



Remedial Investigation Report Public Review Draft

5900 West Marginal Way Site, Seattle,
Washington, Agreed Order No. DE-6000

PREPARED FOR
Glacier Northwest, Inc.

DATE
July 19, 2024

REFERENCE
0656395



Remedial Investigation Report

Public Review Draft

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0656395



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Geologist's Certification

I, Michael Mendes, Licensed Professional Geologist in the State of Washington, hereby certify to the best of my knowledge and belief that this document is true and correct and has been prepared in accordance with general industry standards and applicable federal, state, and local requirements, and hereunto set out hand and affix my seal this 19th day of July 2024.



MICHAEL F. MENDES

A handwritten signature in black ink, appearing to read "Michael F. Mendes", written over a horizontal line.

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Washington Licensed Professional Geologist No. 2863

CONTENTS

1.	INTRODUCTION	1
1.1	REGULATORY FRAMEWORK/AGREED ORDER	2
1.2	DEVIATIONS FROM THE APPROVED RI/FS WORK PLAN	2
2.	SITE DESCRIPTION AND BACKGROUND	3
2.1	SITE CONTACT INFORMATION	3
2.2	SITE AND PROPERTY DESCRIPTION	3
2.3	PROPERTY LAND USE	4
2.4	CURRENT PROPERTY USE	4
2.4.1	Northern Area	4
2.4.2	Southern Area	5
2.5	PROPERTY UTILITIES AND STORMWATER MANAGEMENT	5
2.5.1	Utilities	5
2.5.2	Current Stormwater Management	5
2.5.3	Historical Stormwater Management	7
2.6	HISTORICAL OWNERSHIP AND INDUSTRIAL ACTIVITIES	7
2.6.1	Historical Ownership	7
2.6.2	Operational History	10
2.6.3	Initial Property Development	10
2.6.4	Wood Preserving (1936–1939)	10
2.6.5	Charcoal and Whetlerite Manufacturing and Testing (1940–1944)	11
2.6.6	Chemical Manufacturing (1946–1961)	13
2.6.7	Log and Vessel Mooring (1960–1964)	15
2.6.8	Property Redevelopment (1964–1969)	15
2.6.9	Cement Terminal (1969–Present)	16
2.7	ADJACENT PROPERTIES	17
2.7.1	Duwamish Shipyard, Inc.	17
2.7.2	Port of Seattle Terminal 115	18
2.7.3	Lower Duwamish Waterway Site	20
2.8	REGIONAL AND SITE GEOLOGY	20
2.8.1	Regional Geology	20
2.8.2	Site Geology	21
2.9	LOWER DUWAMISH WATERWAY	25
2.9.1	Hydrodynamics	25
2.9.2	Sediment	26
2.10	GROUNDWATER OCCURRENCE	27
2.10.1	2013 and 2014 Tidal Studies of the Shallow and Deep Aquifers	27
2.10.2	Shallow Groundwater Aquifer	28
2.10.3	Deep Groundwater Aquifer	30
2.11	TERRESTRIAL ENVIRONMENT	32
2.12	AQUATIC ENVIRONMENT	34
3.	SITE CHARACTERIZATION AND PREVIOUS REMEDIAL ACTIONS (1985–2014)	36



3.1	SUMMARY OF HISTORICAL INVESTIGATIONS	36
3.1.1	Previous Soil Investigations (1985–2003)	36
3.1.2	Historical Groundwater Investigations and Monitoring (1990–2007)	37
3.1.3	Seep Sampling	38
3.1.4	Previous Sediment Sampling in and near the Embayment	39
3.1.5	Previous Dredging Characterization	40
3.2	PREVIOUS INDEPENDENT REMEDIAL ACTIONS	43
3.2.1	Pentachlorophenol in Groundwater Remediation – Ozone Sparging	43
3.2.2	Arsenic in Groundwater Remediation – Hydrogen Peroxide Fixation	44
3.3	SUMMARY OF CONTEMPORARY REMEDIAL INVESTIGATION ACTIVITIES (2009–2019)	44
3.3.1	Upland Soil Investigation	44
3.3.2	Riverbank Soil Sampling	45
3.3.3	Ground Penetrating Radar Survey	45
3.3.4	Monitoring Well Installation	45
3.3.5	Groundwater Sampling	46
3.3.6	Stormwater Sampling	46
3.3.7	Stormwater Solids	47
3.3.8	Plugging and Abandonment of Historical Stormwater Pipe	47
3.3.9	Sediment Investigation Activities	49
3.3.10	Data Gaps Investigation	50
3.4	SUBSURFACE IMAGE EVALUATION	50
4.	SCREENING LEVELS AND CONTAMINANTS OF POTENTIAL CONCERN	52
4.1	SCREENING LEVELS	52
4.1.1	Soil Screening Levels	52
4.1.2	Groundwater Screening Levels	53
4.1.3	Sediment Screening Levels	53
4.2	DATA USAGE	54
4.2.1	Qualified Data	54
4.2.2	Shallow and Deep Aquifer Groundwater Data	54
4.2.3	Vadose and Saturated Zone Soil	54
4.2.4	Analyte Concentrations Reported by both VOC and SVOC Methods	54
4.2.5	Field Duplicates	54
4.2.6	Calculated and Summed Concentrations	55
4.3	CONTAMINANTS OF POTENTIAL CONCERN	55
5.	NATURE AND EXTENT OF CONTAMINATION IN UPLANDS MEDIA	57
5.1	SOIL	57
5.1.1	Metals	57
5.1.2	Volatile Organic Compounds	60
5.1.3	Total Petroleum Hydrocarbons	61
5.1.4	SVOCs	62
5.1.5	PAHs	65
5.1.6	Polychlorinated Biphenyls	66
5.1.7	Dioxins/Furans	67
5.2	GROUNDWATER	68
5.2.1	Metals	69
5.2.2	Volatile Organic Compounds	71
5.2.3	Total Petroleum Hydrocarbons	72
5.2.4	SVOCs	72
5.2.5	PAHs	75
5.2.6	Polychlorinated Biphenyls	75



5.2.7	Dioxins/Furans	75
5.3	SEEPS	76
5.4	STORMWATER	77
5.5	CURRENT PROPERTY STORMWATER SYSTEM SOLIDS	78
5.6	SPU STORMWATER SYSTEM SOLIDS	79
5.7	DATA QUALITY	81
6.	SURFACE AND SUBSURFACE SEDIMENT SAMPLING RESULTS	82
6.1	SEDIMENT SCREENING TO IDENTIFY CONTAMINANTS OF POTENTIAL CONCERN	82
6.2	SEDIMENT SAMPLE RESULTS	82
6.2.1	Arsenic	83
6.2.2	Carcinogenic Polycyclic Aromatic Hydrocarbons	83
6.2.3	Polychlorinated Biphenyls	83
6.2.4	Dioxins/Furans	84
6.2.5	Pentachlorophenol	84
6.2.6	Tributyltin	84
6.2.7	Other COPCs	85
6.2.8	Off-Property Sediment Sample Results	85
6.3	DATA QUALITY	86
7.	CONCEPTUAL SITE MODEL	88
7.1	SITE FEATURES	88
7.2	CURRENT AND FUTURE SITE USE	89
7.3	NATURE AND EXTENT OF PRIMARY COPCS	90
7.3.1	Arsenic	91
7.3.2	Copper	92
7.3.3	Zinc	93
7.3.4	Dioxins/Furans	94
7.3.5	SVOCs	94
7.3.6	Petroleum and Carcinogenic Polycyclic Aromatic Hydrocarbons	97
7.3.7	Polychlorinated Biphenyls	98
7.3.8	Tributyltin	99
7.4	PRIMARY SOURCES AND RELEASE MECHANISMS OF CONTAMINANTS OF CONCERN	99
7.4.1	On-Site Primary Sources and Release Mechanisms	99
7.4.2	Off-Site Primary Sources and Release Mechanisms	110
7.5	FATE AND TRANSPORT OF CONTAMINANTS OF CONCERN	114
7.5.1	Chemical Fate of Contaminants of Potential Concern	114
7.5.2	Transport of Contaminants of Potential Concern	118
7.6	CONCEPTUAL SITE EXPOSURE MODEL	124
7.6.1	Potential Receptors	124
7.6.2	Exposure Pathways	126
8.	REFERENCES	130

FIGURES

TABLES



APPENDIX A1	AERIAL PHOTOGRAPHS OF USES OF THE PROPERTY
APPENDIX A2	AERIAL PHOTOGRAPHS OF USES OF ADJOINING PROPERTIES
APPENDIX B	MINERALIZED-CELL WOOD PRESERVING COMPANY HISTORICAL INFORMATION
APPENDIX C	WHETLERITE PRODUCTION PROCESS OF CARLISLE LUMBER COMPANY, UNITED STATES ARMY, AND CROWN ZELLERBACH CORPORATION
APPENDIX D	UNITED STATES ARMY INVENTORIES AND SITE LAYOUT MAP
APPENDIX E	REICHHOLD 1959 SITE LAYOUT AND DEEP WATER OUTFALL
APPENDIX F	GLACIER BAY SW KENNY STORMWATER DRAINAGE BASIN
APPENDIX G	WASHINGTON STATE DEPARTMENT OF ECOLOGY STORM DRAIN INUNDATION EVALUATION
APPENDIX H	PORT OF SEATTLE STORMWATER INFORMATION
APPENDIX I	SITE CONDITIONS CIRCA 1865
APPENDIX J	TIDAL STUDY DATA 2013 AND 2014
APPENDIX K	GROUNDWATER ELEVATION FIGURES 2009 THROUGH 2014
APPENDIX L	TERRESTRIAL ECOLOGICAL EVALUATION SUPPORTING INFORMATION
APPENDIX M	PORT OF SEATTLE ENGINEERING ARCHIVES 1967
APPENDIX N	SAMPLE METHOD SUMMARY TABLES
APPENDIX O	BOREHOLE LOGS AND MONITORING WELL CONSTRUCTION LOGS
APPENDIX P	GROUND PENETRATING RADAR SURVEY REPORT
APPENDIX Q	WELL DEVELOPMENT RECORDS
APPENDIX R	GROUNDWATER TECHNICAL MEMORANDA
APPENDIX S	HISTORICAL STORMWATER PIPE ABANDONMENT PLAN
APPENDIX T	SEDIMENT SAMPLE LOGS
APPENDIX U	SUBSURFACE IMAGE TEST PIT PHOTOLOG
APPENDIX V	COPC PREVALENCE TABLES
APPENDIX W	SOIL AND GROUNDWATER COMPREHENSIVE ANALYTICAL DATA SUMMARY TABLES
APPENDIX X	DATA VALIDATION MEMORANDA
APPENDIX Y	LABORATORY ANALYTICAL DATA PACKAGES
APPENDIX Z	GROUNDWATER QUALITY PARAMETERS
APPENDIX AA	ANALYTICAL SUMMARY TABLE FOR SEEP DATA
APPENDIX BB	ANALYTICAL SUMMARY TABLES FOR STORMWATER DATA
APPENDIX CC	ANALYTICAL SUMMARY TABLES FOR STORMWATER CONVEYANCE SYSTEM SOLIDS DATA
APPENDIX DD	STORMWATER SOLIDS MASS BALANCE BOX MODEL
APPENDIX EE	ANALYTICAL SUMMARY TABLES FOR HISTORICAL STORMWATER PIPE SOLIDS DATA
APPENDIX FF	ANALYTICAL SUMMARY TABLES FOR SEATTLE PUBLIC UTILITIES STORMWATER SOLIDS DATA



APPENDIX GG SEDIMENT ANALYTICAL SUMMARY CONTAMINANTS OF POTENTIAL CONCERN
TABLES

APPENDIX HH 2023 MAINTENANCE DREDGING SAMPLES LABORATORY ANALYTICAL REPORTS

APPENDIX II DEEP SEEP PHOTOLOG

LIST OF FIGURES

(Figures immediately follow the report text)

FIGURE 1-1	SITE LOCATION MAP
FIGURE 2-1	SITE AND AREA PARCEL OWNERSHIP
FIGURE 2-2	LOWER DUWAMISH WATERWAY LAND USE
FIGURE 2-3	CURRENT SITE LAYOUT
FIGURE 2-4	CURRENT SITE PLAN AND HISTORICAL SITE FEATURES
FIGURE 2-5	CURRENT STORMWATER CONVEYANCE SYSTEM
FIGURE 2-6	HISTORICAL STORMWATER PIPE
FIGURE 2-7	CHRONOLOGICAL OWNERSHIP/OPERATOR HISTORY
FIGURE 2-8	HISTORICAL SITE PLAN – MINERALIZED CELL WOOD PRESERVING COMPANY 1936
FIGURE 2-9	HISTORICAL SITE PLAN – ARMY OPERATIONS 1946
FIGURE 2-10	HISTORICAL SITE PLAN – REICHHOLD OPERATIONS 1956–1959
FIGURE 2-11	HISTORICAL SITE PLAN – PORT OF SEATTLE 1967
FIGURE 2-12	HISTORICAL SITE PLAN – KAISER OPERATIONS 1974
FIGURE 2-13	GEOLOGIC CROSS SECTION PROFILES
FIGURE 2-14	GEOLOGIC CROSS SECTION A-A'
FIGURE 2-15	GEOLOGIC CROSS SECTION B-B'
FIGURE 2-16	GEOLOGIC CROSS SECTION C-C'
FIGURE 2-17	GEOLOGIC CROSS SECTION D-D'
FIGURE 2-18	GEOLOGIC CROSS SECTION E-E'
FIGURE 2-19	GEOLOGIC CROSS SECTION F-F'
FIGURE 2-20	TOP OF AQUITARD ELEVATION CONTOUR MAP
FIGURE 2-21	SHORELINE CHANGES OVER TIME
FIGURE 2-22	SHALLOW GROUNDWATER POTENTIOMETRIC SURFACE MAP – 2014
FIGURE 2-23	DEEP GROUNDWATER POTENTIOMETRIC SURFACE MAP (LOW TIDE) – 2014
FIGURE 2-24	DEEP GROUNDWATER POTENTIOMETRIC SURFACE MAP (HIGH TIDE) – 2014
FIGURE 2-25	TERRESTRIAL ECOLOGICAL EVALUATION
FIGURE 3-1	HISTORICAL SOIL, GROUNDWATER, AND SEEP SAMPLE LOCATIONS

FIGURE 3-2	SEDIMENT INVESTIGATION LOCATIONS
FIGURE 3-3	2009–2019 SOIL BORING LOCATIONS
FIGURE 3-4	TOP-OF-RIVERBANK SOIL BORING LOCATIONS
FIGURE 3-5	GPR TRANSECTS AND SOIL BORING LOCATIONS
FIGURE 3-6	EXISTING MONITORING WELL NETWORK
FIGURE 3-7	STORMWATER INVESTIGATION
FIGURE 3-8	HISTORICAL STORMWATER INVESTIGATION
FIGURE 3-9	SUBSURFACE IMAGE EVALUATION TEST PITS
FIGURE 5-1	ARSENIC RESULTS IN UNSATURATED UPLAND SOIL SAMPLES
FIGURE 5-2	ARSENIC RESULTS IN SATURATED UPLAND SOIL SAMPLES
FIGURE 5-3	COPPER RESULTS IN UPLAND SOIL SAMPLES
FIGURE 5-4	ZINC RESULTS IN UPLAND SOIL SAMPLES
FIGURE 5-5	TPH – DRO + MORO RESULTS IN UPLAND SOIL SAMPLES
FIGURE 5-6	PENTACHLOROPHENOL RESULTS IN UPLAND SOIL SAMPLES
FIGURE 5-7	SOIL SCREENING LEVEL EXCEEDANCES NOT CO-LOCATED WITH PRIMARY CONSTITUENTS OF POTENTIAL CONCERN
FIGURE 5-8	CARCINOGENIC PAHS TEQ RESULTS IN UPLAND SOIL SAMPLES
FIGURE 5-9	TOTAL PCB AROCLOR RESULTS IN UNSATURATED UPLAND SOIL SAMPLES
FIGURE 5-10	TOTAL PCB AROCLOR RESULTS IN SATURATED UPLAND SOIL SAMPLES
FIGURE 5-11	DIOXINS/FURANS TEQ (ND=1/2DL) RESULTS IN UPLAND SOIL SAMPLES
FIGURE 5-12	DISSOLVED ARSENIC RESULTS IN SHALLOW GROUNDWATER WELLS
FIGURE 5-13	DISSOLVED ARSENIC RESULTS IN DEEP GROUNDWATER WELLS
FIGURE 5-14	DISSOLVED COPPER RESULTS IN SHALLOW GROUNDWATER WELLS
FIGURE 5-15	DISSOLVED COPPER RESULTS IN DEEP GROUNDWATER WELLS
FIGURE 5-16	TPH – DRO + MORO RESULTS IN SHALLOW GROUNDWATER WELLS
FIGURE 5-17	PENTACHLOROPHENOL RESULTS IN SHALLOW GROUNDWATER WELLS
FIGURE 5-18	SHALLOW GROUNDWATER SCREENING LEVEL EXCEEDENCES NOT CO-LOCATED WITH PRIMARY CONSTITUENTS OF POTENTIAL CONCERN
FIGURE 5-19	PENTACHLOROPHENOL RESULTS IN DEEP GROUNDWATER WELLS
FIGURE 5-20	DIOXINS/FURANS TEQ (ND=1/2DL) RESULTS IN SHALLOW GROUNDWATER WELLS
FIGURE 5-21	DIOXINS/FURANS TEQ (ND=1/2DL) RESULTS IN DEEP GROUNDWATER WELLS
FIGURE 6-1	INTERPOLATED ARSENIC IN SEDIMENT
FIGURE 6-2	INTERPOLATED CARCINOGENIC PAHS IN SEDIMENT
FIGURE 6-3	INTERPOLATED PCBS IN SEDIMENT
FIGURE 6-4	INTERPOLATED DIOXINS/FURANS TEQ IN SEDIMENT

FIGURE 6-5	INTERPOLATED PCP IN SEDIMENT
FIGURE 6-6	INTERPOLATED TRIBUTYL TIN ION IN SEDIMENT
FIGURE 7-1	CONCEPTUAL SITE EXPOSURE MODEL
FIGURE 7-2	EXISTING SITE FEATURES
FIGURE 7-3	FORMER WOOD PRESERVATION OPERATIONS BETWEEN APPROXIMATELY 1936 AND 1939
FIGURE 7-4	FORMER CHARCOAL AND WHETLERITE MANUFACTURING AND TESTING BETWEEN 1940 AND 1944
FIGURE 7-5	FORMER CHEMICAL MANUFACTURING BETWEEN 1946 AND 1961
FIGURE 7-6	FACILITY DEMOLITION AND REDEVELOPMENT BETWEEN 1964 AND 1969
FIGURE 7-7	APPROXIMATE CUT AND FILL AREAS
FIGURE 7-8	CEMENT TERMINAL

LIST OF TABLES

(Tables immediately follow the figures, except for Table 2-0, which is embedded in the report text)

TABLE 2-0	SITE CONTACT INFORMATION
TABLE 2-1	GROUNDWATER ELEVATION MEASUREMENTS
TABLE 2-2	VERTICAL GRADIENTS
TABLE 3-1	SUMMARY OF MONITORING WELL CONSTRUCTION INFORMATION
TABLE 4-1	SATURATED AND UNSATURATED SOIL SCREENING LEVELS
TABLE 4-2	GROUNDWATER SCREENING LEVELS
TABLE 4-3	SEDIMENT SCREENING LEVELS
TABLE 4-4	COPC SELECTION PROCESS FOR VADOSE ZONE SOIL
TABLE 4-5	COPC SELECTION PROCESS FOR SATURATED ZONE SOIL
TABLE 4-6	COPC SELECTION PROCESS FOR GROUNDWATER
TABLE 4-7	COPC SELECTION PROCESS FOR SEDIMENT
TABLE 4-8	SUMMARY OF CONSTITUENTS OF POTENTIAL CONCERN IN MEDIA
TABLE 5-1	PHOTOIONIZATION DETECTOR READINGS AT SOIL BORINGS
TABLE 7-1	SOURCES OF CONTAMINANTS OF CONCERN, RELEASE MECHANISMS AND IMPACTED MEDIA
TABLE 7-2	VERTICAL TRAVEL TIME THROUGH AQUITARD
TABLE 7-3	CHEMICAL PROPERTIES OF CONTAMINANTS OF CONCERN

ACRONYMS AND ABBREVIATIONS

Acronyms	Description
°F	degrees Fahrenheit
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
Agreed Order	Agreed Order No. DE 6000
AML	Alaska Marine Lines, Inc.
Army	United States Department of the Army
Ash Grove	Ash Grove Cement West, Inc.
atm	atmosphere
BEHP	bis-2(ethylhexyl) phthalate
bgs	below ground surface
CDF	controlled density fill
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
cm/yr	centimeters per year
Carlisle	Carlisle Lumber Company
COC	contaminant of concern
COPC	contaminant of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
Crown Zellerbach	Crown Zellerbach Corporation
CSM	conceptual site model
CUL	cleanup level
CWS	Chemical Warfare Service
D/Fs	dioxins/furans
DGR	Data Gaps Report
DMMP	Dredge Material Management Plan
DMMU	dredged material management unit
DRO	diesel-range organics
DSI	Duwamish Shipyard, Inc.
Ecology	Washington State Department of Ecology
Embayment	An embayment within the Lower Duwamish Waterway commonly known as Glacier Bay

Acronyms	Description
ERM	Environmental Resources Management, Inc.
FD-GTI	Fluor Daniel GTI, Inc.
FS	Feasibility Study
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
Glacier Northwest	Glacier Northwest, Inc.
GMA	Growth Management Act
GPR	ground penetrating radar
GRO	gasoline-range organics
K	water solubility
Kaiser	Kaiser Cement & Gypsum Corporation
Koc	organic carbon-water partitioning coefficient
L/kg	liters per kilogram
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
Lone Star	Lone Star Industries, Inc.
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
Mineralized-Cell	Mineralized-Cell Wood Preserving Company
MLLW	mean lower low water
MORO	motor oil-range organics
MSL	mean sea level
MTCA	Model Toxics Control Act
NAPL	non-aqueous phase liquid
ND	non-detect
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCP	pentachlorophenol



Acronyms	Description
pCUL	preliminary cleanup level
pg/g	picograms per gram
pg/L	picograms per liter
pH	power of hydrogen
PID	photoionization detector
PPE	personal protective equipment
ppm	parts per million
Property	Tax Parcel No. 1924049029
PQL	practical quantitation limit
RAL	remedial action levels
RASR	Remedial Activities Summary Report
RCW	Revised Code of Washington
Reichhold	Reichhold, Inc.
RI	Remedial Investigation
RM	river mile
ROD	Record of Decision
SAIC	Science Applications International Corporation
SES	Sound Environmental Strategies
Site	5900 West Marginal Way Site in Seattle, Washington
SL	screening level
SPU	Seattle Public Utilities
SMS	Sediment Management Standards
SQS	sediment quality standards
SVOC	semivolatile organic compound
T115	Terminal 115 and North Terminal 115 operated by the Port of Seattle
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TEE	Terrestrial Ecological Evaluation
TEF	toxicity equivalency factor
TEQ	toxicity equivalency quotient
TOC	total organic carbon
TOX	total organic halides
TPH	total petroleum hydrocarbon



Acronyms	Description
U.S.	United States
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
VP	vapor pressure
WAC	Washington Administrative Code
whetlerite	activated carbon impregnated with copper, silver, or chromium
Windward	Windward Environmental, LLC

1. INTRODUCTION

On behalf of Glacier Northwest, Inc. (Glacier Northwest), Environmental Resources Management, Inc. (ERM) prepared this Remedial Investigation (RI) Report to describe environmental conditions at the 5900 West Marginal Way Site in Seattle, Washington (Site) (Figure 1-1). The Site largely consists of the parcel of real property identified in the property records of King County as Tax Parcel No. 1924049029 (Property). The Property is approximately 18 acres in size and includes an upland portion (approximately 13.68 acres) and an aquatic portion (approximately 4.19 acres).

The Site is located along the western shoreline of the Lower Duwamish Waterway (LDW) between river miles (RM) 1.4 and 1.5. In 2001, the lower 5 miles of the LDW, including the aquatic portion of the Site, was added to the National Priorities List. In 2012, the United States Environmental Protection Agency (USEPA), working with the Lower Duwamish Waterway Group (LDWG), completed an RI and Feasibility Study (FS) of the LDW pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In 2014, the USEPA issued a final Record of Decision (ROD) that selected the cleanup remedy for sediments within the LDW, including sediments within the aquatic portion of the Site (USEPA 2014). The selected remedy applies to the portion of the LDW extending up to an elevation of 11.3 feet above mean lower low water (MLLW). The State of Washington, through the Washington State Department of Ecology (Ecology), has concurred with the USEPA's selected remedy.

The aquatic portion of the Site will be remediated in accordance with the ROD under USEPA oversight. The cleanup remedy USEPA has selected for the aquatic portion of the Site consists of dredging and capping, which will require removal of the riprap that currently supports the shoreline of the Property and reconstruction of the shoreline to coincide with the dredging and capping remedy.

The upland portion of the Site will be remediated under Ecology oversight in accordance with a Cleanup Action Plan approved by Ecology. The RI and subsequent FS need to be completed before a Cleanup Action Plan can be selected for the Site. The purpose of the RI is to collect the data necessary to adequately characterize the Site for the purpose of developing and evaluating cleanup action alternatives for the upland portion of the Site (Washington Administrative Code [WAC] 173-340-350[7][a]). The objectives of the RI are to collect, develop, and evaluate sufficient data to characterize Site conditions, including the nature and extent of hazardous substances at the Site, and risk to human health and the environment, in order to describe the nature and extent of contaminants of potential concern (COPCs) at the Site, as well as the fate and transport of COPCs. This information is used to develop a conceptual site model (CSM) that identifies potential human health and/or environmental risks associated with exposure to COPCs at the Site. The RI has been prepared in accordance with WAC 173-340-350 and the Agreed Order No. DE 6000 (Agreed Order) and is consistent with the LDW ROD.

1.1 REGULATORY FRAMEWORK/AGREED ORDER

In 2009, Glacier Northwest, Reichhold, Inc. (Reichhold), and Ecology entered into the Agreed Order to conduct an RI/FS and prepare a draft Cleanup Action Plan for the Site. The RI was performed in compliance with the Model Toxics Control Act (MTCA), Chapter 173-340 WAC, the Agreed Order, and the *Final Remedial Investigation and Feasibility Study Work Plan*, issued by Ecology on August 31, 2012 (Final RI/FS Work Plan; Ecology 2012), as amended by a *Remedial Investigation and Feasibility Study Work Plan Addendum*, approved by Ecology on September 26, 2013 (RI/FS Work Plan Addendum; Ecology 2013). With Ecology's approval, sediment sampling for the Site was conducted in accordance with a Sediment Sampling Plan included within a previous draft of the RI/FS Work Plan (Draft RI/FS Work Plan; ERM 2012a). The Final RI/FS Work Plan and RI/FS Work Plan Addendum are together referred to in this RI/FS Report as the RI/FS Work Plan.

To address data gaps identified in Ecology's January 9, 2018, comments on the *Draft Remedial Investigation Report* (Ecology 2018a), Glacier Northwest prepared a Data Gaps Investigation Work Plan (Ecology 2018b). Ecology approved the *Data Gaps Investigation Work Plan* (Data Gaps Work Plan; ERM 2018) on April 4, 2019.

1.2 DEVIATIONS FROM THE APPROVED RI/FS WORK PLAN

There were no significant deviations from the approved RI/FS Work Plan or the Data Gaps Work Plan. However, minor deviations, communicated to Ecology in monthly progress reports, included consolidating the archive sample analysis recommendations and redeveloping monitoring well MW-22. These deviations were approved by Ecology.

2. SITE DESCRIPTION AND BACKGROUND

The following sections present Site contact information and describe the Site, including its location, current usage and appearance, current land use and zoning, future land use, and historical ownership and operations. Neighboring properties are also described.

2.1 SITE CONTACT INFORMATION

Site stakeholders and their contact information are presented in Table 2-0 below.

TABLE 2-0 SITE CONTACT INFORMATION

Role	Organization	Contact Name(s)	Contact Information
Site Manager	Ecology	Julia Schwarz	425.515.5992 jusc461@ecy.wa.gov
Current Owner/Operator	Glacier Northwest, Inc.	Pete Stoltz	206.764.3000 pstoltz@calportland.com
Owner Consultant	Environmental Resources Management, Inc.	Michael Mendes	425.214.0458 mike.mendes@erm.com
		Jennifer Barrett	720.323.0183 jennifer.barrett@erm.com

2.2 SITE AND PROPERTY DESCRIPTION

The Site generally includes property located at 5900 West Marginal Way Southwest in the Duwamish industrial corridor of Seattle, Washington (Figure 2-1). The Site largely consists of the parcel of real property identified in the property records of King County as Tax Parcel No. 1924049029, although historically it was comprised of three separate tax lots (collectively, the Property). The Property is approximately 18 acres in size and includes an upland portion (approximately 13.68 acres) and an aquatic portion (approximately 4.19 acres). The aquatic portion forms an embayment within the LDW (Embayment) commonly known as Glacier Bay.

The Property is owned and operated by Glacier Northwest. It is bordered to the north by property owned by Duwamish Shipyard, Inc. (DSI) and operated by Alaska Marine Lines, Inc. (AML), to the east by the main channel of the LDW, to the south by properties owned and operated by the Port of Seattle as Terminal 115 and North Terminal 115, and to the west by West Marginal Way (Figure 2-1). Although Terminal 115 and North Terminal 115 are separate sites with individual MTCA orders (Order No. 18064 and Order No. 8099, respectively), the two sites will be referred to jointly as "T115" hereon.

The Site is defined in the Agreed Order as the geographic extent of contamination caused by the release of hazardous substances at the Site, including upland property, groundwater, the streambank, and adjacent tideflats, and portions of the LDW affected by the release of chemicals from the Site. Sediments contaminated with LDW ROD-listed contaminants of concern (COCs) at concentrations above the remedial action levels (RALs) located within and/or outside the aquatic portion of the Site will be addressed as part of a separate CERCLA Remedial Design/Remedial

Action process in accordance with the LDW ROD. However, the LDW ROD might not cover all COCs in sediment at this Site.

2.3 PROPERTY LAND USE

The Property is zoned for general industrial use (IG1 U/85; City of Seattle Department of Planning and Development) and is anticipated to remain as such in the future. City of Seattle zoning at and around the Property is presented on Figure 2-2. The Property and adjacent properties along the LDW have been industrialized for over 90 years. Historical and current commercial and industrial operations in the vicinity of the Property include cargo handling and storage, marine vessel repair and maintenance, concrete manufacturing, lumber milling, and tin reclamation. A detailed discussion of current operations is provided in Section 2.4 and historical operations at the Property are discussed in Section 2.6. Figure 2-3 shows the current features of the Property, and Figure 2-4 shows historical features at the Property.

2.4 CURRENT PROPERTY USE

During the mid to late 1960s, while the Property was owned by the Port of Seattle, Kaiser Cement & Gypsum Corporation (Kaiser) constructed a cement storage and distribution terminal at the Property. The cement terminal generally occupies the northern portion of the Property and continues to operate in essentially its original configuration today. Glacier Northwest currently operates the Property as a bulk cement storage and wholesale distribution terminal. Cement has never been manufactured at the Property nor has a cement kiln ever been used or located at the Property. The upland portion of the Property is divided into two operational areas—a northern and southern portion. Since at least 1987, these two operational areas have been separated by a chain-link fence.

2.4.1 NORTHERN AREA

The northern portion of the Property is used to receive, store, and distribute dry cement. Smaller volumes of coal bituminous fly ash and slag cement have also been stored and distributed at the Property. Bulk cement is delivered in 30,000-ton ships, up to 26 times per year. The cement is pneumatically conveyed to storage silos using a Docksider™, a high-capacity ship unloader that sits on the Glacier Northwest dock and can be moved on rails with a handheld remote control from one end of the dock to the other. The Docksider™ uses vacuum pressure (analogous to a vacuum cleaner) to automatically unload dry cement from a ship through a mechanical arm into a large filter receiver that conveys the cement into one of four pressurized transfer vessels. The cement then travels through fully enclosed steel piping to one of the 19 storage silos with capacities ranging from 350 to 5,200 tons. One of the benefits of this state-of-the-art equipment is that it fully encapsulates cement in a system of piping, hoses, and vessels, minimizing cement dust associated with the unloading of ships. Fly ash, which was not stored at the Property before December 2004, is delivered by railcar and pneumatically conveyed from the railcars into the storage silos. Cement is stored until it is loaded into customer trucks and railcars for off-Site delivery. The northern portion of the Property includes a warehouse and attached fabrication shop, an operations office, and a truck scale. Glacier Northwest conducts no fueling, maintenance, or repair of ships at the Property.

No process waste is generated from cement terminal operations at the Property. There is a cement tanker rinse system on the western side of the loading area near the silos. The system consists of a series of mist spray bars designed to rinse the outside of customers' bulk container trucks before they exit the terminal onto West Marginal Way. The resulting rinse water is discharged to the sanitary sewer system in accordance with a Minor Discharge Authorization (No. 510-03) issued by King County. The Minor Discharge Authorization does not require sampling or analysis.

2.4.2 SOUTHERN AREA

The southern portion of the Property is not involved in cement terminal operations. The primary operations in the southern portion of the Property are vehicle and equipment storage, warehousing, and maintenance. There is a warehouse on the southern portion of the Property that is primarily used for general records storage (e.g., delivery tickets and accounting records). The remainder of the building is used as an employee lunchroom, a small parts warehouse, and a shop where light-duty maintenance is performed on concrete mixer trucks (e.g., topping off fluids, repairing lights, and other minor safety-related repairs). A third-party vendor fuels concrete mixer trucks parked in the southern portion of the Property on an as-needed basis using a wet-hose service. Heavy maintenance for the trucks is completed off Property. The portion of the Property south of the warehouse is used to park concrete trucks, water trucks, and cement hauling trucks at night and employee cars during the day. From time to time, an area on the southern portion of the Property has been leased to a contractor to store parts for construction projects (e.g., storage of concrete segments for the Sound Transit light rail project).

2.5 PROPERTY UTILITIES AND STORMWATER MANAGEMENT

2.5.1 UTILITIES

West Marginal Way serves as a utility corridor to provide service for the industrial facilities along the western side of the LDW. The Property is provided water service by the City of Seattle Public Utilities (SPU) and sanitary sewer service by King County. Both the water and sewer lines to the Property extend from the utility corridor along West Marginal Way to the northwestern corner of the Property. Electrical service to the Property is provided by Seattle City Light, which owns and operates the existing transformer located adjacent to the northern boundary of the Property (Figure 2-4). Historically, Seattle City Light also supplied, operated, and maintained two other transformers that were removed from the Property before 1979. There are no documented environmental releases from any of the transformers.

2.5.2 CURRENT STORMWATER MANAGEMENT

Glacier Northwest operates the Property in accordance with a Sand and Gravel General Permit (No. WAG 50-3378) issued by Ecology pursuant to and under the authority of the Clean Water Act. Glacier Northwest maintains a Site Management Plan that includes a Monitoring Plan, a Storm Water Pollution Prevention Plan, a Spill Control Plan, and an Erosion and Sediment Control Plan. Stormwater at the Property can contain de minimis amounts of cement but must meet the pH and

turbidity criteria specified for surface water discharge under the Sand and Gravel General National Pollutant Discharge Elimination System (NPDES) Permit.

As shown on Figure 2-5, stormwater at the Property flows toward and is collected in a swale located near the middle of the Property. Check dams have been installed in the swale to reduce stormwater velocity and allow suspended solids to settle. There are five catch basins on the Property; three serve the equipment storage and vehicle parking in the southern area (south of the swale), and two serve the northern area in the vicinity of the truck turning circle and northwest property entrance. Water captured in the catch basins is conveyed to the swale. The water from the truck rinse area shown on Figure 2-5 goes to a separate catch basin and is discharged to the sanitary sewer.

During most storm events, stormwater from the swale is captured and pumped to holding tanks so that no direct surface water discharge occurs. The majority of stormwater infiltrates in the swale. During storm events that produce high volumes, stormwater is pumped into a series of holding tanks where the excess water can be held until the flows return to manageable levels; the held water is then returned to the swale for ultimate discharge. The frequency of discharge varies with the frequency of major storm events. Discharges from the swale during and after storm events that exceed the capacity of the stormwater swale occur approximately 10 to 12 times in a typical year, and are of relatively short duration (e.g., 12 to 18 hours). Stormwater reaching the end of the swale enters an underground steel pipe and is discharged to the Embayment. Stormwater entering the steel pipe is monitored according to the requirements of the Sand and Gravel General Permit, which include turbidity, pH, and oil sheen.

Pursuant to the Sand and Gravel General Permit, sampling of stormwater occurs at two points on the Property (Figure 2-5). Sampling location S-1 is situated in a low area near the center of the Property and is representative of infiltration areas across the Property. S-1 is observed daily for visual oil sheen and samples are collected from the location monthly (if sufficient flow is present to collect a sample) and monitored for acidic or basic conditions (pH). Sampling location S-2 is located at the end of the swale near the underground steel pipe that discharges to the LDW. Location S-2 is observed daily for visible oil sheen and is sampled once per month for pH (if sufficient flow is present), and twice per month to ensure a turbidity of less than 50 nephelometric turbidity units (NTU) (if sufficient flow is present).

2.5.2.1 STORMWATER MANAGEMENT ON NEIGHBORING PROPERTIES

In addition to the outfall that services the Property, two other outfalls discharge stormwater into, or immediately adjacent to, the Embayment, as follows:

- An outfall for a stormwater system that services T115 and West Marginal Way located on the southern shoreline of the Embayment.
- An outfall for a 48-inch-diameter SPU stormwater line that services an extensive drainage area west of the Site located immediately south of the Embayment.

The approximate locations of the three outfalls are shown on Figure 2-3.

2.5.3 HISTORICAL STORMWATER MANAGEMENT

There is no documentation of operations at the Property prior to 1936. An aerial photograph of the Property from 1922 (Appendix A1) shows no apparent stormwater ditches or operations, and the Property appears to be flooded, which would significantly limit operations at that time.

Prior to construction of the cement terminal on the Property during the mid to late 1960s, stormwater was captured in open or gravel-filled ditches oriented west to east across the Property, and during some periods (e.g., 1965; Appendix A1), north/south oriented ditches connected the central and southern ditches. These surface ditches were observed in historical aerial photographs dating from 1936 through 1969, during which years multiple companies and government agencies conducted operations at the Property, including Mineralized-Cell Wood Preserving Company (Mineralized-Cell), Carlisle Lumber Company (Carlisle), the United States of America (U.S.), Crown Zellerbach Corporation, Reichhold, Kaiser, and the Port of Seattle. Based on the aerial photographs, stormwater from the ditches discharged into the Embayment.

In 1975, Kaiser installed a stormwater system in the southern portion of the Property. An as-built drawing of the former stormwater system shows a 15-inch-diameter concrete stormwater pipe with five catch basins in the southern portion of the Property (Figure 2-6). This system tied into the 48-inch-diameter SPU stormwater line located within the City of Seattle easement on the adjoining property to the south owned by the Port of Seattle and operated as T115. The catch basins feeding the stormwater system were filled with concrete before Glacier Northwest acquired the Property in 1991, and Glacier Northwest has never used this system.

The location of the historical stormwater pipe was verified via a camera survey conducted in July 2009. In October 2009, the historical pipe was confirmed visually through excavation of a trench to the top of the pipe where the as-built plans showed the pipe to be located (Figure 2-6). In accordance with the RI/FS Work Plan and regulatory requirements, the historical stormwater pipe was plugged and abandoned in place in August 2014 at the location on the Property closest to where it ties into the 48-inch-diameter SPU stormwater line near the southern entrance to the Property. The plugging and abandonment activities are described in Section 3.3.8.

2.6 HISTORICAL OWNERSHIP AND INDUSTRIAL ACTIVITIES

The following sections identify the individuals and entities that have owned or operated the Property and, where possible, the portion of the Property owned or operated by those individuals or entities. The information is presented chronologically, with the oldest information first. A current Site plan with overlays of the relevant historical features from previous ownership and operations is provided as Figure 2-4. Aerial photographs documenting development of the Property over time are included as Appendix A1.

2.6.1 HISTORICAL OWNERSHIP

This section provides a chronological history of the ownership of the Property. Figure 2-7 illustrates the chronological ownership history along with the operational history of the Property.

- 1911/1912 to September 17, 1973: Port of Seattle owned the Embayment. Before 1922, the Port of Seattle filled a large portion of the Property with material dredged from the LDW.

Between April 19, 1960, and December 11, 1964, the Port of Seattle allowed DSI to moor vessels and store logs in the Embayment pursuant to the terms of a real estate contract.

- Start date unknown to May 29, 1918: King County owned an upland portion of the Property; unknown what operations King County conducted on the Property.
- May 29, 1918: E.L. and Hazel Skeel owned an upland portion of the Property; unknown what operations the Skeels conducted at the Property.
- Start date unknown to May 29, 1918: W.T. Wardell owned an upland portion of the Property; unknown what operations Wardell conducted at the Property.
- May 29, 1918, to December 23, 1924: Puget Sound Bridge & Dredging Company owned an upland portion of the Property. During the years of its ownership, Puget Sound Bridge engaged in shipbuilding, construction, and dredging. It is unknown whether these operations were conducted at the Property; however, an aerial photograph of the Property from 1922 (Appendix A1) shows no apparent stormwater ditches or operations, and the Property appears to be inundated, which would significantly limit operations at that time.
- December 23, 1924, to June 16, 1925: Janet J. Geary owned an upland portion of the Property; unknown what operations Geary conducted at the Property.
- June 16, 1925, to date unknown: General Investment Company owned an upland portion of the Property; unknown what operations General Investment Company conducted at the Property.
- June 28, 1927, to April 28, 1943: King County owned an upland portion of the Property. Mineralized-Cell treated wood on the Property during King County's ownership. Carlisle built and operated an activated charcoal and whetlerite manufacturing plant on the Property during King County's ownership. It is unknown what other operations King County conducted at the Property.
- September 9, 1941, to April 28, 1943: Carlisle owned an upland portion of the Property. Carlisle built and operated an activated charcoal and whetlerite manufacturing and testing facility plant on the Property. Carlisle constructed 16 buildings to produce activated charcoal and whetlerite and added storage tanks.
- Unknown to April 28, 1943: Henri Carlisle acquired an ownership interest in an upland portion of the Property due to bankruptcy of Carlisle.
- April 28, 1943, to July 27, 1943: W.A. Carlisle and W.A. Carlisle Jr. acquired an ownership interest in the Property due to bankruptcy of Carlisle.
- July 27, 1943, to June 2, 1964: The U.S. owned the upland portion of the Property. The U.S. Department of the Army (Army) contracted with third parties to operate the activated charcoal and whetlerite plant, oversaw those operations, and operated testing facilities at the plant. After WWII, the U.S. leased the upland portion of the Property to Reichhold, which retrofitted the plant to produce resins, glues, formaldehyde, pentachlorophenol (PCP), and sodium pentachlorophenate.
- June 2, 1964, to September 17, 1973: The Port of Seattle, and all subsequent owners, owned the Property (both the uplands and Embayment). Between approximately 1967 and 1970, fill was placed along the eastern and southern shorelines of the Property to create the

Embayment. The Port of Seattle leased the Property to Kaiser for construction and operation of a cement distribution terminal. Kaiser demolished the existing structures and built the new terminal.

- September 17, 1973, to April 14, 1987: Kaiser owned the Property. Kaiser operated a cement distribution terminal at the Property. Kaiser leased the southern portion of the Property to Universal Land Construction Company from July 17, 1986, to 1987 for crushing concrete and asphalt. From October 1986 to mid-1988, Kaiser leased the southern portion of the Property to Stinson Container Transport Systems, Inc., for storing containers, equipment, and cargo.
- April 14, 1987, to December 17, 1987: Lone Star Industries, Inc. (Lone Star) owned the Property and leased the northern portion to Ash Grove Cement West, Inc. (Ash Grove) for operation of the cement distribution terminal for the duration of its ownership.
- December 17, 1987, to April 12, 1991: Lone Star Northwest, GP owned the Property and leased the northern portion to Ash Grove for the duration of its ownership. The southern portion of the Property was leased to the following entities:
 - Mobile Crane Company between 1987 and March 1991 for crane equipment storage.
 - French Forest Products and Arlie French around December 21, 1987, for an unknown duration for building wood pallets.
 - Coastal Trailer Repairs, Inc. beginning in July 1990 for the remaining duration of ownership for storage and repair of shipping containers, trailers, chassis, and power equipment.
- April 12, 1991, to April 24, 1991: Onoda Northwest, Inc. and Lone Star owned interests in the Property.
- April 24, 1991, to Present: Glacier Northwest owns the Property. It operates a cement distribution terminal at the Property. Glacier Northwest has leased portions of the Property to various operators over time. The pier was leased to DSI between April 1994 and August 2002 and again between September 2002 and August 2007 for vessel repair operations. Glacier Northwest leased part of the southern portion of the Property to the following entities:
 - Coastal Trailer Repairs until October 30, 1991, for storage and repair of shipping containers, trailers, chassis, and power equipment.
 - General Construction Company between 1992 and 1993 for constructing a concrete model of the anchors for the Interstate 90 (I-90) floating bridge.
 - Gene Summy Lumber Company between April 1, 1993, and March 31, 1998, for wood product storage.
 - Interstate Heavy Hauling, Inc. between May 1, 1993, and September 31, 1997, for equipment storage.
 - Albrecht Birkenbuel between April 1, 1998, and March 31, 2003, for equipment storage.
 - Obayashi Corporation between February 1, 2005, and December 31, 2008, for equipment storage.
 - CDI Corporation between September 30, 2006, and November 24, 2014, for cement truck parking.

- Gresham Transfer from July 16, 2012, to the end of 2015, for cement truck parking.

2.6.2 OPERATIONAL HISTORY

The following sections present a chronological history of the operations at the Property. If an entity owned the Property, but did not conduct operations on it, then the entity is discussed in Section 2.6.1. The relationships between historical owners and operators of the Property are illustrated on Figure 2-7.

2.6.3 INITIAL PROPERTY DEVELOPMENT

Between 1913 and 1922, the U.S. Army Corps of Engineers conducted initial dredging of the LDW to straighten and deepen the waterway. A wooden bulkhead was constructed along the shore before 1922 as shown in a 1922 aerial photograph (Appendix A1). The bulkhead was likely constructed on top of the original land surface, now referred to as the aquitard, with the bulkhead posts driven into the aquitard to an unknown depth. The bulkhead would have served to retain dredged material placed over the aquitard on the upland portion of the Property.

The wooden bulkhead is not readily visible in aerial photographs after 1922, but wood was encountered during the advancement of a boring (MW-45D) in the vicinity of the original shoreline beneath the shallow fill. The wood appears to be part of the anchoring system for the bulkhead, suggesting that remnants of the bulkhead are buried beneath the shallow fill. The bulkhead is noteworthy because of its historical role in retaining dredged material when it was placed in the 1920s, but is not considered to play a significant role hydrogeologically at the Site as it likely began to deteriorate after the dredged material was placed.

There is no documentation of operations occurring on the Property between the time dredged fill was placed and approximately 1936, when Mineralized-Cell began wood preserving operations as described in the following section. The 1922 aerial photograph appears to show logs floating in the river, structures along the shoreline, and flooding of the upland portion of the Property. However, there is no information available to suggest that the logs floating in the river and shoreline structures observed in the 1922 photograph were associated with operations on the upland portion of the Property.

2.6.4 WOOD PRESERVING (1936–1939)

Mineralized-Cell operated a wood preserving facility on a portion of the Property between approximately 1936 and 1939. The area of the Property formerly occupied by Mineralized-Cell is highlighted on a 1936 aerial photograph included as Figure 2-8. (The 1936 aerial photograph is also included in Appendix A1.) The 1936 photograph shows several small structures near the shoreline, a dock structure in the LDW, and areas of north-south-aligned rows of logs and small structures in the southern half of the Property. The photograph also shows disturbed areas in the northern portion of the Property. However, information regarding the construction and use of the structures observed along the shoreline and dock, and the industrial activities conducted in the northern portion of the Site, is limited to what is shown in the 1936 photograph.

Historical records, including a copy of the U.S. Patent issued to Mineralized-Cell (included in Appendix B), indicate that the wood preservation process involved “the forcing into logs under

pressure of a solution consisting of arsenic, copper sulfate, zinc sulfate and eight other unnamed chemicals.” Prior to treatment of the logs, Mineralized-Cell staff removed the ends of the logs with a saw so a fresh cut was available. According to the patent, the fresh cut enabled uniformity of the treatment process by removing dried portions of wood, sap, or resins that may impede the flow of treatment solution. Rubber caps were reportedly clamped to the ends of the logs and secured by way of cables and chains. Depending on the type of wood, between 4 and 12 pounds of pressure were applied through a hose system to the rubber caps. Each of the rubber caps was fitted with a valve that allowed air to escape and the caps to fill completely with treatment solution. Treatment solution was applied until the solution dripped from the exposed end of the logs. The patent also indicates that fresh cuts to the logs may have been made during the treatment process, thereby allowing spills of solution during removal of the rubber caps. Fresh cuts to the logs during treatment would have resulted in impacted wood waste being released to the ground surface.

A 1937 photograph of the Mineralized-Cell operations (Appendix B) shows two small buildings with rows of logs behind it. Hoses can be seen connected to what appear to be rubber caps at the end of each log. The smaller of the two buildings likely housed a boiler, and the larger building was used for storing sacks of chemicals used in the preservation process. The photograph shows, on the right side of the large building, approximately five rubber caps laying on their sides. In addition, on the upper-left side of the photograph, a wooden tripod is visible in the background that appears to have been used to hoist the tank with the treatment solution to generate head pressure for delivery of the solution through hoses to the logs. A pile of wood waste/debris is visible in front of the vehicle that is likely associated with the cutting/treatment of the logs.

The 1945 Pollution Control Commission Report (Foster 1945) includes a description of Mineralized-Cell’s operations in 1945 where they operated on the eastern side of the LDW south of the former Isaacson Iron Works. The report states:

This company employs a process whereby a solution containing arsenic and also sulfate salts of copper and zinc is heated and applied to the base of logs under pressure. A precipitating agent sets the chemicals and thus hardens the wood. The storage tanks in which the solution is heated are washed twice daily. Any sludge or remaining chemicals drains onto the ground. Supply tanks holding fuel oil have occasionally overflowed during filling but the oil seeps into the ground rather than draining into the river. No chemicals reach the waterway except those that leach out of the wood when the poles are shipped by water.

Stormwater during the Mineralized-Cell operational period appears to have either percolated into the ground surface or flowed overland toward the LDW. Historical stormwater management is discussed in Section 2.5.3.

2.6.5 CHARCOAL AND WHETLERITE MANUFACTURING AND TESTING (1940–1944)

On April 29, 1940, Carlisle was awarded Educational Contract No. W266 CWS4 by the Chemical Warfare Service (CWS), a division of the Army. The Educational Contract required that Carlisle construct a plant to make charcoal and activated carbon impregnated with copper, silver, or

chromium (known as whetlerite) for use in gas masks. A detailed discussion of the whetlerite production process is presented in Appendix C.

Carlisle constructed the charcoal and whetlerite plant in the northern portion of the Property. Construction of the plant was initiated in 1940 or 1941 and completed early in 1942 (U.S. Army Corps of Engineers 1994). The plant became known as the Seattle CWS Plant (U.S. Army Corps of Engineers 1994) and included a manufacturing area, laboratories, warehouses, offices, chemical storage, underground storage tanks, and railroad spurs. Appendix A1 includes aerial photographs of the Property in 1940 and 1942 during the Carlisle operational period.

When the Educational Contract ended, the CWS awarded a production contract to Carlisle that ran from August 1942 to February 1943. The Seattle CWS Plant had the capability of producing a reported 5 tons of activated charcoal and 2.5 tons of whetlerite every 24 hours. Carlisle, however, did not meet the Army's production goals. At the end of the production contract, the U.S. purchased the Property, the CWS modified the Seattle CWS Plant, presumably to increase production efficiency, and awarded a new production contract to Crown Zellerbach Corporation (Crown Zellerbach). Crown Zellerbach operated the Seattle CWS Plant until November 1944, at which time the Seattle CWS Plant was placed on standby status. A 1946 aerial photograph (Appendix A1 and Figure 2-9) depicts features of the former Seattle CWS Plant after it was mothballed.

During the plant's period of operations, the CWS oversaw Carlisle and Crown Zellerbach's operations, which produced a cumulative total of 5.2 million pounds of activated charcoal and 2.6 million pounds of whetlerite. Once the whetlerite was produced, the CWS tested the activated carbon for density, heat of wetting, and absorption life, using several apparatuses and chemicals such as arsine, chloropicrin, cyanogen chloride, and phosgene. The canister testing apparatuses simulated heavy breathing to evaluate the canister life—the apparatuses pulled air containing cyanogen chloride and water vapor through the canister to evaluate the service time of the canister. A chloropicrin testing apparatus was used to evaluate the properties "important to gas mask adsorbent" (Slyh et al. 1945). This procedure subjected 10 to 14 mesh carbon to a mixture of air and chloropicrin to evaluate the breakthrough time under various testing conditions. The CWS disposed of a portion of its laboratory waste through a septic system located at the northeast corner of the Property that discharged to the LDW. The boundaries of the Property were adjusted in 1964, and as a result, the septic system was located on what is now the DSI property. Spent carbon (e.g., gas chemical saturated carbon) from the testing was either dumped in portions of the Property, such as ditches, as observed in the subsurface during investigation activities and as documented in the 1945 Pollution Control Commission Report (Foster 1945), or incinerated at the Property.

According to Foster (1945), the charcoal and whetlerite manufacturing process involved the use of a tank with 100 cubic feet (approximately 750 gallons) capacity of copper ammoniate. The tank was reportedly washed out once per month, draining the contents into the LDW. The report recommended that this practice be discontinued and suggested that the tank be dumped onto an adjacent, vacant field. The report also indicated that "this field was already being used as a dumping ground for discarded charcoal and sawdust."

Stormwater during the CWS operational period appears to have either percolated into the ground surface or flowed through surface ditches toward the LDW. Historical stormwater management is discussed in Section 2.5.3.

2.6.6 CHEMICAL MANUFACTURING (1946–1961)

Reichhold leased the Property from the U.S. between 1946 and 1961 (RETEC 1996). Reichhold used the Property to manufacture resins, glues, formaldehyde, PCP, and sodium pentachlorophenate; however, PCP was only manufactured between 1953 and 1956. According to an Army Real Estate Report dated 1963 (Appendix D), capital improvements made by Reichhold included addition of sewer systems, roads, fencing, a railroad spur, a new boiler house, a tank farm area to store chemicals used in the manufacturing processes, plants for the production of PCP and sodium pentachlorophenate, and a plant for the production of formaldehyde.

Historical features associated with Reichhold's operations are illustrated on the 1956 aerial photograph in Appendix A1, the 1956 and 1959 Site layout drawings included as Appendices D and E, respectively, and Figure 2-10 (Historical Site Plan – Reichhold Operations 1956–1959). Former operational features include the following:

- Tank Farms #1 and #2 – There were 11 above ground tanks oriented east-west in a horizontal position within a concrete-bermed containment area with a dirt floor. Products stored in the tanks included methanol, formaldehyde, phenol, urea (solid), chlorine, sodium hydroxide, and hydrochloric acid (product). Tank Farm #1 was removed from the Property by 1961.
- Washwater Impoundment – There was an oval-shaped impoundment located in the northeastern portion of the Property (Figure 2-10) to collect process water for treatment and infiltration into the soil. Reichhold (1958) stated that the planned dimensions of the impoundment were 50 feet long by 50 feet wide by 6 feet deep. The washwater impoundment was constructed in 1955 and closed in 1960.
- Plywood Animal Glue Production Area – Soya flour and dried horse blood were blended together to form a glue product. No wastewater was reportedly produced in this process. The 1959 Site layout drawing included as Appendix E shows the paper glue line process area, but the plywood animal glue production area is not specifically identified on the drawing. As such, it is unclear whether plywood animal glue was produced in the same area as the paper glue line process area.
- Resin Production Area – Phenol formaldehyde resin and urea formaldehyde resin were produced on the Property by reacting components in a closed reaction kettle. The reaction kettle was reportedly surrounded by a sump, which was periodically pumped out and discharged to the LDW. A holding tank located adjacent to the reactor was reportedly used to store the formaldehyde before it was added to the phenol and resin. After the tank was emptied of formaldehyde, it was filled with water in the event it was needed to quench the chemical reaction. If not used, the washwater was discharged into a drain adjacent to the tank, which discharged directly into the LDW (Nielson 1953). Later, in the mid-1950s, the washwater was directed to the washwater impoundment contained within the Reactor Building (Figure 2-10).

- **Process Water Outfall** – In 1956, an 18-inch-diameter outfall pipe was constructed to convey process water from the washwater impoundment to the LDW (Figure 2-10). The outfall was located approximately 240 feet from the riverbank as shown on Figure 2-10. An outfall design drawing prepared by Reichhold in 1955 and a 1956 letter to the State of Washington Pollution Control Commission indicating the installation of the outfall are included as Appendix E. The outfall pipe at the location identified on Figure 2-10 is visible in the 1956, 1965a, and 1965b aerial photographs included in Appendix A1, and is also present in the 1956 Army Real Estate Map included in Appendix D.
- **PCP and Sodium Pentachlorophenate Production Areas** – There were two plants used; one to produce PCP, and one to produce sodium pentachlorophenate. PCP was made using phenol and chlorine, and sodium pentachlorophenate was made using PCP and sodium hydroxide. Hydrochloric acid was produced as a by-product of PCP production. The hydrochloric acid was purified, stored in the on-Site tank farms, and sold as a chemical product. PCP and sodium hydroxide were reacted to produce a solid sodium pentachlorophenate product. Reichhold operated a pilot plant to produce PCP between 1953 and 1956.
- **Septic Tank** – A septic tank (Figures 2-9 and 2-10) that received sanitary sewage discharges and discharges from the control and resin laboratories was located in the northern portion of the Property. Liquids in the septic tank discharged to the LDW at the location shown in Appendix D (1956 U.S. Army Real Estate Map). The boundaries of the Property were adjusted in 1964, and as a result, the former septic tank was located on what is now the DSI property (Figure 2-10).
- **Waste Treatment Tank** – Process water generated from the urea formaldehyde resin and phenol formaldehyde resin processes was discharged to the washwater impoundment (Figure 2-10). Water from the phenol formaldehyde resin process was routed through an aboveground wooden waste treatment tank (Figure 2-10; and visible on the 1959 aerial photograph in Appendix A1) with a total capacity of 40,000 gallons before the water was conveyed to the washwater impoundment to allow retention time for degradation of phenol (Reichhold 1958). A waste treatment tank was identified as being “located near the river” and it was noted that the tank “may have been constructed without a bottom” (RETEC 1995). Review of historical records (including historical photographs) and interviews with Reichhold staff have determined that there was one wastewater tank (40,000 gallons in capacity) located near the LDW (Figure 2-10) and that the tank was constructed with a bottom. The tank was reportedly removed by Reichhold between 1959 and 1961. The boundaries of the Property were adjusted in 1964, and as a result, the former waste treatment tank was located on what is now the DSI property (Figure 2-10).
- **Rail Spurs/Loading Area** – A rail spur was installed by Reichhold during its lease of the Property to access the tank farm area. Reichhold used the existing rail spur to access the loading platform area (Figure 2-10).
- **Surface Ditches** – Various surface ditches were identified during review of aerial photographs (1951, 1956, and 1959) as presented in Appendix A1 and Site layout figures (1956 and 1959) as presented in Appendices D and E, respectively. The surface ditches are shown on Figure 2-

10. As discussed in Section 2.5.3, the surface ditches were used to convey process water to the washwater impoundment as well as to direct stormwater from the uplands to the LDW.

An inventory of equipment at the Property in 1963 shows there were two 15 kilovolt-ampere (kVa) transformers (located in Buildings 9 and 21) and two barrels of transformer oil.

A Pollution Control Commission memorandum dated September 27, 1961, indicates Reichhold had terminated production activities and was using the Property only for office and laboratory functions.

2.6.7 LOG AND VESSEL MOORING (1960–1964)

DSI used the Embayment for log and vessel mooring between 1960 and 1964. The Port of Seattle owned the Embayment at that time.

2.6.8 PROPERTY REDEVELOPMENT (1964–1969)

In 1964, the Port of Seattle leased the Property to Kaiser, which was obligated under the terms of the lease to redevelop the Property. A review of aerial photographs (1961, 1965, and 1966) in Appendix A1 show the progression of Kaiser's redevelopment. Kaiser demolished all existing buildings on the Property and conducted substantial earthwork in the northern portion of the Property where the facilities utilized by the Seattle CWS Plant and Reichhold were located to construct the cement terminal. By 1965, Tank Farm #2 had been completely removed. By 1966, the buildings associated with chemical manufacturing located next to the tank farms were removed. Two surface ditches were also observed in the aerial photographs (1961 through 1966). One ditch crossed the Property in a north-south direction from the former tank farm ultimately connecting with the surface ditch at southern Property boundary; neither ditch was present in the 1967 aerial photograph.

The cement terminal included 19 storage silos, a scale house, a conveyor system, a shop building, and a dock. The scale house and shop building were constructed on the paved area surrounding the storage silos. Kaiser connected the Property to the municipal sanitary sewer system and constructed a swale system to direct stormwater to the LDW. A 1969 aerial photograph (Appendix A1) shows the cement terminal was fully constructed and operational at that time. The 1976 aerial photograph shows that a slab-on-grade warehouse building had been constructed on the west side of the stormwater swale (Appendix A1). Figure 2-11 depicts the progression of the Property redevelopment. Figure 2-12 depicts the cement terminal features during Kaiser's operational period.

Kaiser drawings from 1966 detail the design of the foundation and pilings for the cement silos. The drawings show that the pilings are octagonal and pre-stressed and range in length between 40 and 90 feet. These types of pilings rely on friction between the piling and soil to generate resistive force (they are not driven to bedrock, for example). The pilings were driven through the aquitard, and into the underlying lower sand unit. The drawings also indicate the concrete silo foundation extends a minimum of 4 feet below grade. Approximately 4 to 6 feet of soil would have had to be excavated to construct the silo foundation. Aerial photographs of the Property from 1967 show the excavation area where the silos were constructed and piles of soil or fill material

staged in the central and southeastern portions of the Property (Appendix A1). This material may be from the excavation for the silo foundation.

Changes to the shoreline of the Property are also evident during construction of the cement terminal as shown in aerial photographs from 1966 and 1968 (Figure 2-11; Appendix A1). The photographs show the upland portion of the Property was expanded to the east into the LDW as part of the redevelopment. The 1967 aerial photographs appear to show stockpiled soil in the central portion of the Property, presumably from the excavation to support the construction of the cement terminal that was pushed out over the riverbank into the Embayment to establish a new eastern shoreline. The 1967 aerial photograph also shows tracks leading from the excavation area to the shoreline. In a 1969 aerial photograph, construction of the cement terminal appears complete, including the driveway from West Marginal Way, the cement silos, the turning circle, and the dock. The shoreline also appears to have been armored in its present configuration by this time.

2.6.9 CEMENT TERMINAL (1969–PRESENT)

The cement terminal became operational around 1968 or 1969 and continues to be operated in substantially the same form through present day. In 1973, the Port of Seattle sold the Property to Kaiser. A large, disturbed area in the southeastern corner of the Property is evident in a 1974 aerial photograph. Based on communications with former Kaiser employees, Glacier Northwest understands the material is bentonite that was mistakenly pumped into a cement silo, requiring it to be discharged from the silo onto the ground surface.

As discussed in Section 2.5.3, in 1975 Kaiser installed a stormwater system in the southern portion of the Property that tied into the 48-inch-diameter SPU stormwater line located south of the Property. SPU owns and maintains the 48-inch-diameter stormwater line that collects stormwater from an extensive drainage area west of the Property (including industrial, commercial, and residential areas) and discharges to the LDW at its outfall located immediately south of the Embayment (Figure 2-6). An easement for this stormwater line is located on T115 (Figure 2-6) directly south of the Property. A figure showing the drainage basin for the SPU 48-inch-diameter stormwater line is included as Appendix F.

The SPU 48-inch-diameter stormwater outfall is typically fully submerged during high tide, partially submerged during low tide, and periodically fully exposed during low-low tides. A study completed for Ecology in 2011 (SAIC and NewFields 2011) found that at mean higher high water, the SPU 48-inch-diameter stormwater line is inundated to West Marginal Way and continued to be inundated in both the northern and southern directions along West Marginal Way (Appendix G). Based on these findings, stormwater and stormwater solids already present in the line from upland sources and LDW surface water and suspended sediments, could be backwashed into the 48-inch-diameter stormwater line during high tides and flushed out the line to the LDW during low tides. This also suggests the historical stormwater pipe installed by Kaiser on the Property would have been inundated during these periods. As such, suspended stormwater sediments existing in the 48-inch-diameter stormwater line and from the suspended sediments from the LDW may have been deposited in the pipe. The catch basins connected to the historical stormwater pipe were plugged with concrete before Glacier Northwest acquired the Property in 1991, thus rendering the

historical stormwater system inactive. The remainder of the historical stormwater system was plugged and abandoned in place in accordance with regulatory requirements in August 2014 (see Section 3.3.8). The historical stormwater system is not a current or future conveyance pathway.

Kaiser replaced the original dock sometime between 1976 and 1980 with the dock as is currently configured. Kaiser operated the cement terminal until it sold the Property to Lone Star in 1987.

Between April 14, 1987, and October 16, 1991, Ash Grove leased the Property for continued use as a cement terminal. During its lease term, Ash Grove replaced a bucket unloader (described in Section 2.4.1) with a pneumatic system.

Glacier Northwest acquired the Property in two separate conveyances. The first conveyance occurred on April 24, 1991; the second conveyance occurred on April 26, 1991. Glacier Northwest did not commence operations at the Property until October 17, 1991, when it terminated the lease held by Ash Grove. Glacier Northwest's ownership and operations at the Property continue through the present day. Current operations at the Property are discussed in Section 2.4.

2.7 ADJACENT PROPERTIES

Properties located directly north of the Property are owned, in order of proximity to the Property, by DSI, AML, Chemithon Corporation, and LaFarge Corporation. The Port of Seattle owns and operates T115, which abuts the southern boundary of the Property. West Marginal Way abuts the western boundary of the Property. The eastern boundary of the Property abuts the main channel of the LDW.

2.7.1 DUWAMISH SHIPYARD, INC.

The DSI property borders the Property on the north and includes approximately 5 acres of land located on the western bank of the LDW. The DSI property is currently utilized by AML for container storage. Historical operations at the DSI property between the 1940s and mid-2000s included repair and maintenance of floating vessels including tugboats, barges, dredges, fishing vessels, and small passenger vessels. In the 1940s, DSI activities consisted primarily of hull repairs and painting of wooden fishing vessels. The vessels were pulled ashore onto a railway and sidetracked on timbers. Sidetracking repair activities conducted in this manner ceased in the 1950s in favor of drydocking. DSI constructed a graving dock before 1946, which was expanded by 1956. DSI used the graving dock between 1955 and January 2007. The graving dock was 410 feet long and 138 feet wide. DSI acquired a steel drydock in 1967, which was used until 2007. A second larger wooden drydock was acquired in 1969, which was sold in 1990. During the latter part of its operational history, DSI reportedly serviced between 60 and 65 vessels per year. Ship repair activities included machine and electrical work, carpentry, steel fabrication, pipe-fitting, sand blasting, pressure-washing, and painting. Shipyard-related activities ceased at the DSI property in 2007 (Anchor QEA 2013). DSI used the Embayment for log and vessel mooring between 1960 and 1964.

Review of aerial photographs between 1969 and 1974 show the DSI drydock in the LDW positioned proximate to the Embayment (Appendix A2). The former location of the steel DSI drydock relative to the Embayment is shown on Figure 2-4. As presented in the discussion of sediment results in Section 6, sediment cores completed in the vicinity of the DSI drydock have

identified sand blast grit and elevated concentrations of COPCs, including those associated with shipyard activities.

In 2010, Ecology and DSI entered into an Agreed Order requiring DSI to complete an RI/FS for the DSI property. DSI submitted a draft RI for public review in April 2019 for the upland and aquatic portions of the DSI property (Anchor QEA 2019).

Stormwater from the DSI property was historically captured in a stormwater conveyance system that discharged into the Embayment. In 2011, the stormwater system was re-routed to a series of treatment systems located on the north-adjacent AML property. DSI and AML stormwater are now combined, treated on the AML property, then discharged at the AML stormwater outfall (located north of the former DSI outfall). AML is reportedly responsible for managing the discharge of stormwater (Ecology 2013).

2.7.2 PORT OF SEATTLE TERMINAL 115

The Port of Seattle owns a nearly 100-acre parcel of property that borders the Property to the south and is operated as T115. The Port of Seattle property is situated on the western shore of the LDW between RM 1.6 and RM 2.1 and is currently occupied by several tenants, including seafood facilities, cargo storage and transfer operations, vehicle maintenance facilities, and a commercial fleet vehicle refueling station (SES 2011). Gene Summy Lumber Company and Commercial Fence Group currently occupy 3.2 acres of T115.

The LDW was dredged between 1913 and 1922 to straighten and deepen the waterway. The Port of Seattle property and the east adjoining waterway were dredged between approximately 1915 and 1917. Meanders of the Duwamish River and Foss Island were once located under what is now T115 (SES 2011). Upland portions of the Port of Seattle property were reportedly only a few feet above the river elevation and, as a result, filling of both the old river channel and the upland areas (including Foss Island) was required to build structures or roadways on the Port of Seattle property. According to aerial photographs, regular filling activities were observed in the 1930s, 1940s, 1950s, 1960s, and the early 1970s. The eastern portion of the Port of Seattle property was filled between 1963 and 1970 with gravel, sand, silt, concrete, bricks, coal, wood, garbage, and other miscellaneous materials (SES 2011) when the Port of Seattle owned both T115 and the Property (the uplands and Embayment). The Port of Seattle's filling activities along the southern edge of the Property created the southern shore of the Embayment.

Turning Basin 1, since filled and part of T115, was historically used as a log boom and a point where ships could turn around (SES 2011). The northern portion of the former turning basin was reportedly used as a landfill for "unwanted dredged material and cement kiln dust" (Port of Seattle 1987; Shannon & Wilson, Inc. 1991). Historical operations at the Port of Seattle property included former Boeing Plant #1, retail gasoline service, vehicle maintenance and salvage, gravel and concrete production, and tin reclamation (SES 2011).

A tin reclamation facility operated on the northern portion of the Port of Seattle property between 1963 and 1998. Tin was reclaimed from scrap steel and recycled tin cans. Raw materials included large volumes of loose cans and baled steel scrap, which were stored on the Port of Seattle property. The tin reclamation process utilized sodium hydroxide and sodium nitrate to convert tin

(and other metals) on the cans to salts. The remaining steel from the cans was removed, washed, and bailed. Next, the tin salts were reduced with electricity in a caustic bath to tin metal (Ecology 1987). The reclaimed tin was smelted and sold as ingots. It is estimated that an average of 2,220 tons of de-tinned steel and metal ingot were produced per month between 1991 and 1997 (METRO 1991). The tin reclamation facilities were reported to include “15 storage and processing tanks, a magnetic separator, debris bin, steel shredding machine, can washer, and two 23,000-gallon storage tanks” (SAIC 2007).

Process waste generated at the tin reclamation facility included spent plating solutions, black mud filtrate discharge, and lacquer sludge. Black mud filtrate discharge consisted of paper pulp and paint from can labels, lacquer solids from the interior of cans, residual food, dirt debris, tin compounds, aluminum oxide, and other precipitated metals. The lacquer sludge was reportedly disposed of at a municipal landfill and was included on the facility’s hazardous waste inventory. Prior to 1972, spent plating solution and approximately 3,500 gallons per week of black mud filtrate were discharged to two settling ponds and evaporation lagoons on the eastern portion of the Port of Seattle property. In 1972, the eastern portion of the Port of Seattle property was paved, including the settling ponds and evaporation lagoons. After 1972, wastewaters were discharged to the sanitary sewer system. Aerial photographs of the Port of Seattle property from 1965, 1966, 1967, 1969, and 1970 (Appendix A2) show a light-colored plume of accumulated sediment or liquid discharges into the LDW. The discolored discharges are visible in what is now the Embayment.

It is unclear from the Science Applications International Corporation (SAIC; 2007) report when the stormwater system was first installed at the facility. An as-built drawing dated August 1, 1972, shows several catch basins located within the operational area of the former tin reclamation facility tied into the storm sewer network for the Port of Seattle property and draining into the Embayment via the outfall that services the Port of Seattle property and West Marginal Way (Appendix H). Stormwater from roof drains of a warehouse on the Port of Seattle property was reported to discharge to the LDW via “local storm sewers” (SAIC 2007). It is estimated that 4,000 gallons per day were discharged to the LDW. After 1991, a system was installed at the Port of Seattle property to capture and recycle stormwater for the new can washer system.

In 1997, the Seattle/King County Department of Health conducted a Site Hazard Assessment and discovered several metals including barium, cadmium, chromium, lead, zinc, and tin in the soil. A subsequent investigation by the Port of Seattle in 2009 identified metals, semivolatile organic compounds (SVOCs), and lube-oil-range total petroleum hydrocarbon (TPH) in soil; metals, volatile organic compounds (VOCs), SVOCs, and lube-oil-range TPH in groundwater; and metals and SVOCs in storm drain solids. In 2011, the Port of Seattle and Ecology entered into an Agreed Order to conduct an RI/FS of the Port of Seattle property. The RI is currently underway.

SPU owns and maintains a 48-inch-diameter stormwater line that collects stormwater from an extensive drainage area west of the Site (including industrial, commercial, and residential areas) and discharges to the LDW. An easement for the SPU stormwater line is located on the northern edge of the Port of Seattle property (Figure 2-5) directly south of the Property. A figure showing the drainage basin for the SPU stormwater line is included as Appendix F. The SPU 48-inch-diameter stormwater outfall is typically submerged during low and high tide. Studies completed

for Ecology (SAIC and NewFields 2011) found that at mean higher high water, the SPU 48-inch-diameter stormwater line is inundated to West Marginal Way and in both the northern and southern directions along West Marginal Way (Appendix G). LDW water and sediments are transported into the pipe during high tides and transported out the pipe to the LDW during low tides.

2.7.3 LOWER DUWAMISH WATERWAY SITE

The LDW site, located south of downtown Seattle, Washington, extends over the northern 5 miles of the Duwamish River to the southern tip of Harbor Island (USEPA 2014). The 5900 West Marginal Way Site is located between RM 1.4 and RM 1.5 and on the western shoreline of the LDW. The southernmost portion of the LDW site is located in Tukwila, Washington. The LDW was listed on the National Priorities List on September 13, 2001. The USEPA identification number for the LDW site is WA00002329803. The USEPA and Ecology have divided lead-agency responsibility for the LDW: USEPA is the lead agency for the cleanup of the LDW and Ecology is the lead agency for uplands source control.

In December 2000, the City of Seattle, King County, the Port of Seattle, and Boeing, collectively known as the LDWG, entered into an Administrative Order on Consent with the USEPA and Ecology to conduct an RI/FS pursuant to both CERCLA and MTCA (USEPA 2014). As part of the RI, the LDWG analyzed available data from numerous investigations conducted prior to 2000, collected new data, completed human health and ecological risk assessments, and identified areas to be considered for early action cleanup. The RI was completed in 2010 (Windward 2010), and the FS was completed in 2012 (LDWG 2012). USEPA's Proposed Plan was released in 2013 (USEPA 2013).

The USEPA issued the LDW ROD in November 2014. Among other elements, the ROD identifies cleanup objectives and RALs that are applicable to sediments in the Embayment. Further discussion of the applicable cleanup objectives and RALs is provided in Section 4. The ROD also presents the USEPA's selected remedy for cleanup of the LDW, including sediments within the aquatic portion of the Site. The selected remedy applies to the portion of the LDW extending up to an elevation of 11.3 feet above MLLW and includes a combination of dredging and capping. Implementation of the remedy will require removal of the riprap that currently supports the shoreline of the Property and reconstruction of the shoreline to accommodate and support the dredging and capping remedial actions.

2.8 REGIONAL AND SITE GEOLOGY

2.8.1 REGIONAL GEOLOGY

The Duwamish Valley is a remnant arm of the Puget Sound, which was created by the Vashon Glacier that advanced from British Columbia approximately 15,000 years ago. Until approximately 5,600 years ago, the shoreline of the Duwamish arm reached as far south as the city of Auburn, 20 miles upstream of the present headway at Elliott Bay. After a series of volcanic eruptions, a massive mudflow (the Osceola Mudflow) descended from Mount Rainer spreading sediment in the marine waters at Auburn and down the valley to at least present-day Kent. The mudflow diverted

the White River, at that time a tributary of the Puyallup River, to the Green River (Booth and Herman 1998).

Over time, the deposition of fluvial sediments from the White, Green, and Black Rivers caused the advancement of the shoreline up the Duwamish arm. The lithology is typically characterized by beds of fine silts and sands deposited as riverine and floodplain deposits. Coarser sands and gravels denote the horizontal extent of the water's edge. As the river periodically flooded, the sediments already in place were reworked by the river and supplemented by additional riverine and floodplain deposits (Booth and Herman 1998).

2.8.2 SITE GEOLOGY

Shallow Site geology is divided into the following distinct, lithologic units (from top to bottom):

- Surface coverings
- Shallow fill (including gravel fill)
- Bank fill
- Dredged fill
- Native soil
- Silt aquitard
- Lower sand

The horizontal and vertical distribution of these lithologic units are illustrated on cross-sections A-A' through F-F'. The cross section locations are illustrated on Figure 2-13, and cross-sections A-A' through F-F' are included as Figures 2-14 through 2-19, respectively.

The lithologic units at the Site consist of native Duwamish tidelands deposits (i.e., the lower sand and silt aquitard units) overlain by fill (i.e., the dredged fill and shallow fill units) that was placed in stages. Descriptions of these lithologic units from bottom to top are presented in the following subsections.

2.8.2.1 LOWER SAND

The lower sand consists of black, well to poorly graded, fine to coarse sand with varying silt content. The lower sand layer is saturated and comprises the deep aquifer at the Site. The lower sand is alluvial and marine deposits that are native riverine/floodplain/tidal. As shown on Figures 2-14 to 2-19, the lower sand extends beneath the entire Site and is laterally continuous and depositionally similar with the upper alluvium sediments beneath the LDW. The top of the lower sand (geological unit directly beneath the silt aquitard) is situated at 15 to 22 feet below ground surface (bgs) and is flat to slightly undulating (Figures 2-14 to 2-19). The bottom of the lower sand was not encountered during the RI; however, it was encountered in nine geotechnical soil borings (B-1 through B-5, and B-7 through B-10) completed for a foundation investigation performed by Shannon & Wilson, Inc. (1964 and 1966). Extending west to east across the Site, Shannon & Wilson described the lower sand as a medium, dense sand and silt stratum extending to a depth of approximately 50 to 130 feet bgs. Note that the lower sand unit was not encountered by boring B-6 because it was terminated at a depth of 20 feet bgs, slightly above the top of the lower sand unit.

The lower sand identified at the Site and depositionally similar with the upper alluvium sediments is described in the *Lower Duwamish Waterway Remedial Investigation, Remedial Investigation Report, Final* (LDW RI; Windward 2010) as sand/sand with silt interbeds (Qyal unit) deposited by streams and running water.

According to Shannon & Wilson (1964 and 1966) lower sand is underlain by a medium silt described as a gray, clayey to sandy silt with occasional fine layers.

2.8.2.2 SILT AQUITARD

The silt aquitard overlies the lower sand and consists of slightly clayey silt containing organic material and has low to medium plasticity. The silt aquitard is a native floodplain/tidal deposit, and the top of the silt aquitard represents the exposed intertidal wetland ground surface prior to modern development via placement of dredged fill. The top of the silt aquitard is geomorphically similar to the intertidal surface present during initial development of the Site. It is dry to moist and has a low hydraulic conductivity (approximately 1×10^{-6} centimeters [cm] per second based on its grain size [average for clayey silt to sandy silt]; Freeze and Cherry 1979). Grain size analysis was performed in the lab by ARI in 2013/2014 on nine samples collected from the top of the silt aquitard. As shown on Figures 2-14 to 2-19, the silt aquitard is approximately 3.5 to 12 feet thick. The top of the silt aquitard occurs at depths ranging from 6.5 to 18.7 feet bgs. A contour map showing the elevation of the top of the silt aquitard at the Site is provided as Figure 2-20. The silt aquitard generally grades laterally to the east into recent LDW sediment deposits, which have a similar grain size (Figures 2-14 to 2-17). The recent sediment deposits are described in Section 2.9.2.3. In some areas of the riverbank, the silt aquitard may have been truncated from historic activities (Figures 2-16 and 2-17). For example, the silt aquitard was not encountered at soil boring TB-06 (see Section 3.3.1 for soil boring locations), which is located east of the historical shoreline.

With exception to the areas described below where the silt was potentially disturbed during construction of a wooden bulkhead, the silt aquitard appears to be intact across the upland portion of the Site.

The approximate location of the wooden bulkhead is shown on Figures 2-14 through 2-17. It aligns with the 1936 shoreline (Figure 2-21) and was installed during the period when initial dredged fill was added to the upland portion of the Site. Based on the age of construction, the condition of the bulkhead is deteriorated and likely only remnants exist such as the wood remnants encountered during the RI. The bulkhead likely penetrated the silt aquitard such that the bulkhead could retain the dredge spoils that were placed on the uplands Site. Abandoned borehole MW-45D, which was located in close proximity to the 1936 historical shoreline, likely encountered a remnant of the wooden bulkhead construction when the boring struck wood approximately 2 feet below the interface between dredged fill and the silt aquitard. This resulted in drilling refusal and borehole abandonment, but suggests the bulkhead extends at least 2 feet into the silt aquitard (see Section 3.3.4 for monitoring well locations).

The lithologic logs from more than 40 soil borings, and a hydrogeologic evaluation presented in Section 2.9 provide evidence that the silt aquitard is present and is a competent layer across the Site.

2.8.2.3 NATIVE SOIL

Native soil consisting of gray, interbedded, fine to medium sands and silts are present in the western portion of the Site at depths ranging between 1.7 and 12.5 feet bgs (Figure 2-15). The native soil overlies and is interbedded with the silt aquitard. Based on the Site's proximity to the adjacent steep hillside on the western side of West Marginal Way, the native soils appear to be terrestrial deposits adjacent to the intertidal wetland represented by the silt aquitard. An increasing presence of native soil to the west away from the LDW is observed.

2.8.2.4 DREDGED FILL

The dredged fill overlies the silt aquitard and consists of gray to black, well to poorly graded, fine to medium sandy silt having a high organic content. As shown on Figures 2-14 to 2-19, the dredged fill is approximately 4 to 9 feet thick and is generally continuous beneath the upland portion of the Site. It is truncated to the east by the riverbank, bank fill, and/or riprap deposits (Figures 2-14 to 2-17), and abuts native soils in one area near the west side of the Site (Figure 2-15). Figure 2-14 shows a historic excavation in the vicinity of soil boring GP-63 that penetrates the dredged fill and was backfilled with recent gravel. The lower portion (between the silt aquitard and 5 to 6 feet bgs) of the dredged fill is typically saturated and comprises the majority of the shallow aquifer.

The dredged fill originated from the various dredging episodes of the LDW. The LDW was initially dredged from 1913 to 1922 to straighten and deepen the waterway. This fill was likely added to raise the Site above water level, making the Site more suitable for development. The area of the Site prior to development was historically "riverine tidal wetland" (Appendix I; King County 2005). The dredged fill layer has the lithology, high organic content, and elevation relative to the LDW that consistently identifies it as dredged material. In addition, this fill layer extends above the mean-high and mean higher high water lines at the Site and therefore is likely not native material.

2.8.2.5 BANK FILL

The bank fill originated from construction activities related to property redevelopment as described in Section 2.6.8 and is identified as the fill material present east of the original shoreline, and is currently protected and armored by riprap present at the Site. Bank fill overlies a finer grained sand to silty sand material that was deposited during industrial activities between 1922 after the installation of the wooden bulkhead, and prior to 1964 when property redevelopment began (see Section 2.6.8). The finer grained material overlies the silt aquitard, and in a limited area overlies the lower sand unit to the east of the wooden bulkhead (Figure 2-15 through 2-17). The bank fill consists of a heterogeneous mix of silt, sand, gravel, and construction debris such as bricks, wood, and concrete.

As noted in Section 2.6.9, Kaiser under Port of Seattle ownership altered the shoreline during redevelopment activities during construction of the cement terminal on the northern section of the Property. The shoreline was expanded to the east as evidenced by aerial photographs and the shoreline analysis included on Figure 2-21 depicting the shoreline expansion eastward beyond the original shoreline. Soil borings completed along the riverbank identified the bank fill from the surface to depths ranging between 1.25 and 14 feet bgs.

The bank fill along the eastern shoreline is protected by riprap armoring the northern to the southern portion of the eastern bank of the Property (Figure 2-4). As presented on Figure 2-21, the most significant changes to the eastern bank of the Property occurred between 1967 and 1968. The figure also shows that between 1970 and present day, the eastern shoreline of the Property has remained relatively unchanged, likely due to the bank armoring placed at the time the cement terminal was constructed. The southern bank of the Property in the Embayment was created between 1969 and 1970 by the Port of Seattle's construction of T115. The fill material along the southern bank is generally gravel material varying in diameter. The top of the riverbank is generally silty fine sand with increasing gravel content with depth. The southern bank is also protected by riprap placed by Port of Seattle at the time of T115 construction (Figure 2-4).

2.8.2.6 SHALLOW FILL

Shallow fill was placed over the dredged fill as the upland portion of the Site was developed. The content of the shallow fill differs across the Site because filling occurred in multiple events and for varying purposes. For example, the aerial photographs and historical records show:

- 1967–1968: Filling along the shoreline during development of the Kaiser cement terminal; and
- 1969–1970: Filling by the Port of Seattle to create land surface for T115, which formed the southern end of the Embayment.

The northern portion of the Site contains a layer of shallow fill consisting of silt, sand, gravel, brick, carbon/charcoal, and concrete debris. As shown on Figures 2-14, 2-18, and 2-19, this layer of shallow fill (including the recent gravel) overlies the dredged fill, is generally continuous across the Site, and extends to a depth of approximately 3 to 5 feet bgs. In the vicinity of soil boring GP-63, recent gravel appears to have been used as backfill for a former excavation that extends to a depth of approximately 9 feet bgs (Figure 2-14). No shallow fill is situated in the vicinity of the existing cement silos (Figure 2-18). The top of the shallow fill is at approximately 0.5 to 3.5 feet bgs.

The southern portion of the Site contains a layer of shallow fill material, which consists of silt, sand, gravel, and concrete debris. This fill layer extends to a depth of approximately 3 to 7 feet bgs. Shallow fill consisting of silty sand and concrete was observed to a depth of 10 feet bgs in the southeastern corner of the Site at a top-of-riverbank boring (TB-06F). This boring was completed to the east of the historical shoreline.

Various anthropogenic materials including, but not limited to, carbon/charcoal, reddish-brown vesicular fragments, and sawdust ranging from thin discontinuous lenses to 1.8 feet thick, are present in the shallow fill. Carbon/charcoal was identified in the southeast area of the Site adjacent to the riverbank and within former ditches. Carbon/charcoal was also observed in borings advanced on the northern and central portions of the Site within the operational areas of Carlisle, Crown Zellerbach, and the Army. Sawdust was predominantly observed in the southeast corner of the Site as well as in former ditches. The locations where carbon/charcoal and sawdust were identified are consistent with the 1945 Sources of Pollution in the Duwamish-Green River Drainage Area report that indicated "this field was already being used as a dumping ground for discarded charcoal and sawdust" (Foster 1945). Vesicular fragments were observed in shallow fill along the riverbank and within the former Reichhold washwater impoundment. An exploratory test pit

located approximately 10 feet south of well MW-45D identified carbon/charcoal, refractory brick, wood, and metal debris. In addition, four charcoal briquettes believed to be associated with the production of activated carbon and whetlerite by Carlisle, Crown Zellerbach, and the Army were recovered intact from the excavation (see discussion in Section 3.4).

Shallow fill was also placed as backfill around underground utilities. For example, in 1971 the City of Seattle installed a 48-inch-diameter stormwater line parallel to the southern boundary of the Property in the location shown on Figures 2-4, 2-18, and 2-19. The SPU stormwater line was installed through the shallow and dredged fill and extends into, but not through, the silt aquitard. The SPU stormwater line is bedded in 6 to 8 inches of crushed rock and backfill with 2-inch minus crushed rock. This bedding material serves as a preferential pathway for groundwater migration. The SPU stormwater line is discussed further in Section 2.10.2.1.

2.8.2.7 SURFACE COVERINGS

Because the northern portion of the Property is developed with infrastructure, part of the ground surface is paved. A concrete driveway (and parking area near the office) extends from West Marginal Way to a turning circle for trucks on the eastern portion of the Property. Concrete thicknesses are on the order of several feet in the vicinity of the concrete silos. The concrete driveway is underlain by an angular gravel road base material that varies in thickness from 0.8 to 2.1 feet. Approximately 1 to 1.25 feet of quarry spalls underlie the road base in the driveway area immediately north of the office building. The majority of the ground surface on the southern section of the Property is unpaved and covered with a layer of gravel and crushed rock approximately 1 to 3 feet thick and greater in some areas.

2.9 LOWER DUWAMISH WATERWAY

The LDW is an engineered waterway built in the early 1900s as an industrial corridor. Most of the natural habitat was lost during construction of the LDW; however, some intertidal habitat remains in isolated patches (e.g., Kellogg Island).

2.9.1 HYDRODYNAMICS

The LDW is a salt wedge-type estuary that has a density-driven two-layer flow system influenced by seasonally fluctuating river flow and tidal effects. Under typical conditions (average flows), the less dense freshwater flows downstream in the surface layer and the denser saline water from Elliott Bay moves upstream on flood tides in the bottom layer, forming a saltwater wedge thickest at the downstream end and tapering to a thin layer upstream (Stoner 1967). As discussed in Section 2.10, the shallow and deep groundwater aquifers at the Site have elevated concentrations of total dissolved solids and are tidally influenced by the LDW. The salt wedge also results in lower near-bottom current speeds and a more quiescent depositional environment.

The LDW includes a federally maintained navigation channel and numerous berthing areas that are periodically dredged to remove sediments that are deposited predominantly from upstream sources. Water depths in the navigation channel vary from approximately -56 feet MLLW near the mouth of the LDW to -10 feet MLLW near the Upper Turning Basin (ENSR/AECOM 2009). Water depths in the Embayment range from approximately -30 to +11.3 feet MLLW.

2.9.2 SEDIMENT

Sediment is continually depositing within the LDW, with almost all new sediment (99 percent) originating from the upstream Green/Duwamish River in a river-wide scale. Net sedimentation rates average 1 to 3 cm per year (cm/yr) in most of the subtidal areas, and range up to greater than 70 cm/yr in the Upper Turning Basin (ENSR/AECOM 2009). The Embayment is net depositional with a net sedimentation rate range of approximately 0.5 to 3 cm/yr (Windward 2010). Core radioisotope data (e.g., SC29) show that net sedimentation rates ranged from 0.6 cm/yr around 1916 to 0.4 cm/yr around 1961, prior to the construction of the Embayment (see Table 3-3 in Windward 2010). The core radioisotope data provide an empirical net sedimentation rate estimate of approximately 0.5 cm/yr, whereas the sediment transport modeling projects a current net sedimentation rate range in the Embayment of approximately 2 to 3 cm/yr (Windward 2010). A summary of the sediment stratigraphy (from oldest to youngest) encountered in the LDW is presented below.

2.9.2.1 LOWER ALLUVIUM

The lower alluvium comprises dense silts and silty sands that were compacted during the Vashon glaciation approximately 20,000 years ago. The lower alluvium can be recognized easily by high blow counts noted in drilling records. According to Booth and Herman (1998), these deposits generally occur below 30 feet elevation in the northern portion of the Upper Valley. As illustrated on Figures 2-14 and 2-16, the lower alluvium is the lowermost stratigraphic layer identified in sediment cores obtained from the Embayment and underlies the lower sand unit identified beneath the upland portion of the Site. It is likely laterally continuous with the Vashon Drift.

2.9.2.2 UPPER ALLUVIUM

The upper alluvium consists of coarser, sandy alluvium with small quantities of silt and organics. In the Upper Valley area (at the confluence of the Green and Black Rivers) this stratum is typically 10 to 30 feet thick and in some locations reaches 130 feet thick. The lower areas of the deposit often contain shell deposits (Booth and Herman 1998). As illustrated on Figures 2-14 through 2-17, the upper alluvium is the middle stratigraphic layer identified in sediment cores obtained from the Embayment and is laterally continuous with the lower sand unit identified beneath the upland portion of the Site.

2.9.2.3 RECENT DEPOSITS

Recent deposits are those sediments deposited after the LDW was channelized and industrialized, which occurred in the early 1900s. Recent deposits overlie the upper alluvium and are characterized by wood and organics in a silt and sand matrix and may include sand silt and silty sands with high organic content. As illustrated on Figures 2-14 to 2-19, the recent deposits are the uppermost stratigraphic layer identified in sediment cores obtained from the Embayment and are laterally continuous with the silt aquitard, dredged fill, shallow fill and bank fill deposits on the upland portion of the Site. The depth of the recent deposits (Figures 2-14 to 2-19) is generally about 5 feet and is slightly deeper in offshore areas where up to 8 feet of material is found.

2.10 GROUNDWATER OCCURRENCE

Two distinct, saturated zones have been identified underlying the Site. Shallow unconfined groundwater present within the shallow and dredged fill is encountered beneath the Site between 4 and 13 feet bgs. This shallow aquifer lies above the silt aquitard. The saturated thickness of the shallow aquifer varies across the Site from 2 to 11 feet, and also experiences seasonal fluctuations of approximately 2 to 3 feet. The deep confined aquifer is present in the lower sand, which lies beneath the aquitard and is fully saturated. Discussion of the shallow and deep aquifer hydraulic characteristics of the Site is presented below.

2.10.1 2013 AND 2014 TIDAL STUDIES OF THE SHALLOW AND DEEP AQUIFERS

Two tidal studies were performed at the Site during the RI. The first, completed in July 2013 (July 18 through July 29), included an evaluation of the LDW tidal effects on 15 shallow and five deep monitoring wells. The second tidal study completed in June 2014 (June 12 through June 19) included 11 shallow and 10 deep monitoring wells (Note: the data from MW-2D in June 2014 were corrupt and could not be processed). The objectives of the tidal studies were to evaluate:

- Net hydraulic gradients in the shallow and deep aquifers;
- Tidal response across the aquitard in the existing shallow and deep well pairs to assess competence of the aquitard; and
- Tidal effect lag time observed in Site monitoring wells for timing of groundwater sampling.

A detailed summary of the July 2013 tidal study methodology, data processing, and results from the tidal study are included in Appendix J. The data and figures from the June 2014 tidal study are also included in Appendix J. The tidal study results are briefly presented below and incorporated into the shallow and deep aquifer discussions in the following sections.

During the tidal studies, groundwater levels were monitored in shallow and deep monitoring wells using pressure transducer/data logger systems. A stilling well was also installed in the LDW on the Glacier Northwest dock with a pressure transducer/data logger system to measure the river stage during the studies. Barometric pressure was recorded during the tidal study periods using a barometric pressure/data logger system to compensate the water level measurements for changes in barometric pressure.

Water levels were recorded every 10 minutes resulting in six observations per hour. The 10-minute interval water level data recorded over 71-hour periods were used to calculate mean water levels. The water levels recorded during the tidal studies were corrected for the tidally influenced head changes by calculating the mean hydraulic head and gradient over several tidal cycles using filtering methods. For these studies, a filtering process developed by Serfes (1991) was used to remove the tidal effects from the water level measurements. First, a sequence of moving averages was calculated on 24-hour intervals over a 71-hour period. Second, a similar sequence of moving averages was calculated using the first set of moving averages. Last, the average of the second set of moving averages was calculated, which yielded the mean hydraulic head over a 71-hour interval.

The tidal studies characterized a number of features of the shallow and deep aquifers, as follows:

- Each aquifer is hydraulically influenced by river stage fluctuations; as such, tidal influence is observed in both the shallow and deep aquifers.
- The mean horizontal net gradients in the shallow and deep aquifers are toward the LDW at 0.003 foot per foot (ft/ft) and 0.001 ft/ft, respectively, consistent with previous gradient measurements.
- The net vertical hydraulic gradients ranged from -0.21 to -0.34, indicative of net downward gradient (i.e., from the shallow aquifer to the deep aquifer).
- The tidal responses observed in the shallow and deep well pairs were consistent with a contiguous (i.e., not breached) aquitard present throughout the Site as supported by:
 - An average difference in groundwater elevations between the shallow and deep aquifers of approximately 4 feet, indicative of a confining unit present between aquifers.
 - A larger range of groundwater elevation fluctuations in all deep aquifer monitoring wells (average of 5.47 feet) in comparison to very small fluctuations in the shallow monitoring wells (average of 0.23 feet), which suggests that the deep aquifer is confined.
 - A lag time that is proportional to the distance from the river in the deep aquifer (i.e., lag increases with distance from the river) due to efficient tidal pressure wave propagation in confined aquifer settings.
 - Change in temperature and conductance over time in the deep aquifer correlates with changes in river stage, but no such correlation was observed in the shallow aquifer, indicating that they are independent groundwater regimes separated by a confining unit (i.e., the aquitard).
- The lag time in the shallow aquifer ranged from approximately 5 to 28 hours from the maximum and minimum tidal stages, and in the deep aquifer ranged from 0.5 to 2.3 hours.

2.10.2 SHALLOW GROUNDWATER AQUIFER

The saturated thickness of the shallow aquifer is variable, typically ranging between 2 and 11 feet, with the greatest saturated thickness occurring in the northern portion and thinning toward the south and east. The saturated thickness of the shallow aquifer varies seasonally with fluctuations in the water table elevation. Based on data collected during this RI and previous environmental investigations, the saturated thickness of the shallow aquifer is at a minimum during the drier months between June and October, and increases during the winter months of December through March. Groundwater flow conditions in the shallow aquifer are unconfined with the water table occurring at depths from 4 to 13 feet bgs across the Site.

2.10.2.1 GROUNDWATER ELEVATIONS AND FLOW DIRECTION

Table 2-1 summarizes the shallow aquifer groundwater elevations and the Duwamish River surface water elevations measured between 2009 and 2018. Shallow aquifer groundwater level measurements were collected from the shallow monitoring wells, whereas surface water elevations were measured from the Glacier Northwest dock. Water level measurements were collected on a quarterly basis from 2009 through the third quarter of 2016, and then semi-

annually from the first quarter of 2017 through the first quarter of 2018. Shallow aquifer potentiometric surface maps for the four quarters of 2014 groundwater elevation measurements are shown on Figure 2-22. The groundwater potentiometric surface maps from 2009 through 2018 are included in Appendix K.

As discussed above, groundwater elevations in the shallow aquifer fluctuate sinusoidally with time indicating that this unit is hydraulically connected to the LDW and is tidally influenced, though to a lesser degree than the deep aquifer (see Section 2.9.1; Appendix J). Tidally influenced water level fluctuations were observed at eight monitoring wells within 190 feet from the LDW (Table 3 of Appendix J), with the tidal fluctuations decreasing with distance. Wells observed during the tidal studies further than 190 feet did not appear to be strongly tidally influenced.

Shallow groundwater flow direction and gradients are consistent across the Site throughout the seasons. Based on the quarterly water level measurements and potentiometric surface maps (Appendix K) and the results of the tidal studies (Appendix J), the net groundwater flow direction in the shallow aquifer is toward the LDW. Groundwater generally flows to the east-northeast in the northern portion of the Site, to the south and east in the central portion of the Site, and to the south-southeast in the southern portion of the Site, all toward the Embayment. Throughout the 9 years of groundwater elevation monitoring at the Site, higher groundwater elevations were noted during high precipitation events in the north-central portion of the Site indicating a groundwater mound. This includes the February 2014 monitoring event as shown on Figure 2-22. The groundwater mounding is likely attributed to the grass/vegetated stormwater swale that bisects the Site. Stormwater accumulates at the Site and flows toward the swale. The swale receives stormwater and is a source of recharge to the shallow aquifer.

Groundwater elevation data indicate the presence of a depression in the groundwater table in the southeastern portion of the Site, which is caused by the 48-inch-diameter SPU stormwater line that runs parallel to and south of the Site (Figure 2-22). Groundwater in the southern portion of the Site flows to the south toward the SPU stormwater line. Similarly, groundwater under T115 flows to the north toward the SPU stormwater line (see Figures 4-8 and 4-9 from the Draft T115 RI/FS for groundwater flow direction maps). Where the outfall to the SPU stormwater line discharges to the LDW, on the sloped bank at the northeastern corner of the Port of Seattle property, water has been observed to seep from the outside of the line during dry weather conditions. This could indicate that the bedding and backfill material used during construction of the SPU stormwater line may be acting as a conduit for groundwater migration not only from the Site, but also from the Port of Seattle property and upgradient properties, where this SPU stormwater line bedding elevation is lower than the shallow groundwater table. In addition, groundwater elevations in the shallow aquifer near the SPU stormwater line appear to decrease in elevation in its vicinity, indicating that groundwater flow is toward the SPU stormwater line. No other groundwater preferential pathways are observed based on the shallow groundwater potentiometric surface maps (Figure 2-22).

Groundwater immediately surrounding the SPU stormwater line has not been sampled, but groundwater data from nearby shallow monitoring wells MW-3S, MW-26S, and MW-27S, located on the Property and MW-14, located on the Port of Seattle property are indicative of the quality of groundwater discharging to the bedding material of the SPU stormwater line. Site groundwater

data is discussed in Section 5.2. Groundwater data for T115 is provided in the *Draft Remedial Investigation Report for the Port of Seattle North Terminal 115 Site* (GeoEngineers 2017).

The shallow aquifer also discharges to the LDW along the eastern bank of the shoreline through seeps. Groundwater seeps from the shallow aquifer include small rivulets of water, but they are not clearly identifiable, which may be because of the fill that extends out over the original shoreline and rip-rapped bank.

2.10.2.2 HYDRAULIC CONDUCTIVITY

Slug tests performed in several monitoring wells at the Site were used to estimate the horizontal hydraulic conductivity of the shallow aquifer. The estimated hydraulic conductivities from the slug tests range from 1.81 to 7.86 feet per day (ft/day), with a geometric mean conductivity value of 3.48 ft/day.

2.10.2.3 HORIZONTAL HYDRAULIC GRADIENT

Hydraulic gradients in the shallow aquifer as determined by quarterly water level gauging and tidal studies range between 0.002 and 0.004 ft/ft, with an average hydraulic gradient of 0.003 ft/ft.

2.10.2.4 GROUNDWATER FLOW VELOCITY

The average calculated groundwater flow velocity in the shallow aquifer is approximately 12.7 feet per year (ft/yr), based on a mean hydraulic conductivity of 3.48 ft/day, an average hydraulic gradient of 0.003 ft/ft and an estimated porosity of 0.30. Due to the different geologic and hydrogeologic properties of the aquifer and ranges of hydraulic conductivity measured in the wells, groundwater velocities at individual locations within the aquifer are variable.

2.10.2.5 INFILTRATION AND RECHARGE

The shallow aquifer receives recharge by infiltration of precipitation and surface runoff. Recharge rates are estimated to be 0 to 5 inches per year based on a U.S. Geological Survey water budget modeling analysis for the South King County Groundwater Management Project (Woodward et al. 1995).

2.10.3 DEEP GROUNDWATER AQUIFER

The depth to the top of the deep aquifer generally ranges between 17.5 and 24.5 feet bgs and extends to depths ranging between 50 and 130 feet bgs (Shannon & Wilson, Inc. 1964).

Groundwater in the deep aquifer is confined by the silt aquitard and consists of medium to coarse grained sand with occasional shell fragments and wood debris ranging from depths of approximately 50 feet on the western portion of the Site to 130 feet on the eastern portion of the Site. The deep aquifer is tidally influenced by the LDW.

2.10.3.1 GROUNDWATER ELEVATIONS, TIDES, AND FLOW DIRECTION

Table 2-1 summarizes the groundwater elevations measured in the deep aquifer monitoring wells beginning in 2009. The 2014 deep aquifer potentiometric surface maps for low tide measurement are shown on Figure 2-23, and high tide measurements are shown on Figure 2-24. Groundwater elevation contours for the deep monitoring wells are included in Appendix K.

Beginning in April 2012, groundwater elevations in the deep aquifer monitoring wells were contoured separately. Beginning in July 2012, two separate measurements from the deep aquifer monitoring wells were collected during various LDW tidal stages to evaluate the tidal effects on Site groundwater flow direction. These figures (presented in Appendix K) show the groundwater flow direction in the deep aquifer changes with the LDW tidal stages. However, as observed in the tidal studies, the net groundwater flow direction in the deep aquifer at the Site is toward the LDW. Groundwater from the deep aquifer discharges to the LDW through seeps present in the intertidal portion of the Embayment. The deep groundwater seeps were observed during a low tide event and groundwater was observed to be flowing from the seeps through the recent deposit sediment layer.

Groundwater elevations in the deep aquifer fluctuate sinusoidally with time indicating the aquifer is tidally influenced and hydraulically connected to the LDW. Compared to the shallow aquifer, tidal fluctuations are much greater in the deep aquifer, ranging between 2 and 7 feet. The groundwater elevations in the deep aquifer are significantly lower than the groundwater elevations in the shallow aquifer in all shallow/deep monitoring well pairs, consistent with a downward gradient between these units.

2.10.3.2 HYDRAULIC CONDUCTIVITY

Slug tests were performed in three deep monitoring wells (MW-2D, MW-20D, and MW-38D) to estimate the horizontal hydraulic conductivity of the deep aquifer. The estimated hydraulic conductivities from the slug tests ranged from 3.6 to 106.3 ft/day, with a geometric mean conductivity value of 29.2 ft/day.

2.10.3.3 HORIZONTAL HYDRAULIC GRADIENT

The net horizontal hydraulic gradient in the deep aquifer is toward the LDW and ranges between 0.0005 and 0.001 ft/ft, with an average hydraulic gradient of 0.00075 ft/ft.

2.10.3.4 GROUNDWATER FLOW VELOCITY

The average calculated groundwater flow velocity in the deep aquifer is approximately 23 ft/yr based on a mean hydraulic conductivity of 29.42 ft/day, an average hydraulic gradient of 0.00075 ft/ft, and an estimated porosity of 0.35. Due to the different geologic and hydrogeologic properties of the aquifer and ranges of hydraulic conductivity measured in the wells, groundwater velocities at individual locations within the deep aquifer are variable.

2.10.3.5 INFILTRATION, RECHARGE, AND VERTICAL GRADIENT

The deep aquifer receives recharge from upgradient and surrounding areas to the west and from the shallow aquifer, and is hydraulically connected to the LDW, as previously discussed. The results from the 2013 tidal study were used to calculate the vertical gradients between the shallow and deep aquifers across the Site in five shallow and deep well pairs. Based on the tidal study results, there is a net downward vertical gradient (expressed as a negative [-]) between the shallow aquifer and deep aquifer, which ranged from -0.21 to -0.34 ft/ft (Table 2 in Appendix J). These net vertical hydraulic gradients were consistent in magnitude, indicating substantial hydraulic independence between the two aquifers.

The hydraulic independence of the two aquifers is a substantive line of evidence that there are no significant breaches in the silt aquitard that separates the two aquifers. Although the wooden bulkhead may have penetrated the silt aquitard on the waterward (east) side of the bulkhead, the groundwater potentiometric data suggests the bulkhead does not compromise the aquitard's confining characteristics to the west of the bulkhead. As discussed previously, the aquitard may have been truncated at locations to the east of the wooden bulkhead. For example, the silt aquitard was not encountered at soil boring TB-06 (see Section 3.3.1 for soil boring locations), which is located east of the historical shoreline.

Table 2-2 presents vertical gradients calculated for groundwater elevations data collected in January 2017, August 2017, and January 2018. Similar to the results of the tidal study, gradients between the shallow and the deep aquifer were downward across the Site. The vertical groundwater velocity through the aquitard was calculated for the Site using the vertical gradients presented above and a hydraulic conductivity of 1×10^{-6} cm per second (0.00283 ft/day) for the silt aquitard. The vertical groundwater velocity downward through the aquitard was calculated to range between 0.00779 to 0.01076 ft/day.

Further evidence that the silt aquitard is intact across the upland portion of the Property, to the west of the historic shoreline, is observed in the potentiometric groundwater surfaces for the shallow and deep aquifers. Groundwater elevations in paired monitoring wells screened in the shallow and deep aquifers differ by several feet. The potentiometric head difference between the two aquifers is evidence that the silt aquitard is a confining layer that allows the two aquifers to be independent of one another. Further discussion of the silt aquitard is presented in Section 2.8.2.2.

As shown on the cross section on Figure 2-18, the pilings for the cement silos extend through the fill and silt aquitard into the lower sand unit. Based upon available design drawings for the silos completed in 1966, the pilings used in construction of the silos are octagonal pre-stressed concrete piles ranging in length between 40 and 90 feet (see Section 2.6.8). These types of pilings rely on friction between the piling and soil to generate resistive force (they are not driven to bedrock, for example). The pilings were driven through the aquitard, and into the underlying lower sand unit. Based on groundwater potentiometric surface maps and tidal studies completed at the Site, the silo pilings do not appear to be a conduit for groundwater migration from the shallow aquifer to the deep aquifer.

2.11 TERRESTRIAL ENVIRONMENT

The upland portion of the Site consists of approximately 13.68 acres in the Duwamish industrial corridor of Seattle, Washington. The upland portion of the Site is zoned for general industrial use (IG1 U/85; City of Seattle Department of Planning and Development) and is anticipated to remain as such in the future. The upland portion of the Site is developed and contains structures, paved areas, a gravel lot, and narrow strips of dense vegetation in small areas of the Site and along the shore as shown on Figure 2-25. The terrestrial environment includes the upland portion of the Site that lies above the ordinary high water mark, which identifies where the vegetation changes from terrestrial to aquatic.

For this RI, a Terrestrial Ecological Evaluation (TEE) was completed in accordance with WAC 173-340-7490, because the Site does not qualify for a TEE exclusion under WAC 173-340-7491(1). The purpose of the TEE was to evaluate the terrestrial habitat at the Site and surrounding areas, document the presence or absence of receptors or receptor habitats, rate the quality of habitat, and evaluate potential threats to terrestrial ecological receptors from exposure to contaminated soil having a potential to cause significant adverse effects.

For sites that do not qualify for a TEE exclusion, either a simplified TEE or a site-specific TEE must be conducted to determine if a threat to terrestrial ecological receptors exists or if the site can be removed from further ecological consideration during the RI and cleanup process. The process for conducting a simplified TEE includes an evaluation of the extent of exposure, exposure pathways, and type of contaminants present in site media. Under the simplified TEE process, the evaluation ends if any one of the exposure evaluations determines that there is not a substantial threat of significant adverse effects on terrestrial ecological receptors.

There are four criteria (WAC 173-340-7491[2][a]) to determine whether a site qualifies for a simple or site-specific TEE. The first criterion is whether a site is located on or directly adjacent to an area where management or land use plans will maintain or restore native or semi-native vegetation. The West Duwamish Greenbelt, located west of the Site, is separated from the Site by West Marginal Way (a busy four-lane road with frequent heavy truck traffic), several fences, and other industrial properties on the western side of Marginal Way. West Marginal Way is classified as a Principal Arterial by the Washington State Department of Transportation. This is the third-busiest road classification (after interstate highways and freeways/expressways). In addition, active railroad tracks located on the eastern side of West Marginal Way are present between the Site and the West Duwamish Greenbelt. West Marginal Way and the railroad tracks are expected to provide a significant barrier between the Site and the Greenbelt; thus, this criterion is not met.

The second criterion is whether the site is used by threatened or endangered species; wildlife classified by the Washington Department of Fish and Wildlife as a "priority species" or "species of concern" under Title 77 of the Revised Code of Washington (RCW), or used by a plant species classified by the Natural Heritage Program as "endangered," "threatened," or "sensitive" under Title 79 of the RCW. The websites of both these departments were consulted and showed that the Site does not have any of these types of species mapped on the terrestrial portions of the Site. A site visit was conducted on December 9, 2014, to evaluate the presence of terrestrial species of concern. No terrestrial species of concern or potential habitat expected to support threatened and endangered species was observed; thus, this criterion is not met.

The third criterion is whether the site is located on a property that contains at least 10 acres of native vegetation within 500 feet of the contamination. This criterion is not met. There is approximately 1 acre of vegetated land on the Site, not including areas of deliberate landscaping (Figure 2-25).

The fourth criterion is whether Ecology has determined that the site may present a risk to significant wildlife populations. This criterion is not met. The Site is surrounded by industrial properties and is separated from the nearest greenbelt by West Marginal Way (classified as a

Principal Arterial), railroad tracks, adjacent industrial parcels, and several fences (see Photo 1 in Appendix L).

The Site does not exhibit any of the characteristics identified in WAC 173-340-7491(2)(a) that would require a site-specific TEE. The Site is an industrial property with no known usage by threatened or endangered species and without managed vegetation areas as defined in WAC 173-340-7490(3)(b). As such, the Site qualifies for a simplified TEE that only evaluates future potential exposure to soil by terrestrial wildlife. The simplified TEE is a procedure outlined in Table 749-1 Simplified TEE – Exposure Analysis Procedure under WAC 173-340-7492(2)(a)(ii). A copy of the analysis is provided in Appendix L and the results of each of the potential exposure pathways are discussed below.

1. There is an area of contiguous undeveloped land within a 500-foot radius of the Site consisting of approximately 0.78 acres of the West Duwamish Greenbelt (Figure 2-25). (6 points)
2. The Site is an industrially zoned property with less than 1 acre of undeveloped area (see Figure 2-25). (3 points)
3. The habitat quality is low. The substrate of the Site is composed of historically placed fill and gravel and is unlikely to provide good habitat for burrowing mammals (see Photo 2 in Appendix L). Most of the trees identified at the Site are mature alders (*Alnus rubra*). The shrub layer consists primarily of invasive species such as butterfly bush (*Buddleia davidii*), Scotch broom (*Cytisus scoparius*), Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), and ornamental landscape plants (see Photos 3 through 5 in Appendix L). There are no intact corridors or connections to other habitat used by wildlife. (3 points)
4. The Site and adjacent West Duwamish Greenbelt (Figure 2-25) may attract wildlife. Rodents, raccoons, and feral cats have been observed at the Site. Geese occasionally use the Embayment and pooled surface water at the Site. In addition, two nests were observed in the trees in the southeastern portion of the Site (see Photo 6 of Appendix L). The vegetated areas of the Site may represent habitat islands in an otherwise industrial landscape. (1 point)
5. The soil and sediments at the Site contain elevated concentrations of COPCs (1 point), including bioaccumulative COPCs.
6. The score for Items 2 through 5 is 8 points, which is larger than the score for Item 1 (6 points for 1 acre of undeveloped land).

The results of the simplified TEE indicate that further TEE evaluation is not required because the undeveloped, vegetated area is small, the land use is industrial, and the habitat quality is low. Therefore, wildlife at the Site and surrounding area are unlikely to be exposed to COPCs (WAC 173-340-7492 [2][a][ii]). Based on the simplified TEE score, the ecological evaluation is complete and further TEE is not necessary. The Site is unlikely to pose risks to terrestrial ecological receptors.

2.12 AQUATIC ENVIRONMENT

The aquatic portion of the Site consists of approximately 4.19 acres of submerged tidelands within the Embayment adjacent to the LDW. The Embayment was formed in 1970 when the Port of Seattle completed substantial filling to create land surface for T115.

The high intertidal shoreline of the Embayment is mostly riprap with a vegetated strip along the top of the bank. The intertidal portion of the shoreline is relatively steep and rocky. Tall grasses and shrubs occupy the top of the bank to the high tide elevation. The lower intertidal and shallow subtidal surface is very soft and silty making access to these areas extremely difficult.

Aquatic wildlife that may be found in the vicinity of the Site includes anadromous salmonids, perch, English sole, and others. Mammals including harbor seals and river otters may also be present. Benthic invertebrates including worms and crabs are also found in the LDW and may use the Embayment (Windward 2010).

3. SITE CHARACTERIZATION AND PREVIOUS REMEDIAL ACTIONS (1985–2014)

This section provides an overview of previous investigations, independent remedial actions, and the contemporary RI activities completed at the Site.

3.1 SUMMARY OF HISTORICAL INVESTIGATIONS

A summary of historical investigations completed at the Site is presented below. The soil sampling locations are presented on Figure 3-1.

3.1.1 PREVIOUS SOIL INVESTIGATIONS (1985–2003)

3.1.1.1 FINAL REPORT, KAISER PROPERTY ENVIRONMENTAL AUDIT, PREPARED FOR THE PORT OF SEATTLE BY PARAMETRIX, MAY 21, 1985 (PARAMETRIX 1985)

An environmental audit was performed in anticipation of a property transaction in 1985. The work included a review of Site history and the collection and laboratory analysis of four composite soil samples (Comp-1 through Comp-4) created from 24 soil samples collected from 12 soil borings (three borings per composite sample). The locations of the composite samples are shown on Figure 3-1 and descriptions of the general sample collection areas are as follows:

- Comp-1 – Three borings located in the former Reichhold washwater impoundment area;
- Comp-2 – Three borings located in the former Kaiser bentonite area;
- Comp-3 – Three borings located in the former Reichhold tank farms area; and
- Comp-4 – Three borings located in the southern portion of the Site.

The composite soil samples were analyzed for priority pollutant metals, SVOCs, VOCs, pesticides, and polychlorinated biphenyls (PCBs).

3.1.1.2 PHASE II SITE ASSESSMENT, 5900 WEST MARGINAL WAY, SEATTLE, PREPARED FOR LONE STAR NORTHWEST BY PARAMETRIX, AUGUST 1990 (PARAMETRIX 1990)

A Phase II Site Assessment was completed in 1990, which included:

- Installation of three groundwater monitoring wells (B-1 [later renamed MW-1], B-2 [later renamed MW-2], and B-3 [later renamed MW-3]). Note that MW-1, -2, and -3 are no longer present at the Site.
- Excavation of five shallow soil test pits (TP-1 through TP-5) with a shovel to 1.5 feet bgs.
- Collection of soil samples from the well borings and test pits.

Three soil samples from each monitoring well boring were collected from 4 and 8 feet bgs. A composite sample of the entire boring was also collected. Soil samples collected from the 4- and 8-foot depths were submitted for laboratory analysis of TPH and total organic halides (TOX). The composite soil samples were analyzed for total metals and toxicity characteristic leaching procedure for metals.

Test pit soil samples were collected and analyzed as follows:

- TP-1, TP-2, and TP-3 were analyzed for TPH, TOX, and toxicity characteristic leaching procedure metals.
- TP-4 and TP-6 were analyzed for TPH and TOX.

3.1.1.3 REMEDIAL INVESTIGATION REPORT, LONE STAR/REICHHOLD SITE, PREPARED FOR REICHHOLD CHEMICAL AND LONE STAR NORTHWEST BY REMEDIATION TECHNOLOGIES, MAY 1996 (RETEC 1996)

The RI conducted in 1996 included soil sampling of 14 test pits (TP-1 through TP-14), 25 direct-push borings (GP 1 through GP-25), and seven hollow-stem-auger borings and monitoring well installations (MW-1S, -1D, -3S, -3D, -5S, -6S, and -7S). Monitoring well construction details for these wells are provided in Table 3-1. Selected soil samples were analyzed for PCP, chlorinated phenols, TPH, arsenic, silver, and formaldehyde.

3.1.1.4 PRE-REMEDIAL ACTION CHARACTERIZATION (FD-GTI 1998)

In November 1997, Fluor Daniel GTI, Inc. (FD-GTI) installed monitoring wells and collected soil data to aid in the design of remediation systems. Monitoring wells MW-8S and -9S were installed between monitoring wells MW-6S and -7S to conduct pilot remediation studies in the area where Reichhold's second PCP plant was formerly located. Monitoring well construction details for these wells are provided in Table 3-1.

Between October 13 and 14, 1998, FD-GTI installed monitoring wells MW-10S through MW-14S and MW-16S through MW-21S (Table 3-1). Two soil samples were collected from each soil boring prior to installing the monitoring well. Specifically, one sample was collected from the 5.5- to 6.5-foot-bgs interval, and one sample was collected from the bottom 0.5- to 1-foot interval in each boring. Samples were submitted to North Creek Analytical Laboratories for analysis of arsenic and PCP using USEPA Methods 6020 and 8270C, respectively.

3.1.1.5 ADDITIONAL ARSENIC INVESTIGATION RESULTS, JULY 2003 (SHAW 2003)

In July 2003, Shaw installed six additional groundwater monitoring wells (designated MW-22S through MW-27S; Table 3-1) screened within the shallow aquifer to further delineate arsenic impacts in shallow soil. Soil samples were collected during monitoring well drilling activities. Soil samples were analyzed for arsenic by USEPA 6000/7000 series methods. Three soil samples each were collected from MW-22S, -23S, -24S, and -25S. Four soil samples each were collected from MW-26S and -27S.

3.1.2 HISTORICAL GROUNDWATER INVESTIGATIONS AND MONITORING (1990–2007)

Groundwater investigations and periodic groundwater monitoring activities were carried out at the Site starting in 1990 and continuing through June 2007. Brief descriptions of the groundwater investigations and groundwater monitoring events are presented below. An evaluation of historical Site groundwater data is presented in the Data Gaps Report (DGR; ERM 2009). Current groundwater conditions are discussed in Section 5.2 of this RI report.

- In 1990, Parametrix installed three groundwater monitoring wells (B-1 [MW-1], B-2 [MW-2], and B-3 [MW-3]) to evaluate groundwater flow direction and potential groundwater impacts. One sample from each well was collected and analyzed for VOCs, SVOCs, and dissolved metals.
- In 1996, RETEC installed seven monitoring wells (MW-1S, -1D, -3S, -3D, -5S, -6S, and -7S) and sampled the wells for chlorinated phenols, arsenic, silver, and formaldehyde (MW-2S only). Additionally, 15 direct-push groundwater samples (GP-10 through GP-16 and GP-18 through GP-25) were collected and analyzed for arsenic to delineate arsenic impacts in groundwater.
- In November 1997, FD-GTI installed two monitoring wells, MW-8S and MW-9S, to aid in the design of remediation systems. In October 1998, 12 additional wells (MW-10 through MW-21) were installed. Subsequent groundwater monitoring events and remediation system performance monitoring at selected monitoring wells were completed from 1998 through 2003. Samples were analyzed for arsenic and PCP.
- In July 2003, Shaw installed six additional groundwater monitoring wells (designated MW-22 through MW-27) screened within the shallow aquifer to delineate arsenic impacts in shallow groundwater. Samples were collected from the new monitoring wells, as well as existing monitoring wells MW-2S through MW-4S, MW-6S, MW-10 through MW-14, MW-17 through MW-21, MW-2D, and MW-3D. Groundwater samples were analyzed for arsenic.
- Between 2004 and 2007, Shaw completed periodic groundwater remediation performance and compliance sampling of selected monitoring wells for PCP.

3.1.3 SEEP SAMPLING

Two different seep sampling events have been conducted along the shoreline adjacent to the Embayment. One was conducted by Hart Crowser in 1995. A more extensive survey and sampling of seeps along the LDW was conducted by Windward Environmental, LLC (Windward; 2004). The two investigations are summarized below. The approximate seep sample locations are shown on Figure 3-1.

Hart Crowser collected water samples from three surface water seeps on May 15, 1995. The seeps were observed to discharge from the shoreline adjacent to the Embayment and appeared to reflect discharges from a shallow groundwater zone. Samples collected from these seeps were designated as locations SW-01, SW-02, and SW-03 (Figure 3-1). In order to obtain seep samples with relatively lower dilution by LDW surface water, sampling occurred immediately after a relatively low tide event. The seep samples were submitted for laboratory analysis of total arsenic, total silver, PCP, and diesel-range TPH.

In July 2004, two seeps (SP-61 and SP-62; Figure 3-1) were identified along the shoreline of the Embayment (Windward 2004). The area was characterized as having a high seepage level, as several rivulets were observed flowing along the shoreline. Seep 61 was selected for sampling because the water associated with Seep 61 was discolored, and a sulfide odor was observed during the seep reconnaissance survey (SAIC 2007). Seep 62 was sampled because dioxins/furans (D/Fs) had been detected in the sediment near Seep 62. Samples from Seeps 61 and 62 were analyzed for metals, mercury, SVOCs (including PCP and its breakdown products), polynuclear

aromatic hydrocarbons, VOCs, PCBs, organochlorine pesticides, and dissolved organic carbon. The sample from Seep 61 was also analyzed for total organic carbon (TOC) and total suspended solids. Seep sampling results are discussed in Section 5.3.

These seep samples discussed above were collected from seeps representative of groundwater discharging from the shallow aquifer. A seep representative of groundwater discharging from the deep aquifer was identified by ERM in March 2011 (Figure 3-1 and Appendix II); however, the seep was not sampled. It is reasonable to expect that samples of groundwater discharging from the deep aquifer would not alter the understanding of nature and extent or change the CSM. It is also reasonable to expect that the concentrations of COPCs in the deep groundwater discharging to the river would be lower than those in the shallow seeps on the Property because the deep aquifer groundwater has lower COPC concentrations than shallow aquifer groundwater, and more tidally driven salt water intermixing in groundwater relative to shallow seeps. The contributions of freshwater from the regional confined lower sand unit and salt water from the tidally influenced LDW flow from the north, south, and east make up a majority of the volume of water discharging from the deep groundwater to the river. As such, the shallow aquifer seep sampling (discussed in Section 5.3) where COPCs are more prevalent provides a representative characterization of the seep to surface water and sediments pathway.

3.1.4 PREVIOUS SEDIMENT SAMPLING IN AND NEAR THE EMBAYMENT

Numerous sediment sampling events have occurred in the LDW since 1990. The surface (generally the top 10 cm) and subsurface (below 10 cm) sediment samples collected in or near the Embayment are summarized in this section. The following sediment sampling activities have been performed in and directly upstream/downstream of the Embayment:

- In 1992, one composite sample (C-1) was collected from two sediment cores as part of a pre-dredge sediment characterization effort for Glacier Northwest (Hartman 1992). The sediment represented by this sample location was removed during maintenance dredging in 1993.
- In 1993, five surface sediment samples (SS-1 through SS-5) were collected by DSI to comply with the sediment sampling requirements established in DSI's NPDES waste discharge permit (Hart Crowser 1993). The sediment represented by sample location SS-5 was removed during maintenance dredging in 2005.
- In 1998, surface and subsurface sediment samples (DR121 through DR124) were collected as part of the USEPA investigation of the LDW (Weston 1999). These data were summarized and discussed in the LDWG Phase 1 RI Report (Windward 2003).
- In 2002, three subsurface sediment samples (SCDMMU1 through SCDMMU3) were collected from nine cores as part of a pre-dredge sediment characterization effort for Glacier Northwest (Pacific International Engineering 2002). The sediment represented by all three sample locations was removed during maintenance dredging in 2005. A portion of the dredged section was capped as part of the maintenance dredging.
- After completion of the maintenance dredging in 2005, six additional samples (GNW-02-A, GNW-02-B, GNW-02-C, GNW 03 A, GNW-03-B, and GNW-03-C) were collected from the "Z layer" under the cap that was placed on a portion of the dredged area.

- In 2005, surface sediment samples were collected from the Embayment and immediately downriver/upriver as part of the Phase 2 RI conducted on behalf of the LDWG (Windward 2005a, 2005b, 2005c). The samples were identified as LDW-SS53, LDW-SS55 through LDW-SS59, and LDW-SSB4a.
- In 2006, subsurface sediment samples were collected from two locations (LDW-SC28 located adjacent to the navigation channel and LDW-SC29 located on the Property) as part of the Phase 2 RI for the LDWG (Windward and RETEC 2007) as shown on Figure 3-2.

Analytical data are discussed in Section 6. The majority of these sample locations are provided on Figure 3-2. Locations for older samples (1992 and 1993) or samples that have been dredged (1992, 1993, and 2002) and/or replaced by more recent samples are not presented.

3.1.4.1 PREVIOUS SEDIMENT DEPOSITION STUDIES

Sediment transport modeling of the LDW has been completed as part of the LDWG Phase 1 and 2 RIs and other investigations. The results of the sediment transport model were presented in *Data Report: Sediment Transport Characterization – Final* (Windward 2005d) and summarized in the LDW Phase 2 RI (Windward and RETEC 2007) for three reaches of the LDW:

- Reach 1 includes RM 0.0 to RM 2.2;
- Reach 2 includes RM 2.2 to RM 4.0; and
- Reach 3 includes RM 4.0 to RM 4.8.

Reach 1, which includes the Embayment (located between RM 1.4 and RM 1.5), was determined to be net depositional over multi-year periods with net sedimentation throughout this reach of the LDW. Within Reach 1 (RM 0.0 to RM 2.2), net sedimentation rates greater than 2 cm/yr occur between RM 1.4 and RM 2.2, with lower rates (typically 0.5 to 2 cm/yr) downstream of RM 1.4 (Windward and RETEC 2007).

Average net sedimentation rates in the general Embayment area are approximately 2 to 3 cm/yr (Windward 2010). The net depositional environment in this area was confirmed both by Site-specific measurements (e.g., radioisotope cores collected by LDWG as part of the LDW RI/FS) and by bathymetric surveys and sample observations performed by Glacier Northwest following the 2005 maintenance dredging. It should be noted that sediment accumulation rates are higher within the maintenance dredging area due to the lower energy environment in this deepened area, compared with adjacent LDW areas.

3.1.5 PREVIOUS DREDGING CHARACTERIZATION

Maintenance dredging occurred adjacent to the Embayment in 1986, 1993, 2005, 2017, and 2023 to maintain depths in the berthing area immediately east of the existing Glacier Northwest dock. These activities are described in the following sections. Dredging may have also occurred adjacent to the Embayment in 1967 as indicated by the 1967 dock installation plan included in Appendix M. The second page of the dock installation plan includes a drawing showing the bottom of the channel and the approximate existing grade before dredging, suggesting that dredging was planned; however, records confirming that dredging occurred are not available.

Some information on historical dredging conducted on the neighboring DSI property is presented in the DSI RI Report (Anchor QEA 2019). Maintenance dredging, conducted by DSI, occurred adjacent to the northeast corner of the Site in 1967 and the early 1980s (Windward 2010). This maintenance dredging was performed around the berthing areas of the DSI property to support the use of their dry docks. The volume of material dredged in 1967 is unknown, but the permit allowed for up to 2,000 cubic yards. The material dredged in 1967 was disposed of in the open water in Elliott Bay. In 1981 and 1982, DSI dredged 26,799 cubic yards of material, which was also disposed of in Elliott Bay. The area dredged in 1981/1982 was close to the outfall of a historical Reichold drainage ditch.

3.1.5.1 1986 DREDGING ACTIVITIES

Maintenance dredging around the Glacier Northwest dock was conducted by Lone Star Northwest in 1986 (Windward 2010). The dredged material was disposed of on an upland site as it was determined to not be suitable for open water disposal. The volume of material dredged from around the dock is unknown.

3.1.5.2 1993 DREDGING ACTIVITIES

In 1993, Glacier Northwest completed maintenance dredging in the area adjacent to the Glacier Northwest dock to maintain berthing depths. On May 29, 1992, prior to maintenance dredging, two sediment samples were collected and composited for laboratory analysis (C1—representing a single management unit). In accordance with Dredge Material Management Plan (DMMP) guidelines, these samples were composited into one sample for chemical analyses to characterize the material proposed to be dredged. Several analytes were detected at concentrations above the DMMP screening levels (SLs) in use at that time. Due to these SL exceedances, the composite sample was submitted for biological (bioassay) testing. The sediment sample passed the bioassay criterion and the material was determined to be suitable for open water disposal.

3.1.5.3 2005 DREDGING ACTIVITIES/2005 CAP MONITORING

In 2005, Glacier Northwest completed maintenance dredging to maintain berthing depths adjacent to the Glacier Northwest dock. Prior to maintenance dredging, Glacier Northwest collected and analyzed nine core samples from the proposed dredge prism within the berthing area following the DMMP guidance for characterization of dredge material. The entire dredge prism was divided into three dredged material management units (DMMUs), numbered sequentially DMMU 1 to DMMU 3 from south to north. Individual subsurface sediment samples were collected from each DMMU. The collected samples were composited into three samples, one representing each of the three DMMUs. Only one constituent, total PCBs, was detected in the composite sample representing DMMU 1 and DMMU 2 at a concentration exceeding the DMMP SLs in use at the time. PCBs, arsenic, zinc, and total dichlorodiphenyltrichloroethane were detected in the composite sample representing DMMU 3 at concentrations exceeding the DMMP SLs, and tributyltin was detected in pore water at a concentration that exceeded the bioaccumulation trigger. All three composite samples subsequently underwent biological (bioassay) testing following the tiered testing approach outlined in the DMMP guidance manual. The composite sample from DMMU 1 passed the bioassay criterion and the material was determined suitable for open water disposal. The

composite sample from DMMU 2 failed the bioassay criterion. The composite sample from DMMU 3 passed the bioassay criterion, but because tributyltin concentrations in pore water exceeded the bioaccumulation trigger, the dredged material from DMMU 3 was not considered suitable for open water disposal unless bioaccumulation testing was performed and the testing indicated the material met the relevant criterion. Glacier Northwest determined that conducting bioaccumulation testing on the composite sample from DMMU 3 would not be cost effective and elected to dispose of material dredged from DMMU 3 at an upland facility.

The dredged material from DMMU 2 and DMMU 3 was taken to an upland facility for disposal. Because the dredged material from DMMU 2 and DMMU 3 was considered unsuitable for open water disposal, Glacier Northwest analyzed the archived core samples collected 1 foot below the DMMU 2 and DMMU 3 dredge prisms (designated “Z layer” samples) to characterize the surface sediments that would be exposed following dredging. DMMU 2-Z was analyzed for total PCBs and metals. No PCBs were detected. Arsenic was detected at 64.3 milligrams per kilogram (mg/kg), slightly above the state sediment quality standards (SQS) of 57 mg/kg. The detected mercury concentration of 0.6 mg/kg was above both the SQS and cleanup SL of 0.41 and 0.59 mg/kg, respectively. Sample DMMU 3-Z was analyzed for tributyltin (pore water) only. The detected tributyltin concentration of 3.4 micrograms per liter (µg/L) was above the DMMP SL and bioaccumulation trigger criteria of 0.15 µg/L. Other chemicals such as arsenic, copper, and mercury were assumed to be present in subsurface sediments under DMMU 3 based on observed layers of grit blast in sediment cores from DMMU 3 that ranged between 1.5 and 6 feet thick and occurred between depths of -34.5 MLLW and -41.4 MLLW.

Following dredging to -36 MLLW, Glacier Northwest placed a 1-foot cap comprised of clean sand and gravel over the newly exposed surface of DMMUs 2 and 3. The sand and gravel cap was designed to contain the newly exposed surface sediments and armor the river bottom from propeller wash. Glacier Northwest conducted follow-on bathymetric surveys to ensure proper placement of the cap and that it remained in place.

Glacier Northwest conducted chemical testing of the cap material, which was designed to confirm that the cap did not mix with subsurface sediments or allow chemicals to migrate up through the cap to the surface. Samples collected a week, a year, and 3 years after installation of the cap were analyzed for TOC, grain size, PCBs, arsenic, zinc, and mercury. Results from all three sampling events confirmed that the concentrations in the cap material were well below the SQS for the chemicals.

The rate of sediment deposition within the berthing area following cap placement in 2005 is significant. Silt accumulated on the cap rapidly, with about an inch of accumulation observed at the 3-month post-cap monitoring interval, about 4 to 6 inches at the 1 year post-cap monitoring interval, and 1 to 1.5 feet of accumulated material observed at the 3-year post-cap monitoring interval.

3.1.5.4 2017 DREDGING ACTIVITIES

Between January 27 and February 14, 2017, Glacier Northwest completed maintenance dredging in the area adjacent to the Glacier Northwest dock to maintain berthing depths (Anchor QEA 2017). Based on pre- and post-bathymetry data, a total of 9,316 cubic yards of material were

removed and disposed of at two upland disposal sites licensed to accept the material (Anchor QEA 2017). Pre-dredging characterization was not performed; however, surface sediment sampling was completed following the dredging event to confirm that the maintenance dredging activities did not disturb the cap installed following the 2005 dredging event (Anchor QEA 2017).

On February 14, 2017, six surface sediment samples were collected from the limits of the existing cap and visually assessed for the presence of recently deposited silty sediment accumulated on the cap material placed in 2005. The results of the sediment sampling event indicated that a sufficient buffer was maintained above the existing cap during the maintenance dredging and that the cap was not disturbed (Anchor QEA 2017).

3.1.5.5 2023 DREDGING ACTIVITIES

Between February 23 and March 8, 2023, Glacier Northwest completed maintenance dredging in the area adjacent to the Glacier Northwest dock to maintain berthing depths (Anchor QEA 2023). Based on pre- and post-bathymetry data, a total of 7,849 cubic yards of material were removed and disposed of at an upland disposal site licensed to accept the material (Anchor QEA 2023).

Two grab samples were collected on February 13, 2023, and analyzed to characterize the material for waste disposal. Analytical results are provided in Appendix HH.

3.2 PREVIOUS INDEPENDENT REMEDIAL ACTIONS

In 1998, on behalf of Glacier Northwest and Reichhold, FD-GTI conducted several investigations and treatability studies and began implementing remedial actions for PCP and arsenic in groundwater. Based on previous investigations, PCP impacts were understood to be primarily located in the north-central area of the Site where Reichhold formerly operated a PCP production plant, and in the east-central area of the Site where Reichhold impounded washwater (Figure 2-10) between approximately 1955 and 1960. Based on previous investigations, arsenic impacts were understood to be primarily located in the south-central and southeastern areas of the Site where Mineralized-Cell formerly operated. The remedial actions were performed as independent remedial actions under MTCA (WAC 173-340-515). The independent remedial actions completed at the Site are summarized below and were detailed in the Remedial Activities Summary Report (RASR; Shaw 2008) and DGR (ERM 2009).

3.2.1 PENTACHLOROPHENOL IN GROUNDWATER REMEDIATION – OZONE SPARGING

Ozone has been shown to be effective in the remediation of a variety of organics, including PCP (Nelson and Brown 1994). An ozone sparging system was designed and installed to treat PCP in groundwater in the shallow aquifer at the Site; 22 sparge wells were installed in the north-central area of the Site, and 28 sparge wells were installed in the east-central area of the Site. A soil vapor extraction system was also installed to capture ozone that was not oxidized in the subsurface. Operation of the in situ ozonation system began in April/May 2000. The ozone sparge system operated until post-treatment monitoring commenced in October 2005. The field testing, system installation, operational history, and observed results of the ozone sparge system are detailed in the RASR. A discussion of current PCP concentrations in groundwater is presented in Section 5.2.4.

3.2.2 ARSENIC IN GROUNDWATER REMEDIATION – HYDROGEN PEROXIDE FIXATION

Dissolved arsenic in shallow groundwater was treated by an oxidative process carried out with hydrogen peroxide injections intended to result in the geochemical fixation of the arsenic. Field tests were conducted in March 1998 to determine the feasibility of using an oxidative process for treating arsenic at the Site. A “push-pull” test was conducted in March 1998 by FD-GTI. A detailed summary of the field testing to support arsenic remediation by precipitation and system installation information is presented in the RASR (Shaw 2008).

A hydrogen peroxide infiltration gallery was constructed in the south-central area of the Site. The initial injection of hydrogen peroxide was applied during February and March 2000, with the first round of groundwater monitoring completed on March 16, 2000. The second and final injection event was completed in May and June 2000. Approximately 20,000 gallons of 3 percent hydrogen peroxide solution was piped into the infiltration gallery during the two treatment events. Initially, arsenic concentrations in groundwater after treatment were reduced by as much as two orders of magnitude. After the in situ treatment, the Site likely reverted to reducing conditions, and arsenic concentrations appeared to rebound in the groundwater at several of the monitoring wells. A discussion of current arsenic concentrations in groundwater is presented in Section 5.2.1.

3.3 SUMMARY OF CONTEMPORARY REMEDIAL INVESTIGATION ACTIVITIES (2009–2019)

This section summarizes the RI field data collection activities completed at the Site between March 2009 and August 2014 and the data gaps investigation completed in May 2019. The RI activities were conducted in stages and completed in accordance with the Agreed Order and the methods and procedures in the RI/FS Work Plan as summarized below.

3.3.1 UPLAND SOIL INVESTIGATION

Soil sampling of the upland portion of the Site was conducted via direct-push and sonic drilling methods at 49 soil borings across the Site as shown on Figure 3-3 (GP-26 through GP-75). Shallow boreholes were advanced to the top of the silt aquitard layer. Soil samples were collected from the shallow fill, dredged fill, and the dredged fill interface with the silt aquitard in accordance with the RI/FS Work Plan. Five deep borings (GP-42, GP-51, GP-69, GP-71, and GP-74) were advanced using conductor casing through the aquitard to characterize soil quality within the aquitard and the lower sand unit to depths ranging between 13 and 28 feet bgs.

Soil samples were collected for laboratory analysis from each of the borings as prescribed in the RI/FS Work Plan and based on visual and field screening observations. Soil samples were analyzed in accordance with the analytical parameters in the RI/FS Work Plan and as presented in Table N-1 in Appendix N.

In accordance with the RI/FS Work Plan, Ecology and Glacier Northwest met in June 2014 to select archived soil samples to be analyzed. Soil samples were collected in accordance with the RI/FS Work Plan, and the analytical results are presented and discussed in Section 5. Borehole logs are included as Appendix O.

3.3.2 RIVERBANK SOIL SAMPLING

In January 2014, riverbank soil sampling was performed at seven locations (TB-01 through TB-07) shown on Figure 3-4. Six top-of-riverbank borings (TB-01 through TB-06) were completed using direct-push methods.

Soil samples were collected from the shallow fill, dredged fill, and dredged fill interface with the silt aquitard, where observed. The silt aquitard was observed at the top-of-riverbank locations TB-01 through TB-05, and the target completion depth for each of those borings was 6 inches into the top of the silt aquitard.

The silt aquitard was not observed at location TB-06. The target completion depth for borings at TB-06 was 20 feet bgs. Six attempts were required at TB-06 to penetrate a subsurface layer of concrete encountered between 11.5 and 14 feet bgs. The first five attempts (TB-06A through E) were completed using direct-push methods. The final attempt (TB-06F) was completed to 20 feet bgs using sonic drilling methods. Borehole logs are included as Appendix O.

Top-of-riverbank boring TB -07 was advanced with a hand auger to 1 foot bgs on the embankment near the northern boundary of T115 because of the underlying bank armor. The purpose of this soil sample was to evaluate the nature of fill placed during construction of T115 and the subsequent soil deposition. Top-of-riverbank samples were collected in accordance with the analytical parameters in the RI/FS Work Plan and as presented in Table N-1 in Appendix N.

3.3.3 GROUND PENETRATING RADAR SURVEY

Historical maps as well as aerial photographs, taken at various times and dating back to 1936, show the location and configuration of historical ditches in the northern, central, and southern portions of the Property (Appendix A1). The historical ditches were used by previous owners and operators to convey stormwater and process water from the Property to the LDW. As described in Section 2, the owners and operators that used the historical ditches include King County, Mineralized-Cell, Carlisle, the Army, Crown Zellerbach, Reichhold, the Port of Seattle, and Kaiser. The objective of the ground penetrating radar (GPR) survey was to augment current knowledge of the location and configuration of these ditches, and adjust the locations where samples from soil borings and the riverbank would be collected in proximity to the historical ditches.

On September 20, 2012, GeoPotential of Portland, Oregon, completed a geophysical GPR survey at the Site under ERM supervision. Consistent with the RI/FS Work Plan, the GPR survey consisted of surveying multiple transects perpendicular to the location of the suspected historical drainage ditch locations. In addition, several east-west trending transects were completed as a safety precaution to screen for utilities prior to intrusive field activities (see Figure 3-5 for GPR transects). The results of the GPR survey were summarized in the geophysical report of findings prepared by ERM (Appendix P).

3.3.4 MONITORING WELL INSTALLATION

Eighteen groundwater monitoring wells were installed as part of the RI field activities to supplement the existing groundwater monitoring well network consisting of 26 groundwater monitoring wells. Ten shallow monitoring wells (MW-28S through MW-36S, MW-43S, and MW-45S)

were installed to depths ranging between 7 and 13 feet bgs. Eight deep aquifer monitoring wells (MW-14D, MW-20D, MW-31D, MW-32DR, MW-35D, MW-38D, MW-43D, and MW-45D) were installed to depths ranging between 24 and 29.5 feet bgs. Monitoring well locations are shown on Figure 3-6 and well construction details are included in Table 3-1. Monitoring well construction logs are included in Appendix O.

Soil samples collected for laboratory analysis during monitoring well installation were collected and analyzed in accordance with the RI/FS Work Plan and as described in Table N-1 in Appendix N. Following completion of well construction activities, the wells were developed a minimum of 24 hours after well installation and a minimum of 24 hours prior to collection of groundwater samples. Well development records are included in Appendix Q.

3.3.5 GROUNDWATER SAMPLING

Groundwater sampling activities were completed at the Site between 2009 and 2012 (March 2009, April/June 2010, October 2010, April/July 2011, November/December 2011, and April/May 2012), in 2014 (March 2014 and August 2014), and in 2015 (March/April 2015 and August/September 2015) using a combination of low-flow and no-purge sampling methodologies. Groundwater sampling was conducted in accordance with the analytical parameters presented in the RI/FS Work Plan and as summarized in Table N-2 in Appendix N. The number of wells and groundwater analytical parameters were revised during each event between 2009 and 2012 as the RI/FS Work Plan was refined and finalized. The RI/FS Work Plan Addendum issued in September 2013 identified the groundwater sample parameters for the groundwater sampling in 2014 and 2015. Based on the results of the March 2014 sampling event, and in accordance with the RI/FS Work Plan, the number of monitoring wells selected for analysis of D/Fs and PCBs was modified for the August 2014 and 2015 events, which included the following changes:

- Add D/Fs to three wells (MW-1S, MW-22S, and MW-27S) and sample using no-purge methodology.
- Eliminate PCB sampling in MW-29S.
- Add PCBs to three wells along the riverbank (MW-27S, MW-33S, and MW-45S) and sample using no-purge methodology.
- Eliminate VOCs from MW-17S and MW-34S.

Previous groundwater monitoring events conducted between 2009 and 2012 were completed and reported to Ecology in technical memoranda included as Appendix R.

3.3.6 STORMWATER SAMPLING

Four stormwater sampling events were completed during the 2012 to 2013 sampling season, with four samples collected over three seasons (fall, winter, and spring). Stormwater grab samples and duplicates were collected from the current Sand and Gravel Permit point of compliance sampling location (STW-01; Figure 3-7) on October 30, 2012, December 14, 2012, January 9, 2013, and April 8, 2013. Stormwater sampling was completed in accordance with the methods and procedures described in the RI/FS Work Plan. Stormwater samples were collected and analyzed for metals, VOCs, TPH, SVOCs, polycyclic aromatic hydrocarbons (PAHs), PCBs, and D/Fs in

accordance with the RI/FS Work Plan and as summarized in Table N-3 in Appendix N. The results are presented and discussed in Section 5.

3.3.7 STORMWATER SOLIDS

On September 4, 2012, four stormwater solids samples were collected from the Property stormwater system in accordance with the RI/FS Work Plan. Sample SWD-02 was collected from the stormwater swale before the point where stormwater is conveyed to the final holding tank for settling of solids. The sample collected from the holding tank (TANK-01) represents solids captured in the tank before stormwater is conveyed to the final section of the swale. Stormwater captured from the paved areas in the northern portion of the Property is directed to catch basin CB-01, and subsequently stormwater is conveyed from the catch basin to the final section of the swale. Solids sample SWD-01 was collected from the final section of the swale before the sampling point required by the Sand and Gravel Permit. The sampling locations are shown on Figure 3-7. The stormwater solids samples were collected and analyzed in accordance with the RI/FS Work Plan and are summarized in Table N-4 in Appendix N. The results are presented in Section 5.5.

3.3.8 PLUGGING AND ABANDONMENT OF HISTORICAL STORMWATER PIPE

Solids samples from the historical stormwater pipe were collected between August 4 and 6, 2014, in accordance with the RI/FS Work Plan and Historical Stormwater Pipe Abandonment Plan dated July 2014 (ERM 2014) included as Appendix S. It is important to note that solids samples from the historical pipe may be more representative of stormwater from the SPU 48-inch-diameter stormwater outfall and the LDW than stormwater from the Site. The historical stormwater pipe was connected to the SPU 48-inch stormwater outfall prior to plugging and abandonment according to regulatory requirements in August 2014, but catch basins associated with the system were plugged with concrete prior to 1991. The SPU 48-inch-diameter stormwater outfall is fully inundated during high tide cycles, therefore, the historical stormwater pipe may have also been inundated prior to its plugging and abandonment in 2014.

On August 4, an excavator was used to expose the stormwater pipe upgradient of the location where it ties into the 48-inch-diameter SPU stormwater line near the southern entrance to the Property (Figure 3-8). The top of the stormwater pipe was discovered at a depth of 8.6 feet bgs. The pipe was confirmed to be a 15-inch-diameter reinforced concrete pipe. Each pipe segment was approximately 6 feet in length and constructed with bell and spigot joints. The material around the exterior of the pipe was compact and the same as surrounding soils (i.e., bedding material was not present). To evaluate the interior contents of the pipe, a small 3- to 4-inch hole was created on top of the pipe with the teeth of the excavator bucket. A trace amount of water was observed at the bottom of the pipe and a multi-gas meter was utilized to verify sewer gases were not present within the pipe. Subsequently, an approximate 5- to 6-foot section of pipe was removed with an excavator. ERM's subcontractor manually inspected the interior of the stormwater pipe and confirmed the presence of solids in the up-flow pipe. A solids sample (SWP-01-082414) was collected in accordance with the RI/FS Work Plan.

A camera survey was performed to inspect the stormwater pipe north of the cut. The purpose of the inspection was to evaluate whether the drainage system was fully constructed as mapped in the SPU records and to assess pipe integrity along the length safely accessible to the camera equipment. During the initial survey of the stormwater pipe, the camera was advanced approximately 30 feet up-flow before becoming submerged in wet sediment and water, obscuring the camera footage. Several unsuccessful attempts were made to advance the camera further up-flow beyond the accumulated sediment and water. With the camera lens submerged in water, it was not possible to obtain video footage or guide the camera within the pipe. At this point, the focus of the survey changed from inspecting the integrity of the stormwater pipe to locating the "T" where the stormwater system was shown to branch out to the east and west on the as-built drawings. In lieu of the camera, a sonde was deployed into the stormwater pipe and pushed until it could not be advanced any further, approximately 140 feet up-flow. The location of the pipe was traced out on the ground surface with green spray paint to its terminus, which was assumed to be the approximate location of the "T."

On August 5, ERM's subcontractor began excavating at the approximate location of the "T," as marked by the camera survey crew. A vertical concrete column was encountered at a depth of approximately 3.5 feet bgs and was measured to be 4 feet in diameter. The vertical column was interpreted to be the location of the "T" shown on the as-built drawings. Initial observations of the vertical column appeared to indicate that it had been backfilled with controlled density fill (CDF). A "Type B" catch basin would have likely been fitted on top of the vertical column; however, it had been removed before 1991 when Glacier Northwest acquired the Property.

Excavation continued around the "T" until the main line was exposed on the southern side of the column at a depth of 7.5 feet bgs and a lateral pipe (15-inch reinforced concrete pipe) on the western side of the column was exposed at a depth of 6.9 feet bgs. The western lateral pipe was opened and observed to be filled with water. The main line was also opened a few feet south of the "T" and contained only a small amount of water. The interior of the "T" was inspected from the main line and was confirmed to have been filled with CDF confirming that the historical stormwater pipe was plugged before Glacier Northwest acquired the Property in 1991. No water was observed to flow within the "T" or from the west lateral line into the north-south main line. Per Ecology's request, a second solids sample (SWP-02-082414) was collected from sediment in the down-flow portion of the main line (a few feet south of the "T") in accordance with the procedures outlined in the Historical Stormwater Pipe Abandonment Plan and RI/FS Work Plan. No further investigation of the stormwater system was conducted because of the discovery of the "T"; the western lateral line confirmed the drainage system was fully constructed as mapped in the SPU records.

Upon completion of solids sampling and the camera survey, both ends of the stormwater pipe (near the southern entrance) were capped with a 3-foot plug consisting of hydraulic cement. The down-flow portion of the stormwater pipe at the "T" was also capped with a 3-foot hydraulic cement plug. Prior to backfilling, the cap was inspected and approved by the City of Seattle Department of Planning and Development on August 6, 2014. Each of the excavations was backfilled with approximately 2 yards of CDF to the top of the pipe to permanently seal the pipe ends and to confirm that the pipe is not a preferential pathway for groundwater at the Site. The

CDF was allowed to cure overnight, then each of the excavations was backfilled and compacted in 1- to 2-foot lifts using the stockpiled soil in the reverse order it was excavated. Compaction was performed with a backhoe and a hydraulic compaction plate attachment.

The historical stormwater system ceased being an active stormwater pathway when the catch basins were plugged with concrete before 1991, and the activities completed in August 2014 provided further assurance that the historical pipe is not a current or future conveyance pathway.

3.3.9 SEDIMENT INVESTIGATION ACTIVITIES

Surface and subsurface sediment samples were collected from within the Embayment and the berthing area adjacent to the Glacier Northwest dock to evaluate the lateral and vertical extent of COPCs. Sediment sampling was completed between May 22, 2012, and June 1, 2014. With Ecology's approval, the sediment sampling was conducted in accordance with a Sediment Sampling Plan included in a previous draft of the RI/FS Work Plan (Draft RI/FS Work Plan; ERM 2012a).

A total of 20 surface sediment samples and 17 sediment cores were collected within the Embayment and the berthing area. The surface sediment and subsurface core sample locations are shown on Figure 3-2. Surface grabs and sediment cores were co-located within approximately 6 feet to provide spatial continuity between grabs and cores for purposes of data interpretation. Three sample location pairs, SS/SC-06, SS/SC-15, and SS/SC-18, required relocation due to sediment conditions, which resulted in co-located distances greater than 6 feet. Subsurface sediment core SC-06 was moved approximately 17 feet northeast of surface grab SS-06 following an attempt that did not meet the core acceptance criteria. Several attempts were made to collect an acceptable grab sample at SS-15; however, due to the rocky substrate, the station was relocated approximately 21 feet northeast of the original location where subsurface sediment core SC-15 was collected. Similarly, SC-18 was moved approximately 13 feet east of surface grab SS-18 as a result of multiple core attempts with low recoveries.

Surface sediment samples were collected from the 0 to 10 cm biologically active zone using a Van Veen grab in accordance with the sampling procedures described in the Sampling and Analysis Plan (ERM 2012b). Subsurface samples were collected from 17 locations using a Vibracore sampler with a 4-inch-diameter polycarbonate core tube. Subsurface sediment core tubes were cut open and sampled in 1-foot intervals between the surface and 2 feet below the mud line. Samples were collected from 2-foot core sections starting with the 2- to 4-foot interval to the bottom of the core sample at the depth of refusal. Sediment samples were collected and analyzed in accordance with the Sediment Sampling Plan in the RI/FS Work Plan. The sediment sample analyses are summarized in Table N-5 in Appendix N. The results of the sediment sampling are presented and discussed in Section 6. The surface sediment and subsurface sediment core logs are included as Appendix T.

In May 2013, 17 of the archived subsurface sediments samples were submitted for laboratory analysis to further characterize the vertical and lateral extents of constituents in sediment.

3.3.10 DATA GAPS INVESTIGATION

In May 2019, a soil investigation was completed at the Site to collect the data necessary to further characterize the nature and extent of arsenic, D/Fs, and total PCBs (Aroclors) in soil. Soil sampling in the upland portion of the Site was conducted in accordance with the Ecology-approved *Data Gaps Investigation Work Plan* (ERM 2018).

Eight soil borings (GP-76 through GP-83) were advanced within the upland portion of the Site as shown on Figure 3-3. Soil sampling of the upland portion of the Site was conducted via direct-push and sonic drilling methods. Soil samples for laboratory analysis were collected from the shallow fill, dredged fill, and the dredged fill interface with the silt aquitard in accordance with the Data Gap Investigation Work Plan. Soil samples collected for laboratory analysis were analyzed in accordance with the Data Gaps Investigation Work Plan and as described in Table N-1 in Appendix N. Analytical results of the soil samples are discussed in Section 5.1. Borehole logs are included as Appendix O.

3.4 SUBSURFACE IMAGE EVALUATION

In August 2014, a soil investigation was completed at the Site to evaluate a subsurface image that was observed during utility clearance for the upland investigation work in October 2013 and January 2014. This investigation was not a required scope element in the RI/FS Work Plan; however, the scope of the investigation was detailed in the Historical Stormwater Pipe Abandonment Plan dated July 2014 (included as Appendix S). Based on the utility clearance, the subsurface image was believed to be a metallic line located 2 to 3 feet bgs. As-built drawings and historical documents did not depict utilities in this particular location of the Site. Three test pits were planned to evaluate the subsurface image (see Figure 3-9).

The first test pit was advanced at the eastern extent of the subsurface image, approximately 10 feet south of monitoring well MW-45D. At approximately 3 feet bgs, a 3-inch-diameter welded ductile iron pipe was observed. At the eastern portion of the excavation, the elevation of the iron pipe decreased to 3.3 feet bgs and turned to the northeast toward well MW-45D. Investigation of the iron pipe in this direction was not continued to avoid compromising the integrity of well MW-45D. The contents of the iron pipe were observed by penetrating the pipe. Water was observed to flow under gravity out of the pipe for a minute before the pipe was plugged. A description of the soils encountered in the eastern-most test pit is discussed below.

A second test pit was advanced at the western extent of the subsurface image. An excavation measuring 11 feet by 13 feet was advanced to approximately 6.5 feet bgs. The iron pipe was not observed at this location.

On August 8, a third test pit was advanced approximately 200 feet east of the second test pit (Figure 3-9). At approximately 2 feet bgs, a 4-inch ductile iron pipe was uncovered. The iron pipe was penetrated, but there was no water observed within the pipe at this location, and the pipe was plugged.

Based on the investigation, the subsurface image was interpreted to be a water line. On August 8, each of the exploratory test pits was backfilled and compacted with stockpiled soil.

Soils encountered during the test pitting activities in the eastern-most test pit are described below. A photo log of the test pit evaluation is provided in Appendix U. Brown to gray, gravelly sand was observed from ground surface to 2 feet bgs. At approximately 2 to 3.5 feet bgs, black fine carbon/charcoal-like material with pockets of red/brown sawdust was observed. Between 3.5 and 5 feet bgs, a gray fine silty sand was observed. Groundwater was not observed in the excavation. Along the eastern and, to a lesser extent, the southern sidewalls of the excavation, blue-colored material was observed within the horizon of black carbon material, later confirmed via laboratory analysis to be copper. Within these carbon strata, four charcoal briquettes were observed and recovered. One briquette was observed in situ on the eastern sidewall of the excavation at approximately 2 feet bgs, another briquette was observed within the excavation, and two briquettes were observed in the material stockpiled from the excavation. Each briquette was shaped like a “puck,” approximately 3.5 inches in diameter and 1.5 inches thick, and weighed approximately 375 grams. This material likely originated from the charcoal and whetlerite production process formerly conducted at the Site.

Approximately 3 feet north of the iron pipe in the central portion of the test pit, a small precast concrete box (3.5 feet by 2 feet) was discovered. The concrete box was exposed with the excavator and removed from the excavation for inspection. There was no piping or plumbing systems connected to the box. A brown-gray, sandy-like material with a pungent odor was observed in the box. A sample of the material was collected and submitted for laboratory analysis (sample SIIE-01-080814) in addition to samples of the sawdust material observed in the sidewall of the excavation (SIIE-02-080814), carbon material from the sidewall (SIIE-03-080814), and three charcoal briquettes (SIIE-04-080814, SIIE-05-080814, and SIIE-06-081214) (see Section 5.1 for reference to analytical results summary tables).

4. SCREENING LEVELS AND CONTAMINANTS OF POTENTIAL CONCERN

This section presents the development of SLs for impacted media at the Site for the purposes of identifying COPCs and evaluating the extent of contamination. Selection of SLs and identification of COPCs was undertaken in accordance with Ecology's LDW Preliminary Cleanup Level (pCUL) Workbook dated April 2019 (Workbook; Ecology 2019) using Site characterization data reported in this report. The April 2019 pCUL Workbook was used as the source of SLs.

The overall methodology for identifying SLs and COPCs is as follows:

1. Identify the applicable SLs in the Workbook for each hazardous substance in each media.
2. Organize the RI dataset; establish and apply rules for data usage within the analysis.
3. Determine COPCs by comparing hazardous substance concentrations in Site samples to the SLs.

The details of the methodology are described in the following sections.

4.1 SCREENING LEVELS

As part of source control efforts for the LDW, Ecology developed SLs for soil and groundwater at upland sites that have environmental fate and transport pathways that could potentially impact the LDW. Ecology also refers to the SLs as pCULs, but for clarity, they are only referred to as SLs in this report, as cleanup and remediation levels are developed as part of the FS. Ecology prepared SLs for upland sites following the technical approach described in Ecology's policy memorandum regarding groundwater cleanup levels (CULs) for upland sites along the LDW (Ecology 2016). The SLs for soil and groundwater are published in separate summary tables in the Workbook (Ecology 2019). Ecology also included SLs for sediment within the LDW in the Workbook, based on the LDW ROD CULs and Sediment Management Standards (SMS; WAC 173-206-562).

The Workbook summary tables are accompanied by a supplemental information paper that provides supplemental information and the recommended approach for using the SLs (Ecology 2018c). For soil and groundwater, Ecology compiled sets of SLs consisting of the lowest risk-based SLs developed for each transport and exposure pathway in these media. These SLs are referred to as the most stringent pCULs in the Workbook (Ecology 2019). Ecology's approach for identifying the most stringent pCUL for soil and groundwater in the Workbook is described in the supplemental information paper (Ecology 2018c). The following sections describe the SLs used to identify COPCs in Site soil, groundwater, and sediment.

4.1.1 SOIL SCREENING LEVELS

Soil SLs in the Workbook (Ecology 2019) are based on unrestricted land use and the assumption that the following contaminant transport and exposure pathways are complete¹:

- Human health – direct contact (ingestion and dermal contact);

¹ Site-specific exposure pathways are discussed in Section 7.6 of this report. The exposure pathways presented here are specific to Ecology's process for selection of the most-stringent SLs.

- Soil to groundwater transport pathway, including the protection of surface water and sediment via groundwater discharging through sediment to surface water;
- Protection of sediment via bank erosion; and
- Terrestrial ecological receptor exposure pathways.

Soil SLs are provided for both vadose and saturated zone soil, and for protection of both potable and non-potable groundwater. Ecology determined the lowest risk-based SLs for each of the four following soil/exposure scenario combinations: (1) vadose soil protective of potable groundwater, (2) vadose soil protective of non-potable groundwater, (3) saturated zone soil protective of potable groundwater, and (4) saturated zone soil protective of non-potable groundwater. If the lowest risk-based SL was less than the natural background concentration, the SL was adjusted up to the natural background concentration (Ecology 2018a).

Site groundwater is considered potable for the purposes of selecting SLs; therefore, the soil SLs selected for the Site are the most stringent SLs published in the Workbook for vadose and saturated zone protective of potable groundwater (Ecology 2019). These soil SLs are summarized in Table 4-1.

4.1.2 GROUNDWATER SCREENING LEVELS

Groundwater SLs in the Workbook (Ecology 2019) are provided for potable and non-potable groundwater use and are based on the assumption that the following contaminant transport and exposure pathways are complete:

- Human health – direct contact and ingestion;
- Groundwater to surface water transport pathway;
- Groundwater to sediment transport pathway; and
- Vapor intrusion from contaminants in groundwater.

Ecology determined the lowest risk-based SLs for each transport and exposure pathway and compiled them into two sets of groundwater SLs in the Workbook based on potable and non-potable groundwater. Similar to soil, if the lowest risk-based SL was less than the natural background concentration, the SL was adjusted up to the natural background concentration (Ecology 2018a). The SLs selected for evaluating analytical results of groundwater samples from the shallow and deep aquifers are the most stringent SLs in the Workbook for potable groundwater (Ecology 2019). These groundwater SLs are summarized in Table 4-2.

4.1.3 SEDIMENT SCREENING LEVELS

Sediment SLs in the Workbook (Ecology 2019) are based on the lowest risk-based LDW ROD CUL or the lower tier target concentration from the SMS Sediment Cleanup Objectives (SCOs) if a ROD CUL is not available for a chemical (e.g., tributyltin). The sediment SLs are summarized in Table 4-3.

4.2 DATA USAGE

The Site characterization dataset reported in this report is maintained and managed by ERM using an EQUIS database. Data usage rules described below were adopted for comparing Site data to media-specific SLs.

4.2.1 QUALIFIED DATA

With the exception of rejected data described in Section 5.7 of this report, all chemical concentration data, including qualified data (e.g., J-flagged estimates below reporting limits), were used in this analysis.

4.2.2 SHALLOW AND DEEP AQUIFER GROUNDWATER DATA

Both the shallow and deep aquifers discharge to the LDW; therefore, shallow and deep groundwater data were evaluated as a combined dataset for the purposes of comparing to SLs and identifying COPCs.

4.2.3 VADOSE AND SATURATED ZONE SOIL

Analytical results for soil samples collected from the Site were separated into vadose and saturated zone soils for comparison to the SLs. To categorize samples as vadose or saturated zone soil, the bottom elevation of each sample was compared to the January 25, 2012, groundwater table elevations, the highest groundwater levels observed at the Site since measurements began in 2009. If any portion of a soil sample was collected from a depth below the January 25, 2012, groundwater table, the sample was designated as saturated zone soil. Soil samples collected from a depth completely above the January 2012 groundwater table were designated as vadose zone soil.

4.2.4 ANALYTE CONCENTRATIONS REPORTED BY BOTH VOC AND SVOC METHODS

The following chemicals were, for some samples, analyzed by both the VOC and SVOC methods: 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; naphthalene; and hexachlorobutadiene. In these cases, the VOC method data were moved into the SVOC dataset tabulations for the screening evaluations using the following rules:

- Retain the lower reporting limit when the VOC and SVOC results are both non-detects (ND).
- Retain the higher concentration when VOC and SVOC results are both detects.
- Retain the single detected result when either the VOC or SVOC result is ND.

4.2.5 FIELD DUPLICATES

Analytical data for the field duplicate samples was included without modification in the process of identifying the COPCs. However, the field duplicate dataset was consolidated by averaging field duplicate data with the parent sample data using the following rules:

- Retain the lower reporting limit when the parent and duplicate results are both NDs.
- Retain the average of parent and duplicate results when both are detected.
- Retain the single detected result when either the parent or duplicate is ND.

4.2.6 CALCULATED AND SUMMED CONCENTRATIONS

Carcinogenic polycyclic aromatic hydrocarbons (cPAHs), D/Fs, and PCBs are sets of organic compounds that, under MTCA guidance, have a cumulative cleanup standard. Toxicity equivalency quotients (TEQs) for cPAHs and D/Fs were calculated as described in Ecology's Implementation Memoranda #10 and #11, respectively (Ecology 2015a, 2015b). Risks from exposure to PCBs were evaluated as the sum of the Aroclors (total PCBs). Additional information on, and rules for handling NDs of these parameters are summarized below.

- cPAHs: Toxicity equivalency factors (TEFs) were used from the California Environmental Protection Agency (2005) and WAC 173-340-708(e) Table 708-2 to obtain the TEQ value relative to the toxicity of benzo(a)pyrene. For soil, groundwater, and sediment samples, one-half of the method detection limit (MDL) was used in the calculation for individual cPAHs reported as ND.
- D/Fs: D/F concentrations are presented as Dioxin Furan Calculated TEQ using mammalian TEFs endorsed by the World Health Organization (Van den Berg et al. 2006) and WAC 173-340-708 Table 708-1 to calculate a TEQ relative to the toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD). For constituents reported as ND, one-half of the MDL was used in the calculation.
- PCBs: Total PCB concentrations are presented as the sum of detected Aroclors, and one-half of the MDL for Aroclors not detected in the sample but detected in other Site media (i.e., Aroclors 1242, 1248, 1254, and 1260), using a value of zero for Aroclors reported as NDs but not detected in other Site media (i.e., Aroclors 1016, 1221, 1232, 1262, and 1268).

4.3 CONTAMINANTS OF POTENTIAL CONCERN

COPCs are analytes that require a more detailed evaluation because they were detected in Site media at concentrations exceeding their SLs. Analytes reported in any sample at a concentration greater than a media-specific SL were retained as a potential COPC. Analytes that were not detected or were only detected at concentrations less than the SLs were not retained as COPCs.

Tables 4-4 through 4-7 present the COPC selection process for compounds in vadose zone soil, saturated zone soil, groundwater, and sediment, respectively. The tables show the SL for each analyte, laboratory practical quantitation limit (PQL) range, the total number of samples analyzed for the potential COPC, the maximum concentration detected, the number of samples exceeding the SL, the number of samples with PQLs greater than the SL, and whether the compound was retained as a COPC. The tables also include the exceedance frequency, exceedance factor, and whether the compound was detected in other Site media.

Table 4-8 summarizes the Site COPCs by sample matrix. A total of 28 COPCs were identified in vadose zone soil, 46 COPCs in saturated soil, 13 COPCs in groundwater, and 29 COPCs in sediment. Table 4-8 includes TEQ values and total summations for three constituent classes that were calculated using multiple assumptions for non-detected values (e.g., D/Fs calculated TEQ [ND=0] and D/Fs calculated TEQ [ND = 1/2DL]). Each of these constituent classes was counted as a single COPC. The frequency of analytes detected in each media at concentrations exceeding the SL, and the exceedance ratio of the maximum reported concentrations to the SLs, are

summarized in Tables 4-4 through 4-7. Additional information regarding sample statistics in each media are included in COPC prevalence tables in Tables V-1 through V-4 in Appendix V. Summary data tables showing the comparison of all sample analytical results to the SLs by sample matrix are provided in Tables W-1 through W-20 in Appendix W.

To facilitate the discussion of the magnitude and extent of contamination at the Site, the COPCs were further evaluated and distilled to a set of primary COPCs. The primary COPCs met one or both of the two following criteria:

1. They were detected in all sampled Site media (i.e., vadose zone soil, saturated soil, groundwater, and sediment); or
2. They meet all of the following criteria:
 - a. They were reported at concentrations exceeding the SL in more than one media;
 - b. The frequency of sample SL exceedance is greater than 10 percent; and
 - c. The maximum SL exceedance ratio is greater than or equal to 2.

The primary COPCs are shaded orange in Table 4-8. Primary COPCs selected because they were reported in all sample media are arsenic, copper, zinc, PCP, PCBs, and D/Fs (as TEQ). Primary COPCs selected based on achieving the other criteria are tributyltin, combined diesel-range organics (DRO) and motor oil-range organics (MORO) petroleum hydrocarbons, 2,4,6-trichlorophenol, 2,4-dichlorophenol, phenol, bis(2-ethylhexyl) phthalate (BEHP), hexachlorobenzene, and cPAHs (as TEQ). Note that although individual cPAHs are retained as COPCs in soil and sediment, the toxicity and spatial distribution is accounted for in the TEQ calculation and will not be discussed separately. Primary COPCs are not intended to be used as indicator hazard substances; the FS will consider the extent of all COPCs to select a cleanup alternative.

5. NATURE AND EXTENT OF CONTAMINATION IN UPLANDS MEDIA

This section describes the nature and extent of the primary COPCs in the uplands media (i.e., soil, groundwater, stormwater, and stormwater solids) at the Site. It should be noted that the depth to which certain COPCs exceed SLs along the riverbank is currently unknown. It is not expected that the aquitard and lower sand unit along the riverbank, which are composed of native material, would contain contaminated soil or waste materials. Additional data may be collected during pre-remedial investigations to better determine the depth of contamination along the riverbank in order to inform remedial design.

5.1 SOIL

This section focuses on the magnitude and extent of primary COPCs in vadose and saturated zone soil at the Site. Samples were categorized as vadose or unsaturated as described in Section 4.2.3. The COPCs in vadose and saturated zone Site soil are summarized in Table 4-8. Vadose and saturated zone soil data tables showing the analytical results from the contemporary and historical investigation activities as compared to the SLs described in Section 4 are included as Tables W-1 through W-10 in Appendix W. The laboratory analytical data packages from the contemporary investigation activities are included in Appendix Y, and laboratory analytical packages from the historical investigation activities are included in the RASR (Shaw 2008). The data quality review memoranda are presented in Appendix X.

Figures showing the magnitude and extent of the following COPCs in upland soil are presented on Figures 5-1 through 5-11: arsenic, copper, zinc, TPH-DRO/MORO, PCP, cPAHs, PCBs, and D/Fs. Analytical results from historical and contemporary soil sampling events are depicted on the figures for the sampled soil layers. Although the samples were analyzed in accordance with the methods established in the approved Quality Assurance Project Plan, the MDLs for soil samples for several COPCs exceed the SLs. Soil samples exhibiting no detectable COPC concentrations at the project-specified PQLs are flagged with "N" on figures to indicate that they were ND.

Publicly available upland soil data for the adjacent DSI property and Port of Seattle property are also plotted on the figures. Analytical results of the COPCs detected in soil samples collected from soil borings advanced on the adjacent properties were also plotted with respect to the vadose and saturated zone soil layers at the boring location.

5.1.1 METALS

The following metals were retained as COPCs in both vadose and saturated zone soil: arsenic, chromium, hexavalent chromium, copper, mercury, silver, and zinc (Table 4-8). Tributyltin was retained as a COPC in vadose zone soil, while antimony and barium were retained as COPCs in saturated soil (Table 4-8). Of these metal COPCs, arsenic, copper, tributyltin, and zinc met the criteria for primary COPCs (Table 4-8). With one exception, all the metal COPCs are co-located with the primary metal COPCs arsenic, copper, and zinc (Tables W-1 and W-6, Appendix W); the exception is one upland soil sample located within the former washwater impoundment (TP-10 from 2 to 3 feet bgs; Figure 3-1) where no primary metal COPCs are reported with SL exceedances, but other metal COPCs are reported with SL exceedances. Further, the primary

metal COPC tributyltin is co-located with the other primary metal COPCs. Tributyltin was detected in two of the five vadose zone soil samples at concentrations exceeding the SL (GP-62 and MW-30S), which are co-located with samples with reported arsenic, copper, and zinc concentrations greater than SLs (Figure 5-1). Tributyltin was not detected in the 27 saturated zone soil samples collected. Therefore, the descriptions of the magnitude and extent of the primary metal COPCs arsenic, copper, and zinc presented are representative of all the metal COPCs.

5.1.1.1 ARSENIC

The magnitude and extent of arsenic in vadose and saturated zone soil is illustrated on Figures 5-1 and 5-2, respectively, using the SL of 7 mg/kg. The SL for arsenic is based on the Puget Sound natural background concentration (Ecology 1994).

Arsenic concentrations reported in vadose soil samples range between 1.7 and 1,290 mg/kg, with 40 of the 58 vadose soil samples analyzed having reported arsenic concentrations greater than the SL of 7 mg/kg (Table V-1, Appendix V). As shown on Figure 5-1, vadose soil sample locations with reported arsenic concentrations exceeding the SL are located throughout the southern portion of the Site with sample locations with higher concentrations within the operational area used by Mineralized-Cell in the 1930s, and by Carlisle, Crown Zellerbach, and the Army in the 1940s (Figure 5-1). There are also locations in the north and northeast portions of the Site (GP-34, GP-62, GP-78, MW-30S, TB-01B, TB-02B, TP-4, TP-6) that have vadose zone soil with arsenic concentrations exceeding the SL (Figure 5-1).

Arsenic concentrations reported in saturated soil samples range between 0.82 and 3,070 mg/kg, with 129 of the 269 saturated soil samples analyzed having reported arsenic concentrations greater than the SL (Table V-2, Appendix V). As shown on Figure 5-2, saturated soil samples with reported arsenic concentrations exceeding the SL are present primarily throughout the southeastern portion of the Site with locations across the western, northern, and central portions of the Site also exceeding the SL. The highest concentrations of arsenic reported in saturated soil are in the southeastern portion of the Site within the operational area used by Mineralized-Cell in the 1930s, and by Carlisle, Crown Zellerbach, and the Army in the 1940s (Figure 5-2).

Arsenic concentrations reported in vadose and saturated soil greater than the SL are present along the northern and southern Property boundaries, with the higher arsenic concentrations reported in saturated soil along the southeast Property boundary near MW-14, MW-26S, GP-58, and GP-59 (Figures 5-1 and 5-2).

The vertical extent of arsenic concentrations exceeding the SL in the northern and western portions of the Site are limited to the shallow and dredged fill and do not extend into the aquitard in these locations. In the central portion of the Site, arsenic concentrations exceeding the SL are primarily limited to the shallow and dredged fill with the exception of a few locations in the vicinity of the former washwater impoundment (MW-2D, MW-10S, MW-11S, and MW-12S) and limited to the material deposited between 1922 and 1964 (Section 2.8.2.5) to the bank fill where fill was placed during construction in the late 1960s (TB-02B, TB-03D, and TB-04A) as shown on Figure 5-2.

In the southeast portion of the Site, the vertical extent of arsenic concentrations exceeding the SL is limited primarily to the shallow and dredged fill but extends into the silt aquitard at 10 locations (MW-13S, GP-9, GP-43, GP-73, MW-19S, MW-21S, MW-43D, MW-45D, GP-59, and TB-05B) and into the lower sand unit at three locations (MW-43D, MW-45D, and TB-06F; Figure 5-2).

The primary area of arsenic-impacted soil is within the footprint of the former Mineralized-Cell, Carlisle, Army, and Crown Zellerbach operations area.

5.1.1.2 COPPER

Copper concentrations reported in vadose soil samples range between 14.3 and 337,000 mg/kg (TB-06A), with 25 of the 33 vadose soil samples analyzed having reported copper concentrations greater than the SL of 36 mg/kg (Table V-1, Appendix V). Copper concentrations reported in saturated soil samples analyzed range between 3.4 and 3,500 mg/kg, with 66 of the 183 saturated soil samples having reported copper concentrations greater than the SL (Table V-2, Appendix V). The magnitude and extent of copper concentrations reported in vadose and saturated Site soils is presented on Figure 5-3 using the SL of 36 mg/kg. The SL for copper, which is the same for vadose and saturated soil, is based on the Puget Sound natural background concentrations (Ecology 1994).

As shown on Figure 5-3, copper concentrations reported in vadose and saturated soil samples exceed the SL primarily throughout the eastern and southern portions of the Site along with two samples in the northwest portion of the Site (MW-28S and MW-32S/D; Figure 5-3). The vertical extent of copper concentrations in excess of the SL at these two locations is limited to the shallow fill.

The highest reported copper concentrations are in the central (GP-32, GP-39, GP-50, GP-55, GP-66, GP-71, and GP-74) and southern (GP-51, GP-67, GP-73, MW-14D, MW-43D, and MW-45D) portions of the Site and at four locations along the riverbank (TB-01B, TB-02B, TB-05B, and TB-06A; Figure 5-3). The sample collected at TB-06A from 5 to 6 feet bgs had a reported copper concentration of 337,000 mg/kg, the highest concentration of copper detected in Site soil (Table W-6, Appendix W). Copper concentrations exceeding the SL are also found off Site along the north Property boundary in the vicinity of the former Army operations (Figure 5-3).

The vertical extent of copper concentrations exceeding the SL in the northern and central portions of the Site are limited to the shallow and dredged fill except for one sample collected from the lower sand unit at GP-71. The vertical extent of copper concentrations exceeding the SL in the southern portion of the Site extends into the silt aquitard in a few locations (GP-51, GP-73, MW-43D, and MW-45D) but does not extend into the lower sand unit (Figure 5-3). The vertical extent of copper concentrations exceeding the SL along the riverbank is limited to the bank fill and material deposited between 1922 and 1964 at TB-01B, TB-05B, and TB-06A, and extends into the silt aquitard at TB-02B (Figure 5-3). Limited information exists about potential COPC concentrations in the silt aquitard along the riverbank and the lower sand unit, which consist of native materials and are not expected to be impacted by direct deposition of contaminated soil or materials. Additional data may need to be collected during remedial design to determine the depth to which COPCs exceed SLs along the riverbank. It should also be noted that the upland portion of the Site was altered substantially in the late 1960s for construction of the cement terminal, which

may have resulted in the movement of impacted soil to other areas of the Site, including the riverbank where the top-of-riverbank samples were collected.

The locations of copper-impacted soil are within the footprint of the former Mineralized-Cell, Army, and Reichhold operations areas. The southeastern footprint of the copper-impacted soil lies within the footprint of arsenic-impacted soil exceeding SLs, and will likely be addressed in conjunction with arsenic remediation.

5.1.1.3 ZINC

Zinc concentrations reported in vadose soil samples range between 12 and 208 mg/kg, with 10 of the 33 vadose soil samples analyzed having reported zinc concentrations greater than the SL of 86 mg/kg (Table V-1, Appendix V). Zinc concentrations reported in saturated soil samples range between 6 and 4,030 mg/kg, with 25 of the 177 saturated soil samples analyzed having reported zinc concentrations greater than the SL (Table V-2, Appendix V). The magnitude and extent of zinc concentrations reported in vadose and saturated Site soils is presented on Figure 5-4. The SL for zinc in vadose zone soil (86 mg/kg) is slightly higher than the SL for zinc in saturated soil (85 mg/kg); however, for visualization purposes, all upland soil samples are compared to the saturated soil SL.

As shown on Figure 5-4, zinc concentrations reported in vadose and saturated soil samples exceed the SL at locations in the southeast portion of the Site within the footprint of the former Mineralized-Cell operations area and in a few locations in the north and northeastern portions of the Site. Zinc concentrations in upland soil exceed the SL on the Port of Seattle property and the DSI property. Zinc concentrations reported in the soil on the Port of Seattle property are greater than those reported on the Site (Figure 5-4). The vertical extent of zinc concentrations in excess of the SL in Site soil is limited to the shallow fill in the north and northeastern portions of the Site. Within the footprint of the former wood preserving operations, the vertical extent of zinc impacts extends into the silt aquitard but not into the lower sand unit (Figure 5-4).²

5.1.2 VOLATILE ORGANIC COMPOUNDS

In vadose zone soil, ethylbenzene, methylene chloride, and toluene were detected above SLs in one soil boring (GP-75) located in the northeastern upland section of the Property (Table W-2, Appendix W). Soil samples at this location also contained concentrations of petroleum hydrocarbons above SLs. Benzene was detected in saturated soil samples at concentrations above the SL at several locations in the eastern portion of the Property; however, the only detection more than two times the SL was at boring GP-28 near the northern property boundary. Ethylbenzene, methylene chloride, and toluene were retained as COPCs in vadose zone soil (Table 4-8), and benzene was retained as a COPC in saturated soil (Table 4-8). The vertical extent of VOC impacts are limited to the shallow and dredged fill and do not extend into the silt aquitard. None of these VOC COPCs achieve the criteria for a primary COPC; therefore, the nature and extent of the VOC COPCs are not discussed further (Table 4-8).

² It is unlikely that additional soil data for zinc will be needed to support the development, evaluation, and selection of a cleanup action for upland portion of the Site. Zinc is not determined to be a COC in the FS.

5.1.3 TOTAL PETROLEUM HYDROCARBONS

Both contemporary and historical soil samples collected from the Site were analyzed for TPH. However, the laboratory analytical reports for the historical samples did not identify the analytical method (i.e., diesel, heavy oil, or gasoline-range). Therefore, the historical analytical results were determined to be unsuitable for this RI. Only the contemporary soil sampling data were carried forward in this RI.

Gasoline-range (GRO), DRO, and MORO petroleum hydrocarbons were retained as COPCs in vadose and saturated zone soils (Table 4-8). Because soil impacted with TPH-DRO and TPH-MORO is co-located and chromatograms from these samples suggest that the DRO and MORO fractions are part of the same petroleum product, TPH-DRO and TPH-MORO results are reported as a combined TPH-DRO/MORO value for comparison to the SLs as prescribed in Ecology's Implementation Memorandum #4 – *Determining Compliance with Method A Cleanup Levels for Diesel and Heavy Oil* (Ecology 2004). Of the TPH COPCs, only TPH-DRO/MORO meet the criteria of a primary COPC (Table 4-8). The vadose and saturated soil samples having reported TPH-GRO concentrations exceeding its SL are co-located with soil impacted by TPH-DRO/MORO (Figure 5-5).

TPH-DRO/MORO concentrations reported in vadose soil samples range between 5.3 and 16,900 mg/kg, with 2 of the 5 vadose soil samples analyzed having reported TPH-DRO/MORO concentrations greater than the SL of 260 mg/kg (Table W-2, Appendix W). TPH-DRO/MORO concentrations reported in saturated soil samples range between 6.5 and 30,000 mg/kg, with 9 of the 56 saturated soil samples analyzed having reported TPH-DRO/MORO concentrations greater than the SL (Table W-7, Appendix W). The magnitude and extent of TPH-DRO/MORO in vadose and saturated zone soil samples is shown on Figure 5-5 using the SL of 260 mg/kg and is representative of the TPH contamination in soil at the Site.

Table 5-1 summarizes photoionization detector (PID) field screening measurements recorded at 99 soil boring locations that can be used as a supplemental line of evidence in areas where fewer soil samples were analyzed for TPH-DRO/MORO. Seven of the 99 locations had PID field screening measurements above 20 parts per million (ppm) in the vadose zone (GP-31, GP-34, GP-36, GP-75, MW-32D, MW-32DR, and MW-35S). The highest reading in the vadose zone was from 3 to 4 feet bgs at GP-31 (89.1 ppm). Reported concentrations of TPH-DRO/MORO in the soil samples collected at GP-31 were below the SL. Soil borings GP-34, GP-36, and GP-75 are located in the vicinity of soil samples exceeding the TPH-DRO/MORO SL. Soil boring MW-35S was co-located with a soil sample that did not exceed the SL, and MW-32D and MW-32DR were not co-located with any soil samples.

In the saturated zone, three locations had PID field screening measurements above 20 ppm (MW-32D, MW-32DR, and MW-43D). The highest PID reading in the saturated zone was from 10 to 11 feet bgs at MW-43D (123.5 ppm). Reported concentrations of TPH-DRO/MORO in the two saturated soil samples collected from MW-43D were 2,760 mg/kg (collected from 5.25 to 6.7 feet bgs) and 5,600 mg/kg (collected from 6.9 feet bgs), higher than the SL of 260 mg/kg. There are no TPH-DRO/MORO samples taken in the vicinity of MW-32D and MW-32DR.

Soil having TPH-DRO/MORO concentrations exceeding the SL are localized in the northern, northeastern, and south-central portions of the Site. The TPH-impacted soil in the northeast

portion of the Site (i.e., borings GP-75 and MW-30S) is in the vicinity of former Carlisle, Crown Zellerbach, Army, and Reichhold operational areas, and a surface drainage ditch formerly used by Carlisle, Crown Zellerbach, the Army, Reichhold, the Port of Seattle, and Kaiser. The TPH-impacted soil in the central portion of the Site (e.g., MW-43D) is located in the vicinity of a surface drainage ditch formerly used by Mineralized-Cell, Carlisle, Crown Zellerbach, and the Army. The vertical extent of TPH-DRO/MORO in soil at concentrations exceeding the SLs is limited to the shallow and dredged fill and does not extend into the silt aquitard (Figure 5-5).

5.1.4 SVOCs

The following SVOCs were retained as COPCs in both vadose and saturated zone soil: PCP; 2,4,6-trichlorophenol; 2,4-dichlorophenol; hexachlorobenzene; and phenol (Table 4-8). Eleven additional SVOCs were retained as COPCs in saturated soil: 1,4-dichlorobenzene; 2,3,4,6-tetrachlorophenol; 2,4-dimethylphenol; ethylene dibromide; 2-chlorophenol; o-cresol; benzoic acid; benzyl butyl phthalate; BEHP; dibutyl phthalate; and diethylphthalate (Table 4-8). Of these SVOC COPCs, only PCP; 2,4,6-trichlorophenol; 2,4-dichlorophenol; hexachlorobenzene; BEHP; and phenol meet the criteria of a primary COPC (Table 4-8).

Vadose and saturated zone soil samples with reported concentrations of SVOC COPCs exceeding their respective SLs are primarily co-located with vadose and saturated zone soil samples with reported PCP concentrations exceeding its SLs. Figure 5-6 shows the vadose and saturated soil sampling locations where PCP was detected in concentrations exceeding the SLs. These locations are within the former Reichhold operational areas, including the location of the former wastewater impoundment, and the riverbank. The one exception in the vadose zone soil is GP-58, located on the southern boundary of the Property, which had a reported phenol concentration twice the SL, but no PCP SL exceedance (Table W-3, Appendix W). The four exceptions in the saturated zone soil are:

- MW-2S, located within the footprint of the former wastewater impoundment, which had a reported 2-chlorophenol concentration exceeding its SL;
- MW-14D, located between the two former drainage ditches associated with former Reichhold operational area had reported BEHP concentrations exceeding its SL;
- GP-59, located at the southeast corner of the riverbank, which had exceedances of 2-chlorophenol and benzoic acid above their SLs; and
- MW-43D, located between the two former drainage ditches within the former Reichhold operational area, had reported dibutyl phthalate and diethyl phthalate concentrations exceeding their saturated soil SLs (Table W-3, Appendix W).

Figure 5-7 displays the locations of the above exceptions. Moreover, the soil samples with SL exceedances of 2,4,6-trichlorophenol and 2,4-dichlorophenol are also co-located with soil samples having PCP SL exceedances. Therefore, the magnitude and extent of PCP impacts in vadose and saturated zone soil (Figure 5-6) is generally representative of the magnitude and extent of all SVOC COPCs at the Site.

5.1.4.1 PENTACHLOROPHENOL

PCP concentrations reported in vadose soil samples range between 0.0095 and 7.7 mg/kg, with 11 of the 29 vadose soil samples analyzed having reported PCP concentrations greater than the SL of 0.000032 mg/kg (Table V-1, Appendix V). PCP concentrations reported in saturated soil samples range between 0.0064 and 1,000 mg/kg, with 111 of the 224 saturated soil samples analyzed having reported PCP concentrations greater than the SL of 0.0000018 mg/kg (Table V-2, Appendix V). The samples reported as ND for PCP (17 vadose soil and 113 saturated soil) had PQLs greater than the respective SLs (Tables W-3 and W-8).

The magnitude and extent of PCP in vadose and saturated zone soil is illustrated on Figure 5-6. As shown in Tables 4-4 and 4-5, the SLs for PCP in vadose and saturated zone soil are 0.000032 and 0.0000018 mg/kg, respectively. These SLs are less than the PQL; therefore, the magnitude and extent of PCP in upland soil samples is compared to the PQL of 0.05 mg/kg for visualization purposes and compared to the SLs in Tables W-3 and W-8 (Appendix W).

As shown on Figure 5-6, vadose and saturated soil samples with reported PCP concentrations exceeding the PQL and the SL are present in the northern, central, and eastern portions of the Site in the former Reichhold operational areas, with the highest PCP concentrations found primarily in the footprint of the former washwater impoundment (Figure 5-6). The horizontal extent of impacts are within the Site boundaries with the exception of the detections noted on the DSI property (Figure 5-6).

The vertical extent of soil impacted with PCP at concentrations exceeding the SL are primarily limited to the shallow and dredged fill layers but extend to the interface between the dredged fill, material deposited between 1922 and 1964, and silt aquitard in several borings advanced in the northeast and southeast portions of the Site (GP-30, GP-31, GP-60, GP-61, GP-62, GP-64, GP-65, GP-66, GP-74, MW-35D, GP-53, GP-55, GP-72, TB-02B, TB-04A, GP-7, GP-56, TP-13, GP-67, GP-73, and GP-70; Figure 5-6). Soil having PCP concentrations exceeding the SL extends into the silt aquitard at four boring locations (GP-2, MW-10S, MW-11S, and MW-13S).

No PCP SL exceedances were detected in the two samples collected from the lower sand unit (TB-06F and MW-2D). Both of these samples had a laboratory reporting limit greater than the SL. While the PCP dataset for the lower sand is limited, the lower sand soil sample collected directly beneath the former washwater impoundment (MW-2D) suggests that the aquitard limited the vertical migration of PCP to the underlying lower sand unit.

Saturated soil samples with reported PCP concentrations exceeding the SL are located primarily in the former Reichhold operational areas, including the location of the former washwater impoundment (e.g., GP-44, GP-45, GP-46), the location of the former PCP production plants (GP-2, GP-55, GP-74), the location of the former phenate process area (GP-36), the location of the former southern drainage ditch (GP-16), and in the vicinity of the former laboratory building (GP-27, GP-28, GP-54). Two saturated soil samples exhibiting PCP concentrations exceeding the SL are in dredged fill beneath the location of the former washwater impoundment (GP-7; 7 to 8 feet bgs) and the location of the former southern drainage ditch (GP-16; 7 to 8 feet bgs).

5.1.4.2 2,4,6-TRICHLOROPHENOL

Concentrations of 2,4,6-trichlorophenol reported in 3 of the 28 vadose soil samples analyzed range between 26 and 390 mg/kg, with 3 vadose soil samples having reported concentrations greater than the SL and 25 samples having PQLs greater than the SL of 3.3 mg/kg (Table V-1, Appendix V). Concentrations of 2,4,6-trichlorophenol reported in saturated soil samples range between 21 and 910 mg/kg, with 30 of the 192 saturated soil samples analyzed having reported concentrations greater than the SL and 162 samples having PQLs greater than the SL of 0.19 mg/kg (Table V-2, Appendix V). The locations where 2,4,6-trichlorophenol concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances shown on Figure 5-6.

5.1.4.3 2,4-DICHLOROPHENOL

Concentrations of 2,4-dichlorophenol reported in 1 of the 28 vadose soil samples analyzed exceed the SL, with 11 samples with PQLs greater than the SL of 69 mg/kg (Table V-1, Appendix V). Concentrations of 2,4-dichlorophenol reported in saturated soil samples range between 26 and 1,800 mg/kg, with 39 of the 192 saturated soil samples analyzed having reported concentrations greater than the SL and 153 samples having PQLs greater than the SL of 9.2 mg/kg (Table V-2, Appendix V). The locations where 2,4-dichlorophenol concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances shown on Figure 5-6.

5.1.4.4 HEXACHLOROBENZENE

Hexachlorobenzene concentrations reported in 4 of the 10 vadose soil samples analyzed range between 9.5 and 69 mg/kg, with 4 vadose soil samples having reported concentrations greater than the SL and 6 samples having PQLs greater than the SL of 0.008 mg/kg (Table V-1, Appendix V). Hexachlorobenzene concentrations reported in saturated soil samples range between 12 and 920 mg/kg, with 12 of the 124 saturated soil samples analyzed having reported concentrations greater than the SL and 112 samples having PQLs greater than the SL of 0.0004 mg/kg (Table V-2, Appendix V). The locations where hexachlorobenzene concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances shown on Figure 5-6.

5.1.4.5 BEHP

The BEHP concentration reported in 1 of the 3 vadose soil samples analyzed was 18 mg/kg, which is less than the SL of 100 mg/kg (Table V-1, Appendix V). BEHP concentrations reported in saturated soil samples range between 16 and 450 mg/kg, with 19 of the 87 saturated soil samples analyzed having reported concentrations greater than the SL and 68 samples having PQLs greater than the SL of 5.1 mg/kg (Table V-2, Appendix V). The locations where BEHP concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances shown on Figure 5-6.

5.1.4.6 PHENOL

Phenol concentrations reported in 11 of the 20 vadose soil samples analyzed range between 13 and 840 mg/kg, with 2 vadose soil samples having reported concentrations greater than the SL of 420 mg/kg (Table V-1, Appendix V). Phenol concentrations reported in saturated soil samples

range between 9.4 and 5,200 mg/kg, with 29 of the 159 saturated soil samples analyzed having reported concentrations greater than the SL and 1 sample having a PQL greater than the SL of 120 mg/kg (Table V-2, Appendix V). With one exception, the locations where phenol concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances shown on Figure 5-6. The one exception in the vadose zone soil is GP-58, which had a reported phenol concentration twice the SL, but no PCP SL exceedance (Table W-3, Appendix W).

5.1.5 PAHS

One non-carcinogenic PAH was retained as a COPC for both vadose and saturated zone soil (naphthalene), and 6 non-carcinogenic PAHs (acenaphthene, anthracene, benzo(g,h,i)perylene, fluoranthene, fluorene, and pyrene) were retained as COPCs for saturated zone soil only (Table 4-8). Each location where non-carcinogenic PAHs identified in Table 4-8 exceed their respective saturated soil SLs is co-located with cPAHs in soil exceeding the cPAH SL (Table W-8 in Appendix W). Therefore, non-carcinogenic PAHs will not be included as primary COPCs and the magnitude and extent of non-carcinogenic PAHs is not discussed herein.

Four individual cPAHs (benzo(a)anthracene, benzo(a)pyrene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene) and cPAH TEQ (ND=0 and ND=1/2DL) were retained as cPAH COPCs for both vadose zone and saturated zone soil (Table 4-8). Additionally, chrysene and total [B+J+K] benzofluoranthenes were retained as cPAH COPCs for saturated soil only (Table 4-8). Of these cPAH COPCs, benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, and cPAH TEQ (ND=0 and ND=1/2DL) meet the criteria of a primary COPC (Table 4-8). Soil samples having cPAH TEQ concentrations exceeding its SL are co-located with soil samples having individual primary cPAH concentrations exceeding their SLs. Therefore, the magnitude and extent of cPAH COPC impacts in the Site soil can be illustrated using cPAH TEQ data.

The cPAH TEQ concentrations reported in vadose soil samples range between 0.00051 and 0.046 mg/kg (TEQ ND=0) and 0.0054 and 0.046 mg/kg (TEQ ND=1/2DL). For both TEQs, all 4 vadose soil samples reported cPAH TEQ concentrations greater than the SL of 0.00031 mg/kg (Table V-1, Appendix V). cPAH TEQ concentrations reported in saturated soil samples range between 0.000025 and 5.8 mg/kg (TEQ ND=0) and 0.0013 and 5.8 mg/kg (TEQ ND=1/2DL). For both TEQs, 62 of the 89 saturated soil samples reported cPAH TEQ concentrations greater than the SL of 0.000016 mg/kg (Table V-2, Appendix V). The cPAH TEQ concentrations reported in vadose and saturated soil samples are also less than the direct contact SL of 0.19 mg/kg.

As shown in Tables 4-4 and 4-5, the SLs for cPAHs in vadose and saturated zone (0.00031 and 0.000016 mg/kg, respectively) are lower than the PQLs for cPAHs in soil; therefore, for visualization purposes, the magnitude and extent of cPAHs in upland soil samples is compared to the PQL for cPAHs of 0.005 mg/kg. Because the PQL applies to both the vadose zone and saturated zone soil, the data from both zones are evaluated together against the PQL. The magnitude and extent of cPAH TEQ concentrations reported in vadose and saturated Site soils are presented on Figure 5-8.

As shown on Figure 5-8, upland soil with reported cPAH TEQ concentrations exceeding the SL are present primarily in the vicinity of the former Reichhold operational areas, including the location of the former wastewater impoundment (i.e., GP-44, GP-45, GP-46, and GP-56) and the location of the process areas (MW-32S, GP-26, GP-49, GP-40, MW-38D, GP-35, GP-36, GP-39, GP-70, GP-71, GP-74, and GP-50), and the vicinity of the former southern drainage ditch (MW-43S). Soil with cPAH TEQ concentrations exceeding the SLs is also present in the northeast portion of the Site within the vicinity of the former Carlisle, Crown Zellerbach, Army, and Reichhold operational areas (GP-31, GP-32, GP-61, GP-62, GP-63, GP-64, GP-66, GP-34, GP-75, and MW-31S; Figure 5-8). The highest cPAH TEQ concentrations in upland soil were reported at GP-63, which is located within the vicinity of soil with TPH-DRO/MORO concentrations exceeding SLs (Figures 5-8 and 5-5, respectively). The locations of soil with cPAH TEQ concentrations exceeding the SL are located in the southeast portion of the Site (MW-14D, GP-58, and GP-59; Figure 5-8). Soil with cPAH TEQ concentrations exceeding the SLs is also present throughout DSI property to the north and on T115 to the south.

Soil impacted with cPAH TEQs at concentrations exceeding the SLs is present in the shallow and dredged fill. Of the 89 saturated soil samples collected for cPAH analysis, six samples were collected from the interface with the silt aquitard and the remainder were collected from dredged fill. No saturated soil samples were collected from or below the aquitard. Of the six samples collected from the interface, three samples, two located in the central portion (GP-36 and GP-39) and one located in the southern portion of the Site (GP-59; Figure 5-8), had reported cPAH TEQ concentrations exceeding the cPAH TEQ SL of 0.016 micrograms per kilogram ($\mu\text{g}/\text{kg}$) (13 to 27 $\mu\text{g}/\text{kg}$; Table W-8, Appendix W).

It is unlikely that substantive cPAH impacts to soil extend deeper than the top of the silt aquitard because the aquitard consists of a competent layer of native material that was present during initial development of the Property. There is no evidence that early development of the Property resulted in the direct deposit of contaminated material within or below the aquitard. Investigations completed at the Site show that the aquitard remains intact throughout the Site. Furthermore, no non-aqueous phase liquid (NAPL) has been observed during Site investigations and cPAHs have not been detected in the deep monitoring wells sampled (i.e., MW-2D, MW-14D, MW-32DR, MW38-D, and MW43-D; Figure 3-6).

5.1.6 POLYCHLORINATED BIPHENYLS

Total PCBs were retained as a COPC for both vadose zone and saturated zone soil and meet the criteria of a primary COPC (Table 4-8). The PCB concentrations reported in vadose soil samples range between 0.0165 and 0.2 mg/kg (ND=0) and 0.018 and 0.21 mg/kg (ND=0/ND=1/2DL). For both TEQs, 9 of the 12 vadose soil samples reported PCB concentrations greater than the SL of 0.000043 mg/kg (Table V-1, Appendix V). PCB concentrations reported in saturated soil samples range between 0.0032 and 2.3 mg/kg (ND=0) and 0.0044 and 2.5 mg/kg (ND=0/ND=1/2DL). For both TEQs, 15 of the 54 saturated soil samples reported PCB concentrations greater than the SL of 0.000022 mg/kg (Table V-2, Appendix V). The samples reported as ND for PCBs (1 vadose soil and 39 saturated soil) had PQLs greater than the respective SLs (Tables W-4 and W-9, Appendix W).

The magnitude and extent of total PCBs in vadose and saturated zone soil is illustrated on Figures 5-9 and 5-10, respectively. As shown in Tables 4-4 and 4-5, the SLs for PCBs in vadose and saturated zone soil (0.000043 and 0.000022 mg/kg, respectively) are less than the PQL; therefore, the magnitude and extent of PCBs in upland soil samples is compared to the PQL for PCBs of 0.004 mg/kg for visualization purposes.

The 12 vadose zone soil samples analyzed for PCBs had reported PCB concentrations greater than the SL. Three of the 12 samples (GP-77, GP-79, and MW-31S) were reported as not detected. The PQLs for these three samples ranged between 0.0016 and 0.004 mg/kg, which exceeds the SL. As shown on Figure 5-9, the highest reported PCB concentrations in vadose zone soil occur along the riverbank at TB-02B and TB-05B. Detections of PCBs exceeding the SL were also present in vadose zone soil at GP-37 along the western property boundary, at GP-82 in the north-central portion of the Site, near the southern Site boundary at GP-83 and TB-06, and along the northern property boundary at GP-81 (Figure 5-9). Detections of PCBs exceeding the SL were also noted on T115 to the south and the DSI property to the north (Figure 5-9).

The highest reported PCB concentrations in saturated zone soil occur along the riverbank at TB-02B, TB-03D, and TB-06E and along the northern Site boundary at MW-29S (Figure 5-10). Detections of PCBs exceeding the SL in soil were also present along the northern boundary of the property at GP-28, GP-81, GP-32, and GP-82 in the north-central portion of the Property, and at GP-38 and GP-39 in the central portion of the Property. PCBs in saturated soil were also present on T115 to the south and the DSI property to the north (Figure 5-10). The vertical extent of soil with reported PCB concentrations exceeding the SLs are limited to the shallow, bank, and dredged fill with the exception of one sample collected from the interface of the material deposited between 1922 and 1964 and silt aquitard. This sample was collected from TB-02 at a depth of 9.5 to 10.5 feet bgs (Figure 5-10; Table W-9, Appendix W).

5.1.7 DIOXINS/FURANS

TCDD and total D/F TEQ were retained as a COPCs for both vadose zone and saturated zone soil, and total D/F TEQ meets the criteria of a primary COPC (Table 4-8). The D/F TEQ concentrations reported in vadose soil samples range between 0.726 picograms per gram (pg/g) and 9,290 pg/g (ND=0) and 1.15 and 9,290 pg/g (ND=1/2DL). For both TEQs, 12 of the 16 vadose soil samples reported D/F TEQ concentrations greater than the SL of 5.2 pg/g (Table V-1, Appendix V). D/F TEQ concentrations reported in saturated soil samples range between 0.0282 and 13,400 pg/g (ND=0) and 0.300 and 13,400 pg/g (ND=1/2DL). For both TEQs, 28 of the 63 saturated soil samples reported D/F TEQ concentrations greater than the SL of 5.2 pg/g (Table V-2, Appendix V).

The magnitude and extent of D/F TEQ concentrations reported in vadose and saturated Site soils is presented on Figure 5-11 using the SL of 5.2 pg/g. Figure 5-11 presents D/F TEQ concentrations calculated with ND equal to one-half the MDL.³

As shown on Figure 5-11, soil samples with reported D/F TEQ concentrations exceeding the SL are located in the north, central, and eastern portions of the Site. The soil sample locations with the highest D/F TEQ concentrations are situated along the riverbank (TB-02B, TB-03D, TB-04A, TB-05B, and TB-06; 0.5 to 10.5 feet bgs) and in the following former Reichhold operational areas: the location of the former washwater impoundment (GP-45; 4.5 to 6.5 feet bgs), the location of one of the former PCP production plants (GP-74; 3 to 4 feet bgs), and the location of the former tank farms (GP-49; 3.5 to 5.5 feet bgs). It should be noted that the former Reichhold operational areas overlap with those of Carlisle, Crown Zellerbach, and the Army. In addition, the upland portion of the Site was altered substantially in the late 1960s for construction of the cement terminal, which may have resulted in the movement of impacted soil to other areas of the Site including the shore where the top-of-riverbank samples were collected.

Soil samples with the highest D/Fs TEQ concentrations are generally observed in the upper 3 to 6 feet of shallow fill at the Site and concentrations decline with depth, except at the top-of-riverbank borings TB-02B and TB-06E. TB-02B is located east of the original shoreline and downgradient of two drainage ditches in the southern portion of the Site. The highest D/F TEQ concentration (13,400 pg/g) detected in uplands soil was reported in the material deposited between 1922 and 1964 (Section 2.8.2.5) at TB-06E (8.8 to 10.6 feet bgs). TB-06 is situated east of the original shoreline near the discharge point of the former surface drainage ditch located near the southern boundary of the Site. The drainage ditch previously conveyed stormwater and wastewater to the LDW from the former tin reclamation facility located in the northern area of T115, and stormwater to the LDW from upland properties located west, north, and south of West Marginal Way. The drainage ditch was filled in the early 1970s when it was replaced with the 48-inch-diameter SPU stormwater line installed parallel to the southern boundary of the Site. The source of material used to fill the drainage ditch is unknown.

5.2 GROUNDWATER

This section focuses on the magnitude and extent of primary COPCs in shallow and deep groundwater at the Site. Groundwater data collected from Site monitoring wells between March 2009 and September 2015 were used for this evaluation. Results from the March 2009 sampling event were discussed in the DGR (ERM 2009). Results from the April 2010 and May 2012 sampling events are summarized in memoranda included in Appendix R. Groundwater data tables showing all of the analytical results from investigation activities are included as Tables W-11 through W-15 in Appendix W. The laboratory analytical data packages from the RI groundwater sampling events

³ The generally accepted method for comparing D/Fs results against a given criteria consists of calculating a TEQ relative to 2,3,7,8-TCDD. The results for individual congeners are multiplied by a factor, and the results totaled to provide an overall concentration value for the sample. In this document, TEFs for D/Fs (WAC 173-340-708, Table 708-1) endorsed by the World Health Organization (Van den Berg et al. 2006) were used to calculate the TEQs. TEQs summarized in Tables W-5 and W-10 in Appendix W were calculated assuming ND (U) congeners were equal to a concentration of one-half of the sample-specific MDL.

are included as Appendix Y, and associated data quality review memoranda are presented in Appendix X.

Groundwater elevations measured during each monitoring event are summarized in Table 2-1, and water quality parameters collected during each groundwater sampling event are included in Table Z-1 of Appendix Z.

The COPCs in groundwater are arsenic; copper; nickel; zinc; TPH-DRO/MORO; PCP; BEHP; 2,4,6-trichlorophenol; 2,4-dichlorophenol; cPAHs; total PCBs; TCDD; and D/Fs (Table 4-8). Of these groundwater COPCs, all but nickel and TCDD meet the criteria of a primary COPC. The magnitude and extent of the primary groundwater COPCs arsenic, copper, TPH-DRO/MORO, PCP, and D/Fs in the shallow and deep aquifer are discussed individually below and plotted individually on Figures 5-12 through 5-21. Because of the limited number of groundwater samples having SL exceedances of zinc; nickel; 2,4,6-trichlorophenol; 2,4-dichlorophenol; BEHP; and PCBs, these primary groundwater COPCs are discussed together in Section 5.2.6 and are not mapped. Discussion of TCDD is included with the discussion of D/Fs in Section 5.2.7. Moreover, the groundwater samples having SL exceedances of these other primary groundwater COPC are generally co-located samples having SL exceedances of arsenic, copper, TPH-DRO/MORO, PCP, and/or D/Fs. Therefore, the magnitude and extent of the other primary groundwater COPCs is generally represented by the magnitude and extent of the primary groundwater COPCs arsenic, copper, TPH-DRO/MORO, PCP, and/or D/Fs.

Tables W-11 through W-15 in Appendix W summarize reported concentrations of COPCs in Site groundwater as compared to SLs. Although both the shallow and deep aquifer discharge to the LDW and have the same SLs, the aquifers are separated by a confining unit (i.e., the silt aquitard; see Section 2.8.2.2); therefore, the magnitude and extent of COPCs reported in shallow and deep groundwater data were evaluated separately.

Analytical results collected between November/December 2011 and August/September 2015 from the six most recent monitoring events are included on Figures 5-12 through 5-21. Although the samples were analyzed in accordance with the methods established in the approved Quality Assurance Project Plan, the MDLs for multiple COPCs exceeds the SLs. Samples exhibiting no detectable COPC concentrations at the project-specified PQLs are flagged with "N" on figures depicting the extent and magnitude of COPC impacts at the Site to indicate that they were ND.

Publicly available groundwater data for the adjacent DSI and Port of Seattle properties are also plotted on these figures.

5.2.1 METALS

5.2.1.1 ARSENIC

Arsenic was retained as a COPC for groundwater and meets the criteria of a primary COPC (Table 4-8). Dissolved arsenic concentrations reported in groundwater samples range between 0.12 and 15,600 µg/L, with 212 of the 282 groundwater samples analyzed having reported dissolved arsenic concentrations greater than the SL of 8 µg/L (Table V-3, Appendix V). The magnitude and extent of arsenic in shallow and deep groundwater is illustrated on Figures 5-12 and 5-13, respectively, using the SL of 8 µg/L. The extent of arsenic impacts in groundwater at the

upgradient Property boundary has not been fully characterized, but this is not expected to interfere with remedy selection.

The SL for arsenic is based on natural background concentration. As shown on Figure 5-12, shallow groundwater with reported arsenic concentrations exceeding the SL of 8 µg/L extends from the northwest central portion of the Site to the southeast along the shoreline. Arsenic in groundwater exceeding the SL is present on the DSI property and is laterally delineated to the east but not to the north and west. Similarly, on the Port of Seattle property, arsenic in groundwater exceeding the SL is laterally delineated to the east and west, but not to the south.

Groundwater samples from 12 shallow monitoring wells located in the southeast and south-central portion of the Site contained the highest concentrations of arsenic (Figure 5-12). The area of shallow groundwater with the highest concentrations of arsenic is bounded by wells to the west (MW-24S, MW-23S, and MW-36S), to the north (MW-22S, MW-43S, MW-12S, and MW-10S), and by the Embayment to the east (Figure 5-12). The southern extent of groundwater with elevated arsenic concentrations is bounded by wells on the Port of Seattle property (MW-3, MW-10, MW-12, MW-13, MW-6, MW-17, and MW-19).

The arsenic plume in shallow groundwater on the Property is present within the footprint of the former Mineralized-Cell operational area and an area where Carlisle, Crown Zellerbach, and the Army are known to have released wastewater solutions, sawdust, and charcoal from the whetlerite production process (Figure 5-12).

As shown on Figure 5-13, deep groundwater with measured arsenic concentrations exceeding the SL is present along the eastern and southeastern portions of the Site. Groundwater samples from two deep monitoring wells (MW-14D and MW-43D) located in the southeast and south-central portion of the Site contained the highest concentrations of arsenic in deep groundwater of 427 and 882 µg/L, respectively. However, groundwater concentrations attenuate by an order of magnitude over the approximate 100 to 300 feet horizontal distance between these wells and downgradient monitoring wells MW-2D and MW-45D. The highest measured concentrations at these wells are 38.4 and 72 µg/L, respectively. The arsenic plume in the deep aquifer is delineated in each direction by wells MW-20D, MW-32DR, MW-38D, MW-31D, the Embayment on the east, and MW-2D on the Port of Seattle property to the south, but is not bounded in the southeast and east directions on the Port of Seattle property.

Geotechnical borings B-4 and B-6 (shown on Figures 2-13 and 2-16) were completed by Shannon & Wilson in 1964 in the south-central portion of the Property in the vicinity of MW-14D and MW-43D. Shannon & Wilson geotechnical boring B-5 was completed in the vicinity of MW-2D. These geotechnical borings were completed through the aquitard to depths of approximately -8 feet mean sea level (MSL) (B-6), approximately -75 feet MSL (B-4), and -105 feet MSL (B-5). Documentation regarding the methods and procedures used to complete and abandon these boreholes is not available for review. Without this information, these geotechnical borings cannot be ruled out as a secondary source and migration pathway from shallow groundwater through the aquitard into the lower sand unit.

5.2.1.2 COPPER

Copper was retained as a COPC for groundwater and meets the criteria of a primary COPC (Table 4-8). Dissolved copper concentrations reported in groundwater samples range between 0.24 and 61.7 µg/L, with 26 of the 185 groundwater samples analyzed having reported dissolved copper concentrations greater than the SL of 3.1 µg/L (Table V-3, Appendix V). The magnitude and extent of copper in shallow and deep groundwater is illustrated on Figures 5-14 and 5-15, respectively, using the SL of 3.1 µg/L. The SL for copper is based on a concentration protective of surface water.

As shown on Figure 5-14, shallow groundwater with reported copper concentrations exceeding the SL is limited to a five locations in the central, eastern, and southern portions of the Site. The locations with copper SL exceedances include monitoring wells MW-4S, MW-5S, MW-33S, MW-34S, and MW-20S, with the highest copper concentrations reported in MW-5S and MW-33S (Figure 5-14). The locations with copper SL exceedances in shallow groundwater in the central and eastern portions of the Site are bounded on the north, west, and south by monitoring wells MW-29S, MW-35S, MW-2S, MW-17S, and MW-32S, and by the Embayment to the east. The copper plume in shallow groundwater at the southern Property boundary is bounded by MW-21S, MW-18S, and MW-24S, and monitoring wells MW-1, MW-13, and MW-2 (Figure 5-14) on the Port of Seattle property. The locations of copper-impacted groundwater are within the footprint of the former Mineralized-Cell, Army, and Reichhold operations areas.

Copper concentrations in deep groundwater ranging from 3.5 to 36.9 µg/L and exceeding the copper SL were detected in samples from five monitoring wells located in the central and northeast sections of the Site (MW-1D, MW-31D, MW-32DR, MW-35D and MW-38D; Figure 5-15). Copper was not detected at concentrations greater than the SL in the deep aquifer wells in the southern portion of the Site (Figure 5-15). The groundwater dataset for copper concentrations in the northern and western sections of the Site may need to be supplemented to refine our understanding of the lateral and vertical extent of contamination as part of a pre-design investigation to support remedy design.

5.2.1.3 ZINC

Zinc was retained as a groundwater COPC and meets the criteria of a primary COPC. This COPC is discussed in text only and not presented on figures because only two samples at MW-13S exceeded the SL concentration of 81 µg/L, located in the southeast portion of the Site (Figure 3-6).

Samples collected from deep aquifer wells all had detected concentrations of zinc below the SL or concentrations below the detection limit and SL (Table W-11, Appendix W), indicating that impacts were limited to the shallow aquifer.

5.2.2 VOLATILE ORGANIC COMPOUNDS

No VOCs meet the criteria of a COPC in groundwater.

5.2.3 TOTAL PETROLEUM HYDROCARBONS

TPH-DRO/MORO was retained as a COPC for groundwater and meets the criteria of a primary COPC (Table 4-8). TPH-DRO/MORO concentrations reported in groundwater samples range between 0.11 and 3.2 mg/L, with 2 of the 13 groundwater samples analyzed having reported TPH-DRO/MORO concentrations greater than the SL of 0.5 mg/L (Table W-12, Appendix W).

As shown on Figure 5-16, TPH-DRO/MORO concentrations exceeding the SL of 0.5 mg/L (Table 4-2) are limited to one shallow monitoring well (MW-3S) located in the northeastern portion of the Site. TPH-DRO/MORO concentrations in MW-3S ranged from 2 to 3.2 mg/L (Table W-12, Appendix W). No other detections of TPH-DRO/MORO in shallow groundwater exceeded the SL. The shallow TPH-DRO detection is located in the vicinity of former Carlisle, Crown Zellerbach, Army, and Reichhold operational areas, and a surface drainage ditch formerly used by Carlisle, Crown Zellerbach, the Army, Reichhold, the Port of Seattle, and Kaiser. The shallow TPH-DRO/MORO detection is bounded to the southwest by MW-1S, northwest by MW-29S, north by MW-30S, northeast by MW-31S, and east by the Embayment. Other areas of the Site (e.g., MW-43D, GP-28, and GP-36) contained concentrations of petroleum hydrocarbons in soil above SLs, and groundwater samples were not collected in all of these areas. However, additional delineation of TPH in groundwater is not expected to be needed to select a remedy because the alternatives presented in the FS will be protective if petroleum-impacted groundwater is present in these areas.

While no soil or groundwater data was collected within or beneath the aquitard, it is unlikely that substantive TPH-DRO/MORO impacts extend deeper than the top of the silt aquitard. The aquitard is native material. There is no evidence that early development of the Property (e.g., filling) resulted in direct deposit of petroleum-contaminated material within or below the aquitard. Further, there is no evidence of NAPL at the Site and cPAHs (a common chemical component of TPH) have not been detected in the deep monitoring wells sampled (i.e., MW-2D, MW-14D, MW-32DR, MW38-D, and MW43-D; Figure 3-6). TPH-DRO/MORO analytical results in soil at MW-35S were either ND or at a low concentration (e.g., 5.3 mg/kg compared to the 260 mg/kg SL), and NAPL is not present in this or any wells on the Site. As of the authoring of this report, there is no surface water criteria for TPH-DRO/MORO.

5.2.4 SVOCs

The following SVOCs were retained as COPCs in shallow and deep zone groundwater: PCP; 2,4,6-trichlorophenol; 2,4-dichlorophenol; and BEHP (Table 4-8). All these SVOC COPCs met the criteria of a primary COPC (Table 4-8).

Groundwater samples from shallow and deep monitoring wells with reported concentrations of SVOC COPCs exceeding their respective SLs are primarily co-located with groundwater samples with reported PCP concentrations exceeding its SLs. Figure 5-17 shows the shallow groundwater sampling locations where PCP was detected in concentrations exceeding the SLs that are co-located with SVOC COPCs exceeding their respective SLs. These locations are within the former Reichhold operational areas, including the location of the former washwater impoundment, and the riverbank. The three exceptions are:

- MW-26S, located on the southern boundary of the Property near a former Reichold drainage ditch, where 2,4-dichlorophenol was detected at a concentration exceeding its SL.
- MW-32S, located near the western boundary of the Property, where BEHP was detected at a concentration exceeding its SL.
- MW-43S, located between two former Reichold drainage ditches, where BEHP was detected at a concentration exceeding its SL (Table W-11, Appendix W).

These locations are shown on Figure 5-18. Therefore, the magnitude and extent of PCP impacts in shallow and deep zone groundwater (Figures 5-18 and 5-19) is generally representative of the magnitude and extent of all SVOC COPCs at the Site.

5.2.4.1 PENTACHLOROPHENOL

PCP was retained as a COPC for groundwater and meets the criteria of a primary COPC (Table 4-8). PCP concentrations reported in groundwater samples range between 0.14 and 7,700 µg/L, with 62 of the 291 groundwater samples analyzed having reported PCP concentrations greater than the SL of 0.002 µg/L (Table V-3, Appendix V). The magnitude and extent of PCP in shallow and deep groundwater is illustrated on Figures 5-18 and 5-19, respectively.

The SL for PCP in groundwater (0.002 µg/L) is based on the protection of surface water but is less than the PQL (Table 4-2). The 209 samples reported as ND for PCP had PQLs greater than the respective SLs (Table W-13). Therefore, the magnitude and extent of PCP in shallow and deep groundwater is compared to the PQL of 0.5 µg/L for visualization purposes.

As shown on Figure 5-18, groundwater samples from 12 shallow monitoring wells on the Site had reported PCP concentrations exceeding its SL. The locations of groundwater containing PCP SL exceedances are located in the central portion of the Site (MW-4S, MW-6S, and MW-16S) where one of the former Reichold PCP production plants was located, and along the shoreline (MW-35S in the northeast to MW-26S in the southeast). The PCP exceedances in shallow groundwater along the shoreline are in the vicinity of the former washwater impoundment and the former surface drainage ditches in the north and south portions of the Site. The area of PCP SL exceedances in groundwater in the central portion of the Site is situated near the former PCP production plant and is bounded by monitoring wells MW-34S, MW-5S, MW-7S, MW-17S, MW-32S, and MW-29S. The area of PCP SL exceedances in groundwater along the shoreline is bounded to the north and west by monitoring wells MW-31S, MW-1S, MW-7S, MW-17S, MW-14S, MW-3S, and MW-27S, and to the east by the Embayment. While there is no groundwater data in the general area of GP-31, GP-32, and GP-66, and limited groundwater data from MW-28S and MW-29S, shallow groundwater flows to south/southeast, and PCP was not detected in samples from downgradient monitoring wells MW-1S, MW-5S, MW-7S, MW-14S, MW-17S, MW-31S, and MW-35S.

PCP SL exceedances occur in shallow groundwater on the Port of Seattle property in monitoring wells MW-15, MW-16, and MW-10, and are bounded by monitoring wells MW-4, MW-3, MW-6, MW-5, and MW-18 on the Port of Seattle property (Figure 5-18). According to aerial photographs, regular filling activities were observed in the 1930s, 1940s, 1950s, 1960s, and the early 1970s (see also Section 2.7.2). The eastern portion of the Port of Seattle property was filled between 1963 and 1970 with gravel, sand, silt, concrete, bricks, coal, wood, garbage, and other miscellaneous materials (SES 2011) when the Port of Seattle owned both T115 and the Property

(the uplands and Embayment). These filling activities could have transported COPCs, such as PCP, from the Property onto T115.

PCP SL exceedances were reported in deep groundwater at two monitoring well locations (Figure 5-19). Two samples from MW-45D and one sample from MW-43D, located in the southeast portion of the Site, had reported PCP SL exceedances. The PCP concentrations in the shallow groundwater samples from MW-45S were the highest concentrations reported in shallow groundwater (110 to 330 µg/L), which suggests that PCP migrated from the shallow to the deep aquifer at this location. PCP was not detected in the other samples collected from the deep aquifer, and soil samples collected from MW-45D also did not have PCP concentrations exceeding the SL.

A more refined understanding of the extent of PCP in groundwater is not critical for the evaluation or selection of a cleanup action for the Site.

5.2.4.2 2,4,6-TRICHLOROPHENOL

The compound 2,4,6-trichlorophenol was retained as a groundwater COPC and meets the criteria of a primary COPC. Of the 291 shallow groundwater samples analyzed, 2 reported concentrations of 2,4,6-trichlorophenol exceeding the SL of 0.28 µg/L. One sample was collected from MW-7S in June 2010 and one was collected from MW-16S in October 2010 (Table W-13, Appendix W). Both wells are located in the vicinity of one of the former PCP plants (Figure 3-6). These two samples also had reported PCP concentrations exceeding the PCP SL. This COPC was not detected in deep groundwater.

2,4,6-Trichlorophenol has not exceeded the groundwater SL since October 2010. 2,4,6-Trichlorophenol is discussed in text only and is not presented on figures because of its low frequency of SL exceedances.

5.2.4.3 2,4-DICHLOROPHENOL

The compound 2,4-dichlorophenol was retained as a groundwater COPC and meets the criteria of a primary COPC. Three shallow groundwater samples collected from MW-26S, located along the southern Site boundary, had reported 2,4-dichlorophenol concentrations exceeding the SL of 10 µg/L (Figure 3-6). The three samples were collected in December 2011, April 2012, and August 2014 (Table W-13, Appendix W). The samples collected in December 2011 and April 2012 also had reported PCP concentrations in excess of the PCP SL. This COPC was not detected in deep groundwater.

The 261 samples reported as ND for 2,4-dichlorophenol had PQLs greater than the respective SLs (Table W-13, Appendix W). 2,4-Dichlorophenol has not exceeded the groundwater SL since August 2014. 2,4-Dichlorophenol is discussed in text only and is not presented on figures because of its low frequency of SL exceedances.

5.2.4.4 BEHP

BEHP was retained as a groundwater COPC. One shallow groundwater sample collected from MW-32S in May 2012 had a reported concentration exceeding the SL (Table W-13, Appendix W). MW-32S is located in the northeastern corner of the Site. One shallow groundwater sample collected from MW-43S in March 2015 had a reported concentration exceeding the SL (Table W-13,

Appendix W). MW-43S is located in the south center of the Site, south of the former Reichhold operations area. BEHP was not detected in subsequent samples from this well or other wells at the Site.

Further, BEHP was reported as detected in groundwater samples collected from the following deep aquifer wells: MW-1D, MW-2D, MW-31D, MW-32DR, MW-38D, and MW-43D. The PQLs for these samples ranged between 1 and 2.1 µg/L, which exceeds the SL of 0.046 µg/L (Table W-13, Appendix W). BEHP is not presented on figures because of its low frequency of SL exceedances.

5.2.5 PAHS

cPAH TEQ (ND=0 and ND=1/2DL) was retained as a groundwater COPC and as a primary COPC. cPAH TEQ was not detected in shallow or deep groundwater at concentrations greater than the PQLs, which range between 0.023 and 0.2 µg/L, and are greater than the cPAH SL of 0.000016 µg/L (Table W-13, Appendix W). However, because the PQL for cPAHs in groundwater is greater than the SL, cPAHs are retained as a COPC in groundwater at this time.

5.2.6 POLYCHLORINATED BIPHENYLS

PCBs were retained as a groundwater COPC and meet the criteria of a primary COPC. One shallow groundwater sample collected from MW-33S in September 2015 had a reported concentration of PCBs exceeding the SL (Table W-14, Appendix W). MW-33S is located in the north-central portion of the Site near the shoreline. PCBs were not detected in subsequent samples from this well or other wells at the Site.

Ten groundwater samples collected in 2014 and 2015 from shallow groundwater monitoring wells MW-27S, MW-29S, MW-33S, and MW-45S were reported as ND for PCBs. However, all 10 of these samples had PQLs greater than the respective SLs (Table W-14, Appendix W). PCBs results are not presented on figures in this RI report because of their low frequency of detection and SL exceedances.

5.2.7 DIOXINS/FURANS

Total D/F TEQ and TCDD were retained as COPCs for groundwater and D/F TEQ meets the criteria of a primary COPC (Table 4-8). TCDD was reported as ND in the 73 samples analyzed; however, the PQLs for all the samples exceeded the SL of 0.0051 picograms per liter (pg/L). D/F TEQ concentrations in groundwater are calculated in two ways, one with ND equal to zero, and one with ND equal to one-half the MDL. The D/F TEQ concentrations reported in groundwater samples range between 0.000206 and 18 pg/L (ND=0) and 0.802 and 19 pg/L (ND=1/2DL). For D/F TEQ (ND=0), 60 of the 73 groundwater samples reported D/F TEQ concentrations greater than the SL of 0.0051 pg/L (Table V-3, Appendix V). For D/F TEQ (ND=1/2DL), 68 of the 73 groundwater samples reported concentrations greater than the SL. The magnitude and extent of D/F TEQs in shallow and deep groundwater is illustrated on Figures 5-20 and 5-21, respectively, using the D/F TEQ SL of 0.0051 pg/L. The SL for D/F TEQs is based on a concentration protective of surface water but is less than the PQL of 4.4 pg/L as shown in Table 4-2.

Shallow groundwater samples collected from each of the 13 monitoring wells sampled had reported D/F TEQ concentrations exceeding the SL (Figure 5-20). Groundwater samples collected

from MW-33S and MW-35S had the highest D/F TEQ concentrations reported during the RI monitoring period (Figure 5-20). These locations are within the former Reichhold operational areas, which overlap with those of Carlisle, Crown Zellerbach, and the Army.

Each of the groundwater samples collected from the four deep monitoring wells had detected D/F TEQ concentrations exceeding the SL (Figure 5-21). The extent of D/F impacts in shallow and deep groundwater has not been fully characterized, but this is not expected to interfere with remedy selection.

5.3 SEEPS

As discussed in Section 3.1.3, Hart Crowser collected water samples from three surface water seeps on May 15, 1995, designated as locations SW-01, SW-02, and SW-03 (Figure 3-1). In July 2004, two seeps (SP-61 and SP-62; Figure 3-1) along the shoreline of the Site were sampled by Windward. The analytical results for the seep samples are summarized in Table AA-1 of Appendix AA. Because seeps are a potential pathway for contaminants to surface water and sediment in the LDW, analytical results of compounds detected in seep samples were compared to the groundwater SLs protective of the groundwater to surface water and groundwater to sediment pathways (Table AA-1, Appendix AA). Note that the SL protective of surface water for arsenic is less than the natural background concentration of 8 µg/L, which is adopted as the most stringent groundwater SL (Ecology 1994).

According to Hart Crowser (1995), total arsenic was reported at concentrations ranging from 30 to 82 µg/L in seep samples SW-01 through SW-03, which exceed the groundwater SL protective of surface water of 0.14 µg/L but are less than the groundwater SL protective of sediment of 221 µg/L. These results suggest that the total arsenic concentrations in seeps are protective of sediment but not surface water. The same seep samples were also analyzed for silver, PCP, and TPH-DRO; however, no detectable concentrations of these analytes were reported in the seep samples, suggesting that shallow seeps are not a source of silver, PCP, or TPH-DRO to the LDW.

According to Windward (2004), dissolved arsenic was reported in SP-61 at 72.4 µg/L and SP-62 at 6.84 µg/L, both exceeding the groundwater SL protective of surface water of 0.14 µg/L but less than the groundwater SL protective of sediment of 221 µg/L. Dissolved cadmium, lead, mercury, silver, and zinc concentrations were reported in both seep samples but at concentrations less than the groundwater SLs protective of surface water and sediment. Dissolved copper and chromium were not detected (Table AA-1, Appendix AA). The groundwater SLs are established for total metals concentrations, not dissolved. Dissolved metals concentrations are likely to be lower than corresponding total metals concentrations.

SVOCs, PAHs, PCBs, TPH-DRO, VOCs, and organochlorine pesticides were not detected in the Windward seep samples. Overall, the data suggest that seeps are not a source of copper, chromium, cadmium, lead, mercury, silver, zinc, SVOCs, PAHs, PCBs, TPH-DRO, VOCs, or organochlorine pesticides.

5.4 STORMWATER

As described in Section 3.3.6, a total of four stormwater samples were collected at location STW-01 (the Sand and Gravel Permit sampling location upstream of the discharge point to the Embayment [Figure 3-7]) between October 2012 and April 2013. Analytical results of the stormwater samples collected from STW-01 between October 2012 and April 2013 are summarized in Tables BB-1 through BB-5 in Appendix BB. Section 2.4.2 provides a description of the stormwater system shown on Figure 3-7. Field parameters collected during each sampling event are included in Table BB-6 of Appendix BB. The laboratory analytical data packages from the RI activities are included as Appendix Y, and associated data quality review memoranda are presented in Appendix X.

Detectable concentrations of antimony, arsenic, chromium, copper, and zinc were reported in stormwater samples (Table BB-1 in Appendix BB). In general, concentrations of total metals were higher than concentrations of dissolved metals, indicating particle-association in the samples (e.g., copper and zinc results). In each case, the variability of metal concentrations in the sample group was narrow, an indication of sample-to-sample consistency.

Detectable concentrations of 1,2,4-trichlorobenzene, acetone, and hexachlorobutadiene were reported in stormwater samples (Table BB-2, Appendix BB). Neither TPH-DRO nor TPH-MORO were detected in the stormwater samples with one exception (Table BB-2, Appendix BB). The exception is an estimated (j-flagged) low concentration of TPH-MORO reported for the October 30, 2012, sample and associated duplicate. The sample was the first sample of the stormwater season (Table BB-2).

The only SVOC detected in the stormwater samples was BEHP (Table BB-3, Appendix BB). PAHs were not detected in any of the stormwater samples (Table BB-3, Appendix BB). PCBs were not detected in any of the stormwater samples (Table BB-4, Appendix BB).

The reported D/Fs TEQ concentrations in the 2012 to 2013 stormwater samples ranged from 2.4 to 8.35 pg/l (Table BB-5, Appendix BB). D/Fs have low solubility, are highly hydrophobic, and are consequently extremely sensitive to bias from even very low levels of suspended solids in sample water. The stormwater samples collected and analyzed for D/Fs during the RI were not filtered. While the total suspended solids data for the stormwater sampling is limited, the variability in reported D/F TEQ concentrations may be in part associated with suspended solids present at the time of sampling. As shown in Table BB-6 of Appendix BB, turbidity measured in the four RI stormwater samples ranged from 7.31 to 79.4 NTU; whereas turbidity readings collected for permit compliance and reported on Ecology's Water Quality Permitting and Reporting Information System ranged between 5.3 and 32 NTU. The large difference between the turbidity readings collected for the RI stormwater samples and those collected by Glacier Northwest for compliance purposes indicate that the stormwater samples collected during RI stormwater sampling may not have been representative of typical conditions. As presented in Table BB-5 of Appendix BB, D/F TEQ concentrations reported in stormwater varied between each sampling event and varied between the primary and field duplicates samples collected on January 9, 2013. One possible explanation of this variability could be temporal susceptibility of the stormwater samples

to suspended solids. A discussion of D/F fate is presented in Section 7.5.1.1 and stormwater transport is presented in Section 7.5.2.3.

5.5 CURRENT PROPERTY STORMWATER SYSTEM SOLIDS

As described in Section 3.3.7, five stormwater solids samples were collected from the Property stormwater system in September 2012. The stormwater solids sampling locations are shown on Figure 3-7. Stormwater solids were sampled from four locations (CB-01, SWD-01, SWD-02, and Tank-01) on September 4, 2012. Analytical results of the September 2012 stormwater solids samples are presented in Tables CC-1 through CC-7 in Appendix CC. The laboratory analytical data packages from the RI activities are included as Appendix Y, and associated data quality review memoranda are presented in Appendix X.

The primary COPCs detected in the stormwater solids samples include arsenic, copper, zinc, BEHP, PCP, phenol, cPAHs (as TEQ), PCBs, and D/Fs. Arsenic and zinc concentrations reported in stormwater solids from the catch basin, one stormwater swale location (SWD-01), and both tank solids samples exceeded the sediment SLs of 7 and 410 mg/kg, respectively (Table CC-1, Appendix CC). Copper concentrations reported in the stormwater solids samples did not exceed the sediment SL. TPH-DRO/MORO was detected in one stormwater swale sample (SWD-02) and the catch basin sample at concentrations ranging between 111 and 18,200 mg/kg (Table CC-6, Appendix CC). PCP was detected in one stormwater swale sample (SWD-01) at a concentration less than the sediment SL (Table CC-2, Appendix CC). The cPAH TEQ concentrations reported in the catch basin sample and one stormwater swale sample (SWD-01) exceeded the sediment SL of 0.09 mg/kg (Table CC-2, Appendix CC). PCBs were reported in all four stormwater samples (as well as one field duplicate) at concentrations less than the sediment SL (Table CC-4, Appendix CC). D/F TEQs reported in all four stormwater samples (as well as one field duplicate) exceeded the sediment SL (Table CC-5, Appendix CC).

Chemicals detected in stormwater solids that are Site COPCs in sediment were evaluated on their potential to cause recontamination of sediments using a simple mass balance box model.

Chemicals evaluated in the mass balance include:

- Metals (arsenic, copper, mercury, and zinc);
- SVOCs (PCP, hexachlorobenzene, benzyl butyl phthalate, phenol);
- cPAHs;
- PCBs (mixtures); and
- D/Fs.

The mass balance box model evaluates outfall discharges using a single box and conservatively assumes that all of the solids discharged become part of the bedded sediments within a semi-circle radius of 200 feet from the outfall (King County 2012). The model uses Site-specific values (i.e., the upland drainage area representative of stormwater captured by catch basins and the stormwater swale, [Figure 2-4] and measured total solids concentrations reported in surface sediment samples [Table GG-6, Appendix GG]) and typical values from the LDW (e.g., sedimentation rate and solids loading rate [Herrera 2007]) for other parameters. In addition, the model conservatively assumes no solids are retained in the stormwater system, and that all

stormwater is discharged to the LDW. As discussed in Section 2.4.2, the stormwater system only discharges to the LDW 10 to 12 times per year, and the system is designed to reduce suspended solids via catch basins, holding tanks, and check dams within the stormwater swale. The results of the mass balance box model for each COPC parameter is presented in Tables DD-1 through DD-11 (Appendix DD).

The results of this model suggest that under current conditions, settling of stormwater solids in the nearshore area of the Embayment does not, by itself, cause nearshore sediment concentrations to exceed sediment SLs. The maximum concentrations of copper, mercury, PCP, hexachlorobenzene, and benzyl butyl phthalate in stormwater solids are already below their sediment SLs. It should be noted that the results of this SL evaluation do not determine whether stormwater source control will be needed in the future and that the potential for stormwater solids to impact sediments under post-remediation conditions may be different from that under current Site conditions.

5.6 SPU STORMWATER SYSTEM SOLIDS

Between 2006 and 2014, stormwater solids samples were collected from three stormwater drainage lines that tie into the 48-inch SPU stormwater line that parallels the southern boundary of the Site. The three stormwater drain lines sampled include the plugged and abandoned 15-inch stormwater pipe located in the southern portion of the Property described in Section 3.3.8, an active stormwater trunk line underlying West Marginal Way SW, and a stormwater pipe on the Port of Seattle property (Figure 3-8). Stormwater solids samples were also collected from the SPU stormwater line.

Two solids samples (SWP-01 and SWP-02; Figure 3-8) were collected from the 15-inch stormwater pipe, upstream of the location where it tied into the 48-inch SPU stormwater line (Figure 3-8), before the 15-inch stormwater pipe was plugged and abandoned in August 2014 (Section 3.3.8).

Between 2006 and 2013, SPU collected solids samples from a stormwater trunk line and from the 48-inch SPU stormwater line that discharges to the LDW (Figure 3-8). SPU sample locations RCB53, RCB54, and RCB55 were collected from locations within the stormwater trunk line underlying West Marginal Way SW, and SPU sample location KEN-ST1 was sampled from the catch basin located upstream of the outfall (Figure 3-8). Stormwater passing these sample locations discharges to the LDW from the outfall of the 48-inch stormwater line (Figure 3-8). The SPU data were collected as part of SPU's source tracing work in the LDW drainage basin (SPU 2010).

On January 16, 2014, five solids samples were collected from a stormwater catch basin on the Port of Seattle property that all tie into the 48-inch-diameter SPU stormwater line (Figure 3-8).

The stormwater solids samples were analyzed for metals, VOCs, TPH, SVOCs, PAHs, PCBs, and D/Fs. Analytical results for solids samples obtained from the 15-inch historical stormwater pipe are presented in Tables EE-1 through EE-5 in Appendix EE. The laboratory analytical data packages from the RI activities are included as Appendix Y, and associated data quality review memoranda are presented in Appendix X. Table FF-1 in Appendix FF includes analytical results of the stormwater solids samples collected by SPU between 2006 and 2013, and Table FF-2 presents

the analytical results of the stormwater solids samples collected from the catch basin on the Port of Seattle property in 2014.

COPCs detected in the two solids samples collected from the 15-inch stormwater pipe include arsenic, copper, zinc, PCBs, and D/Fs (Tables EE-1 through EE-4, Appendix EE). The arsenic concentrations reported in both solids samples exceeded the sediment SL. The copper concentration reported in one solids sample (SWP-02) exceeded the sediment SL, and the zinc concentration reported in solids sample SWP-01 exceeded the sediment SL. The PCB concentrations reported in both solids samples did not exceed the sediment SL of 0.128 mg/kg; however, the D/F TEQ concentrations reported in both samples did exceed the sediment SL.

As presented in Table FF-3 of Appendix FF, the reported PCBs and zinc concentrations in SPU samples collected from locations RCB53, RCB54, and RCB55 along the stormwater trunk line underlying West Marginal Way SW are of similar magnitude in concentration to the PCBs and zinc detected in the solids collected from the 15-inch historical stormwater pipe. As shown in Table FF-3 the reported PCBs and zinc concentrations in the stormwater solids samples from the Port of Seattle property are greater in concentration than the concentration of these compounds detected in the solids collected from the 15-inch stormwater pipe. However, arsenic, copper, and D/F TEQ concentrations were greater in magnitude in the solids samples collected from the stormwater pipe than in SPU samples and the sample from the catch basin on the Port of Seattle property (Table FF-3, Appendix FF).

As shown on Figure 3-8, the 15-inch stormwater pipe on the Property was situated within the operational area used by Mineralized-Cell in the 1930s where soil with arsenic, copper, and D/F TEQ concentrations exceeding SLs is present (Figures 5-1, 5-2, 5-3, and 5-10). The elevated concentrations of arsenic, copper, and D/F TEQs reported in solids samples collected from the historical pipe may be from soils that entered the pipe before the catch basins were plugged.

Another potential source of elevated COPC concentrations reported in the solids samples could be the mixing of stormwater solids entrained in the stormwater conveyed by the 48-inch SPU stormwater line or surface water from the LDW that inundates the stormwater line. This is because the catch basins that served the historical stormwater pipe were plugged with concrete before Glacier Northwest acquired the Property in 1991, but the pipe remained connected to the 48-inch stormwater line until it was cut and capped in 2014. As discussed in Section 2.5.3, the 48-inch-diameter stormwater line is fully inundated during high tide cycles (Appendix G), which means the historical stormwater pipe may have also been inundated before it was cut and capped in 2014.

The 15-inch stormwater pipe was installed in 1975 and used only for a short period of time. Sometime before 1991, the catch basins that tied into the 15-inch stormwater pipe were plugged with concrete, thus rendering the pipe inactive. Furthermore, in August 2014 the historical pipe was cut and capped at the location on the Property closest to where it ties into the 48-inch-diameter SPU stormwater line. The historical pipe ceased being an active stormwater conveyance system when the catch basins were plugged before 1991, and the activities completed in August 2014 provided further assurance that the 15-inch pipe is not a current or future conveyance pathway.

5.7 DATA QUALITY

The quality of the uplands analytical data was assessed and qualifiers were applied following the protocol described in *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA 1999), *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (USEPA 2004), and *EPA Region 10 SOP for the Validation of Polychlorinated Dibenzodioxin (PCDD) and Polychlorinated Dibenzofuran (PCDF) Data* (USEPA 1996). The only data determined to be unusable for this RI were:

- Hexavalent chromium analytical results for three soil samples (GP-69-0-2, MW-45D-2.3-4.2, and MW-31D-8.25-9.25) were rejected because the percent recoveries for the associated matrix spike ranged from 0 to 2.4 percent (the acceptable limit is 75 to 125 percent recovery).
- Hexavalent chromium analytical results for multiple groundwater samples from the March 2014 (MW-1S, MW-1D, MW-26S, MW-35S, MW-35D, and MW-38D) and the August 2014 (MW-1S, MW-1D, MW-14S, MW-34S, MW-35S, MW-35D, and MW-38D) sampling events were rejected because the percent recoveries for the associated matrix spikes were 0 percent (the acceptable limit is 75 to 125 percent recovery).

All other data, including qualified data, was determined to be suitable for use in this RI; however, the limitations indicated by the applied qualifiers should be considered when using the data. The quality of the data generated during this investigation is acceptable for the preparation of technically defensible documents. The data quality review memoranda are presented in Appendix X. Publicly available data collected by others in the LDW and on the DSI property and Port of Seattle property are used in this report as reported in Ecology's Environmental Information Management system.

6. SURFACE AND SUBSURFACE SEDIMENT SAMPLING RESULTS

This section presents surface and subsurface sediment data collected during the RI and compares the data to the SLs shown in Table 4-3. As discussed in Section 4.1.2, the SLs for sediment are from the Target Sediment Concentrations presented in the Workbook (Ecology 2019), which are the most conservative of the minimum LDW ROD CULs (USEPA 2014) and the SMS SCOs (i.e., lower tier target concentration). This report focuses on the results of sediment samples collected within the aquatic portion of the Site, whether collected pursuant to the Agreed Order, during the LDW RI/FS, or other investigations. Sediment samples collected outside the aquatic portion of the Site are described in documents prepared by others for the LDW site. The aquatic portion of the Site will be addressed in a separate CERCLA Remedial Design/Remedial Action process in accordance with the LDW ROD.

Tables GG-1 to GG-6 of Appendix GG present surface and subsurface sediment analytical data for the aquatic portion of the Site. Sample locations are presented on Figure 3-2. Laboratory analytical data packages from the RI activities are included as Appendix Y, and data quality review memoranda are included as Appendix X.

For the purposes of the following discussion, the shore of the Embayment within the aquatic portion of the Site can be divided into two sections: (1) the northern shore that extends generally north to south along the eastern boundary of the upland portion of the Site and (2) the southern shore that extends generally west to east along the southern boundary of the upland portion of the Site.

6.1 SEDIMENT SCREENING TO IDENTIFY CONTAMINANTS OF POTENTIAL CONCERN

As discussed in Section 4.1, sediment concentrations were compared to sediment SLs to identify COPCs. A total of 29 COPCs were identified by screening sediment concentrations against the sediment SLs presented in Table 4-3. Table 4-8 summarizes the COPCs identified in sediment.

Although 29 COPCs were identified for sediment, this section focuses on the primary COPCs in sediment: arsenic, copper, zinc, cPAHs (as TEQ), PCBs, D/F TEQs, PCP, phenol, and tributyltin. The magnitude and extent of arsenic, cPAHs, PCBs, D/F TEQs, PCP, and tributyltin are depicted on Figures 6-1 through 6-6, respectively. The magnitude and extent of copper, zinc, and phenol are discussed together in Section 6.2.7 and are not mapped because of the limited number of sediment samples having SL exceedances of these primary sediment COPCs. Moreover, the sediment samples having SL exceedances of these primary sediment COPCs are generally co-located samples having SL exceedances of arsenic, cPAHs, PCBs, D/F TEQs, PCP, and tributyltin. Therefore, their magnitude and extent are generally represented by the magnitude and extent of arsenic, cPAHs, PCBs, D/F TEQs, PCP, and/or tributyltin.

6.2 SEDIMENT SAMPLE RESULTS

As described earlier, the primary sediment COPCs were identified using the SLs provided in the Workbook (Ecology 2019). Because the SLs are elevation-, location-, and depth-specific, separate

evaluations were performed for surficial and subsurface sediment, and the results are presented as Thiessen polygons on Figures 6-1 to 6-6.

The SLs are applicable to the top 45 cm of sediment; however, sediment samples collected as part of the RI were collected from the 0 to 10 cm interval (surface sediments) or from 0 to 1 foot, 1 to 2 feet, 2 to 4 feet, and 6 to 8 feet intervals. Therefore, sediment samples collected within the top 2 feet (i.e., 0 to 60 cm) of sediment were compared to the SLs. For surface sediment samples collected from the 0 to 10 cm sediment interval, sediment data were compared directly to the SL. For sediment within the 0 to 60 cm interval, average concentrations in sediment samples were calculated following the data management rules from the LDW RI/FS (see Appendix E to the LDW RI; Windward 2010) and were then compared to the SLs.

As detailed below, this evaluation indicates that the locations where PCP in surface and subsurface sediment exceed the SLs are confined to locations near the shoreline of the Embayment. The locations where arsenic, cPAHs, PCBs, D/Fs, and tributyltin exceed the SLs cover a greater portion of the Embayment and are also present outside the Embayment. Summaries of the distributions of individual COPCs are provided below.

6.2.1 ARSENIC

Arsenic was detected at concentrations greater than the SL of 7 mg/kg in each of the 25 surface sediment samples collected within the aquatic portion of the Property (Table GG-1 in Appendix GG; Figure 6-1). The arsenic concentrations reported in the surface sediment samples range from 13.9 to 269 mg/kg (Table GG-1, Appendix GG).

Arsenic was detected at concentrations exceeding the SL in each of the 16 subsurface sediment samples collected within the 0 to 60 cm interval of the aquatic portion of the Property (Figure 6-1). The arsenic concentrations reported in subsurface sediment samples range from 10.9 to 207 mg/kg (Table GG-1, Appendix GG).

6.2.2 CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

As shown on Figure 6-2, each of the 26 surface sediment samples collected within the aquatic portion of the Property exhibit cPAH TEQ concentrations exceeding the SL of 0.09 mg/kg (Figure 6-2). The cPAH TEQ concentrations reported in surface sediment samples range from 0.12 to 1.7 mg/kg (Table GG-2, Appendix GG).

Thirteen of the 15 subsurface sediment samples collected within the 0 to 60 cm interval of the aquatic portion of the Property exhibit cPAH TEQs exceeding the SL (Figure 6-2). The cPAH TEQ concentrations in the subsurface sediment samples range from 0.049 to 1.9 mg/kg (Table GG-2, Appendix GG).

6.2.3 POLYCHLORINATED BIPHENYLS

PCBs were reported at concentrations exceeding the SL of 0.128 mg/kg in 14 of 26 surface sediment samples collected within the aquatic portion of the Property (Figure 6-3). PCB concentrations reported in the surface sediment samples ranged from 0.053 to 0.81 mg/kg (Table GG-4, Appendix GG).

Twelve of the 20 subsurface sediment samples collected from the 0 to 60 cm interval of the aquatic portion of the Property had reported PCB concentrations exceeding the SL (Figure 6-3). PCB concentrations reported in the subsurface sediment samples range from 0.0326 to 1.3 mg/kg (Table GG-4, Appendix GG).

6.2.4 DIOXINS/FURANS

As shown in Table 4-3, the SL for D/F TEQs in sediment is 2 pg/g. This SL is less than the PQL; therefore, the magnitude and extent of D/F TEQs in sediment are compared to the PQL of 5 pg/g for visualization purposes. D/F TEQs were detected at concentrations exceeding both the SL for D/F TEQs and the PQL in each of the 23 surface sediment samples collected within the aquatic portion of the Property (Figure 6-4). D/F TEQ concentrations reported in the surface sediment samples range from 11.2 to 2,100 pg/g (Table GG-5, Appendix GG).

As shown on Figure 6-4, the reported D/F TEQ concentrations in all 17 of the subsurface sediment samples collected from the 0 to 60 cm interval of the aquatic portion of the Property exceeded both the SL and the PQL. D/F TEQ concentrations reported in subsurface sediment samples range from 1.03J to 4,335 pg/g (Table GG-5, Appendix GG).

6.2.5 PENTACHLOROPHENOL

PCP was reported at concentrations exceeding the SL of 0.36 mg/kg in one surface sediment sample collected from intertidal sediments in the middle of the northern shore of the Embayment (Figure 6-5). PCP concentrations reported in the surface sediment samples collected within the aquatic portion of the Property range from 0.08 to 0.41 mg/kg.

PCP was reported at concentrations exceeding the SL in four of the 15 subsurface sediment samples collected within the 0 to 60 cm interval of the aquatic portion of the Property (Figure 6-5). These four samples were collected from subsurface sediments along the north shore of the Embayment. PCP concentrations reported in subsurface sediment samples range from 0.018 to 20 mg/kg (Table GG-2, Appendix GG).

6.2.6 TRIBUTYLTIN

As shown in Table 4-3, the SL for tributyltin in sediment (0.0021 mg/kg) is less than the PQL; therefore, the magnitude and extent of tributyltin in surface and subsurface sediment samples are compared to the PQL of 0.00386 mg/kg for visualization purposes. The 14 samples reported as ND for tributyltin had PQLs greater than the respective SLs (Table GG-1, Appendix GG). Tributyltin was detected in each of the four surface sediment samples collected within the aquatic portion of the Property at concentrations exceeding both the SL and the PQL (Figure 6-6). The concentrations of tributyltin reported in the surface sediment samples range from 0.028 to 0.22 mg/kg (Table GG-1, Appendix GG).

Tributyltin was detected in 13 of 14 subsurface sediment samples collected within the aquatic portion of the Property at concentrations exceeding both the SL and the PQL (Figure 6-6). Tributyltin concentrations reported in the subsurface sediment samples range from 0.0066 to 0.2 mg/kg (Table GG-1, Appendix GG).

6.2.7 OTHER COPCS

Although copper was identified as a primary sediment COPC, only one sediment sample of the 78 samples collected had a reported copper concentration exceeding the SL (SED-SS-14; Figure 3-2; Table GG-1, Appendix GG). This sample was located along the northern shore of the Embayment.

Zinc was also identified as a primary sediment COPC, but only three samples of the 78 samples collected had reported zinc concentrations exceeding the SL. Zinc was detected in two surface sediment samples (SED-SS-14 and LDW-SS56; Figure 3-2) and one subsurface sediment sample (SED-SC-05 [2 to 4 feet]; Figure 3-2) at concentrations exceeding the sediment SL (Table GG-1, Appendix GG). The two surface sediment samples are located near the northern shoreline by the dock. The subsurface sediment sample was collected from a location north of the dock near the southern boundary of the DSI property.

Phenol was identified as a sediment COPC and meets the criteria of a primary COPC. Phenol was reported at concentrations exceeding the SL in five of the 77 sediment samples collected (SED-SC-03 [0 to 1 feet], SED-SC-03 [2 to 4 feet], SED-SC-14 [0 to 1 feet], SED-SC-15 [0 to 1 feet], SED-SC-16 [0 to 1 feet]). The five samples were collected from intertidal sediments along the north shoreline and are co-located with subsurface sediment samples with concentrations of PCP exceeding the SL (Figure 6-5).

6.2.8 OFF-PROPERTY SEDIMENT SAMPLE RESULTS

Arsenic, cPAHs, PCBs, D/Fs, PCP, and tributyltin have been detected in LDW sediments at concentrations exceeding the SLs in locations outside the aquatic portion of the Property, including near the shore of the DSI property, the shore of the Port of Seattle property, and the eastern shore of the LDW upgradient of the Property. As discussed below, the COPCs detected in these areas are likely attributable to sources with no correlation to the Property.

As shown on Figure 6-1, concentrations of arsenic exceeding the SLs were detected in surface and subsurface sediment samples collected near the shore of the DSI property, the shore of the Port of Seattle property, and the eastern shore of the LDW upgradient of the Property. One sediment core sample collected near the former DSI dry dock contained sand blast grit, gravel with scattered debris, foliated chips (likely paint), and orange flecks, and exhibited some of the highest concentrations of arsenic detected in the LDW as well as elevated concentrations of copper, lead, mercury, zinc, chlorinated benzenes, PCBs, PCP, PAHs, tributyltin, and phthalates. The potential sources of the arsenic in the areas near the DSI shore include discharges from the former DSI stormwater outfall (SAIC 2007) and historical ship repair activities conducted on DSI's former marine railway and drydock. DSI received numerous warnings, citations, violations, and fines for its environmental practices and releases to the LDW (SAIC 2007). The majority of the issues were associated with drydock operations, but also included the stormwater system. Arsenic was also detected in soil and groundwater samples collected from the DSI property at concentrations exceeding MTCA CULs (Anchor 2006).

As shown on Figure 6-2, concentrations of cPAHs exceeding SLs were detected in surface and subsurface sediment samples collected near the shoreline of the DSI property, the shoreline of the

Port of Seattle property, and the eastern shoreline of the LDW upgradient of the Property. The potential sources of the cPAHs near the DSI shoreline are the same DSI outfall discussed above and historical ship repair activities. cPAHs were detected in soils and groundwater at the DSI property in concentrations above MTCA CULs and in stormwater catch basin solids at concentrations above the sediment quality objective (Ecology 2007). In general, the cPAH concentrations in surface and subsurface sediments along the DSI shore are higher than the cPAH concentrations detected in sediments within the aquatic portion of the Property.

As shown on Figure 6-3, concentrations of PCBs exceeding the SLs were detected in surface and subsurface sediment samples collected near the shore of the DSI property, and eastern shore of the LDW upgradient of the Property. The potential sources of the PCBs near the DSI shore are the same DSI outfall discussed above and historical ship repair activities. PCBs were a common ingredient in historical ship paints and coatings. PCBs were detected in soil at the DSI property, but at concentrations lower than MTCA CULs.

As shown on Figure 6-4, concentrations of D/F TEQs exceeding the SLs were detected in surface and subsurface sediment samples collected near the DSI property. D/Fs were also detected at concentrations exceeding the SLs in surface and subsurface sediments near the navigation channel along the eastern shoreline of the LDW downgradient of the Site. The potential source of the D/Fs in these areas may be the same DSI outfall discussed above. The D/F dataset available for upland sites along the LDW is very limited.

As shown on Figure 6-6, concentrations of tributyltin exceeding the SLs were detected in surface and subsurface sediment samples collected near the DSI property. As described in Section 2.7.1, historical operations at the DSI property included repair and maintenance of floating vessels, including hull repairs and painting. DSI also used the aquatic portion of the Property for log and vessel mooring between 1960 and 1964. Tributyltin was a common ingredient in hull paint until the 1980s when countries began banning its use. The potential sources of the tributyltin in these areas include historical ship repair and mooring activities on the DSI property.

6.3 DATA QUALITY

The sediment data quality was assessed and qualifiers were applied following the *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA 1999), *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (USEPA 2004), and the *EPA Region 10 SOP for the Validation of Polychlorinated Dibenzodioxin (PCDD) and Polychlorinated Dibenzofuran (PCDF) Data* (USEPA 1996). The data quality review memoranda are presented in Appendix X. All data, including qualified data, were determined to be suitable for characterization of the Site.

Sediment calculations described below were performed in a manner consistent with the LDW studies (Windward 2010). Organic constituents having organic content-normalized (OC-normalized) SLs were converted from the dry weight concentrations and reported by the analytical laboratory to their corresponding OC-normalized values using the sample-specific TOC concentrations. Cumulative constituent concentrations (e.g., total low molecular weight PAHs, high molecular weight PAHs, and total PCBs) were calculated as the sum of the individual detected chemicals, and ND values were assumed to be zero for the purpose of totals. cPAH concentrations

are also presented as cPAH TEQs using the potency equivalency factors from the California Environmental Protection Agency (2005) as presented in the LDW RI/FS (Windward 2010; AECOM 2012), and for this calculation one-half of the MDL was used in the calculation when individual constituents were not detected.

Concentrations of D/Fs (Table GG-5, Appendix GG) are presented as D/F TEQs calculated for the suite of congeners using TEFs (WAC 173-340-708, Table 708-1) endorsed by the World Health Organization (Van den Berg et al. 2006). TEQs were calculated using one-half the MDL for ND congeners, and used the same summing procedures and TEFs used in the LDW RI/FS calculations (Windward 2010; AECOM 2012).

7. CONCEPTUAL SITE MODEL

This section describes the CSM for the Site. The CSM is a conceptual understanding of the Site that summarizes:

- The Site features, including the hydrogeologic and aquatic setting and the current and likely future uses of the Site;
- The nature and extent of COPCs in Site media (soil, groundwater, surface water, and sediment);
- The primary sources of COPCs and their release mechanisms;
- The fate and transport of the COPCs (i.e., secondary sources and release mechanisms); and
- The potential receptors and exposure pathways to the COPCs.

The CSM guides the development of the RI/FS, as well as selection of cleanup standards and cleanup action alternatives. An important function of the CSM is to identify a complete link between a COPC source, release, transport pathway, and exposure to receptors (Ecology 2015c).

Primary sources are confirmed or presumed sources of COPCs at the Site and may consist of industrial activities (e.g., manufacturing, chemical processing, waste handling, and disposal) or structures (e.g., tanks, impoundments, stormwater lines, transformers, vehicles, etc.) that released or may have released COPCs that have impacted Site media. The term “primary source” does not refer to the importance or magnitude of the source relative to other sources. Primary release mechanisms are the means (e.g., leaks, spills, direct discharge, air emissions, etc.) by which COPCs are disseminated to Site media (i.e., soil, groundwater, sediment, air, and/or surface water) from primary sources.

Secondary sources consist of Site media that have been impacted by releases of COPCs from primary sources and have the potential to migrate (e.g., erosion of COPC-impacted soil) or release COPCs to other media (e.g., leaching of COPCs from soil to groundwater). Secondary release mechanisms are the means (e.g., leaching, volatilization, adsorption, etc.) by which COPCs are disseminated to Site media from secondary sources.

Based on the fate and transport of the COPCs in Site media and the current and future anticipated land use and Site characteristics, a conceptual site exposure model can be developed for the Site. Figure 7-1 presents the conceptual site exposure model developed for the Site and is described in Section 7.6.

7.1 SITE FEATURES

The Site as it exists today and for the foreseeable future is shown in plan-view on Figure 2-3 and as an orthogonal schematic on Figure 7-2. The northern area of the upland portion of the Site is used to receive, store, and distribute dry cement. The southern area of the upland portion of the Site is used for vehicle and equipment storage, warehousing, and light maintenance. A stormwater swale and outfall are located near the center of the upland portion of the Site.

The geology (from bottom to top) consists of the lower sand unit, silt aquitard, dredged material, and shallow fill, overlain with a gravel layer placed at the surface to support vehicle operations. The dredged material was placed on the Property behind a wooden bulkhead constructed on top of

the silt aquitard when the waterway was dredged in the 1920s (see 1922 photograph in Appendix A1). From aerial photographs, it appears that the shoreline of the Property maintained the same general configuration from the time the dredged material was placed until the Property was redeveloped in the late 1960s. No remnants of the wooden bulkhead are apparent in photographs taken during Reichhold's operation of the Site in the 1950s (Appendix A1), indicating that the wooden bulkhead had decayed or been removed before that time.

The Property was purchased by the Port of Seattle and redeveloped into a cement terminal in the 1960s. During redevelopment, material likely comprised of soil and debris from the demolition of the Army and Reichhold facility structures, was placed waterward of where the wooden bulkhead once stood. Riprap, consisting of concrete debris from the former Army and Reichhold facility structures, was placed along the riverbank between 1967 and 1968, creating the current configuration of the Property's shoreline.

Between 1969 and 1970, the Port of Seattle installed the protected bank that forms the southern shore of the Embayment as part of the Port of Seattle's construction of T115. The southern shore of the Embayment was constructed to support and protect the 48-inch SPU stormwater line that is within an easement that parallels the northern boundary of the Port of Seattle property. Material used to construct the southern shore of the Embayment includes riprap and engineered fill generally consisting of gravel material of varying diameters.

Although the shoreline is currently armored and protected by riprap, some of the originally placed riverbank fill material likely eroded into the Embayment before it was covered with riprap. The riprap remains in good condition and maintains the structural integrity of the shoreline.

Groundwater is hydraulically interconnected with the surface water of the Embayment. Both the shallow and deep aquifers are tidally influenced, and there is net groundwater flow from both aquifers toward the Embayment. In addition, shallow groundwater migrates toward the Embayment along the backfill of the 48-inch-diameter SPU stormwater line located south of the Property that discharges through Outfall 2127 to the LDW (Figure 7-2). The shallow aquifer is unconfined and the deep aquifer is confined.

In the vicinity of the Site, the LDW is a salt wedge-type estuary having predominant flow to the north, tidally influenced flow to the south, and recirculation/eddy currents in the Embayment (Figure 7-2). The Embayment is net depositional with average measured and modeled net sedimentation rates of approximately 0.5 to 3 cm/yr (Windward 2010).

7.2 CURRENT AND FUTURE SITE USE

Under current and anticipated future conditions, the upland portion of the Site meets the criteria of an industrial property under WAC 173-340-200. As described in Section 2.2, the Site and adjacent properties have been industrialized for over 90 years, are zoned for general industrial use by the City of Seattle, and are anticipated to remain industrial for the foreseeable future. Per WAC 173-340-200, industrial properties:

...are or have been characterized by, or are to be committed to, traditional industrial uses such as processing or manufacturing of materials, marine terminal and transportation areas and facilities, fabrication, assembly, treatment, or

distribution of manufactured products, or storage of bulk materials, that are either:

- *Zoned for industrial use by a city or county conducting land use planning under chapter 36.70A RCW [Growth Management Act (GMA)]; or*
- *For counties not planning under chapter 36.70A RCW (GMA) and the cities within them, zoned for industrial use and adjacent to properties currently used or designated for industrial purposes.*

The City of Seattle and King County both conduct land use planning under the GMA, and any property zoned for industrial use is generally considered an industrial property.

The Site also must meet the following criteria to be considered an industrial property per WAC 173-340-745 (1)(a)(i):

- People do not live on the property and the primary potential exposure route is to adult employees of businesses located on the property.
- Access to the property by the general public is generally not allowed or is severely limited and controlled.
- Food is not normally grown or raised on the property.
- Operations are often, but not always, characterized by the use and storage of chemicals, noise, odors, and truck traffic.
- The surface of the property is usually covered by buildings or paved, minimizing potential exposure to soil.
- Support facilities such as offices, restaurants, and other facilities may be present on the property, but are primarily devoted to administrative functions necessary for the industrial use.

Although the submerged lands within the aquatic portion of the Site are private property, surface water within the Embayment is considered waters of the state; therefore, access to the Embayment via surface water is not strictly prohibited. However, the sheltered configuration of the Embayment, the nature of the industrial operations at the Site, and the security procedures that keep people away from the existing dock discourage the general public from accessing the aquatic portion of the Site.

7.3 NATURE AND EXTENT OF PRIMARY COPCS

The CSM focuses on the following primary COPCs: arsenic, copper, zinc, PCP and its daughter products (phenol; 2,4,6-trichlorophenol; and 2,4-dichlorophenol), hexachlorobenzene, BEHP, PCBs, D/Fs, TPH-DRO/MORO, cPAHs (as TEQ), and tributyltin. These primary COPCs were selected based on the criteria presented in Section 4.3. These primary COPCs exceeded their SLs by at least a factor of 2, and at a rate of at least 10 percent of the samples collected. The SL exceedance frequency greater than 10 percent and exceedance ratio greater than or equal to 2 criteria is consistent with two of the three-part statistical rule (WAC 173-340-740[7][e][i & ii]).

These primary COPCs also meet the following criteria:

- Pose the greatest human health and ecological risks;

- Have large footprints within the Site, such that addressing these COPCs will result in cleanup of other COPCs that are less frequently detected, or detected at lower concentrations;
- Represent each major analytical group associated with the Site, particularly where multiple sources may have different vertical or horizontal distributions; and
- Illustrate releases from all of the known primary sources.

For each of these primary COPCs, a subsection describing its magnitude and extent at the Site has been prepared, describing the vertical and lateral extent of soil, groundwater, and/or sediments at the Site having concentrations of that primary COPC exceeding its SLs. Because collectively the nature and extent of these primary COPCs is representative of all Site COPCs, other individual COPCs are not described or illustrated herein.

The built environment (structures, pavement, gravel cover, and riprap) at the Site is interpreted as not containing COPCs. These structures or materials were placed over contaminated media, and there is no evidence the existing structures or materials are an independent source of COPCs to the Site. Therefore, the built environment is not included in the descriptions of the nature and extent of COPCs.

7.3.1 ARSENIC

Arsenic was detected at concentrations exceeding SLs in all sampled Site media and had an SL exceedance frequency greater than 10 percent along with an exceedance factor greater than 2 in vadose, saturated and riverbank soil, shallow and deep groundwater, and surface and subsurface sediment (Table 4-8). Figures 5-1, 5-2, 5-12, 5-13, and 6-1 show that most areas of the Site have arsenic concentrations exceeding SLs and several locations have SL exceedances in two or more media.

Arsenic SL exceedances in soil and shallow groundwater are co-located in an area extending from the northwest to the southeast corner of the Site, an area covering approximately two-thirds of the upland portion of the Site (Figures 5-1, 5-2, and 5-12). The highest concentrations of arsenic in soil (greater than 198 mg/kg) are situated in the saturated soil in the southern portion of the Site, beneath the operational area used by Mineralized-Cell (Figure 5-2). This area also exhibits the highest concentrations of arsenic in shallow and deep groundwater (Figures 5-12 and 5-13). The only place where arsenic SL exceedances were reported in the aquitard and lower sand is directly beneath the operational area used by Mineralized-Cell and the area of dredged fill and shallow groundwater exhibiting the highest concentrations of arsenic (Figure 5-12). The deep groundwater in this area also exhibits arsenic SL exceedances (Figure 5-13).

It is also noted that geotechnical borings B-4 and B-6 (Figure 2-13) were completed by Shannon & Wilson in 1964 in the south-central portion of the Site in the vicinity of MW-14D and MW-43D, where the highest concentrations of arsenic were reported in deep groundwater. Shannon & Wilson geotechnical boring B-5 was completed in the vicinity of MW-2D, located in the east-central portion of the Site. These geotechnical borings were completed through the aquitard to depths of approximately -8 feet MSL (B-6), approximately -75 feet MSL (B-4), and -105 feet MSL (B-5). Documentation regarding the methods and procedures used to abandon these boreholes is not

available for review, but these geotechnical borings could have presented a secondary source and migration pathway from shallow groundwater through the aquitard into the lower sand unit.

Arsenic concentrations in vadose and saturated soil in the east-central portion of the Site are significantly lower than the arsenic concentrations reported in the southern half of the Site (less than 88 mg/kg). Arsenic concentrations in the vadose soil are generally lower than reported in saturated soil in this area (Figures 5-1 and 5-2). The shallow and deep groundwater that has arsenic SL exceedances in the east-central portion of the Site is generally co-located with soil exceeding the arsenic SL (Figures 5-1, 5-2, 5-12, and 5-13). The reported concentrations of arsenic in the shallow groundwater (mostly less than or equal to 80 µg/L with localized spikes greater than 221 µg/L; Figure 5-12) and deep groundwater (mostly less than or equal to 80 µg/L; Figure 5-13) are significantly lower than in the southern portion of the Site. These areas of arsenic SL exceedances underlie the operational areas used by Carlisle, Crown Zellerbach, and the Army (Figures 5-2, 5-12, and 5-13). In these areas, the arsenic SL exceedances are limited to the shallow and dredged fill and do not extend into the aquitard, except in the vicinity of the former wastewater impoundment and one location along the northern riverbank. Shallow groundwater containing arsenic SL exceedances are situated beneath the arsenic-impacted soils within an area where Carlisle, Crown Zellerbach, and the Army are known to have released wastewater solutions, sawdust, and charcoal from the whetlerite production process (Figures 5-1, 5-2, and 5-12).

Arsenic SL exceedances in soil extend to and include the riverbank soil (Figures 5-1 and 5-2), and arsenic SL exceedances in shallow groundwater extend to the riverbank, where it discharges via seeps to the Embayment (Section 5.3). As discussed in Section 5.3, seep samples collected within the intertidal zone immediately adjacent to the riverbank also have arsenic SL exceedances, consistent with this discharge pathway. While arsenic SL exceedances in deep groundwater are present landward of the riverbank, SL exceedances do not extend to the shoreline (Figure 5-13).

Surface and subsurface sediment that have arsenic SL exceedances extend throughout the Embayment (Figure 6-1). There is no substantive difference in the lateral extent of surface and subsurface sediment that have arsenic SL exceedances (Figure 6-1). Vertically, the arsenic SL exceedances extend through the full 10 cm of the surface sediment and 2 feet (60 cm) of the subsurface sediment (Figure 6-1).

7.3.2 COPPER

Copper has a smaller contamination footprint compared with arsenic. Copper was detected at concentrations exceeding SLs in all sampled Site media and had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose, saturated and riverbank soil, and shallow and deep groundwater (Table 4-8). Copper did not have an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in surface and subsurface sediment. Figures 5-3, 5-14, and 5-15 show that approximately 75 percent of the upland portion of the Site has copper concentrations exceeding SLs and several areas have SL exceedances in both soil and groundwater. Upland areas that have no copper SL exceedances are situated along the south-central, west-central, and north-central boundaries of the Site (Figures 5-3, 5-14, and 5-15).

Copper SL exceedances are scattered throughout the upland portion of the Site. The higher concentrations of copper (i.e., greater than 350 mg/kg) are located in the southeastern, east-central, and northeastern areas of the upland portions of the Site (Figure 5-3). The southeastern area of higher copper concentrations in soil is generally co-located with the southeastern area of higher arsenic concentrations in soil described in Section 7.3.1. As shown on Figures 5-3 and 5-2, the area of higher copper concentrations is smaller than the area of higher arsenic concentrations, but both are situated beneath the operational area used by Mineralized-Cell. The vertical extent of copper SL exceedances in the southeastern area extends into the silt aquitard in a few locations but does not extend into the lower sand unit (Figure 5-3). Although this area exhibits the highest copper concentrations in soil, including saturated soil, the groundwater in this area does not exceed the SL for copper (Figure 5-14).

The east-central area of higher copper concentrations in soil underlies the operational areas used by Carlisle, Crown Zellerbach, and the Army (Figure 5-3). The vertical extent of copper concentrations exceeding the SL in the east-central area is limited to the shallow and dredged fill zones (Figure 5-3). Shallow and deep groundwater with copper concentrations exceeding the SL are located in isolated areas in the central portion of the Site underlying areas of copper-impacted soil (Figures 5-3, 5-14, and 5-15). As shown on Figures 5-13, 5-14, and 5-15, the east-central area of higher copper concentrations in soil generally aligns with areas of copper SL exceedances in shallow and deep groundwater.

The northeastern area of higher copper concentrations in soil is within the area of riverbank soil that was placed during demolition of the former Army and Reichhold facility structures and construction of the Kaiser cement terminal. The vertical extent of copper concentrations in soil exceeding the SL along the northeastern shoreline includes the bank fill and the top of the underlying silt aquitard (Figure 5-3). Shallow and deep groundwater with copper concentrations exceeding the SL is located along the northeastern shoreline (Figures 5-14 and 5-15). As shown on Figures 5-3, 5-14, and 5-15, the northeast area of higher copper concentrations in soil generally aligns with areas of copper SL exceedances in shallow and deep groundwater.

Although copper was identified as a COPC in sediment, only 1 sediment sample of 78 collected samples had a reported copper concentration exceeding the SL (SED-SS-14; Figure 3-2). The surface sediment sample is located off shore of the northeastern area of higher copper concentrations in soil and shallow and deep groundwater and near the former operational area of DSI (Figures 3-2, 5-3, 5-14, and 5-15). The surface sediment containing higher concentrations of copper may be an extension of the bank fill material placed along the shoreline during demolition of the former Army and Reichhold facility structures and construction of the Kaiser cement terminal.

7.3.3 ZINC

Zinc was detected at concentrations exceeding SLs in all sampled Site media, but only had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose, saturated, and riverbank soil (Table 4-8). Zinc did not exhibit an exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in shallow and deep groundwater or surface and subsurface sediment (Table 4-8).

Figure 5-4 shows that less than approximately 10 percent of the upland portion of the Site has zinc concentrations exceeding SLs. Zinc concentrations reported in vadose and saturated soil samples exceed the SL in the southeast area of the upland portion of the Site and a few isolated locations in the north and northeastern areas of the upland portion of the Site (Figure 5-4). The northeastern area of zinc exceedances in soil appears to be the southern extent of an area of higher zinc concentration in soil on the DSI property (Figure 5-4), whereas the southeastern area of zinc exceedances in soil is situated beneath the operational area used by Mineralized-Cell (Figure 5-4). The vertical extent of zinc concentrations exceeding the SL in Site soil is limited to the shallow fill in the north and northeastern portions of the Site. Within the footprint of the operational area used by Mineralized-Cell, the vertical extent of zinc SL exceedances extends into the silt aquitard but not into the lower sand unit.

Shallow groundwater containing zinc concentrations exceeding the SL is isolated to one monitoring well located within the footprint of the former Mineralized-Cell operational area (MW-13S; Figure 3-6). Surficial sediments with zinc concentrations exceeding the sediment SL are limited to two locations near the northern shoreline by the dock. Zinc concentrations exceeding the sediment SL in subsurface sediment are isolated to one location north of the dock near the DSI property.

7.3.4 DIOXINS/FURANS

D/Fs as measured by D/F TEQ were detected at concentrations exceeding SLs in all sampled Site media and had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose, saturated and riverbank soil, shallow and deep groundwater, and surface and subsurface sediment (Table 4-8). Figures 5-11, 5-20, 5-21, and 6-4 show that D/F TEQ concentrations exceeded SLs in approximately half of the upland portion of the Site and all of the aquatic portion of the Site. The western third of the Site as well as areas in the northeastern and south-central upland portion of the Site have no D/F TEQ SL exceedances (Figures 5-11, 5-20, 5-21, and 6-4).

Areas of vadose and saturated soil containing D/F TEQs at concentrations exceeding the SL are located in the north, central, and eastern portions of the Site, with the highest D/F TEQ concentrations situated along the riverbank and in the former Reichhold operational area (Figure 5-11). The vertical extent of D/F TEQs in soil is limited to shallow and dredged fill with the exception of two locations along the riverbank (Figure 5-11). Shallow and deep groundwater with reported D/F TEQ concentrations exceeding the SL are present beneath the footprint of D/F-impacted soil, with higher concentrations reported along the riverbank (Figures 5-20 and 5-21). Surface and subsurface sediments with D/F TEQ detected at concentrations exceeding the sediment SL are present throughout the Embayment (Figure 6-4).

7.3.5 SVOCS

7.3.5.1 PCP AND DAUGHTER PRODUCTS

PCP was detected at concentrations exceeding SLs in all sampled Site media and had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose, saturated and riverbank soil, and shallow and deep groundwater (Table 4-8). PCP did not exhibit an exceedance frequency greater than 10 percent and an exceedance factor greater than 2

in surface and subsurface sediment. Figures 5-6, 5-17, and 5-19 show that approximately half of the upland portion of the Site has PCP concentrations exceeding SLs and several areas have SL exceedances in both soil and groundwater. The western and southern upland portions of the Site as well as scattered areas in the northeastern and central upland portion of the Site have no PCP SL exceedances (Figures 5-6, 5-17, and 5-19). Surface and subsurface sediments with reported PCP concentrations exceeding the SL are limited to the intertidal area along the northern shoreline, not extending beyond the Embayment (Figure 6-5).

Vadose and saturated soil with reported PCP concentrations exceeding the soil SL are present in the northern, central, and eastern portions of the Site in the former Reichhold operational area, with the highest PCP concentrations found primarily in the footprint of the former washwater impoundment (Figure 5-6). The vertical extent of PCP-impacted soil is primarily limited to the shallow and dredged fill layers but extends to the interface between the dredged fill and silt aquitard in several borings advanced in the northeast and southeast areas of the upland portion of the Site (Figure 5-6).

Shallow groundwater containing PCP concentrations exceeding the groundwater SL are located in the central portion of the Site where one of the former Reichhold PCP production plants was located and along the shoreline in the vicinity of the former washwater impoundment and the former surface drainage ditches in the north and south portions of the Site (Figure 5-18). Deep groundwater with PCP concentrations exceeding the groundwater SL is isolated to one monitoring well located in the southeast portion of the Site where the highest concentrations of PCP were detected in shallow groundwater (MW-45D; Figure 5-17).

Surface sediments containing PCP concentrations exceeding the sediment SL are localized to one isolated offshore area along the northern shoreline of the Embayment (Figure 6-5). Subsurface sediments with reported PCP concentrations exceeding the SL are present in intertidal areas along the northern shoreline of the Embayment (Figure 6-5).

Phenol was retained as a primary COPC in vadose and saturated zone soil. This compound had an exceedance frequency of 10 percent in vadose soil and greater than 10 percent in saturated soil. The exceedance factor was 2 for vadose soil and greater than 2 in the saturated soil. With one exception at GP-58, the locations where phenol concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances as shown on Figure 5-6. The exceedances in the vadose zone are limited to the shallow fill layer and extend down into the silt layer for the saturated soil.

2,4,6-Trichlorophenol was retained as a groundwater COPC and as a vadose and saturated soil COPC and meets the criteria of a primary COPC. In shallow groundwater, the exceedance frequency was less than 10 percent but maximum exceedance factor greater than 2, with exceedances occurring only in the shallow fill. These locations correspond with the location of a former PCP plant (Table W-13, Appendix W) but have not exceeded the SL since 2010. In vadose soil, 2,4,6-trichlorophenol had an exceedance frequency of greater than 10 percent and maximum exceedance factor of greater than 2. The three locations where 2,4,6-trichlorophenol concentrations exceed SLs in vadose zone soil are co-located with PCP SL exceedances as shown on Figure 5-6. More saturated soil samples exceeded the SL than in vadose soil, with an

exceedance frequency greater than 10 percent and an exceedance factor greater than 2 and these exceedances occurred throughout shallow fill, dredged fill, and into the interface at the top of the silt layer. Similar to the vadose zone soil, locations where 2,4,6-trichlorophenol concentrations exceed SLs in saturated zone soil are co-located with PCP SL exceedances (Figure 5-17).

Similar to 2,4,6-trichlorophenol, daughter compound 2,4-dichlorophenol was also retained as a groundwater COPC and as a vadose and saturated soil COPC and meets the criteria of a primary COPC. In groundwater samples, the exceedance frequency was less than 10 percent with an exceedance factor of greater than 2. These detections occurred at MW-26S located on the southern fenceline of the Site in 2011, 2012, and 2014 and samples from this location have not been exceeded groundwater SLs since. In vadose soil, the exceedance frequency was less than 10 percent with an exceedance factor of greater than 2. The single exceeding concentration at GP-56 was in the shallow fill layer. In saturated soil, the exceedance frequency was higher at greater than 10 percent and the exceedance factor was greater than 2. These detections occurred in the shallow fill, dredged fill, and into the interface at the top of the silt layer. The locations in the vadose and saturated zone soil and shallow groundwater exceeding the respective 2,4-dichlorophenol SLs are primarily co-located with PCP SL exceedances (Figures 5-6 and 5-17).

7.3.5.2 HEXACHLOROBENZENE

Hexachlorobenzene was retained as a COPC in both vadose and saturated zone soil and meets the criteria of a primary COPC. In vadose soil, the exceedance frequency was greater than 10 percent and the exceedance factor greater than 2. These exceedances occurred in the shallow fill along the riverbank. In saturated soil, the exceedance frequency was less than 10 percent and the exceedance factor greater than 2. These exceedances occurred in the shallow fill, dredged fill, and into the interface at the top of the silt layer. The locations where hexachlorobenzene concentrations exceed SLs in vadose and saturated zone soil are co-located with PCP SL exceedances as shown on Figure 5-6.

7.3.5.3 BEHP

BEHP was retained as a COPC in vadose and saturated soil and groundwater but did not meet the criteria of a primary COPC. In groundwater, the exceedance frequency was less than 10 percent with an exceedance factor greater than 2. The locations of SL exceedances were limited to two shallow wells (MW-32S and MW-43S), located in the northeastern corner and south-central portion of the Site, respectively. Exceedances have not occurred since 2015. Detections and exceedances of BEHP have also occurred in deep wells across the Site, as SL was less than the range of PQLs for the samples. The locations where BEHP concentrations exceed SLs in shallow groundwater are primarily co-located with PCP SL exceedances as shown on Figure 5-17. Section 5.2.4 discusses relevant exceptions.

In vadose soil, no exceedances occurred. For saturated soil, the exceedance frequency was greater than 10 percent and an exceedance factor greater than 2. These exceedances occurred in the shallow fill, dredged fill, and into the interface at the top of the silt layer. The locations where BEHP concentrations exceed SLs in saturated zone soil are co-located with PCP SL exceedances as shown on Figure 5-6. Section 5.1.4 discusses relevant exceptions.

7.3.6 PETROLEUM AND CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

Petroleum as measured by TPH-DRO/MORO and cPAH TEQ (ND=0 and ND=1/2DL) are primary COPCs at the Site. TPH-DRO/MORO was reported at concentrations exceeding SLs in vadose, saturated soil, and shallow groundwater and had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose soil and shallow groundwater (Table 4-8). cPAH TEQ was reported at concentrations exceeding SLs in vadose, saturated and riverbank soil, and surface and subsurface sediment and had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose, saturated and riverbank soil, and surface and subsurface sediment (Table 4-8). cPAH TEQ was not detected in shallow or deep groundwater at concentrations greater than the PQLs, which range between 0.023 and 0.2 µg/L, and are greater than the cPAH SL of 0.000016 µg/L (Table 4-8).

Approximately half of the upland portion of the Site has petroleum (as represented by TPH-DRO/MORO and/or cPAH TEQ) concentrations exceeding SLs in soil, but only one location has an SL exceedance in groundwater (Table 4-6 and Figures 5-5, 5-8, 5-16). Although the two areas of TPH-DRO/MORO SL exceedances in shallow soil in the central portion of the Site (i.e., GP-36 and MW-43S and MW43-D) do not have corresponding TPH-DRO/MORO groundwater data, NAPL was not observed in any monitoring well or soil boring advanced at the Site. Based on a review of the boring logs for indications of petroleum impacts (e.g., PID readings and odors), 10 borings noted petroleum-like odors (i.e., MW-43S, MW-43D, MW-45S, GP-27, GP-31, GP-33, GP-34, GP-36, GP-58, and GP-75; Appendix O and Figure 5-5) and 8 were sampled for TPH-DRO/MORO. Further, cPAHs, a common chemical component of TPH, have not been detected in the shallow monitoring wells sampled (i.e., MW-4S, MW-12S, MW-28S, MW-29S, MW-30S, MW-31S, MW-32S, MW-33S, MW-34S, MW-35S, and MW43-S; Figure 3-6). Therefore, it is unlikely that substantive TPH-DRO/MORO impacts in groundwater are present in these areas. Surface and subsurface sediment having cPAH SL exceedances extend throughout the Embayment (Figure 6-2). There is no substantive difference in the lateral extent of surface and subsurface sediment having cPAH SL exceedances (Figure 6-2). There is no sediment SL for TPH-DRO/MORO.

Soils with TPH-DRO/MORO concentrations exceeding the SL are localized in the northern, northeastern, and south-central portions of the Site (Figure 5-5). The vertical extent of TPH-DRO/MORO in soil at concentrations exceeding the SLs is limited to the shallow and dredged fill and does not extend into the silt aquitard (Figure 5-5). Shallow groundwater containing TPH-DRO/MORO concentrations exceeding the SL is isolated to one monitoring well in the northeast portion of the Site (MW-35S; Figure 5-16). Groundwater with TPH-DRO/MORO concentrations exceeding the SL are limited to the shallow zone and do not extend deeper than the top of the silt aquitard that underlies the shallow groundwater (Figure 5-16).

Soil with reported cPAH TEQ concentrations exceeding the SL are present in the central and northeastern areas of the upland portion of the Site, within the vicinity of the former Reichhold, Carlisle, Crown Zellerbach, and Army operational areas (Figure 5-8). The highest cPAH TEQ concentrations in soil are generally co-located with TPH-DRO/MORO concentrations exceeding SLs (Figure 5-8). Two smaller areas of soil with cPAH TEQ concentrations exceeding the SL are located in the southeast area of the upland portion of the Site (Figure 5-8). Soil with cPAH TEQ concentrations exceeding the SLs are limited to the shallow and dredged fill but extend into the

interface with the silt aquitard at two locations in the central portion of the Site and one location in the southern portion of the Site (Figure 5-8).

cPAHs were not detected in Site groundwater at a PQL greater than the SL, but they are a COPC in sediment. cPAH SL exceedances in surface sediment extends throughout the Embayment (Figure 6-2). Although surface and subsurface sediments containing cPAH TEQ concentrations exceeding the SL are present throughout the Embayment, cPAH TEQ concentrations in LDW sediments outside the Embayment are generally higher than cPAH TEQ concentrations detected in sediment within the Embayment (Figure 6-2).

7.3.7 POLYCHLORINATED BIPHENYLS

PCBs were reported at concentrations exceeding SLs in all media sampled and had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose, saturated and riverbank soil, and surface and subsurface sediment (Table 4-8). Except for one sample collected from MW-33S where PCB was detected in groundwater at a concentration of 0.006 µg/L, PCBs were not detected in groundwater at concentrations exceeding the PQL of 0.0025 µg/L, which is greater than the groundwater SL of 0.000007 µg/L. As a result, PCBs did not have an exceedance frequency greater than 10 percent but had an exceedance factor greater than 2 in shallow or deep groundwater (Table 4-8). Figures 5-9 and 5-10 show that the upland portion of the Site has PCB concentrations exceeding SLs in soil and PCB SL exceedances exist throughout the Embayment (Figures 5-9, 5-10, and 6-3). There is a substantive difference in the lateral extent of surface and subsurface sediment having PCB SL exceedances in the vicinity of the Property (Figure 6-3). The extent of subsurface sediment with PCB SL exceedances is generally larger and more laterally contiguous than surface sediment extents.

Vadose and saturated soil with reported concentrations of PCBs exceeding the soil SL are limited to the riverbank with a few isolated areas in north, west, and southern areas of the upland portion of the Site (Figures 5-9 and 5-10). The vertical extent of soil with reported PCB concentrations exceeding the SL is limited to the shallow and dredged fill with the exception of one sample collected along the riverbank from the interface of the dredged fill and silt aquitard (Figures 5-9 and 5-10).

PCB concentrations exceeding the SL are present in surface and subsurface sediment throughout the LDW consistent with diffuse, non-point sources of PCBs in the LDW (Windward and RETEC 2007). Sediment with PCB concentrations are also present in some areas of the Embayment (Figure 6-3). However, the footprint of surface sediment with PCB concentrations greater than the SL within the Embayment are not laterally contiguous with surface sediment with PCB concentrations greater than the SL outside of the Embayment. Surface sediments containing PCB concentrations exceeding the LDW sediment CULs are present in portions of the LDW more than 200 feet away from the on-Property locations where surface sediment concentrations exceeded the LDW sediment CULs (Figure 6-3). The footprint of subsurface sediment with PCB concentrations greater than the SL within the Embayment are generally laterally contiguous with subsurface sediment outside of the Embayment with PCB concentrations greater than the SL.

7.3.8 TRIBUTYLTIN

Tributyltin was detected at concentrations exceeding SLs in vadose soil and sediment (Table 4-8). Tributyltin had an SL exceedance frequency greater than 10 percent and an exceedance factor greater than 2 in vadose soil and surface and subsurface sediment (Table 4-8). There are no known historic or current sources of tributyltin on the Property; however, sources of tributyltin are well documented for the DSI property; therefore, sampling for tributyltin was limited to the northern portion of the Site. A total of 4 vadose zone and 23 saturated zone samples, collected from the northern portion of the Site, were analyzed for tributyltin. The upland tributyltin SL exceedances are limited to surface soil at the northeastern corner of the upland portion of the Site (Figure 5-1). This area of tributyltin exceedances in soil is the southern extent of an area of higher tributyltin concentrations in soil on the DSI property.

The vertical extent of tributyltin concentrations in excess of the SL in Site soil is limited to the shallow fill in the northeastern corner of the upland portion of the Site (Figure 5-1). Tributyltin concentrations exceeding the sediment SL are located in surface and subsurface sediment throughout the Embayment (Figure 6-6) and throughout the portion of the LDW near the DSI property, consistent with a DSI source (Figure 6-6).

7.4 PRIMARY SOURCES AND RELEASE MECHANISMS OF CONTAMINANTS OF CONCERN

A summary of confirmed and presumed primary sources, associated operators, operation dates, locations, related COPCs, release mechanisms, and impacted media is included in Table 7-1. This summary is based on historical information, sampling data for the Site and adjacent properties, and published literature regarding the types of operations conducted at the Site and adjacent properties. The primary sources of COPCs at the Site can be divided into on-Site and off-Site sources.

7.4.1 ON-SITE PRIMARY SOURCES AND RELEASE MECHANISMS

On-Site sources are associated with five known industries that operated on the Site:

- Wood preserving
- Charcoal and whetlerite manufacturing
- Chemical manufacturing
- Facility demolition and redevelopment
- Cement terminal

Operations of these industries at the Site are detailed in Section 2.6. The specific industrial operations or activities that produced the COPCs and the mechanisms by which the COPCs were released to the environment are described below for each of the primary sources.

7.4.1.1 FORMER WOOD PRESERVING OPERATIONS

Mineralized-Cell operated a wood preserving facility at the Site between approximately 1936 and 1939. The former wood preserving operations are a primary source of arsenic detected in soil, groundwater, and sediment at the Site (Table 7-1). The wood preservation operations and their

primary and secondary release mechanisms, based on detected arsenic impacts in soil, groundwater, and sediment, are illustrated on Figure 7-3. Most of the arsenic-impacted soil and groundwater is situated in the southern portion of the Site immediately below the main operational area of Mineralized-Cell. Photographs and descriptions of the wood preservation operation show that leaks, spills, and direct discharge of wood treatment chemicals to the soil were the primary release mechanisms. Because of its toxicity and high usage in the wood preservation process, arsenic is the most significant COPC associated with this primary source. However, copper and zinc were also present in the wood treatment chemicals and were released along with arsenic, particularly in the southern portion of the Site.

Sampling data define an isolated area of elevated arsenic concentrations in the silt aquitard and deep groundwater aquifer directly beneath the former wood preservation area and beneath the highest concentrations of arsenic in the shallow groundwater aquifer (Figure 7-3). Arsenic concentrations detected in the deep aquifer are approximately 15 to 20 times lower than concentrations measured in the overlying shallow aquifer, consistent with reduced contaminant migration via vertical diffusion and/or advective flow through the aquitard. Exceedances in deep groundwater are also located in close proximity to Shannon & Wilson geotechnical borings completed in 1964 (B-4 and B-6; Figure 2-13) that extend through the silt aquitard to depths up to -75 feet MSL. Completion and abandonment methods for these borings are not documented in the Shannon & Wilson reports (Shannon & Wilson 1964, 1966). These geotechnical borings have not been ruled out as a secondary source and migration pathway from shallow groundwater through the aquitard into the lower sand unit because documentation regarding the methods and procedures used to complete and abandon these boreholes is not available.

Diffusion migration can occur when a chemical concentration is higher in one stratum than in an adjacent stratum (Fetter 1993). As discussed in Section 2.10.3.5, breaches to the aquitard are limited to the area east of the wooden bulkhead that aligns with the 1936 shoreline. This breach is outside of the footprint of the former wood preservation area. While the hydraulic conductivity is low within the silt aquitard (approximately 0.00283 feet/day), data collected in January 2018 shows that groundwater travels at a downward vertical gradient between -0.11 to -0.51 ft/ft. Table 7-2 summarizes calculations showing that it takes approximately 4.3 to 7.2 years for groundwater to travel from the shallow aquifer, through the silt aquitard, and into the underlying deep aquifer in the vicinity of the former wood preserving operations area.

The combination of historical information and sampling data indicate that the highest concentrations and largest mass of arsenic detected at the Site are near the former wood preservation area; however, areas of elevated arsenic concentrations in soil, groundwater, and sediment were also identified around a dock situated on the shoreline immediately to the east of the former wood preservation area and near former roadways traversing east-west across the central and northern portions of the Site. Historical information suggests that wood treatment activities or handling of treated logs or chemicals occurred in these areas.

A historical photograph from 1936 (Appendix A1) shows log rafts staged in the LDW to the east of the Site and the shoreline to the east of the former wood preservation area being used for pre- and/or post-treatment staging of logs. The information regarding the construction and use of structures observed along the shoreline and dock is limited to what is shown in the 1936

photograph. Although not conclusive, it appears likely that the former dock was used to handle, load, and unload treated logs or chemicals, and the roadways were used to transport treated logs or chemicals. The presence of elevated arsenic concentrations in soil, groundwater, and sediments near the former dock and roadways suggests that wood treatment chemicals were released via spills, leaks, discharge, or disposal in these areas.

The former wood preserving operations ceased as a primary source around 1939 and, as described in Section 3.2.2, a hydrogen peroxide injection program was implemented in 2000 in an effort to reduce arsenic concentrations in soil and groundwater near the main wood preservation area. However, the RI results show that soils, groundwater, and sediments continue to be secondary sources of arsenic at the Site.

7.4.1.2 FORMER CHARCOAL AND WHETLERITE MANUFACTURING AND TESTING

Carlisle, Crown Zellerbach, and the Army operated a charcoal and whetlerite (activated carbon impregnated with copper, hexavalent chromium, and silver) manufacturing and testing facility at the Site between 1940 and 1944. Former operation of this facility is a significant primary source of copper, hexavalent chromium, and silver and a contributing primary source of arsenic, zinc, and D/Fs detected in soil, groundwater, and/or sediment at the Site (Table 7-1). These manufacturing and testing operations and their release mechanisms are illustrated on Figure 7-4. Most of the former charcoal and whetlerite manufacturing and testing operations were situated in the northern portion of the Site, but disposal areas for charcoal, sawdust, and/or briquettes were described in historical documents and discovered in shallow fill at numerous locations on the Site (Figure 7-4). The historical documents state that charcoal and sawdust were dumped in the southern portion of the Site as recommended in the 1945 Pollution Control Commission Report, and that a 100-cubic-foot (approximately 750 gallons) tank containing copper ammoniate was reportedly washed out once per month and the contents drained into the Embayment (Foster 1945). Sample results from sawdust and charcoal encountered during the RI confirmed elevated concentrations of arsenic, chromium, copper, and D/Fs.

Soil containing elevated concentrations of copper, arsenic, and/or D/Fs is present near former facility structures in the northern portion of the Site, in isolated areas to the south of the former facility structures, in and adjacent to disposal areas in the southern portion of the Site, and along the shoreline to the northeast, east, and southeast of the disposal areas (Figure 7-4). Sediment containing elevated D/F TEQ concentrations was detected along the shoreline of the Embayment. Based on the historical evidence and sample results generated during the RI, arsenic, copper, hexavalent chromium, silver, zinc, and/or D/Fs were released to the Site via leaks, spills, discharge, or disposal incidental to former operation of the charcoal and whetlerite manufacturing and testing facility.

The production of charcoal, specifically the process of charring Pres-To-Logs, likely contributed to the D/Fs detected in Site soil, groundwater, and sediment. D/Fs formation requires: (1) an organic starting material, (2) a chlorine source, and (3) high temperatures, or in processes with relatively lower temperatures, a metallic catalyst (Kobylecki et al. 2001). As described in Appendix C, the organic starting material for Pres-To-Logs consisted primarily of Douglas fir plant mill shavings. Sources of chlorine used to produce Pres-To-Logs likely included zinc chloride and salt water.

Whetlerite was produced by impregnating wood sawdust and shavings (i.e., organic starting material) with a dehydrating or carbonizing agent such as zinc chloride (i.e., chlorine source) prior to generating the material entering the charcoal production and calcination processes (i.e., high temperature source). If zinc chloride was used to impregnate the wood shavings, D/Fs could be produced through the charcoal production and calcination processes. Similarly, if wood containing salt water (i.e., logs rafted in through Puget Sound or the LDW⁴) was used to make the Pres-To-Logs, then the organic starting material (wood and mineral oil used to lubricate the feed shoot for the charring process) and the chlorine source (zinc chloride and/or sodium or potassium chloride from the salt water) were both present, and the temperatures (1,450 to 1,800 degrees Fahrenheit [°F]) in the calciner (i.e., a slightly inclined steel rotary kiln used to produce the charcoal char) were sufficiently high to produce D/Fs.

As outlined in Ecology's *Rayonier Mill Off-Property Soil Dioxin Study* (Ecology 2011a), the burning of wood containing salt water at high temperatures can produce D/Fs. Additionally, copper (used during production of whetlerite) is reportedly a powerful catalyst for D/F formation (Hinton and Lane 1991). A comparison of the D/F congener data from Site samples to data for the Port Angeles Harbor Sediment Dioxin Source Study (NewFields 2013) suggests that burning of wood containing salt water is not a major source of D/Fs at the Site. However, the burning of wood impregnated with zinc chloride may be a significant contributing source of D/Fs at the Site. The D/F concentrations in the charcoal and charcoal briquettes samples are low in comparison to the concentrations detected in Site soil and sediment, but the number of charcoal and briquette samples collected and tested is too small to provide a statistically significant characterization of the D/F concentrations in waste charcoal and briquettes disposed at the Site. Therefore, the relative contribution of D/Fs from the disposal of waste charcoal and briquettes is unknown.

In addition to manufacturing charcoal and whetlerite, Carlisle, Crown Zellerbach, and the Army tested the quality of the whetlerite using chemical agents the whetlerite was intended to protect against, such as arsine (arsenic and hydrogen). The Army tested the activated carbon for density, heat of wetting, and absorption life using various apparatuses and chemicals such as arsine, chloropicrin, cyanogen chloride, and phosgene. The canister testing apparatuses simulated heavy breathing to evaluate the canister life. Air containing cyanogen chloride and water vapor were pulled through the canister to evaluate the service life of the canister. The chloropicrin testing apparatus was used to evaluate the properties "important to gas mask adsorbent" (Slyh et al. 1945). This procedure subjected 10 to 14 mesh carbon to a mixture of air and chloropicrin to evaluate the breakthrough time under various testing conditions. As described in Appendix C, the inventory of reagents and chemicals used by the Army laboratory included numerous chemicals that contain arsenic and zinc. These compounds include arsenous acid, magnesium arsenite, magnesium arsenide, zinc metal analyte reagent, and zinc metal. Laboratory waste was routed to a septic system that discharged directly to the Embayment.⁵ Spent carbon (i.e., gas chemical saturated carbon) from the testing was either dumped in portions of the Site, such as ditches, as

⁴ Aerial photographs taken during operation of the whetlerite manufacturing facility show logs floating in the LDW adjacent to the Site (Appendix A1).

⁵ The septic system was located on what is now the DSI property.

observed in the subsurface during investigation activities and as documented in the 1945 Pollution Control Commission Report (Foster 1945), or incinerated on the Site.

Elevated arsenic and zinc concentrations were detected in samples of charcoal and charcoal briquettes collected from the Site, which indicates the former whetlerite testing process is a contributing primary source of the arsenic and zinc detected in the soil, groundwater, and sediment at the Site. Elevated concentrations of arsenic and zinc detected in soil and groundwater in the northern portion of the Site on both sides of the former whetlerite testing facilities and near the charcoal, sawdust, and briquette disposal areas are likely the result of leaks, spills, discharge, or disposal from the whetlerite testing activities and from the wood preservation operations of Mineralized-Cell. Although the arsenic and zinc concentrations in the charcoal and charcoal briquettes samples collected from the Site are low in comparison to the concentrations detected in Site soil and sediment, the number of charcoal and briquette samples collected and tested is too small to provide a statistically significant characterization of the D/F concentrations in waste charcoal and briquettes disposed at the Site. For example, charcoal tested in the facility laboratory for arsenic adsorption capacity may have resulted in some charcoal waste having high concentrations of arsenic, whereas other charcoal would have been used in production and not exposed to arsenic. Therefore, the relative contribution of arsenic and zinc from the disposal of waste charcoal and briquettes cannot be accurately assessed from the few samples collected.

The charcoal and whetlerite manufacturing and testing operations ceased as a primary source in 1944; however, soils and sediments affected by those operations continue to be a secondary source of copper, hexavalent chromium, silver, arsenic, zinc, and D/Fs at the Site. These secondary sources have the potential to migrate to other media (e.g., leaching of COPCs from soil to groundwater and sediments) from when they were first released and again when the Property was redeveloped by the Port of Seattle and Kaiser in the 1960s.

7.4.1.3 FORMER CHEMICAL MANUFACTURING

Reichhold manufactured resins, glues, formaldehyde, PCP, and sodium pentachlorophenate at the Site between 1946 and 1961. The former manufacturing operations are a primary source of elevated concentrations of PCP and D/Fs detected in soil, groundwater, and sediment at the Site (Table 7-1). The manufacturing operations and their release mechanisms are illustrated on Figure 7-5. Most of the soil and groundwater containing elevated PCP and D/F concentrations is located in the east-central portion of the Site, in the immediate vicinity of the former PCP production plants and the location of the former washwater impoundment (Figure 7-5). Isolated areas of elevated PCP concentrations in soil and groundwater were identified along the northern boundary of the Site near the former laboratory and rail spur and loading area, in the central portion of the Site near the former tank farms, along the riverbank downgradient of the washwater impoundment, and near the former surface stormwater drainage ditches in the southern and central portions of the Site (Figure 7-5). Sediment containing PCP concentrations exceeding the pCULs was detected at two locations in the Embayment immediately adjacent to the northern shoreline.

D/Fs are a known impurity associated with the manufacture of PCP (USEPA 2006; Ecology 2011a). Soil containing elevated D/F concentrations was identified in the immediate vicinity of the former

PCP production plants and at the location of the former washwater impoundment (Figure 7-5). Elevated D/F concentrations were also identified in isolated areas to the south of the former tank farms, along the shoreline to the east of one of the PCP production plants, in the wastewater impoundment, and near the discharge points from the former surface stormwater drainage ditches (Figure 7-5). Sediments containing D/F concentrations exceeding the sediment SL are present along the shoreline of the Embayment.

The combination of historical information documenting production, testing, storage, distribution, and waste discharge of PCP at the Site, and sampling results indicating the presence of elevated concentrations of PCP and D/Fs in soils, groundwater, and sediments in areas proximate to the former Reichhold facility structures indicates these COPCs were likely released to the Site via leaks, spills, discharge, or disposal incidental to Reichhold's production of PCP. In 1956, Reichhold constructed a 240-foot outfall to convey process water from the washwater impoundment to the LDW (Figure 7-5). Although this outfall reportedly was in operation for less than a year, sampling results documenting the presence of PCP and D/Fs in soils and sediment in the area of the washwater impoundment suggest that PCP and D/Fs were directly discharged to the Embayment from the washwater impoundment before installation of the outfall. In addition, Reichhold also conveyed laboratory waste to a septic system that discharged directly to the Embayment.⁶ It also appears that PCP and D/Fs were released near or into the former surface stormwater drainage ditches that ran from west to east across the southern portion of the Site and discharged to the Embayment (Figure 7-5). Elevated concentrations of D/Fs were detected in soil and sediment near the discharge points of the three southernmost drainage ditches (Figure 7-5).

Reichhold's production of PCP ceased being a primary source of contamination in the late 1950s or early 1960s. Reichhold stopped producing PCP at the Site in 1956 and ceased all operations at the Site in 1961. It is assumed that Reichhold removed all PCP materials from the Site when it ceased operations, thereby eliminating PCP as a primary source. As described in Section 3.2.1, an ozone sparge system was operated from 2000 to 2006 in an effort to reduce PCP concentrations in soil and groundwater near the former PCP production plants and washwater impoundment. However, the soils, groundwater, and sediments affected by Reichhold's operations continue to be a secondary source of PCP and D/Fs at the Site as presented on Figure 7-1.

7.4.1.4 FORMER OPERATIONS INVOLVING PETROLEUM PRODUCTS

Ancillary operations associated with the manufacturing of: (1) charcoal and whetlerite by Carlisle, Crown Zellerbach, and the Army, and (2) PCP, sodium pentachlorophenate, and resin glues by Reichhold are potential primary sources of petroleum-related COPCs, including cPAHs and TPH-DRO/MORO (Table 7-1). Soils, groundwater, and sediment containing elevated petroleum concentrations were detected in the northeastern area of the upland portion of the Site near former Carlisle, Crown Zellerbach, Army, and Reichhold facility structures (e.g., machine shop, boiler house, fuel tanks, and furnaces) that would have involved the use of petroleum oils and lubricants. Moreover, the housekeeping practices of the time would have allowed on-Site disposal of waste petroleum products. The presence of petroleum-related COPCs in Site soils, groundwater, and sediment, combined with known operations that included the use of petroleum, indicate that

⁶ The septic system was located on what is now the DSI property.

these COPCs likely released via spills, leaks, discharge, or disposal incidental to those operations. These operations ceased as a potential primary source in 1961; however, soil, groundwater, and sediment affected by releases related to those previous operations continues to be a secondary source of petroleum-related COPCs at the Site.

7.4.1.5 FORMER FACILITY DEMOLITION AND REDEVELOPMENT

Demolition of the former Army and Reichhold facility structures and construction of the Kaiser cement terminal (e.g., building, silos, dock, etc.) began in 1964 and was completed in 1969. As described below and documented in aerial photographs from 1961, 1965, 1966, 1967, and 1969 (Appendix A1), and Section 2.6.8, the demolition and redevelopment activities removed soils with elevated COPC concentrations from some areas of the Site and placed it in other areas, including the riverbank. In addition, construction stormwater management practices during that time allowed disturbed soils to migrate across the upland portion of the Site and into the Embayment. These actions created new and larger secondary sources of COPCs. The demolition and redevelopment activities, the secondary release mechanisms, and the new secondary source areas generated by these activities are illustrated on Figure 7-6.

Shallow fill and possibly dredged fill containing elevated concentrations of COPCs (likely arsenic, copper, zinc, D/Fs, PCP, and petroleum) from previous Site operations in the northern portion of the Site were excavated for construction of the footings for the cement silos (Figure 7-6). Kaiser engineering drawings indicate the cement silo foundation would have required the excavation and removal of 4 to 6 feet of soil in an area approximately 100 feet wide by 100 feet long. The estimated volume of material removed for the foundation is approximately 2,000 cubic yards. Based on historical aerial photographs (Appendix A1), it appears that the excavated material was likely staged in the central and southern portions of the Site then redistributed across portions of the Site, but mostly the riverbank (Figure 7-6). Surface soil in the area where the excavated soil was placed contains arsenic, copper, zinc, PCP, and D/Fs at concentrations exceeding SLs.

In addition to the excavation of the cement silo foundation, other earthwork activities resulting in redistribution of shallow fill and dredged fill containing COPCs from the northern and central portions of the Site include grading after the removal of former Army and Reichhold facility structures, construction of the stormwater swale system, and construction of other warehouse and office buildings. Aerial photographs indicate grading of shallow fill occurred after the Army and Reichhold facility structures were removed. The volume of soil removed or redistributed during grading operations is unknown; however, the grading activities would have, at minimum, involved removal of the foundations of the Army and Reichhold facility structures. Construction of the stormwater swale likely removed both shallow fill and dredged fill containing elevated COPC concentrations from the northern portion of the Site. Grading of the shallow fill also occurred during construction of the warehouse and office buildings on the central portion of the Site, likely resulting in removal of up to 2 feet of soil from that area. The areas where soil was likely removed and the areas that were graded or filled are highlighted on Figure 7-7. COPCs in these areas include arsenic, zinc, copper, PCP, and D/Fs (Table 7-1).

The demolition and redevelopment activities may also explain the presence of elevated concentrations of PCBs in soils along the riverbank. No soil containing PCBs at concentrations

exceeding pCULs has been identified in the vicinity of the former transformers (see Section 7.4.1.7). The presence of PCBs in the riverbank soils may have resulted from removal of soils with elevated PCB concentrations from other areas of the Site and placement of those soils on the riverbank (Figures 7-6 and 7-7).

Aerial photographs show that the shoreline of the Embayment was filled and extended during construction of the Kaiser cement terminal during the 1960s. These photographs show tire tracks and disturbed ground surface revealing that stockpiled soil from excavation for the cement silos may have been relocated to construct the current riverbank. Fill material may also have been imported to the Site for placement along the shoreline. The soils and/or fill material that was used to extend the shoreline covered the original bed of the Embayment and the submerged portion of those soils and/or fill material are considered sediments within the Embayment. The demolition and redevelopment activities ceased as a primary source in 1969; however, the soils and sediments affected by those operations, particularly those along the riverbank, continue to be a secondary source of COPCs at the Site.

7.4.1.6 FORMER AND CURRENT CEMENT TERMINAL OPERATIONS

Stormwater conveyance during former and current cement terminal operations conducted by Kaiser, Ash Grove, and Glacier Northwest is a potential secondary release mechanism for COPCs in on-Site soil. The cement terminal operations and the associated secondary release mechanisms are illustrated on Figure 7-8.

Former Operations

A stormwater system consisting of catch basins connected to a 15-inch-diameter concrete stormwater pipe was installed in 1975 by Kaiser in the southern portion of the Site and connected to the 48-inch SPU stormwater line located on the Port of Seattle property south of the Site (Figure 3-8). The historical stormwater system was taken out of service by Ash Grove before 1991. An investigation completed in 2014 showed that the catch basins associated with the historical stormwater system had been removed and the voids filled with CDF when the system was taken out of service, effectively eliminating the ability for stormwater and soil to enter the stormwater pipe. A camera survey of the historical stormwater pipe showed that the pipe was filled with wet sediments approximately 30 feet north of its connection point with the 48-inch SPU stormwater line. Very little water was observed in the north end of the 15-inch stormwater pipe, showing that the stormwater pipe was plugged with solids prohibiting the free flow of water. In 2014, the historical stormwater pipe was cut and capped at the closest point to its connection with the 48-inch SPU stormwater line.

The primary source of solids within the 15-inch stormwater pipe is likely on-Site soils that entered the catch basins via stormwater during the period of operation from 1975 to 1991. However, suspended stormwater sediments from the LDW or the 48-inch-diameter stormwater line may also have been deposited in the historical stormwater pipe as a result of tidal inundation during the period that the historical 15-inch stormwater pipe was open to the 48-inch SPU stormwater line (1975 to 2014).

Analytical results of stormwater solids samples collected from the 15-inch stormwater pipe, the 48-inch SPU stormwater line, and the stormwater line that services T115, show elevated concentrations of arsenic, copper, D/Fs, and PCBs. The concentrations of arsenic, copper, and D/Fs detected in the solids samples collected from the 15-inch stormwater pipe were greater than the concentrations detected in solids samples collected from the SPU stormwater line and T115 stormwater line. The concentrations of PCBs detected in the solids samples collected from the 15-inch stormwater pipe were less than the concentrations detected in solids collected from the SPU stormwater line and T115 stormwater line.

The location of the historical stormwater system in the southern part of the Site (Figure 3-8) coincides with areas of soil containing elevated concentrations of arsenic, copper, zinc, D/Fs, PCP, TPH, cPAHs, and/or PCBs (Figures 5-1 through 5-11). When the historical stormwater system was operational (1975 to 1991), precipitation events would have transported impacted soils via sheet flow to the historical catch basins and into the 15-inch stormwater pipe. Therefore, on-Site soils are the likely primary source of the elevated concentrations of arsenic, copper, and D/Fs detected in stormwater solids samples collected from the historical stormwater pipe.

The source of elevated PCB concentrations in stormwater solids within the historical stormwater pipe is likely the mixing of stormwater solids entrained in the stormwater conveyed by the 48-inch SPU stormwater line or surface water from the LDW that inundated the historical stormwater pipe. As described in Section 2.6.9, a 2011 study by Ecology shows that, during mean higher high water, the SPU stormwater line is inundated with surface water from the LDW to West Marginal Way and continues to be inundated in both the northern and southern directions along West Marginal Way (Appendix G). Based on the results of that study and the elevation of the 15-inch historical stormwater pipe, it appears the historical stormwater pipe would have also been inundated at mean higher high water (Appendix G). This conclusion is supported by the discovery of wet sediment in the 15-inch stormwater pipe during the 2014 investigation. Reported PCB concentrations in stormwater solids collected from the SPU stormwater line were greater than the PCB concentrations in solids within the 15-inch historical stormwater pipe (Tables EE-3 and FF-1; Appendices EE and FF, respectively). Further, the concentration of PCBs in the solids sample collected within the 15-inch stormwater pipe (SWP-02) are lower than the PCB concentration reported in the sample collected at the connection to the SPU stormwater line (SWP-01; Table EE-3, Appendix EE).

The short duration of its usage and the fact that the 15-inch historical stormwater pipe is plugged with stormwater solids suggests that the historical stormwater system may have had design and/or constructed flaws. Specifically, the system may have been designed or constructed with insufficient slope to generate the flow velocities needed to transport stormwater solids through the historical 15-inch stormwater pipe and into the 48-inch stormwater SPU line. This would explain the accumulated stormwater solids observed in the historic 15-inch pipe during the 2014 plugging and abandonment activities. If this theory is correct, the historical stormwater system would not have been an effective transport pathway for stormwater solids from the Site to the Embayment during its operation (1975 to 1991) and was likely an insignificant contributor of COPCs to the Embayment. After the catch basins were plugged with concrete in 1991, transport of stormwater solids into the historical stormwater system would have ceased and the driving force for transport

of stormwater solids out of the historical 15-inch stormwater pipe and into the 48-inch stormwater SPU line would have been reduced to transport via occasional tidal inundation. As discussed in Section 3.3.8, the historical stormwater pipe was cut and capped in 2014 at the closest point to its connection with the 48-inch SPU stormwater line to provide additional assurance that the historical stormwater pipe is not a current or future conveyance pathway.

Based on its apparent design flaws, short duration of usage, presence of residual solids more than 20 years after the historical catch basins were filled, and cutting and capping of the historical stormwater pipe in 2014, the historical stormwater system was a minor and finite historical transport mechanism prior to the abandonment and an incomplete current transport mechanism at the Site. Based on conditions observed during the 2014 plugging and abandonment activities, the pipe was mostly filled with solids, which is evidence that the stormwater system did not operate as designed. The volume of solids expected to have been transported by this 15-inch-diameter pipe over the 16 years the system was active (i.e., 1975 to 1991) is considered to be insignificant in comparison to the volume of sediments that are transported and deposited by the Green River/LDW on a daily basis.

Current Operations

Current improvements at the Site reduce the potential for stormwater to contact soils with elevated COPC concentrations resulting from historical operations. These improvements consist of a layer of clean gravel placed over the southern portion of the Site and concrete pavement in the northern portion of the Site (Figure 2-3). As shown on Figure 2-3, most of the soil containing elevated COPC concentrations from historical operations is covered by clean gravel or pavement. These improvements reduce the potential for COPCs to be transported via stormwater to the Embayment.

The current stormwater system at the Site consists of a series of catch basins and a swale in the middle of the Site (Figure 7-8). The stormwater swale transects areas of soil with elevated concentrations of arsenic, copper, PCP, and D/Fs (Figure 7-8). Stormwater collected in the catch basins flows toward and into the swale, where the majority of stormwater infiltrates the swale and is not discharged to the Embayment via the outfall. Approximately 10 to 12 times per year, storm events generate volumes of stormwater sufficient to require discharge to the Embayment via the outfall. These limited duration events can also result in stormwater overflowing the tanks and the banks of the swale leading to increased infiltration of stormwater into the COPC-impacted soils surrounding these areas.

Four stormwater samples were collected from the stormwater system between October 2012 and April 2013 in accordance with the RI Work Plan and contained low concentrations of arsenic, copper, zinc, and D/Fs. PCP was not detected in the stormwater samples. The low concentrations of arsenic, copper, zinc, and D/Fs detected in stormwater suggest that these COPCs may be periodically discharged to the Embayment during times when the capacity of the stormwater system is exceeded, which occurs approximately 10 to 12 times per year. Stormwater is routinely managed in compliance with the Sand and Gravel Permit (Section 2.5.2).

Stormwater solids samples collected from the stormwater system contained arsenic, copper, mercury, zinc, PCP, cPAHs, PCBs, D/Fs, and other COPCs. The results of mass balance box

modeling presented in Section 5.5 show that under current conditions, settling of stormwater solids in the nearshore area of the Embayment does not, by itself, cause nearshore sediment concentrations to exceed sediment SLs for these COPCs.

Due to the infrequent discharge of stormwater to the Embayment from the current stormwater system at the Site and low concentrations of COPCs reported in stormwater, discharges of stormwater and stormwater solids to the Embayment during high volume stormwater events is not a significant transport mechanism at the Site.

7.4.1.7 ELECTRICAL EQUIPMENT AND BUILDING MATERIALS CONTAINING PCBs

Historical electrical equipment containing PCBs (e.g., transformers, capacitors, etc.) formerly used at the Site are potential primary sources of PCBs and associated petroleum oils in riverbank soils and sediments at the Site. As shown on Figures 7-4 and 7-5, transformers were situated on the northern portion of the Site between the 1940s and 1960s during operation of the former Army and Reichhold facilities. Capacitors and other electrical equipment associated with manufacturing charcoal and whetlerite were used and maintained during this same time period, but the location of that equipment is unknown. Transformers may have also been present at the Site during Mineralized-Cell's wood preserving operations. The 1940s to 1960s era transformers would have contained PCB oil; however, those transformers were removed when Kaiser constructed the cement terminal and demolished all of the Army and Reichhold facility structures. Kaiser replaced these transformers with new ones. It is not known whether PCB oils from the 1940s to 1960s era transformers were released to on-Site soils during their operation. It is also not known whether the replacement transformers contained PCB oils.

Building materials used before 1979 to construct the current cement terminal on the Property may contain PCBs. The only pre-1979 building material that remains on the Property and that might include PCBs is the caulking in the cement silos. No other building materials potentially containing PCBs have been identified at the Property.

Currently, electrical service to the Site is provided by Seattle City Light, which owns and operates existing transformers along the northern boundary of the Property. Glacier Northwest owns and operates an additional four transformers and six capacitors located in an enclosed area in the northeast portion of the Property (Figure 2-3). These transformers have been certified to contain less than 50 ppm of PCB content in the oil. There are no documented releases of PCB-containing oils on the Property, and the presence of electrical equipment containing PCBs ceased as a primary source when the older electrical equipment was removed from the Site between 1964 and 1969.

Although extensive sampling was performed in the vicinity of the 1940s and 1960s era transformers, PCBs were not detected in these areas at concentrations exceeding SLs. PCBs were detected in riverbank soils at concentrations less than the pCULs. As discussed in Section 7.4.1.5, the presence of PCBs in riverbank soils is likely the result of demolition or redevelopment activities incidental to construction of the cement terminal in the 1960s. PCBs were also detected in stormwater solids samples and in shallow sediment samples along the shoreline of the Embayment. The occurrence of PCB exceedances in soil do not show a strong correlation with

petroleum-related COPCs (TPH and/or cPAH) exceedances in soil, indicating that the PCBs are likely old and any associated carrier oils have long since degraded.

The lack of PCB concentrations exceeding SLs in soils in areas of historical transformer usage suggests that the release of PCBs to soils via spills, leaks, discharge, or disposal from historical usage of electrical equipment was either insignificant or the PCB-impacted soils were moved to new areas (e.g., the riverbank) during demolition and redevelopment of the Property. The presence of PCBs in riverbank soils, stormwater solids, and sediments suggest that soils with elevated PCB concentrations may have been placed on the riverbank and in the intertidal zone during Kaiser's demolition of the former Army and Reichhold facility structures and construction of the cement terminal. The riverbank soils may have been subsequently transported via stormwater or bank erosion to sediments in the Embayment. Riverbank soil and sediment continue to be secondary sources of PCBs at the Site.

7.4.1.8 VEHICLE OPERATIONS

Vehicle operations at the Site before 1991 are potential primary sources of petroleum-related COPCs, including cPAHs and TPH-DRO/MORO. Soils, groundwater, and sediment with elevated concentrations of petroleum- and petroleum-related COPCs were identified in the northeastern portion of the Site. Although no specific spill or vehicular operation can be linked to the petroleum detected in this portion of the Site, historical operations at the Site before 1991 involved the use of vehicles, which could have released petroleum hydrocarbons. The presence of petroleum-related COPCs in the Site soils, groundwater, and sediment, combined with known vehicle operations that included the use of petroleum, suggest that these COPCs may have released via spills or leaks from accidents or poor housekeeping practices.

Currently, Glacier Northwest conducts light-duty maintenance on concrete mixer trucks, consisting of topping off fluids, repairing lights, and other minor safety-related repairs. Heavy maintenance for trucks is completed off the Site. A third-party vendor fuels concrete mixer trucks parked in the southern portion of the Site on an as-needed basis using wet-hose services. All operations are conducted in accordance with the stormwater pollution prevention plan for the Site and in compliance with requirements of the NPDES permit for the Site. No reportable releases of petroleum hydrocarbons have occurred at the Site during Glacier Northwest operations.

The soil, groundwater, and sediment affected by historical releases of petroleum hydrocarbons are a continuing secondary source of petroleum- and petroleum-related COPCs at the Site.

7.4.2 OFF-SITE PRIMARY SOURCES AND RELEASE MECHANISMS

There are three known categories of off-Site sources of COPCs that have impacted and/or may continue to impact the Site:

- Stormwater from off-Site sources
- LDW surface water and sediments from off-Site sources
- Groundwater and bank erosion from off-Site sources
- Regional atmospheric deposition

The locations of the identifiable off-Site sources are illustrated on Figures 7-6 and 7-8.

7.4.2.1 STORMWATER FROM OFF-SITE SOURCES

Stormwater from off-Site sources is a significant primary source of COPCs detected in the sediments at the Site. Five separate stormwater systems have directed or continue to direct off-Site stormwater to sediments within the Embayment including:

- The former drainage ditch along the southern edge of the Site that serviced the former tin reclamation facility; the Port of Seattle property; and other properties located north, south, and west of the Site;
- The current stormwater line and outfall that services T115;
- The current 48-inch-diameter SPU stormwater line and outfall that services a large off-Site drainage basin; and
- The former DSI stormwater line and outfall that serviced the DSI property and stormwater sheet flow associated with DSI operational areas and the former DSI drydock.

During the 1960s, a surface drainage ditch observed in aerial photographs in the southern portion of the Site apparently captured stormwater from the southern portion of the Site and from properties to the north, south, and west of the Site, and directed the stormwater to the Embayment. COPCs associated with the former drainage ditch are not known, however, they are presumed to include common stormwater contaminants such as TPH, SVOCs, metals, PCBs, VOCs, and D/Fs. The surface drainage ditch was filled between 1969 and 1970 as observed in aerial photographs.

Between approximately 1963 and 1998 (Figures 7-6 and 7-8), a tin reclamation facility formerly located in the northwest corner of the Port of Seattle property discharged industrial wastewater and stormwater to the Embayment via the surface drainage ditch on the southern portion of the Site. Aerial photographs of the Site in 1965, 1966, 1967, 1969, and 1970 (Appendix A) show a light-colored plume of accumulated sediment and/or liquid discharges emanating from the tin reclamation facility. The hazardous substances within the discharge are unknown; however, the operators of the tin reclamation facility reclaimed tin from scrap steel and recycled tin cans. An investigation by the Port of Seattle of the tin reclamation facility identified metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, tin, and zinc), SVOCs (including PAHs), TPH, and VOCs in various soil and groundwater media (Landau 2009). The samples were not analyzed for D/Fs, but D/Fs were identified in soil and sediment at the discharge location of the wastewater and stormwater released from the former tin reclamation facility.

Stormwater from T115 is directed to stormwater outfalls on the Port of Seattle property. As described in Section 5.6, stormwater solids samples collected from T115 catch basins had detectable concentrations of copper, lead, tin, zinc, and SVOCs consisting of cPAHs, pyrene, fluoranthene, phenanthrene, BEHP, and benzo(g,h,i)perylene (Landau 2009).

Stormwater from T115 also discharges directly to the Embayment via Outfall 2128, which is located on the southern shore of the Embayment (Appendix H). The drawing in Appendix H shows at least four catch basins on T115 tying into this outfall. The entire capture area serviced by this outfall is unknown.

The 48-inch-diameter SPU stormwater line was constructed south of the Site in the early 1970s and has discharged stormwater to the LDW through Outfall 2127 since that time. This outfall collects stormwater from approximately 110 acres, and the land uses within the basin include residential, park, industrial, and commercial properties. Stormwater solids data collected from the SPU stormwater line indicate that elevated concentrations of arsenic, lead, mercury, zinc, cPAHs, benzyl alcohol, PCP, phenol, PCBs, and D/Fs are discharged to the LDW at a point directly upstream of the Embayment. Stormwater and stormwater sediment load discharged from Outfall 2127 likely deposits in Site sediments. From 2000 to 2007, combined wastewater and stormwater overflows were discharged an average of three times per year with an annual average volume of approximately 3.52 million gallons per year (Ecology 2011b).

DSI discharged stormwater from the outfall located along the north shore of the Embayment from the 1930s/1940s through 2011. In addition to the stormwater point source discharges from the outfall, non-point stormwater discharges such as sheet flow from the operational areas of DSI and the former DSI drydock also likely contributed stormwater and stormwater solids (e.g., dust and paint) to the Site and vicinity. Copper and zinc have been detected in stormwater at the DSI property and PAHs, SVOCs, tributyltin, copper, mercury, and zinc have been detected in stormwater solids at the DSI property. Stormwater and stormwater sediment load discharged from the DSI outfall is likely deposited in Site sediments.

7.4.2.2 LDW SURFACE WATER AND SEDIMENTS FROM OFF-SITE SOURCES

The Embayment is a net depositional area for sediments from the LDW, as documented in the LDW RI and FS documents (Windward 2010; AECOM 2012). As observed in aerial photographs of the Site dating from 1922 through 1969 (Appendix A1), the hydrology within the reach of the LDW adjacent to the Site was a low energy net depositional area for sediments transported down the LDW prior to the construction of the Embayment. The Embayment was created by the Port of Seattle during filling activities in the late 1960s to early 1970s for the purpose of creating land surface for T115. During that time period, the existing meander of the LDW was filled to form what is now T115. That fill project altered the natural course of water flow in front of the Site, creating what is now the Embayment. The resulting changes to hydrology within the LDW likely increased sedimentation rates within the Embayment.

Based on the limited data collected from the mouth of the Embayment during the LDW RI (i.e., LDW-SC29), historical net sedimentation rates were estimated to range between 0.4 and 0.6 cm/yr (Windward 2010). Sediment transport modeling completed as part of the LDW RI projects a sedimentation rate of 2 to 3 cm/yr in the Embayment (Windward 2010). The available data indicate that the sedimentation rates within the Embayment ranges between 0.4 and 3 cm/yr and is likely on the lower end of this range (i.e., if 3 cm/yr or 1 ft/decade of sedimentation was occurring, it would result in obvious changes to the Embayment).

Many chemical constituents have been documented to be present in the LDW sediments upriver and downriver of the Site at concentrations greater than LDW sediment SLs, including arsenic, D/Fs, cPAHs, PCBs, and tributyltin. According to the LDW FS (AECOM 2012), "more than 99% of the incoming sediment load to the LDW (1,850,850 metric tons) originates from the Green/Duwamish River (upstream); less than 1% (12,580 metric tons, or an annual average of

85,000 metric tons per year) enters the LDW from lateral sources. Over a 30-year period, a cumulative total of 6.2 million metric tons enters the LDW (for an annual average of approximately 207,000 metric tons per year)."

7.4.2.3 GROUNDWATER AND BANK EROSION FROM THE PORT OF SEATTLE PROPERTY

COPCs may have been released, and may continue to be released, to the Embayment through erosion of riverbank soils or migration of groundwater from the Port of Seattle property to the Embayment. As described in Section 2.7.2, the Port of Seattle property has undergone significant filling, a majority of which occurred between the 1950s and 1971 (SES 2011). The Port of Seattle owned both T115 and the Property, including the uplands and Embayment, from June 2, 1964, to September 17, 1973. Beginning in November 1969, the Port of Seattle initiated a project to expand the Port of Seattle property through extensive filling, dredging, and excavation (SES 2011). The Port of Seattle property was filled with 722,000 cubic yards of dredged material and 1.1 million cubic yards of fill material. The nature of the fill material is not well known; however, dredged material from the LDW during this time period likely contain elevated concentrations of arsenic, cPAHs, PCBs, PCPs, D/Fs, and likely other contaminants consistent with concentrations present in the LDW.

The erosion of riverbank soils at the Port of Seattle property and discharge of groundwater from the Port of Seattle property to the Embayment is a continuing potential source of COPCs in the aquatic portion of the Site.

Groundwater and bank erosion from the area of the Port of Seattle property formerly occupied by the tin reclamation facility also likely affected sediments at the Site. Aerial photographs of T115 from 1965, 1966, 1967, 1969, and 1970 (Appendix A2) show a light-colored plume of accumulated sediment and/or liquid discharges into the LDW. The discolored discharges are visible in what is now the Embayment. COPCs from the tin reclamation facility include metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, tin, and zinc), SVOCs (including PAHs), TPHs, and VOCs in various soil and groundwater media (Landau 2009). The samples were not analyzed for D/Fs, but D/Fs were identified in soil and sediment at the discharge location of the wastewater and stormwater released from the former tin reclamation facility.

7.4.2.4 GROUNDWATER AND BANK EROSION FROM DSI PROPERTY

Historical operations at the DSI property included repair and maintenance of tugboats, barges, dredges, fishing vessels, and small passenger vessels. Historical aerial photographs show the former DSI drydock in the LDW positioned proximate to the Embayment (Figure 2-4 and Appendix A2). Sediment cores advanced in the vicinity of the DSI drydock contained sand blast grit, gravel with scattered debris, foliated chips (possibly paint), and orange flecks. Samples of these materials contained elevated concentrations of arsenic, copper, lead, mercury, zinc, chlorinated benzenes, PCBs, PCP, PAHs, tributyltin, and phthalates, including some of the highest detections of arsenic in the LDW. Direct deposit of these waste materials in the immediate vicinity of the Embayment likely affected sediments at the Site.

Groundwater discharges and bank erosion from the DSI property might also be a continuing source of COPCs to the upland and aquatic portions of the Site. The DSI RI Report (Anchor QEA

2019) reported COPCs, including dissolved arsenic, copper, nickel, zinc, benzo(a)anthracene, and chrysene above SLs in shallow groundwater beneath the DSI property, with arsenic reported at greater than 50 µg/L near the northern boundary of the Property. As described in the DSI RI Report, shallow groundwater beneath the DSI property generally flows to the west toward the LDW, shifting to the west-southwest in the vicinity of the northeastern Property boundary during low-low tide. This groundwater could therefore represent a continuing source of COPCs to surface water and sediment in the LDW and aquatic portion of the Site, as well as to shallow groundwater (primarily arsenic) in the northeastern portion of the Site.

7.4.2.5 REGIONAL ATMOSPHERIC DEPOSITION

Gases and particulates released to the atmosphere from combustion sources such as motor vehicle emissions, backyard burning, and industrial sources contain nitrogen, sulphur, metals, PCBs, D/Fs, and PAHs, which eventually settle to the ground as dust or by precipitation. These COPCs may be deposited directly into waterbodies, land surfaces, and in urban areas may be transported via stormwater from land, roads, rooftops, and parking lots into surface waters. The particulate-bound chemicals transported by atmospheric processes can eventually accumulate in sediments.

A LDW bulk atmospheric deposition study completed in 2011/2012 (King County 2013) found that metals (arsenic, cadmium, copper, lead, nickel, and vanadium), PCBs, PAHs, and D/Fs are continuously deposited throughout the LDW area. Atmospheric deposition is a historic and ongoing primary off-Site source of COPCs to the surface soil, stormwater, surface water, and sediment at the Site.

7.5 FATE AND TRANSPORT OF CONTAMINANTS OF CONCERN

7.5.1 CHEMICAL FATE OF CONTAMINANTS OF POTENTIAL CONCERN

The chemical fate and transport of COPCs is affected by their chemical properties and the physical, chemical, and biological processes to which they are exposed at the Site. The Site-related COPCs can be categorized as either persistent or degradable based on their chemical characteristics. The pertinent chemical properties of the Site COPCs are summarized in Table 7-3. These properties and how they impact the chemical fate of the Site COPCs are briefly discussed below.

7.5.1.1 PERSISTENT CONTAMINANTS OF POTENTIAL CONCERN

Contaminants that are persistent in the environment are characterized by low solubilities and low volatilities, and are not easily degraded by biological or physical mechanisms. Persistent COPCs at the Site include D/Fs, arsenic, copper, zinc, cPAHs, and PCBs.

Dioxins/Furans

D/Fs are considered persistent because they are hydrophobic, highly lipophilic, and biodegrade very slowly. As shown in Table 7-3, the water solubility (K) and vapor pressure (VP) of D/Fs (based on TCDD) is very low ($K=2 \times 10^{-4}$ milligrams per liter [mg/L] and $VP=1.97 \times 10^{-12}$ atmosphere [atm]). This indicates that D/Fs do not easily migrate in groundwater or surface water

as dissolved molecules and do not easily evaporate into the atmosphere from soil and other solid matrices. Conversely, the organic carbon-water partitioning coefficient (K_{oc}) values for D/Fs are very high (2.5x10⁵ liters per kilogram [L/kg]; Table 7-3), which suggests that D/Fs will strongly attach to organic matter found in soil and sediments. Therefore, D/Fs are expected to be relatively immobile in soil and sediment and are not easily transported via groundwater or surface water unless they are attached to particulates or colloids that are entrained in the water.

The sampling data from the Site show large areas of soil and/or sediment having D/F SL exceedances, but relatively small areas of groundwater having D/F SL exceedances (Figures 5-11, 5-20, and 5-21). The hydrophobic and lipophilic characteristics of D/Fs combined with the relatively high concentration of organics in the soils and sediments at the Site retards the transport of D/Fs in soil and groundwater. The limited areas of D/F SL exceedances in shallow and deep groundwater (Figures 5-11, 5-20, and 5-21) are likely the result of water that contains D/Fs attached to particulates or colloids. Colloids are particles having diameters less than 10 micrometers. Research by Huling (1989) and Fang et al. (2006) has shown that in a laboratory setting, hydrophobic organic contaminants, like D/Fs, can sorb to organic colloids and migrate through soil. However, the migration of D/Fs via colloidal transport in a site-setting, particularly one having highly organic soils to which D/Fs readily sorb, is much less likely.

Biodegradation of D/Fs occurs very slowly. The most rapid degradation process for D/Fs is through photolysis and, as shown in Table 7-3, the estimated half-life of D/Fs (based on TCDD) exposed directly to sunlight ranges from 9 to 15 years. For D/Fs not exposed to sunlight, the biodegradation half-life is estimated at 25 to 100 years (USEPA n.d.). Because most of the D/Fs detected at the Site are in subsurface soils and sediments, degradation via photolysis is not occurring and biodegradation of the D/Fs occurs very slowly.

The lipophilic nature of D/Fs means that they are bioavailable to plants and animals and will be retained in tissues longer than a contaminant that is water soluble. The bioconcentration factor for D/Fs is 5,000 L/kg (Table 7-3), indicating that low concentrations in the environment can lead to high concentrations in aquatic or terrestrial organisms.

Arsenic, Copper, and Zinc

Arsenic, copper, and zinc are considered persistent because they cannot be degraded by natural processes and are not volatile; however, inorganic compounds such as those found at the Site are soluble. The solubility of inorganic compounds is governed by groundwater geochemistry (i.e., pH, oxidation-reduction potential), and the presence or absence of various cations and anions that drive chemical reactions to the mineral phase or to stay in the aqueous phase. Geochemical data collected from the Site groundwater indicates neutral to acidic pH and reducing conditions. Arsenic is soluble and less sensitive to changes in pH under reducing conditions, which is consistent with the sampling data from the Site, where arsenic is detected at concentrations exceeding its SLs in soil, groundwater, and sediment samples. These data suggest that the Site conditions are conducive to the leaching of arsenic from Site soils and transport of arsenic in the groundwater to the Embayment. However, the geochemistry of the pore water in the Embayment sediments suggests that the arsenic will remain soluble and may not precipitate in high concentrations in Site sediments.

The predominant form of arsenic at the Site is arsenite (As +3), which is also consistent with the moderately reducing conditions observed at the Site. Copper and zinc were detected at elevated concentrations in soil, groundwater, and sediments (Figures 5-3, 5-4, 5-14, and 5-15); however, these metals were not detected at elevated concentrations in groundwater as commonly as arsenic, indicating that these metals are not as soluble and mobile as arsenic under the geochemical conditions found at the Site. Therefore, copper and zinc are most likely primarily transported via erosion and re-deposition of Site soils and/or sediment and not as commonly via groundwater. Arsenic, copper, and zinc are not biodegradable but can be bioaccumulated by plants and animals. Arsenite is more bioavailable than arsenate, which contributes to its elevated toxicity. The bioconcentration factors of arsenic, copper, and zinc are 44 L/kg, 36 L/kg, and 47 L/kg, respectively (Table 7-3), indicating that these inorganic compounds do not concentrate in aquatic or terrestrial organisms to the degree that the more persistent organic contaminants do.

cPAHs

The water solubility and vapor pressure of cPAHs (based on benzo[a]pyrene), as presented in Table 7-3, show that cPAHs are hydrophobic compounds that are only slightly soluble in water, are not volatile, and have a strong tendency to sorb to organic matter found in soil and sediment ($K = 0.0016$ mg/L, $VP = 7.2 \times 10^{-12}$, $K_{oc} = 5.9 \times 10^5$ L/kg). Therefore, cPAHs are expected to be relatively immobile in soil and sediment and are not easily transported via groundwater or surface water unless they are attached to particulates that are entrained in the water or migrate via colloidal transport. Sampling data from the Site show cPAHs at concentrations exceeding their SLs in soil and sediment samples. cPAHs were not detected in groundwater samples at concentrations greater than the best available laboratory PQLs, which are higher than the SLs (Table W-13, Appendix W). Because the best available PQL for cPAHs in groundwater is greater than the SL, it is not possible to rule out the groundwater pathway for cPAHs; therefore, cPAHs are retained as a COPC in groundwater at this time. However, cPAHs have hydrophobic and lipophilic characteristics that are not conducive for the transport of cPAHs via groundwater. Therefore, it is unlikely that groundwater is a pathway between Site soil to the Embayment sediment and surface water.

Natural degradation of cPAHs can occur via photolysis and biodegradation, although biodegradation of cPAHs is moderate to slow (Nagpal 1993). The half-lives for cPAHs in soil range from 28 days for anthracene to 179 days for dibenzo(a,h,)anthracene (Nagpal 1993). Similar to D/Fs, cPAHs at the Site are found primarily in subsurface soils and sediments; therefore, degradation by photolysis is not likely occurring.

The lipophilic nature of cPAHs makes them bioavailable in soils and sediments. The bioconcentration factor for cPAHs (based on benzo[a]pyrene) in fish is 583, indicating that moderate concentrations in the environment can lead to significant concentrations in aquatic and terrestrial organisms.

PCBs

PCBs, similar to D/Fs, are considered persistent contaminants due to their low solubility, low volatility, and slow degradation rates. As shown in Table 7-3, the water solubility and vapor pressure of the more chlorinated PCBs (based on Aroclor 1254, the predominant PCB congener detected in soil at the Site) are low ($K = 0.043$ mg/L and $VP = 1.04 \times 10^{-7}$ atm). This indicates

that PCBs are not typically found as dissolved molecules in surface and groundwater and do not easily evaporate. PCBs will strongly attach to organic matter found in soil and sediments as indicated by the very high K_{oc} values (130,000 L/kg; Table 7-3). Therefore, PCBs are expected to be relatively immobile in soil and sediment and are not easily transported via groundwater or surface water unless they are attached to particulates or colloids that are entrained in the water.

PCBs were detected in soil and sediment at concentrations greater than their respective SLs, but, with one exception, they were not detected in groundwater (Figures 5-9, 5-10, and 6-3). Because the best available PQL for PCBs in groundwater exceeds the SL, transport of PCBs from soil to sediment via the groundwater pathway cannot be ruled out. However, the well-documented hydrophobic and lipophilic characteristics of PCBs significantly limit the transport of PCBs via groundwater and, if observed, may be the result of colloidal transport. Therefore, PCBs are most likely primarily transported via bank erosion and re-deposition of Site soils and/or sediment, and less likely as a groundwater or surface water plume.

PCBs are degradable by biodegradation and photolysis, but the degradation rate depends on the PCB congener. The half-life of PCBs in the atmosphere can range up to 1.3 years (USEPA n.d.). PCBs at the Site are found primarily in subsurface soils and sediments that are not exposed to sunlight; therefore, photolysis is not likely occurring. The predominant form of PCBs at the Site are the higher chlorinated congeners (i.e., Aroclor 1242, 1254, and 1260) that are less amenable to biodegradation.

PCBs are bioavailable in soil and sediment and have a bioconcentration factor of 31,200 (based on Aroclor 1254; Table 7-3), indicating that low concentrations of PCBs in the environment can lead to high concentrations in aquatic or terrestrial organisms.

7.5.1.2 DEGRADABLE CONTAMINANTS OF CONCERN

Contaminants that are amenable to degradation processes are generally characterized by higher solubilities and volatilities and are easily degraded by biological or physical processes. The degradable COPCs at the Site include petroleum and PCP.

Petroleum

Petroleum is readily biodegraded. As shown in Table 7-3, the solubility of DRO (K = 0.22 to 27.8 mg/L) and MORO (K = 0.26 mg/L to 3.7x10⁻³ mg/L) is generally higher than the persistent COPCs. The vapor pressures of TPH-DRO and TPH-MORO (vapor pressure ranges from 2.9x10⁻³ to 3.2x10⁻⁵ atm; Table 7-3) show that petroleum hydrocarbons are generally more volatile than the persistent COPCs at the Site. The partitioning coefficients for TPH-DRO and TPH-MORO are low compared to the persistent compounds indicating that petroleum hydrocarbons can be mobile in soil. Elevated concentrations of TPH were detected in Site soil and groundwater, which is consistent with higher solubility allowing leaching from soil into the groundwater. Light non-aqueous phase liquid has not been measured in monitoring wells at the Site during the RI, which indicates that the TPH concentrations in soil are less than the residual saturation concentrations for the TPH.

Biodegradation of petroleum is most efficient under aerobic conditions. The subsurface conditions at the Site are reducing; therefore, biodegradation of the TPH-DRO and TPH-MORO present in the

Site soils and groundwater is expected to be slow. Biodegradation of petroleum also results in reducing conditions as the available oxygen in the substrate is consumed during aerobic biodegradation. Anaerobic biodegradation of petroleum also occurs, but it is a slower process than aerobic biodegradation.

Pentachlorophenol

PCP can be degraded via biodegradation and photolysis. PCP's half-life in soil ranges from weeks to months; whereas the biodegradation rate in sediment is more rapid. PCP has a high affinity for organic matter, making its transport in soil and groundwater slow (i.e., $K_{oc} = 592 \text{ L/kg}$; Table 7-3).

PCP solubility in groundwater is pH-dependent with alkaline and reducing conditions resulting in more desorption. As shown in Table 7-3, PCP has low water solubility ($K = 14 \text{ mg/L}$) and moderate vapor pressure ($VP = 1.3 \times 10^{-7} \text{ atm}$), which indicates that it is only slightly soluble in water and evaporation from water is slow. Groundwater pH at the Site ranges from 6 to 7. At this pH range, PCP has relatively low solubility. The distribution of PCP in Site media further suggests that PCP is not easily solubilized and mobilized in groundwater. PCP was detected in both soil and groundwater at concentrations exceeding SLs, but the footprint of PCP exceeding its SL in soil is significantly larger than the footprint of PCP exceeding its SL in groundwater (Figures 5-6, 5-17, and 5-19). The remediation of PCP in groundwater using ozone sparging between April/May 2000 and October 2005 (Section 3.2.1) contributed to the diminished footprint of PCP in groundwater in the former Reichhold washwater impoundment area.

PCP is bioavailable and has a bioconcentration factor of 11 L/kg (Table 7-3), indicating that PCP does not concentrate in aquatic or terrestrial organisms to the degree that the more persistent contaminants do.

7.5.2 TRANSPORT OF CONTAMINANTS OF POTENTIAL CONCERN

A summary of the secondary release mechanisms and impacted media for Site-related COPCs is included in Table 7-1. The specific secondary release mechanisms by which Site-related COPCs have been and may continue to be transported at and from the Site are described below.

7.5.2.1 TRANSPORT FROM DEVELOPMENT ACTIVITIES

As described in Section 7.4.1.5, demolition of the former Army and Reichhold facility structures and construction of the Kaiser cement terminal is a secondary COPC release mechanism for soil at the Site. Demolition and redevelopment activities moved soils with elevated COPC concentrations from the excavation for the footings and foundations of the cement silos; the grading associated with the removal and construction of other facilities resulted in their placement in other areas of the Site. These actions created new and larger secondary COPC sources. Based on aerial photographs, it appears that the excavated material was staged in the central and southern portions of the Site and redistributed across portions of the Site including the riverbank. These photographs show that the shoreline of the Embayment was filled and extended during construction of the Kaiser cement terminal. The photographs also appear to show that soil from excavation for the cement silos may have been pushed to form the current riverbank. The soils

and sediments impacted by the redevelopment activities are a secondary source of contamination that continues to affect the Site.

7.5.2.2 GROUNDWATER TRANSPORT

Groundwater transport of COPCs involves migration via infiltration/leaching, advection, diffusion, and preferential migration pathways, as described below.

Infiltration/Leaching

Infiltration of precipitation at the Site in areas of impacted soil (e.g., former operational areas and ditches) can mobilize contaminants from the soil column to the percolating water. COPCs that are soluble may enter solution and remain in solution until reaching groundwater or may become sorbed to soil in route. The rate of desorption in shallow soil and subsequent concentrations of COPCs in deeper soil or in groundwater is dependent on the COPC's chemical properties (e.g., solubility and adsorption affinity) and the properties of the soil (e.g., organic carbon content, grain size, etc.). Arsenic, copper, zinc, PCP and its associated daughter products (i.e., 2,4-dichlorophenol, 2,4,6-trichlorophenol, and phenol), and TPH-DRO/MORO are the soil COPCs that were detected in groundwater at concentrations exceeding the SLs, suggesting that they are susceptible to the infiltration/leaching transport mechanism. Although the possibility of transport of cPAHs and PCBs in soil via the infiltration/leaching pathway cannot be ruled out due to PQLs exceeding their respective SLs, the possibility is low due to the hydrophobic and lipophilic nature of these compounds. This is supported by the lack of cPAHs detected in groundwater and only one groundwater sample with detected PCBs at concentrations exceeding the SL.

Arsenic is soluble in the reducing conditions observed in the shallow and deep aquifers at the Site. The area of shallow groundwater having arsenic SL exceedances is mostly co-located with vadose and saturated soil having arsenic SL exceedances, which empirically demonstrates that at least some of the arsenic concentrations in this area of soil are high enough to result in arsenic SL exceedances in groundwater (Figures 5-1, 5-2, and 5-12). Therefore, arsenic transport from soil to groundwater via infiltration/leaching is a complete transport mechanism for some areas of the Site.

Copper, PCP, and TPH-DRO/MORO are slightly soluble in water and are present in soil and groundwater at concentrations exceeding their SLs (Figures 5-3, 5-5, 5-6, 5-14, 5-15, 5-16, 5-17, and 5-19). Therefore, infiltration/leaching is a complete transport mechanism for copper, PCP, and TPH-DRO/MORO.

The areas of shallow and deep groundwater having copper SL exceedances typically correlate with areas of soil having copper concentrations greater than 10 times the SL (Figures 5-3, 5-14, and 5-15). Seven soil sampling locations were identified as having a co-located groundwater sample where the groundwater concentration of copper was below the MDL. These soil concentrations ranged from 10.2 to 88.3 mg/kg. All seven soil samples exhibited concentrations exceeding the vadose and saturated zone pCULs for protection of surface water and sediment via groundwater. Even with these soil pCULs exceeded, groundwater impacts were not observable, suggesting that low concentrations of copper in soil are not measurably impacting groundwater and present less of a leaching risk than locations with copper concentrations greater than 10 times the SL.

Similarly, areas of shallow and deep PCP SL exceedances primarily correlate with soil having PCP concentrations greater than 10 times the PQL and greater than 32 times the SL (Figures 5-6, 5-17, and 5-19). Twenty-four soil sampling locations were identified as having a co-located groundwater sample where the groundwater concentration of PCP was below the MDL. Fifteen of the soil samples had concentrations below the reporting limits, which ranged from 1.1 to 1,400 µg/kg. Of the remaining nine soil samples, eight samples exhibited detectable concentrations exceeding the vadose and saturated zone pCULs for protection of drinking water, surface water, and sediment via groundwater. These soil concentrations ranged from 10 to 630 µg/kg. This suggests that locations with low concentrations of PCP in soil are not measurably impacting groundwater and present less of a leaching risk.

The area of shallow groundwater having TPH-DRO/MORO SL exceedances (in the vicinity of MW-35S and DSIP2-29) is co-located and/or downgradient of soil sampling locations MW-35S and GP-75 having TPH-DRO/MORO SL exceedances and/or PID readings above 20 ppm (Figures 5-5 and 5-16). However, there are other areas of the Site exhibiting TPH-DRO/MORO SL exceedances in soil, but do not exhibit TPH-DRO/MORO SL exceedances in groundwater (Figures 5-5 and 5-16) where groundwater data exist proximal to these areas (e.g., MW-29S and MW-30S). This suggests that concentrations of TPH-DRO/MORO SL exceedances in soil in these areas are low enough to not measurably impact groundwater and present less of a leaching risk to groundwater.

Shallow Aquifer Solute Transport via Advection

COPCs present in groundwater in the shallow aquifer include arsenic, copper, zinc, PCP, TPH-DRO/MORO, and D/Fs. Dissolved COCs can migrate in the direction of groundwater flow via advection. Advection is the movement of groundwater through a porous media (e.g., soil), which is governed by properties of the aquifer such as hydraulic conductivity and the hydraulic gradient. As discussed in Section 2.10.2, the groundwater flow direction in the shallow aquifer is toward the LDW with an average calculated groundwater flow velocity of 12.7 ft/yr. The shallow aquifer discharges to the Embayment via seeps and toward the 48-inch-diameter SPU stormwater line located south of the Site (a preferential pathway discussed below).

The concentrations of COPCs in groundwater are influenced by their solubility, the presence of specific ions and reducing agents, pH, oxidation-reduction potential, and to some degree, the duration moving groundwater is in contact with contaminated soil. The partitioning of COPCs to aquifer solids (i.e., organics, sands, and silts) results in a reduction of concentration in the aqueous phase and a retardation of the velocity of contaminant migration. Nonetheless, transport of both arsenic and PCP to surface water and sediments in the Embayment via groundwater is a complete migration pathway because both COPCs are present in shallow groundwater adjacent to the Embayment at concentrations exceeding their SLs. In addition, groundwater from the DSI property and T115 discharges to the Embayment via seeps. Under current conditions, solute transport via advection is a complete transport pathway for shallow groundwater discharging to the Embayment.

Diffusion

As discussed in Section 2.8.2.2, a continuous silt aquitard separates the shallow and deep aquifers at the Site. The potentiometric head differences between the shallow and deep aquifers indicate

that there is a net downward vertical gradient (0.21 to 0.34 ft/ft; Section 2.10.3.3), and no conduit of higher permeability material has been observed that could serve as a short-circuit for groundwater from the shallow to the deep aquifer. It should be noted that the aquitard is not present at all locations along the riverbank to the east of the former 1920s shoreline; as such, vertical groundwater migration in these areas may occur (although this area represents a small portion of the Site as a whole). As discussed in Section 7.4.1.1, an isolated area with elevated arsenic concentrations in the silt aquitard and dissolved arsenic in the deep groundwater aquifer is present directly beneath the former Mineralized-Cell wood treatment area. Further, as discussed in Section 7.3.5, PCP was detected at concentrations exceeding the SL in deep groundwater samples at one monitoring well. The monitoring well (MW-45D) is next to the shallow monitoring well that had the highest PCP concentrations reported in the shallow aquifer and no SL exceedances in soil. PCP concentrations measured in the deep aquifer were approximately 100 times lower than those measured in the shallow aquifer.

Diffusion is the process by which a chemical in water 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 a fluid is not moving, and as a result a constituent may spread away from the place where it is introduced into a porous medium. Diffusion can also occur when a chemical concentration is higher in one stratum than in an adjacent stratum (Fetter 1993). The concentrations of arsenic detected in the deep aquifer are consistent with migration via diffusion, supported by the fact that the concentration of arsenic detected in the deep aquifer as compared to the shallow aquifer is consistently 15 to 20 times lower. Diffusion from the shallow to the deep aquifer is a complete secondary transport mechanism.

Deep Aquifer Solute Transport via Advection

Arsenic, copper, PCP, and D/Fs are the COPCs detected in the deep aquifer at concentrations exceeding SLs. Solute transport via advection in the deep aquifer is a potential transport pathway for these COPCs.

Preferential Migration Pathways

Utility trenches and corridors having highly permeable bedding material or leaky piping surrounded by lower permeability soils can form preferential pathways for groundwater migration. As discussed in Section 2.10.2.1, groundwater in the southern portion of the Site and under the Port of Seattle property appears to be influenced by a preferential pathway along the 48-inch-diameter SPU stormwater line located south of the Site. Groundwater under the Port of Seattle property flows to the north toward the SPU stormwater line and groundwater in the southern portion of the Site flows south toward the SPU stormwater line (see Figure 2-22). Groundwater intercepted by the SPU stormwater line is directed toward the Embayment. Water has been observed to seep from the outside of the SPU stormwater line during dry weather conditions. Based on current shallow groundwater data collected from shallow monitoring wells near the SPU stormwater line (i.e., MW-3S, MW-18S, MW-20S, MW-24S, MW-26S, and MW-27S), dissolved arsenic, total and dissolved copper, PCP, and D/Fs are COPCs that have the potential to migrate through groundwater to the bedding material around the SPU stormwater line.

No other preferential groundwater migration pathways have been identified at the Site. As discussed in Section 3.3.8, the 15-inch historical stormwater pipe in the southern portion of the Site was backfilled with the same material as surrounding soils and was observed to be tightly compacted around the pipe when evaluated in 2009 and 2014. Moreover, a 5- to 6-foot section of the historical stormwater pipe was removed during the 2014 abandonment, the end of the pipe was capped, and the base of the excavation was filled with CDF to provide further assurance that the historical stormwater pipe is not a current or future migration pathway.

7.5.2.3 STORMWATER TRANSPORT

As stormwater flows across the Site, surface soils can be eroded, transported with the stormwater, and re-deposited when stormwater flow is no longer of sufficient energy to transport the soil particles. Particulate-bound COPCs can be transported with the stormwater and collect in low points in the stormwater system on the northern portion of the Site. Stormwater is directed from catch basins and via surface runoff to the grass-lined stormwater swale. Stormwater is treated for suspended solids and turbidity through settling and filtration dams. Stormwater is then conveyed to a steel pipe and ultimately discharged to the Embayment.

The majority of Site stormwater infiltrates into the ground, thereby limiting the frequency and volume of discharges to the Embayment. The volume of stormwater that enters the system together with the configuration and capacity of the system results in no more than 10 to 12 discharge events per year. Stormwater from large precipitation events has the potential to scour fine soil particles from surface soils in upland areas where contamination may be near the surface and transport the suspended particles to the Embayment where they may be deposited. As discussed in Section 5.5, the results of mass balance box modeling indicate that under current conditions, settling of stormwater solids in the nearshore area of the Embayment does not, by itself, cause nearshore sediment concentrations to exceed sediment SLs. The stormwater system is an active system; therefore, it is considered a secondary release mechanism because of its continued potential to mobilize stormwater solids to the Embayment.

7.5.2.4 BANK EROSION

Erosion can affect the distribution of soil-bound particulates in the environment and influence the distribution of COPCs in soil and sediments. Vessel and wind wakes have the potential to scour fine particles from the riverbank soil surface in sloped areas not covered with vegetation or armoring and redistribute these particles in nearby surface water and sediments. These physical processes frequently represent the primary mechanism for transport of otherwise immobile constituents, such as D/Fs, PCBs, PCP, and cPAHs, in soil. As discussed in Section 7.5.2.1, redevelopment activities in the 1960s resulted in the shoreline being extended via placement of fill (likely from both on-Site and off-Site sources). Riverbank soil at the Site contains concentrations of D/Fs, PCP, arsenic, and PCBs at concentrations exceeding the SLs. The soil samples collected from the top of the riverbank are assumed to be of similar magnitude to soil concentrations present on the potentially erodible surface of the riverbank at the elevation below the mean higher high water. Significant erosion of the riverbank is unlikely under current conditions because the riverbank is protected from waves and wakes by both the dock and riprap armor. Nonetheless, COPCs are present at elevated concentrations in riverbank soil. Accordingly, erosion of riverbank

soils is a potential migration pathway for on-Site COPCs to the Embayment. The erosion of contaminated riverbank soil from neighboring properties and subsequent transport into the Embayment is also a potential migration pathway for off-Site COPCs.

7.5.2.5 SEDIMENT TRANSPORT

The Embayment is a net depositional area for sediments from the LDW, as documented in the LDW RI and FS (Windward 2010; AECOM 2012). The sediment transport model created for the LDW RI estimated a net sedimentation rate of 2 to 3 cm/yr for the Embayment and a radioisotope core collected for the LDW RI near the mouth of the Embayment had a measured deposition rate of 0.4 to 0.6 cm/yr (core LDW-SC29; Windward 2010). As would be expected for an off-channel area, the modeling of the 2-, 10-, and 100-year floods conducted for the LDW RI did not show any erosion occurring within the Embayment. These findings indicate that COPC-impacted sediments in the Embayment are not likely to migrate out of the Embayment and impact other portions of the LDW.

The quiescent, depositional nature of the Embayment was demonstrated visually in January 2011 when fuel released at T115 entered the 48-inch-diameter SPU stormwater line located south of the Property and discharged to the LDW. The sheen formed by the fuel was observed to slowly circulate on the water surface in the eddy formed by the Embayment for several hours before dissipating. This observation was communicated to Ecology via email on January 25, 2011, by ERM on behalf of Glacier Northwest and Reichhold.

Modeling of sources of sediment to various areas of the LDW was performed as part of the LDW FS. Included in this modeling are calculations of the percentage of upstream sediment deposited in the Embayment. The modeling estimated that between 75 and 100 percent of the surficial sediment (0 to 10 cm) deposited in the Embayment is from upstream sources and that more than 80 percent of the fines is from upstream sources (AECOM 2012). Similarly, the LDW FS modeling estimated the surficial sediment content sourced to lateral sources in the Embayment ranges from 1 to 10 percent, with the majority of the area estimated to contain 2 to 10 percent sediment from lateral loads. Lateral sources include sediment and solid materials discharged from combined sewer overflows, storm drains, and streams. The COPCs present in the LDW suspended sediments and lateral loading include but are not limited to arsenic, copper, zinc, phthalates, PCBs, PCP, and D/Fs.

7.5.2.6 BIOACCUMULATION

Some organic pollutants, particularly those with low water solubility, as well as some metals tend to accumulate in the sediment where they can be taken up and accumulated by benthic organisms. The consumption of these organisms by larger fish, shellfish, and wildlife provides a mechanism for the contaminants to move from the sediment and water up through the food chain. PCBs, cPAH, D/Fs, and arsenic are examples of COPCs in the Embayment sediments that are potentially subject to this pathway of uptake and movement through the food chain. The bioconcentration factors for Site COPCs are presented in Table 7-3. PCB Aroclors 1260 and 1254 and D/Fs have the highest factors of bioconcentration in organisms indicating they are more likely to be removed from the sediments and bioaccumulate in benthic organisms. Conversely, PCP has the lowest bioconcentration factor and is less likely to bioaccumulate.

7.6 CONCEPTUAL SITE EXPOSURE MODEL

As discussed in the following sections, under current and anticipated future conditions, the upland portion of the Site meets the criteria of an industrial property under WAC 173-340-200 (see Sections 7.2 for details). The potential human receptors associated with the upland portion of the Site include current and future industrial and construction workers, and the potential human receptors associated with the aquatic portion of the Site including future subsistence and recreational fish and shellfish consumers (Section 7.6.1.1). The TEE completed as part of this RI (Section 2.11) determined that terrestrial wildlife is not a potential receptor for the Site; however, aquatic wildlife found in the Embayment and vicinity (including benthic invertebrates, fish, and mammals) are potential receptors for the Site.

The direct contact pathway is considered a potentially complete exposure pathway because Site soils and groundwater less than 15 feet bgs contain elevated concentrations of COCs and on-Site industrial workers (particularly construction workers) under current and future conditions are potential receptors under this pathway. The seafood consumption pathway is also considered a potentially complete exposure pathway under future conditions because subsistence and recreational fish and shellfish harvesters may ingest food that has bioaccumulated COCs from Site surface water and/or sediment. Although the Embayment is not currently used and is not likely to be used in the future for seafood harvesting, access is not strictly prohibited. USEPA has identified portions of the Embayment as potential clamming areas. Embayment sediments contain elevated concentrations of COCs and future subsistence and recreational fish and shellfish harvesters could harvest and ingest seafood from the Embayment.

Aquatic wildlife species can become exposed to COCs through multiple exposure routes (direct and indirect) due to their activity and proximity to the Embayment; however, the complete ecological exposure pathways for aquatic wildlife associated with the Site include ingestion of sediments and surface water, as well as consumption of COCs that may accumulate in food consumed by aquatic wildlife.

7.6.1 POTENTIAL RECEPTORS

Potential receptors of hazardous substances detected in Site soil, groundwater, and sediment were evaluated based on current and anticipated future land use and Site characteristics. As described in Section 7.2, under current and anticipated future conditions, the upland portion of the Site meets the criteria of an industrial property under WAC 173-340-200 and WAC 173-340-745 (1)(a)(i). The submerged lands within the aquatic portion of the Property (i.e., the Embayment) are private property. Certain Tribes may access these submerged lands to exercise treaty rights, but the general public has no right to enter upon or take anything from the submerged lands. Although surface water within the Embayment is considered waters of the state, the sheltered nature of the Embayment, the industrial operations at the Site, and the security procedures that keep people away from the existing dock, effectively prevent the general public from accessing the aquatic portion of the Site. Site groundwater is hydraulically connected to the Embayment and LDW and is not currently used as a source of drinking water. Groundwater is not likely to be used as a future source of drinking water; however, for the purposes of developing pCULs and identifying COCs for the FS, Site groundwater is considered potable. Therefore, the highest

beneficial use of Site groundwater is discharge to surface water and, to a lesser extent, as a potential source of drinking water.

7.6.1.1 HUMAN RECEPTORS

Based on the current and anticipated future land use and Site characteristics, the following potential human receptors were evaluated for the Site:

- Current and future on-Site industrial and construction workers
- Future on-Site subsistence and recreational fish and shellfish consumers

Each of these potential human receptors is described in the following sections.

Current and Future On-Site Industrial and Construction Workers

Current and future on-Site industrial workers are considered potential receptors. Industrial workers include persons involved with current and future cement terminal operations. Current terminal operations occur primarily in paved and gravel-covered areas, which significantly limits the potential exposure to hazardous substances. There is no current construction at the Site; however, future construction at the Site is reasonable to expect for an industrial property. Construction may include excavation of Site soils, and because groundwater at the Site is shallow, excavation activities may encounter groundwater. Construction may also involve shoreline work, dredging, and other activities involving on-Site surface water and sediment. Future on-Site construction workers are potential receptors of Site contamination based on infrequent use of the Site for short-term construction activities.

Future On-Site Subsistence and Recreational Users

Future subsistence and recreational users who harvest edible biota (e.g., fish and shellfish) are considered potential receptors based on their potential to contact COCs in sediment and/or ingesting edible biota that contains COCs (USEPA 2014). Subsistence users are anticipated to have a greater risk of exposure than recreational users due to a higher estimated rate of consumption of edible biota and longer exposure time. Although there is no known current use of the Embayment by subsistence and/or recreational users and access to the Embayment is restricted by security and control measures implemented at the Site, future use of the Embayment for subsistence and/or recreational edible biota harvesting is possible. The LDW sediment CULs developed by the USEPA (2014) are protective of potential subsistence and recreational user exposure pathways.

7.6.1.2 ECOLOGICAL RECEPTORS

Two types of potential ecological receptors were evaluated for the Site: terrestrial and aquatic. The results of these evaluations are described in the following sections.

Terrestrial Receptors

As described in Section 2.11 of the Draft RI Report (ERM 2015), a TEE was completed for the Site in accordance with WAC 173-340-7490 to evaluate terrestrial ecological receptors, exposure pathways, and resultant risks at the Site. The results of the TEE (Section 2.11 and Appendix L of the Draft RI Report [ERM 2015]) show that terrestrial wildlife habitat at the Site is of poor quality

because the Site is industrial, has little undeveloped vegetated area, and there are no intact corridors or connections to other wildlife habitat. Therefore, terrestrial wildlife is not considered a potential receptor for the Site.

Aquatic Receptors

As described in Section 2.12 of the Draft RI Report (ERM 2015), an evaluation of aquatic receptors in the LDW (including the Embayment) performed for the LDW RI (Windward 2010) determined that benthic (i.e., sediment-dwelling) invertebrates (e.g., worms, crabs, clams, etc.), fish (e.g., perch, anadromous salmonids, English sole, etc.), and mammals (e.g., waterfowl river otters, harbor seals, etc.) are found in the Embayment and vicinity.

7.6.2 EXPOSURE PATHWAYS

Exposure pathways have five necessary elements: (1) a source and mechanism of chemical release to the environment; (2) an environmental media and transport mechanism; (3) a point of potential receptor contact with the media containing the Site-related chemical; (4) a route of exposure; and (5) a human or ecological receptor. When all five elements are present, the exposure pathway is considered complete. Conversely, if any one of these elements is missing, the pathway is incomplete, resulting in no exposure. In some circumstances, an exposure pathway may be considered complete (i.e., meets all five of the elements), but insignificant. An exposure pathway is considered complete but insignificant if one or more of the following three conditions are met (USEPA 1989):

- The exposure resulting from the pathway is much less than the exposure resulting from another pathway involving the same medium.
- The potential magnitude of exposure from the pathway is low or of limited toxicological importance (i.e., low toxicity chemical).
- The probability of the exposure occurring is very low, and the risks associated with the occurrence are not high.

The three primary potential routes of exposure for human receptors are inhalation (breathing), ingestion (eating or drinking), and dermal contact (contact with the skin). Aquatic plant and wildlife species can become exposed to COCs through multiple exposure routes (direct and indirect) due to their activity and proximity to surface water and sediment. Ingestion is the primary exposure route for aquatic plants and wildlife. Although dermal contact may be a complete pathway for aquatic wildlife, it is less significant relative to other routes of exposure (USEPA 2005 and 2014; Peterle 1991).

Figure 7-1 presents transport mechanisms applicable to the Site for human and ecological receptors and complete, complete but insignificant, and incomplete exposure routes. The potentially exposed receptors and their potential routes of exposure based on each affected media are discussed in the following sections.

7.6.2.1 VADOSE ZONE SOIL

The potential human receptors for vadose zone soil are limited to on-Site industrial and construction workers. Exposure to the vadose zone soil by other potential human receptors

(including subsistence and recreational users) and ecological receptors, is not a complete pathway because the Site's industrial land use makes access to the vadose zone soil extremely unlikely.

On-Site industrial and construction workers may be exposed to contaminants in the vadose zone soil via dermal contact, incidental ingestion, and/or inhalation of dust. Dermal contact, incidental ingestion, and inhalation of dust from vadose zone soil are considered complete pathways for current and future on-Site industrial and construction workers (Figure 7-1). The direct contact pathway is considered a potentially complete exposure pathway because Site soils less than 15 feet bgs contain elevated concentrations of hazardous substances. However, current on-Site industrial work occurs within areas of the Site that are paved or covered with gravel, which significantly limits exposure to subsurface hazardous substances.

Vadose zone soil along the riverbank may be transported to the Embayment via erosion, wind, and stormwater, where it may contribute to sediments. Discussion of potential exposure to "riverbank soils" is included in the discussion of the sediment exposure pathways (Section 7.6.2.5).

7.6.2.2 SATURATED ZONE SOIL

The potential human receptors for saturated zone soil are limited to on-Site construction workers, who may encounter contaminated saturated zone soil via excavation because the groundwater table is less than 15 feet bgs, the standard point of compliance for on-Site construction workers. No other human receptors or ecological receptors are expected to encounter saturated zone soils; therefore, no exposure pathways are complete for those other receptors. On-Site construction workers may become exposed to contamination in the saturated zone soil via dermal contact and/or incidental ingestion during excavation work that extends to and below the groundwater table.

7.6.2.3 GROUNDWATER

On-Site construction workers are potential human receptors for contaminated groundwater for the same reasons stated for saturated zone soil (Section 7.6.2.2). The exposure pathway is limited to dermal contact with the groundwater during excavation work that extends below the groundwater table. Any construction activities performed deep enough to encounter groundwater will likely involve a dewatering program and appropriate personal protective equipment (PPE) to prevent dermal contact with groundwater. Therefore, exposure through this pathway is considered complete but insignificant. No other human receptors (including on-Site industrial workers) or ecological receptors are expected to have dermal contact with groundwater; therefore, this exposure pathway is incomplete for the other receptors. Further, groundwater CULs derived for protection of construction workers are less conservative than those developed for protection of surface water; therefore, this exposure pathway will not drive development of pCULs in the FS.

On-Site groundwater is not a current source of drinking water; however, for the purposes of this evaluation, on-Site groundwater is considered a potential future source of drinking water. Therefore, ingestion of contaminated groundwater is a potential exposure pathway for on-Site industrial workers and on-Site construction workers. The exposure would occur via a potential future on-Site water supply well. This exposure pathway is considered complete but unlikely

because the City of Seattle already provides drinking water to the Site and existing state and local regulations prohibit the installation and operation of drinking water wells in the Site area. Further, wells installed close to the river would likely draw in brackish water from the river. No other human or ecological receptors are expected to ingest groundwater at the Site; therefore, this exposure pathway is incomplete for other receptors.

7.6.2.4 SURFACE WATER

Potential human receptors to contamination in on-Site surface water (i.e., water in the Embayment) are limited to on-Site industrial and construction workers and subsistence and recreational users. Additionally, on-Site marine wildlife that inhabit the Embayment are potential receptors of contamination in the Embayment surface water. On-Site industrial workers and construction workers may be exposed to contamination in the Embayment surface water via dermal contact and/or incidental ingestion while working in the Embayment through boat docking operations or working along the shoreline. Subsistence and recreational users may be exposed to contamination in the Embayment surface water via dermal contact or incidental ingestion while harvesting edible biota (i.e., fish) from the Embayment or by ingestion of edible biota that has bioaccumulated contamination from Embayment surface water. Industrial or construction activities performed in the Embayment would involve limited dermal contact and/or incidental ingestion having very low risk of adverse health impacts or use of a dewatering program and/or appropriate PPE to prevent significant dermal contact with or ingestion of surface water. Harvesting edible biota in the Embayment would involve dermal contact and/or incidental ingestion having very low risk of adverse health impacts because the concentrations of COPCs are low in surface water. Therefore, exposure of human receptors through these pathways is considered complete but insignificant.

The Embayment has not historically been used, is not currently used, and is not likely to be used in the future for harvesting edible biota. However, ingestion of edible biota harvested from the Embayment is considered a complete exposure pathway for subsistence and recreational users because access to the Embayment is not strictly prohibited.

On-Site marine plants and wildlife may be exposed to contamination in the Embayment surface water via:

- Incidental ingestion of and dermal contact with the surface water;
- Uptake from the surface water (specifically by aquatic/emergent plants and subsequent ingestion by herbivorous aquatic wildlife);
- Ingestion of surface water to meet water needs (specifically by marine wildlife); and
- Ingestion of surface water (specifically by amphibians and other large aquatic prey and subsequent ingestion by carnivorous aquatic wildlife).

These exposure pathways for on-Site marine aquatic plants and wildlife are considered complete because the potential receptors are long-term residents in the Embayment.

7.6.2.5 SEDIMENT

Potential human receptors to contamination in on-Site sediment (i.e., sediment in the Embayment) are limited to on-Site construction workers and subsistence and recreational users. On-Site industrial workers are not considered potential receptors to contamination in on-Site sediment because their work is not expected to expose them to Embayment sediments. On-Site marine aquatic plants and wildlife that inhabit the Embayment are potential ecological receptors of contamination in the sediment.

On-Site construction workers may be exposed to contamination in the sediment via dermal contact or incidental ingestion by performing dredging or other construction activities in the Embayment; however, it is highly unlikely that construction workers would be in contact with contaminated sediment without wearing PPE. Therefore, construction worker exposure through the incidental ingestion and dermal contact pathways is considered complete but insignificant.

Similarly, subsistence and recreational users may be exposed to contaminated sediment via dermal contact and incidental ingestion while wading in the Embayment and harvesting edible biota. However, shoreline and soft sediment conditions in the Embayment make wading highly unlikely. Therefore, exposure through this pathway is considered complete but insignificant. Subsistence and recreational users also may be exposed to contamination from Site sediment via ingestion of edible biota harvested from the Embayment. As indicated previously, harvesting edible biota is not strictly prohibited in the Embayment because the USEPA considers this a clamming area accessible by boat (Windward 2010); therefore, this pathway is considered complete for potential subsistence and recreational users.

The same ecological receptors and exposure pathways relevant for surface water in the Embayment (Section 7.6.2.4) apply to sediment in the Embayment.

7.6.2.6 OUTDOOR/INDOOR AIR

The outdoor and indoor air pathways are not complete for on-Site industrial or construction workers. Four COPCs were retained in vadose zone soil (ethylbenzene, toluene, naphthalene, and methylene chloride) and two COPCs were retained in saturated soil (benzene and naphthalene; Table 4-8). No VOCs were retained as COPCs in groundwater because they did not exceed the SL protective of surface water and sediment. Ecology has developed SLs for groundwater to evaluate potential for vapor intrusion to indoor and outdoor air exposure risk (Ecology 2009). Comparing the concentrations of VOCs detected in Site groundwater to the most conservative of the non-cancer or cancer values of the Vapor Intrusion Groundwater Screening Levels for MTCA Method B and Commercial Workers published in the July 2022 Cleanup Levels and Risk Calculation (CLARC) Master Spreadsheet show that the Site groundwater data did not exceed the vapor intrusion screening values. Based on the nature of volatile contaminants detected at the Site and discussed in Section 5, the inhalation exposure pathway is incomplete for all potential human and ecological receptors.

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