. The potential exposure pathways for on-site and off-site surface drainage waters is considered incomplete, therefore no unacceptable risks are anticipated.

11.2.2 Ecological Risks

Overall, the results of the Tier 1 ERA identified that risks to terrestrial birds at the Site are driven mainly by:

- Barium in the RCRA Canyon Area and the Former Ponds and Pads Areas;
- Cadmium in the RCRA Canyon Area and WCSA;
- Chromium in the RCRA Canyon Area, Roadway Area, and WCSA;
- Copper in the WCSA, Roadway Area, and WCSA;

- Lead in the RCRA Canyon Area, Roadway Area, and WCSA;
- Zinc in the RCRA Canyon Area and WCSA;
- Aroclor 1260 in the Roadway Area; and
- Total PCBs in the Former Ponds and Pads Areas.

Based on the results of the Tier 1 ERA, the invertivorous bird (based on the invertivorous meadowlark) was predicted to be the most sensitive terrestrial bird to potential adverse effects from exposure to these chemicals in soil 0 to 0.5 feet bgs except for the herbivorous bird (based on the herbivorous meadowlark) from barium. Further evaluation was warranted for these risk drivers in the exposure areas listed above, for which no presumptive remedies are planned.

Tier 1 risks to terrestrial mammals at the Site are driven mainly by:

- Barium in the RCRA Canyon Area;
- Cadmium in the RCRA Canyon Area and WCSA;
- Chromium in the RCRA Canyon Area, Roadway Areas, and WCSA;
- Copper in the RCRA Canyon Area, Roadway Areas, and WCSA; and
- Zinc in the Roadway Area, RCRA Canyon Area, and WCSA;
- Aroclor 1260 in the Roadway Areas; and
- Total PCBs in the Former Ponds and Pads Areas.

Based on the Tier 1 ERA, the invertivorous mammal (based on the shrew) was predicted to be the most sensitive terrestrial mammal to potential adverse effects from exposure to metals in soil 0 to 5 feet bgs. The carnivorous mammal (based on the skunk) was predicted to be the most sensitive terrestrial mammal to potential adverse effects from exposure to organics in soil 0 to 5 feet bgs. Potential adverse risk to deep burrowing mammals (0 to 10 feet bgs) via inhalation of burrow air or by ingestion of soil is expected to be unlikely from exposure to chemicals at the Site Further evaluation was warranted for these risk drivers in the exposure areas listed above, for which no presumptive remedies are planned.

Tier 1 risks to terrestrial ecological communities (plants and soil invertebrates) at the Site are driven mainly by:

- Barium in the RCRA Canyon Area and the Former Ponds and Pads Area;
- Chromium in the RCRA Canyon Area, Roadway Area, and WCSA;
- Copper in the RCRA Canyon Area, Roadway Area, and WCSA; and
- Zinc in the RCRA Canyon Area and WCSA.

Tier 1 risks to aquatic wildlife at the Site are driven mainly by:

- Chromium, manganese, selenium, and vanadium in A-Series Pond;
- Barium and selenium in Pond A-5;
- Selenium in Pond 18; and
- Barium in RCF Pond.

Based on the Tier 1 ERA, the invertivorous bird (based on the killdeer) was predicted to be the most sensitive aquatic bird to potential adverse effects from exposure to these chemicals in

surface sediment. However, all of these risk drivers are based on the maximum detected concentrations and may be overestimating potential risk to aquatic wildlife. Additionally, the diet for the aquatic wildlife was based on a mixture of sediment invertebrates and aquatic invertebrates, assuming 50% of each, and this general assumption could potentially introduce uncertainty to the risk estimates.

Tier 1 risks to sediment-dwelling invertebrates at the Site are mainly by:

- Cadmium in the A-Series Pond, Pond 18, and Pond A-5;
- Nickel in A-Series Pond, Pond 13, Pond 18, and Pond A-5;
- Selenium in A-Series Pond, Pond 18, and Pond A-5;
- MCPP in RCF Pond, Pond 18, and Pond A-5;
- Acetone in RCF Pond; and
- 1,1-Dichloroethane in Pond A-5 and RCF Pond.

Based on the Tier 1 ERA, potential risk to aquatic life, aquatic plants, and amphibians are mainly from metals in the onsite ponds. Risks to amphibians for the RCRA Canyon runoff were estimated based on a conservative scenario. This scenario evaluated the potential risk to aquatic receptors under the hypothetical scenario that water pools in RCRA Canyon, which based on site observations, does not occur under current site conditions. Additional evaluations of RCRA Canyon runoff and the potential for pooling once a remedy is in place for A-Series Pond will be evaluated in the FS. The seeps are currently dry and onsite facilities (e.g., Sump 9B and Road Sump) are in place to control these seeps. Therefore, onsite seeps are not expected to be sources of exposure to amphibians, aquatic life, or aquatic plants.

Risks to aquatic life in surface water from the RCRA Canyon runoff are from:

- Arsenic, barium, cadmium, selenium, vanadium, benzo(b)fluoranthene, and ethylene glycol.

Risks to amphibians in surface water from the RCRA Canyon runoff are from:

- Arsenic, barium, beryllium, cadmium, chromium, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

Risks to aquatic plants in surface water from the RCRA Canyon runoff are from:

- Arsenic, cadmium, nickel, and selenium.

All of the ponds will have presumptive remedies in place as part of the USEPA-approved closure plan for the site and will be backfilled/graded to prevent accumulation of water, they will be unavailable as a pathway for aquatic receptors, essentially eliminating the potential for adverse effects to aquatic receptors. Presumptive remedies for all onsite ponds will be further detailed as part of the FS process. Therefore, none of the chemicals in the ponds with HQs greater than 1 were identified for further evaluation.

11.3 Additional Work

The data obtained during the various phases of the RI, along with historical data, were evaluated with respect to the Data Quality Objectives (DQOs) identified in Section 4.0 the RI/FS Work Plan. The following sections summarize whether additional studies and related data gathering may be merited.

11.3.1 Soils

Sufficient data have been collected to adequately define surface and subsurface soil conditions, and the nature and extent of soil impacts detected in the various site study areas. Available data are judged sufficient to assess appropriate future management alternatives and/or remedial measures for these areas as part of the forthcoming Feasibility Study.

11.3.2 Sediments

Sufficient data have been collected in to adequately define sediment conditions in the stormwater ponds, treated liquids impoundments, and off-site drainages, as well as the nature and extent of sediment impacts detected in the areas. Available data are judged sufficient to assess appropriate future management alternatives and/or remedial measures for these areas as part of the forthcoming Feasibility Study.

11.3.3 Soil Vapor

Concentrations above the sample quantitation limits were reported for the soil vapor data collected from the perimeter of the landfills, the Burial Trench Area, and Central Drainage Area. Consequently, these data may be used to evaluate the migration of vapors from these source areas. The collected soil vapor data are sufficient to calculate risk estimates for relevant exposure pathways for human health and ecological receptors. The data have been used in the human health and ecological risk assessments (Appendices T and U, respectively). Based on Phase I sampling results, additional data needs were outlined and met during Phase II of the soil vapor investigation to delineate the soil vapor plumes in these areas of the site, as well as evaluate off-site step-out locations. These data are considered adequate for risk assessment and RI purposes, thus no additional data are necessary to complete the RI. As we discussed above, the CSC is now conducting long term soil vapor monitoring at three offsite locations to ensure there are no adverse temporal trends and that the chemical concentrations in the soil vapor do not pose any unacceptable risks.

11.3.4 Surface Drainage Water

Sufficient data have been collected to adequately define the surface-water conditions in the surface drainages at and surrounding the site. Available data are judged sufficient to assess appropriate future management alternatives and/or remedial measures for these areas as part of the forthcoming Feasibility Study.

11.3.5 Groundwater and NAPL

The groundwater data collected as a part of the RI are adequate for evaluating groundwater contaminant fate, extent and transport. Sufficient data have been collected to evaluate presence, nature, and extent of NAPL at the site; within the LHSU only 3 boreholes of the 408 installed encountered DNAPL, as such although the horizontal and vertical extent of DNAPL in

the Lower HSU is not known with certainty, it is not feasible or practical to delineate DNAPL in all Lower HSU fractures. The only exception to that may be a requirement to complete additional investigations associated with the DNAPL found in RIPZ-13 and RIPZP-27 within the P/S Landfill. As we have discussed in previous sections of this RI Report, we are not able to draw final conclusions about the results from this work at this time.

The CSC is in continuing discussions with EPA about any appropriate next steps to develop more information to test whether the DNAPL present in RIPZ-13 originated from a discreet release of a relatively small volume of DNAPL from drums pierced during CPT or piezometer installation activities, or is instead a larger in-situ pool of DNAPL at the base of the P/S Landfill. The CSC proposed some additional activities in a supplemental RIPZ-13 Work Plan dated February 27, 2009.

11.3.6 Human Health Baseline Risk Assessment

Sufficient data have been collected to identify COPCs for the various environmental media, evaluate potential exposure pathways, and assess potentially unacceptable risks to human receptors. These data are judged sufficient to identify those areas and media at the site that may require corrective actions.

11.3.7 Ecological Risk Assessment

As discussed in Appendix U of this report, a Tier 2 ERA was completed to further evaluate pathways, receptors, and COIs requiring further evaluation (risk drivers), which included additional studies and evaluations designed to make the ecological risk assessment more site-specific and less generic.

The Tier 2 ERA included the following additional data collection and further evaluation efforts to further refine the ecological risks at the Site:

- Tissue sampling (plants, soil invertebrates, and/or small mammals); and
- Refinement of ecological benchmarks, including developing tissue TRVs to use as additional weight-of-evidence in the risk characterization. Bioavailability tests were also recommended.

The results of the Tier 2 assessment are discussed in detail in Section 9 and Appendix U of this RI Report. As those sections note, we have been able to further evaluate the areas of the Site that showed unacceptable risks narrowed the areas of concern as well as the COPCs.

A Tier 2 assessment was conducted to further evaluate pathways, receptors, and risk drivers or chemicals of interest (COIs) based on the results of the Tier 1 assessment. The Tier 2 assessment was conducted by building on the results of the Tier 1 assessment and incorporating Site-specific tissue and bioaccumulation data. The objectives of Tier 2 were to provide valuable information for refining risks, reduce the overall uncertainty in the risk estimates by incorporating Site-specific information into exposure estimates, and to provide additional lines of evidence to provide a clearer understanding of the environmental benefit of reducing concentrations at the Site.

The Tier 2 ERA focused on the COIs, receptors, and exposure areas for which there is no presumptive remedy planned or contemplated. The Tier 1 ERA predicted that invertivorous bird and mammal populations were the most sensitive terrestrial wildlife, and their risks were driven

by exposure to chemicals in surface soil. The aquatic invertivorous bird (based on the killdeer) was generally predicted to be the most sensitive aquatic bird, exposed to chemicals in surface sediment. The risks to aquatic birds are similar with those for terrestrial birds when the Tier 1 ERA was conducted assuming the ponds would be drained. The pathway that generally contributed most to the risk estimate for all wildlife was food ingestion.

As discussed above, presumptive remedies will be in place as part of the USEPA-approved closure plan for the Site for the treated liquid impoundments (Pond 18 and Pond A-5). Also, as part of the USEPA-approved closure plan for the Site, a potential remedy for the stormwater ponds or impoundments (A-Series Pond, RCF pond, and Pond 13), Central Drainage Area, Liquid Treatment Area, Burial Trench, and Maintenance Shed areas are also likely to be implemented and will be further detailed as part of the FS process. Therefore, the Tier 2 ERA focused on the remaining exposure areas and COIs which included the following terrestrial areas:

- Administration Building Area;
- RCRA Canyon;
- West Canyon Spray Area;
- Roadway Areas;
- Remaining Onsite Areas; and
- Former pond and pad areas south of the PSCT.

Overall, the results of the Tier 2 ERA identified that risks to terrestrial birds at the Site are driven mainly by:

- Barium, chromium, copper, and zinc in the RCRA Canyon Area; and
- Chromium, copper, and zinc in the WCSA.

The invertivorous bird (based on the invertivorous meadowlark) is predicted to be the most sensitive terrestrial bird to potential adverse effects from exposure to these chemicals in soil 0 to 0.5 feet bgs except for the herbivorous bird (based on the herbivorous meadowlark) from barium.

For terrestrial mammals, a comparison of site-specific tissue data to tissue-based TRVs developed for kidney and liver tissue indicates that cadmium, chromium, copper, lead, and zinc are not expected to accumulate in target tissues at levels that would result in potential adverse risks. Tier 2 risks to terrestrial mammals at the Site are driven mainly by:

- Barium in the RCRA Canyon Area.

The invertivorous mammal (based on the shrew) is predicted to be the most sensitive terrestrial mammal to potential adverse effects from exposure to metals in soil 0 to 5 feet bgs.

The results of the spatial analysis indicate that for all receptors, potential risk from barium is the most wide-spread in the RCRA Canyon Area and sample-specific risks for the other receptors are co-located in RCRA Canyon and tend to be located on the west side of RCRA Canyon. In the WCSA, sample-specific risks are generally located in the central portion of WCSA and are co-located among receptors. Barium is the only COI in the Former Ponds and Pads Areas and

the potential for cumulative risk to soil invertebrates beyond those identified for barium are likely minimal.

11.4 Remedial Action Objectives

Remedial action objectives (RAOs) consist of media-specific goals for protecting human health and the environment. The CSC initially identified preliminary RAOs for the Casmalia site in Section 3.9.2 of the EPA-approved RI/FS Work Plan. We have developed these further based on the additional information obtained during the RI regarding the nature and extent of contamination at the site. The CSC sent EPA a memorandum dated August 21, 2009 that discussed the updated RAOs (as well as provided EPA a preliminary list of remedy alternatives). We have attached a copy of that memorandum to this RI Report.

As noted in the RI/FS Work Plan and as we noted in the RAO memorandum we sent EPA, the CSC will finalize soil, soil vapor and sediment RAOs as part of the forthcoming Feasibility Study, and those RAOs will address those specific site areas identified as requiring remediation. The RAOs will ensure that the proposed remedies target the appropriate chemicals and are adequately protective of both human health and the environment. For areas where soil removal actions are considered, concentration-based remediation standards will be proposed as part of final remedy selection. For groundwater, the CSC will define cleanup standards based on data developed as part of the RI and the concurrent RGWMEW. At this time we expect to define groundwater standards based on MCLs, and on Region IX PRGs for chemicals that do not have MCLs. As detailed in Section 10 of this report, groundwater RAOs for portions of the site will incorporate a TI waiver zone for groundwater restoration. As discussed in that section, the location and extent of the TI zone was specifically established based on both groundwater flow conditions (as defined by the groundwater flow model) as well as contaminant distribution. The final groundwater remedial objectives also include performance-based objectives to control contamination at the source area and to preclude contaminant migration beyond the site boundary.

The information developed during the RI and included in the Human Health and Ecological Risk Assessments is sufficient to define those chemicals present in the various environmental medial at the site that pose potential risks to human and ecological receptors. The COPCs and applicable human health and ecological screening levels are identified and discussed in Appendices T (Baseline Human Health Risk Assessment) and U (Ecological Risk Assessment) of this RI Report.

The CSC also will ensure that the performance standards established for the RI/FS are addressed in the final RAOs for each study area (see RI/FS Work Plan Table 1-1). The performance standards also will be used to plan site remediation. The specific SOW performance standards relevant to remedy development and selection are as follows:

A. “Develop and evaluate response action alternatives for controlling contaminated groundwater that, among other things, focus on (1) capturing hazardous substances, pollutants and contaminants as close to the site’s former waste management units as practicable, and (2) minimizing both the generation of contaminated groundwater and the extraction of uncontaminated groundwater.”

B. "Develop and evaluate options for controlling surface water that consider institutional controls supplemented by engineering controls that are consistent with the surface-water analysis completed as part of the EE/CA."
C. "Investigate, assess and characterize the non-capped areas of the site, including previous pond and pad areas, Pond 18 area, Pond A-5, access roads, runoff containment areas, groundwater treatment areas, and former burial trench and injection well areas. Develop and evaluate options for response actions in these areas, including cleanup, closure and/or revegetation."
D. "Investigate, assess and characterize the RCRA Landfill area to determine whether the former landfill can be closed without a RCRA cap. Develop and evaluate options for response actions, including capping and the need for a buttress, cleanup, and/or revegetation."