PORTLAND HARBOR RI/FS

DRAFT FEASIBILITY STUDY

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Prepared for
The Lower Willamette Group

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µg/kg	micrograms per kilogram
2,3,7,8-TCDD	Tetrachlorodibenzo-p-dioxin
95 UPL	95th percentile upper prediction limit
AC	Activated Carbon
ACM	Active Channel Margin
ACPS	Activated Carbon Pilot Study
AOC	Administrative Order on Consent
AOPC	Area of Potential Concern
ARAR	Applicable or Relevant and Appropriate Requirement
ATL	Acceptable Treatment Levels
AWQC	Ambient Water Quality Criteria
BA	Biological Assessment
BaP	Benzo(a)pyrene
BaPEq	Benzo(a)pyrene equivalent
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
BMP	Best Management Practice
CAD	Confined Aquatic Disposal
CAG	Community Advisory Group
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CDF	Confined Disposal Facility
cfs	cubic feet per second
CFR	Code of Federal Regulations
CH_4	Methane
CLE	Contingency Level Event
cm	centimeter
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO2-eq	Caron Dioxide Equivalent
COI	Chemical of Interest
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
cPAH	carcinogenic Polycyclic Aromatic Hydrocarbon
CRD	Columbia River Datum
CSM	Conceptual Site Model
CSO	Combined Sewer Overflow
CWA	Clean Water Act
cy	cubic yards
DDD	Dichloro-diphenyl-dichloroethane
DDE	Dichloro-diphenyl-dichloroethene
DDT	Dichloro-diphenyl-trichloroethane

DDx	2,4′ and 4,4′-DDD, -DDE, -DDT
DEQ	Oregon Department of Environmental Quality
DL	Detection Limit
DMR	Discharge Monitoring Report
DNAPL	Dense Non-Aqueous Phase Liquids
DOI	Depth of Impact
DRET	Dredge Elutriate Test
DSL	Oregon Department of State Lands
DW	Dry Weight
ECSI	Oregon Environmental Cleanup Site Inventory
EE/CA	Engineering Evaluation/Cost Analysis
EF	Engineering Factor
EMNR	Enhanced Monitored Natural Recovery
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentrations
ERAGS	Ecological Risk Assessment Guidance for Superfund
ESA	Endangered Species Act
FEMA	Federal Emergency Management Act
FPM	Floating Point Model
FMD	Future Maintenance Dredge Area
FS	Feasibility Study
$g/cm^2/d$	grams of sediment per square centimeter per day
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
GRA	General Response Actions
GWP	Global Warming Potential
HC	Hydrocarbons
HI	Hazard Index
HPAH	High Molecular Weight Polycyclic Aromatic Hydrocarbon
HQ	Hazard Quotient
HST	Hydrodynamic and Sediment Transport
H:V	Horizontal to Vertical
IC	Indicator Chemical
JSCS	Joint Source Control Strategy
L2	Level 2
L3	Level 3
LOE	Line of Evidence
LPAH	Low Molecular Weight Polycyclic Aromatic Hydrocarbon
LRM	Logistic Regression Model
LWG	Lower Willamette Group
MCL	Maximum Contaminant Level
mg/kg	milligram per kilogram
mg/L	milligram per liter
MGP	Manufactured Gas Plant

MNR	Monitored Natural Recovery
MOU	Memorandum of Understanding
mph	miles per hour
MQ	Mean Quotient
N_2O	Nitrous Oxide
NAPL	Non-Aqueous Phase Liquid
NAVD88	North American Vertical Datum of 1988
NC	Navigation Channel Area
NCP	National Contingency Plan
ng/g	nanograms per gram
ng/L	nanograms per liter
NGI	Norwegian Geotechnical Institute
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NN	Natural Neighbors
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen oxides (NOx)
NRC	National Research Council
NRDA	Natural Resource Damage Assessment
NRWQC	National Recommended Water Quality Criteria
NTCRA	Non-Time Critical Removal Action
NV	Neatline Volume
OAR	Oregon Administrative Regulations
OC	Organic Carbon
OCCRI	Oregon Climate Change Research Institute
ODFW	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
OHW	Ordinary High Water
OLW	Ordinary Low Water
OMMP	Operations, Maintenance and Monitoring Plan
OPA	Oil Pollution Act
ORS	Oregon Revised Statutes
OSWER	EPA Office of Solid Waste and Emergency Response
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated Diphenyl Ethers
PCB	Polychlorinated Biphenyl
PCDD/F	Polychlorinated Dibenzo-p-dioxin/furan
2,3,4,7,8-PCDF	Polychlorinated Dibenzofuran
PHNRT	Portland Harbor Natural Resource Trustees
PM10	Particulate Matter Less than 10 Microns in Diameter
PM2.5	Particulate Matter Less than 2.5 Microns in Diameter
pMax	Maximum Probability of Toxicity
pg/g	picograms per gram

POTW	Publicly Owned Treatment Works
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PRG	Preliminary Remediation Goal
PRP	Potentially Responsible Party
PTM	Principal Threat Material
QAPP	Quality Assurance Project Plan
RAL	Remedial Action Level
RAO	Remedial Action Objective
RBC	Risk-Based Concentrations
RCRA	Resource Conservation and Recovery Act
RG	Remediation Goal
RHV	Relative Habitat Value
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RISG	Ross Island Sand and Gravel Company
RM	River Mile
RME	Reasonable Maximum Exposure
RNA	Regulated Navigation Area
ROD	Record of Decision
RPD	Relative Percent Difference
RSET	Regional Sediment Evaluation Team
RSL	Regional Screening Levels
SCRA	Site Characterization and Risk Assessment
SDWA	Safe Drinking Water Act
Site	Portland Harbor Superfund Site
SMA	Sediment Management Area
SMU	Sediment Management Unit
SO_2	Sulfur Dioxide
SOW	Statement of Work
SPI	Sediment Profile Imaging
SPMD	Semi-Permeable Membrane Devices
S/S	stabilization/solidification
SQV	Sediment Quality Values
SVOC	Semivolatile Organic Compound
SWAC	Surface-area Weighted Average Concentration
TAT	Technical Assistance Team
TBC	To Be Considered
TBT	Tributyltin
TCDD	Tetrachlorodibenzo-p-dioxin
TCE	Trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TEF	Toxicity Equivalency Factor
TEQ	Toxic Equivalent

TI	Technical Impracticability
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TRV	Toxicity Reference Value
TSCA	Toxic Substances Control Act
TTL	Target Tissue Levels
TZW	Transition Zone Water
UCL	Upper Confidence Limit
UPL	Upper Prediction Limit
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
UST	Underground Storage Tanks
UTL	Upper Tolerance Limit
VOC	Volatile Organic Compound
WHO	World Health Organization
WQS	Oregon Water Quality Standards

1.0 INTRODUCTION

This report presents the draft Feasibility Study (FS) for the Portland Harbor Superfund Site (Site) in Portland, Oregon (Figure 1.0-1). This draft FS has been prepared on behalf of the Lower Willamette Group (LWG). A portion of Portland Harbor, which is located in the downstream portion of the Willamette River, was listed on the National Priorities List (NPL) in 2000 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The LWG is performing the Remedial Investigation (RI) and FS for the Site pursuant to a U.S. Environmental Protection Agency (EPA) Administrative Settlement Agreement and Order on Consent for RI/FS (AOC; EPA 2001a, 2003a, 2006a). The general goal of the RI/FS process is to address sediment contamination in Portland Harbor to protect human health and ecological receptors. More specifically, the objectives of the Portland Harbor FS, as provided in the Statement of Work (SOW) to the AOC, are to:

- Develop and evaluate potential remedial alternatives to reduce risks to acceptable levels
- Support EPA's identification and selection of a preferred alternative (per Section 10.1.2 of the SOW).

> *The LWG has collected extensive data to support development of the draft FS, which provides the tools and analyses necessary to fully support EPA evaluations of the National Contingency Plan (NCP) criteria and EPA selection of a harbor-wide sediment remedy for the Proposed Plan.*

The draft FS is the result of a focused and collaborative effort between LWG and EPA to reach these objectives. The series of comments and responses reflecting these collaborative efforts are detailed in Appendix O. The LWG has collected extensive data to support development of the draft FS, which provides the tools and analyses necessary to fully support EPA evaluations of the National Contingency Plan (NCP) criteria and EPA selection of a harbor-wide sediment remedy for the Proposed Plan. In summary, the tools and analyses indicate that all of the sediment remedial alternatives in the draft FS provide overall protection of human health and the environment over the long term, with the exception of a "no action" alternative (which is required to be evaluated under the NCP for comparative purposes). However, there are notable differences in how the alternatives achieve this protection, with some alternatives having substantially more environmental, community, and worker impacts; differing implementability issues; and varying high costs.

1.1 EPA FS GUIDANCE AND PRINCIPLES

The organization and content of this draft FS adhere to CERCLA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final* (EPA 1988) as well as *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005a). The draft FS focuses on key principles in this and other EPA guidance (2002b) specific to cleanup of contaminated sediment sites. Particularly at complex sites like this one, these principles are intended to guide the selection of sediment remedies that are protective as well as cost-effective, and consistent with the overall objectives of CERCLA and the NCP.

EPA's (2002b) *11 Risk Management Principles Memorandum* was developed to provide guidance to site managers in, "*making scientifically sound and nationally consistent risk management decisions at contaminated sediment sites*" (EPA 2002b). These include:

1. Control sources early
2. Involve the community early and often
3. Coordinate with states, local governments, Tribes, and natural resource trustees
4. Develop and refine a conceptual site model (CSM) that considers sediment stability
5. Use an iterative approach in a risk-based framework
6. Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models
7. Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals
8. Ensure that sediment cleanup levels are clearly tied to risk management goals
9. Maximize the effectiveness of institutional controls and recognize their limitations
10. Design remedies to minimize short-term risks while achieving long-term protection
11. Monitor during and after sediment remediation to assess and document remedy effectiveness

These 11 risk management principles were subsequently incorporated into and expanded upon in EPA's (2005a) *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. This guidance document embodies current national EPA policy on contaminated sediment, the focus of which is to reduce potentially unacceptable risks to human health and the environment posed by contaminated sediment sites. There are six key principles in the EPA (2005a) guidance document, which are followed in this draft FS:

1. First and foremost, the focus of sediment remediation should be on risk reduction, not simply on contaminant mass removal (EPA 2005a – p. 7-1, 7-16)

2. A realistic, site-specific evaluation of the potential effectiveness of each remedial technology should be incorporated into the selection of sediment remedies at a site (EPA 2005a – p. 7-3)

3. As part of the remedy selection process, an appropriate evaluation of the comparative net risk reduction potential of the comprehensive alternatives, including a realistic evaluation of their respective advantages and site-specific limitations should be conducted, including the risks introduced by implementing the alternatives (EPA 2005a – p. 7-13, 7-14)

4. At large and/or complex sediment sites, consideration of the use of combinations of remedies is appropriate (EPA 2005a – p. 7-3).

5. Monitoring and contingency planning concepts, which involve a step-wise approach to sediment remediation, should be applied where appropriate (EPA 2005a – p. 2-22, 3-1, 7-16)

6. Comparing and contrasting the costs and benefits of the various sediment remedies is part of the risk management decision-making framework (EPA 2005a – p. 7-1).

Following these principles, the draft FS identifies the remedy alternatives that are 1) best suited to achieving protection of human health and the environment and 2) are consistent with the overall objectives of CERCLA and the NCP.

Consistent with these guidance documents and principles, this draft FS presents the development and analysis of remedial alternatives including development of remedial action objectives (RAOs), remedial goals (RGs), remedial action levels (RALs), areas of potential concern (AOPCs), and sediment management areas (SMAs). These topics are basically described in Section 1.2, which references other draft FS sections that contain detailed descriptions of these terms.

This draft FS also presents and discusses sediment modeling results including estimated future sediment concentrations and background levels. The draft FS examines the ranges associated with the calculation of RGs and RALs (i.e., uncertainties and sensitivities) as well as sediment quality estimates. Evaluation of these ranges is in accordance with EPA (2005a) guidance, which states: "*The uncertainty of factors very important to the remedy decision should be quantified, so far as this is possible.*" The purpose of evaluating these ranges is to ensure that the comparisons between parameters is appropriately considered in the context of the uncertainties involved.

1.2 DRAFT FS DOCUMENT ORGANIZATION

The Portland Harbor draft FS follows steps described in CERCLA guidance (EPA 1988), as well as additional considerations described in the NCP, *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005a). Following these guidance documents, the major sections of this draft FS are as follows:

- Section 2, Site Description – This section summarizes the results of the RI and identifies Site characteristics that are most relevant to the draft FS objectives. It provides information on the status of other sites within Portland Harbor that are under separate orders with EPA, the database used for FS development, proposed segmentation of the Site to assist in FS evaluations, and an update to the RI CSM to better support draft FS objectives.

- Section 3, Refined RAOs and RGs – This section defines the RAOs—and additional considerations for application of those RAOs—against which the alternatives will be evaluated. The section also provides RGs for specific contaminants that are used to assess attainment of the RAOs. The contaminants addressed in the draft FS are identified based on the results of the Baseline Ecological Risk Assessment (BERA) and Baseline Human Health Risk Assessment (BHHRA)[1] including contaminants posing potentially unacceptable risk, recommended Contaminants of Concern (COCs), and the related ecological risk receptors and human health risk scenarios. The factors that most impact the calculation of RGs and the uncertainties associated with RGs are discussed. Section 3 also summarizes the applicable or relevant and appropriate requirements (ARARs) that are used in the detailed evaluation of alternatives.
- Section 4, RALs Development – This section presents the range of RALs used to define a set of remedial action alternatives that meet the RGs over various spatial extents and time periods. The section defines the general concept and rationale for RALs, the specific RAL development methods, the rationale for RAL development of bounding contaminants, and discusses the factors and uncertainties that most impact calculation of RALs.
- Section 5, AOPC and SMA Development – This section describes the horizontal and vertical spatial extents where the primary potentially unacceptable risks exist at the Site from exposure to surface sediment contamination (top 1 foot), subsurface sediment contamination (below the top 1 foot), and other media (e.g., transition zone water [TZW]). These areas are the focus of active remediation in remedial alternatives as defined through the SMA development process. Potentially unacceptable risks that are outside of these SMAs are also characterized in this section. Also discussed are the Oregon hot spot and EPA Principal Threat Material (PTM) analyses, methods for developing and further subdividing SMAs to assist in alternatives development, and the factors and uncertainties that most impact calculation of SMAs.
- Section 6, Identification and Screening of Remedial Technologies – This section describes a broad evaluation of known potential technologies for sediment remediation/disposal and then screens those technologies based on Site-specific factors. Technology screening provides a valuable step in the overall FS process allowing the detailed evaluation steps that occur later in the process to focus on those technologies that are feasible.
- Section 7, Development of Comprehensive Alternatives – This section describes the process of assembling the screened-through technologies, ranges of RALs and

[1] The BERA and BHHRA are under review by EPA and have not been finalized as of the writing of this draft FS.

SMAs, and screened-through disposal options into a series of comprehensive Site-wide alternatives. This section provides an overall description of the comprehensive alternatives as a foundation for the detailed analysis in Section 8.

- Section 8, Detailed Analysis of Comprehensive Alternatives – This section individually evaluates each of the comprehensive alternatives following the specific NCP criteria, steps, and guidelines described in EPA guidance (EPA 1988).
- Section 9, Comparative Analysis of Comprehensive Alternatives – This section comparatively evaluates the comprehensive alternatives following the specific NCP criteria, steps, and guidelines described in EPA guidance (EPA 1988).
- Section 10, Conclusions – This section summarizes the overall findings of the draft FS with a focus on the results of the detailed and comparative evaluation. These findings are discussed in the context of the NCP, national guidance on contaminated sediment sites, and risk management principles presented above. This section also discusses risk management decisions and uncertainties related to those decisions.
- Section 11, References – Contains the publication details for the references cited throughout the text.
- Appendices – Details that support various analyses in the draft FS are presented in the appendices, which are listed in the draft FS table of contents.

Throughout the draft FS, the Portland Harbor Superfund Site is referred to for purposes of this document as “Site.” The exact boundaries of the Site have not yet been defined by EPA, which will do so in the Proposed Plan. In some instances where the physical extent, study requirements, or boundaries of the RI/FS study are specifically being discussed, the draft FS may use the term “Study Area.” The “Study Area” was defined by EPA as Lower Willamette River mile (RM) 1.9 to 11.8 extending up to a vertical elevation of 13.3 feet North American Vertical Datum of 1988 (NAVD88).

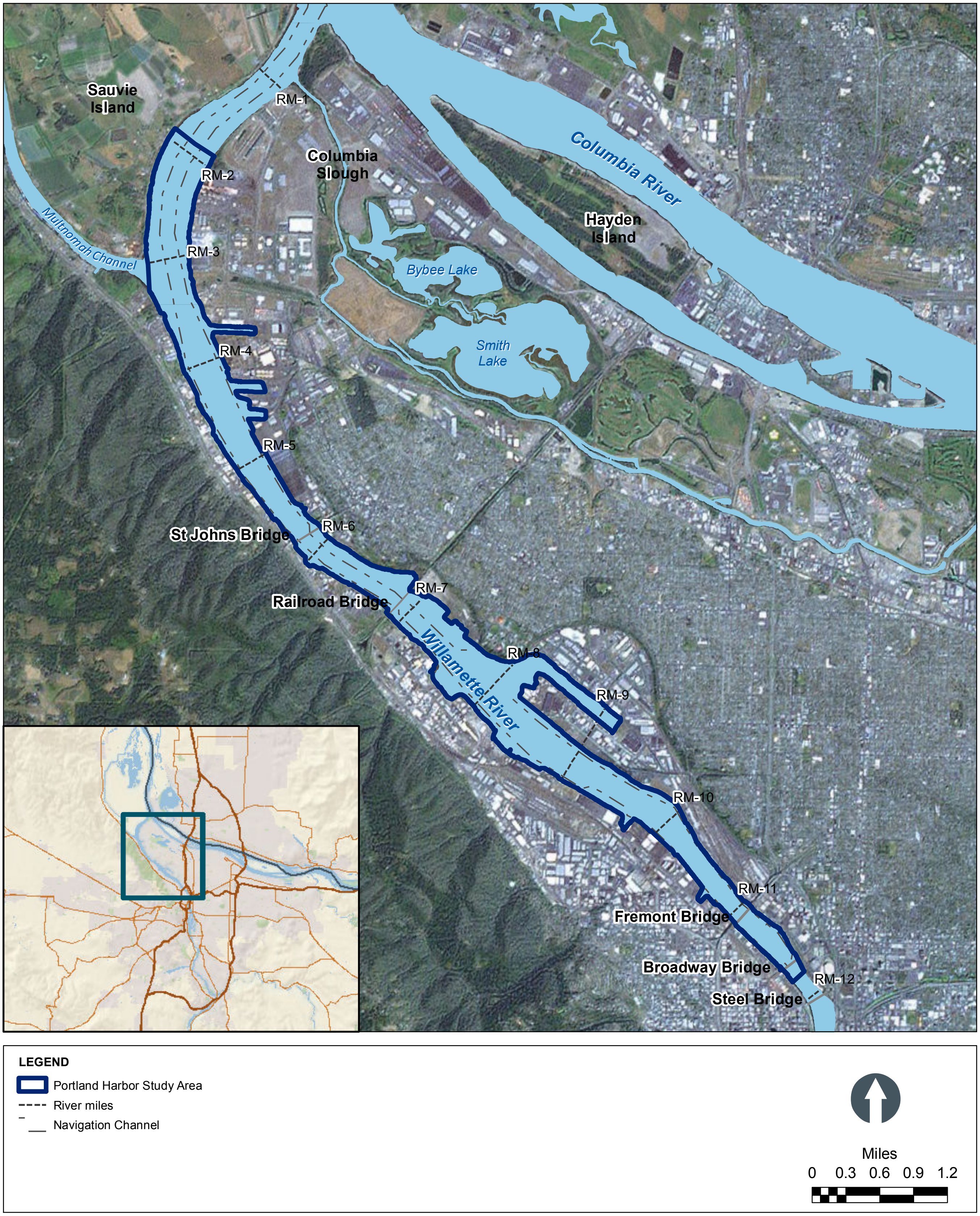

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Figure 1.0-1
Portland Harbor RI/FS
Draft Feasibility Study
Site Overview and Study Area

This section provides a summary of existing information about the Site most relevant to the draft FS development. Much of this information comes from studies (such as the RI) already completed for the project; however, some new information developed specifically for the draft FS is also presented. This section is organized as follows:

- *Section 2.1 presents a physical description of the Site including hydrology, riverbed characteristics, erosion/deposition, and debris.*
- *Section 2.2 summarizes the chemical system for bounding indicator chemicals (ICs) as detailed in the draft RI.*
- *Section 2.3 presents a summary of biological communities and habitat within the Site.*
- *Section 2.4 summarizes the historical and current Site uses including Site ownership, shoreline conditions, structures, vessel traffic patterns, current and future navigation requirements, maintenance dredging history and status, environmental dredging and capping history, and preliminary potential future restoration Site uses.*
- *Section 2.5 reviews the existing status of sources and source controls within the Site and describes, where possible, how quantitative estimates of existing sources were made for the FS and the overall results of those estimates of existing sources.*
- *Section 2.6 includes a refined CSM for the Site. This CSM portrays the general relationship among sources, chemicals, transport mechanisms, and in-water receptors and focuses on the key issues for the draft FS.*
- *Section 2.7 details the status of other Portland Harbor remediation action or removal orders.*
- *Section 2.8 gives a description of the FS databases.*
- *Section 2.9 explains that the Site is broken into four segments for FS evaluation purposes.*

2.0 SITE DESCRIPTION

This section provides a summary of existing information about the Site most relevant to the draft FS development. Much of this information comes from studies (such as the RI) already completed for the project; however, some new information developed specifically for the draft FS is also presented. This section includes a refined CSM for the Portland Harbor Site. This CSM provides general information on and portrays the general relationship among sources, chemicals, transport mechanisms, and in-water receptors and focuses on the key issues for the draft FS. It is a refinement of the CSM presented in the draft final RI.

2.1 PHYSICAL DESCRIPTION

The Portland Harbor RI/FS Study Area (RM 1.9 to 11.8) is located near the confluence of the Willamette River and the Columbia River. Originally a relatively shallow, meandering portion of the Lower Willamette River surrounded by forested wetlands and floodplains, this portion of the river has been redirected, straightened, filled, and deepened by more than a century of urban development and industrialization into a working industrial waterway. A federally maintained navigation channel, approximately twice as deep as the original river in Portland Harbor, runs the length of the Site altering the river's cross-section and hydrology. Some riverbank areas and adjacent parcels include naturally vegetated areas and beaches, but shallow-profile beaches, nearshore benches, and submerged and overwater vegetation are rare relative to historic conditions. The result of this physical alteration and the associated anthropogenic activity as part of a working industrial waterway, (e.g., ship and boat traffic) is that this river reach differs substantially from its pre-developed characteristics related to hydrodynamics, sediment transport, and ecological habitat and function. As further discussed in Section 2.4, the Site is within a working harbor with ongoing industrial and urban activities and contains a federally maintained navigation channel, which allows transit of large ships into the active harbor. Much of the shoreline has been raised, filled, stabilized, and/or engineered and contains overwater piers and berths, port terminals and slips, stormwater and industrial wastewater outfalls and combined sewer overflows (CSOs), and other engineered features. Armoring covers approximately half of the harbor shoreline, which is integral to the operation of activities that characterize Portland Harbor.

2.1.1 Hydrology

The Willamette River drains the Willamette Basin, which lies between the Cascade Range and the Coast Range and extends from headwater streams in the mountains southeast of Eugene, Oregon, to the confluence with the Columbia River at Columbia RM 103. The section of the river from Willamette Falls to the Columbia River is considered the Lower Willamette River and includes the Study Area from RM 1.9 to 11.8 (see Figure 1.0-1). Portland Harbor is dependent on the authorized federal navigation channel, which extends from RM 0 (Columbia River) upstream to RM 11.7 (Broadway Bridge). The channel is authorized to be improved and maintained by the U.S. Army Corps of Engineers (USACE) to a depth of -43 feet Columbia River Datum (CRD), but the navigation channel maintenance is currently based on the prior authorized depth of -40 feet CRD. The Multnomah Channel is a channel of the Lower Willamette River that begins at RM 3.1 and flows approximately 21 miles to its confluence with the Columbia River at Columbia RM 86.5.

River stage and currents at the Site are influenced by hydrologic conditions in both the Willamette and Columbia Rivers, and are further affected by the operations of federal and non-federal dams along these two rivers, as well as tidal stages of the Pacific Ocean, which causes tidal fluctuations of up to a maximum of 3 feet per day throughout the Site (Integral et al. 2011). Annual low flows occur during the regional dry season from August to November. Winter (November to March) flows are relatively high but variable due to short-term changes in precipitation levels in the Willamette Basin. A distinct and persistent period of relatively high Willamette River stage occurs from late May through June when the Willamette River discharge to the Columbia River is restricted by high flows in the Columbia associated with the spring freshet, as a result of snowmelt in the much larger Columbia River watershed. Under certain river stages, flows, and flood tidal conditions, typically in the late summer and fall, the influence of the Columbia River causes periodic slack water and flow reversals in the lower portion of the Willamette River.

Average annual mean discharge in the Willamette River during the water years 1973 through 2007 was approximately 33,000 cubic feet per second (cfs) as measured at the Morrison Bridge (near RM 12.8) in Portland. Late summer discharge levels were typically equal to or less than 10,000 cfs and December/January averages approached 100,000 cfs. The two highest peaks in the daily mean discharge record occurred during the winters of 1996 and 1997, when peak flows reached 420,000 cfs on February 9, 1996 and 293,000 cfs on January 2, 1997, respectively. Most of the Willamette River discharge is from upstream flow sources. Appendix E of the draft final RI estimated total groundwater discharge to the Study Area to be between 4.5 and 10.9 cfs, with an average of 7.3 cfs. The draft final RI also estimated that the Portland Harbor area stormwater runoff volume contributions are between 0.06 percent for the wet year conditions (1997) and 0.08 percent for dry year conditions (2001) of the total Willamette River flow. A detailed review and discussion of flows on the Lower Willamette River are provided in the draft final RI and Appendix La, Sediment Transport Modeling.

As discussed in the draft final RI, unlike the Columbia River, the Willamette River flows generally increase in response to regional storms due to the comparatively small size of the basin. Record winter floods (e.g., 1964 and 1996) occurred when periods of heavy snowfall at lower elevations were followed by warming periods and heavy rains, resulting in rapid increases in runoff.

Upstream flooding is largely controlled by 13 major tributary reservoirs (Uhrich and Wentz 1999). These 13 federal reservoirs on the Willamette River and its tributaries have a combined storage capacity of over 1.6 million acre-feet. These reservoirs reduce the river flow during the winter snow and rain events by storing water. With each major storm, water is retained and then released at the end of the storm to dampen hydrographic peaks and valleys.

2.1.2 Riverbed Characteristics/Dynamics and Sediment Transport

The river is predominately depositional. Over the period from July 2003 to January 2009, the Study Area was 88 percent depositional or showed no substantial change.

Channel morphology at the Site is largely a consequence of maintenance dredging to maintain the federally authorized navigation channel. Approximately 60 percent of the riverbed at the Study Area lies within the federal navigation channel (Figure 2.1-1). The nearshore areas between the riverbank and the channel edge are often narrow and steep sloped along much of the mainstem of the river. Larger, more gently sloping off-channel areas include embayments (e.g., Willamette Cove and Willbridge Terminal), Swan Island Lagoon, and slips (e.g., Terminal 4 and International Slip).

Sediment deposition or erosion at the Site has been measured by an extensive and accurate set of periodic bathymetric surveys conducted from 2003 to 2009. This type of dataset is unusual for an FS-level evaluation and is very useful for alternative evaluation. Figure 2.1-2 illustrates areas of shoaling and deepening during this period. The river is predominately depositional with the most substantial sediment deposition in the left (west) side of the channel between RM 8.5 and 10 and on the right (east) side of the channel between RM 1.5 and 3. Over the period noted in Figure 2.1-2, the Study Area was 88 percent depositional or showed no substantial change (Table 2.1-1). The reaches between RM 5 and 7 and RM 10 and 11.8, where the river is relatively narrow, contain areas of small-scale net erosion interspersed with areas of net deposition. Some of the areas showing net elevation decrease in some nearshore slips and embayments in Figure 2.1-2 are due to maintenance dredging that occurred in this period, which is discussed more in Section 2.4.5.

Areas of sediment net deposition in the channel approximately correspond with relatively high percentages of fine-grained material in the surface sediments. Conversely, areas with no net change or decreases in depth generally correspond with a relatively high composition of coarser grained material. Figure 2.1-3 shows surface sediment grain size (as percent fines; i.e., coarse silt [63 µm] and finer) across the Study Area.

A detailed analysis of sediment transport processes in the Lower Willamette River is presented in Appendix La including predictions for periods outside the observations from 2003 to 2009. For example, Figure 2.1-4 shows expected bathymetry changes over the 30 years of flows as estimated by the draft FS numerical hydrodynamic and sediment transport (HST) model. The model predicts that, over the long term, net erosion would be expected in the channel of RMs 5 to 7 and the upstream end of the Study Area, while net deposition is expected in most other regions of the river. This prediction, although over a longer period encompassing a wider range of potential flow conditions, generally matches well with the large-scale areas of erosion and deposition observed in the 2003 to 2009 bathymetry. Appendix La discusses the sediment transport model parameters and approaches that generated this result. Overall, both empirical information and model simulations clearly indicate that the Site is predominantly depositional or stable with some localized exceptions as further discussed in Section 6.2. As shown in Table 2.1-1, the percentage of erosion and deposition measured by bathymetric elevation change and predicted using the HST model match closely with both lines of evidence, showing 10 to 12 percent as erosional areas and 88 to 90 percent as no substantial change or depositional areas.

2.1.3 Debris

A high resolution sidescan sonar survey was conducted on the Lower Willamette River in 2008 to determine the approximate distribution of debris in the river channel and along both banks of the river. The sidescan sonar survey area extended from RM 1 to RM 12.2, and included the half mile uppermost segment of the Multnomah Channel. The sidescan sonar survey identified 7,257 discrete targets from the sonar record from the area surveyed. A detailed presentation of targets and their locations are provided in the *Lower Willamette River Sidescan Sonar Data Report* (Anchor QEA 2009b).

As shown in Table 2.l-2, approximately two thirds of the targets identified were clearly man-made objects (piers, pilings, dolphins, and structures) placed in the river for navigational, operational, or engineering purposes. Approximately 25 percent of the remaining material was broadly classified as debris. Debris was commonly found along the margins of dock structures, a pattern that is consistent with vessel activity patterns. Logs accounted for approximately 5 percent of the targets, with their occurrence often associated with areas that are or were log booming areas. Other geologic and cultural features observed using sidescan sonar included the occurrence of gravel, depressions, anchor drags, and dredge artifacts. A map presenting more substantial areas of debris and pilings within the Study Area is provided as Figure 2.1-5.

2.1.4 Hydrogeology

The Site is located along the southwestern edge of a large geologic structure known as the Portland Basin. The Portland Basin has been filled with up to 1,400 feet of alluvial and glacio-fluvial flood deposits since the middle Miocene (approximately 12 million years ago). These sediments overlie older rocks including the Columbia River Basalt Group and older marine sediments. The geologic units found in the vicinity of the Site and their general relationships to one another are presented in Figure 2.1-6.

Generally, groundwater flow adjacent to the Study Area is toward the river. In the absence of preferential pathways, groundwater flow to the river and sediments is diffuse along the length of the interface of each flow system with the river. However, permeability contrasts of several orders of magnitude occur where alluvial processes create lenses and channels of sand within or surrounding finer grained materials. Groundwater discharge tends to be heavily influenced by the location and geometry of higher permeability layers (e.g., sands) in relation to the river.

The gradient and the resultant flux from these systems vary with seasonal river stage changes. Diurnal tidal stage changes also result in temporary gradient and thus flow changes, particularly where the degree of connection between the river and adjacent aquifer is greater. Groundwater discharge through the river sediments to surface water is controlled by: 1) the permeability contrast between the sediments and underlying aquifer, and 2) the difference between the hydraulic head in groundwater at the aquifer/sediment interface and the river stage (the hydraulic gradient).

Direct measurements of groundwater seepage rates to the river were taken during the RI. These data are important for cap design, and more precise estimates will be needed for remedy designs. Ultrasonic seepage meter measurements were taken primarily during the season of presumed maximum groundwater flux (high upland groundwater levels and low river stage). Daily average measurements ranged from -18.2 cm/day (recharge) to 14.2 cm/day (discharge to the river), with an average of 1.5 cm/day. These measurements were taken in areas of suspected higher groundwater flux, as part of the investigations of upland plume discharges. As such, these values are expected to be higher than the average flux rate for the entire channel. Measured groundwater flux rates showed substantial variability between measurement sites; in general, the highest seepage rates were observed in sandy areas, and the lower values were observed in less conductive silty or clayey zones, as expected.

In addition to the empirical seepage measurements, a calculated estimate of groundwater discharge to the river was made based on Darcy's Law (which describes flow rates through permeable media) and observed upland groundwater hydraulic conductivity values. This calculation estimated total groundwater discharge to the Study Area to be between 4.5 and 10.9 cfs, with an average of 7.3 cfs. This average corresponds to a seepage discharge rate of 0.1 foot/day (3.0 cm/day) across the entire channel surface of the Study Area, which is almost 10 miles long. Figure 2.1-7 presents estimated groundwater fluxes to the Study Area based on an analysis of both measured and calculated seepage rates and near-surface sediment grain size (see Section 3.2.4.3 of Appendix Ha for the analysis methods).

A groundwater/surface water transition zone was identified (EPA 2008a). The physical and chemical properties of water within the transition zone reflect the effects of mixing between groundwater and surface water that occurs within the sediments, as well as biological and geochemical processes occurring within the sediment matrix and porewater. The transition zone is further discussed in Section 2.2.3.

2.2 CHEMICAL SYSTEM

Four contaminants—total polychlorinated biphenyls (PCBs), total dioxins/furans, total DDx,[1] and total polycyclic aromatic hydrocarbons (PAHs)—were identified in the RI as "bounding" Indicator Chemicals (ICs). These four contaminant groups are considered "bounding" because their distribution generally encompasses the spatial extent of all contaminants posing potentially unacceptable risks identified in the baseline risk assessments. This concept is further evaluated in Section 5 for SMA development relative to other contaminant risks. Further, these four contaminant groups, or specific contaminant surrogates that can be used to represent the entire group, are recommended COCs for the Site as determined by the draft final risk assessments.[2]

Four contaminants—total PCBs, total dioxins/furans, total DDx and total PAHs—were identified in the RI as "bounding" ICs. The distribution of these four contaminant groups generally encompasses the spatial extent of other contaminants that pose potentially unacceptable risk.

[1] Total of 2,4′- and 4,4′-DDD (dichloro-diphenyl-dichloroethane), -DDE (dichloro-diphenyl-dichloroethene), and -DDT (dichloro-diphenyl-trichloroethane).

[2] Based upon the conclusions of the BHHRA and the BERA, the LWG has recommended COCs for the Portland Harbor Site as described in the report entitled, *Portland Harbor RI/FS, Risk Management Recommendations* (July 22, 2011). These and other recommended COCs are carried forward into this draft FS as explained in Section 3.

Consequently, focusing descriptions of Site chemical conditions for this draft FS in terms of these four contaminant groups is appropriate.

For some human health or ecological exposure scenarios, risk from dioxins/furans was evaluated using toxic equivalents, either as the combined toxicity of all dioxins/furans (as total dioxin/furan toxic equivalent concentration [TEQ][3]), or as the combined toxicity of all dioxins/furans and dioxin-like PCBs, expressed as total TEQ. Similarly, for some human health exposure scenarios, risk from PAHs was evaluated using the combined toxicity of all carcinogenic PAHs (cPAHs).[4] See Sections 8 and 9 of the draft final RI report for descriptions of methods for assessing risks from dioxins/furans, PCBs, and PAHs and resulting risk estimates. Sections 3, 4, and 5 of the draft FS discuss specific surrogates from these groups that are used to conduct evaluations in the draft FS.

2.2.1 Sediment

RI surface and subsurface sediment samples were collected by the LWG and analyzed for a full range of chemicals of interest (COIs) and conventional parameters over three rounds of sampling between 2002 and 2007 in the Lower Willamette River. The RI and FS also utilize sediment samples were collected and analyzed by entities other than the LWG through March 2010. Sediment samples were collected throughout the Study Area—but biased toward areas of known or suspected contamination based on existing information—with additional sampling upstream and downstream of the Study Area. In addition to sediment chemistry, toxicity testing (sediment bioassays) was conducted on more than 200 surface sediment samples collected by the LWG. Surface sediment summary statistics for contaminants potentially posing unacceptable risks are presented in Table 2.2-1.

Total PCB concentrations are typically greater in the subsurface than in surface sediments, indicating PCB sources are primarily historical.

On a harbor-wide basis, the elevated[5] PCB surface sediment concentrations occur, with few exceptions, in nearshore areas outside the navigation channel and proximal to local currently known or suspected upland sources (Figure 2.2-1). The natural neighbors (NN) surface-area weighted average concentration (SWAC) for PCBs in the Study Area is 84 parts per billion (ppb which is µg/kg when referring to sediments and µg/L when referring to water).[6,7] There are several areas with total PCB concentrations above the 200 ppb contour in the eastern and western nearshore zones, in Swan Island Lagoon, and in a few scattered areas in the navigation channel. Similar spatial and concentration

[3] The total dioxin/furan TEQ was calculated for detected values only using WHO 2005 toxicity equivalency factors (TEF) and does not include dioxin-like PCB congeners.
[4] A benzo(a)pyrene equivalent (BaPEq) concentration was calculated by multiplying the cPAHs by their respective potency equivalent factors relative to benzo(a)pyrene (BaP) and summing the resulting concentrations.
[5] For this discussion, elevated total PCBs are considered to be those samples with results greater than 200 ppb.
[6] The SWAC concentrations for the CSM chemicals were calculated using the NN interpolation method in GIS with 10-foot cells using the draft FS surface sediment database.
[7] The Study Area SWACs reported in this section are based on the FS dataset and are slightly different than the values reported in the draft final RI, which are based on the pre-June 2008 RI dataset.

trends are observed for subsurface sediments (Figure 2.2-2). Total PCB concentrations are typically greater in the subsurface than in surface sediments, indicating PCB sources are primarily historical. Overall, surface sediment PCB concentrations in the Study Area are greater than those in the upriver (upstream of Ross Island) and downstream (mainstem of the Lower Willamette River downstream of RM 1.9 and Multnomah Channel) reaches.

Except for a few localized areas with highly elevated concentrations, surface sediment total dioxin/furan TEQ concentrations in the Site are similar to those in the upstream and downstream reaches.

Elevated total dioxin/furan TEQ concentrations[8] in Site sediments are limited to localized areas in nearshore zones near RM 7 (Figures 2.2-3 and 2.2-4). The SWAC for total dioxin/furan TEQ in the Study Area is 0.018 ppb. Except for a few localized areas with highly elevated concentrations, surface sediment total dioxin/furan TEQ concentrations in the Study Area are similar to those in the upstream and downstream reaches.

Total DDx concentrations are typically greater in the subsurface than in the surface layer, indicating DDx sources are primarily historical.

Overall, elevated[9] total DDx concentrations in Site sediments are limited to localized areas in nearshore zones in RMs 6 and 7, and small areas in RMs 8 and 11 (Figures 2.2-5 and 2.2-6). The SWAC for total DDx in the Study Area is 33 ppb. Total DDx concentrations are typically greater in the subsurface than in the surface layer, indicating DDx sources are primarily historical. The concentrations of total DDx in surface sediments are greater in the Study Area than those in the upriver, downtown, Multnomah Channel, and downstream reaches.

Total PAH concentrations are generally higher in subsurface sediments within the Site, indicating sources are primarily historical.

On a harbor-wide basis, elevated[10] PAH concentrations in sediments generally occur downstream of RM 7 (Figures 2.2-7 and 2.2-8). Total PAH concentrations are generally higher in subsurface sediments within the Site as a whole, pointing to higher historical inputs to the Site. The SWAC for total PAHs at the Study Area is 20,700 ppb. Except for limited areas of relatively higher concentrations, total PAH levels are generally 1,000 ppb or less upstream of RM 7. The surface sediment SWAC for total cPAHs at the Study Area is 1,700 ppb. The mean PAH concentration for Study Area surface sediments is markedly greater than the mean value in the upriver, downtown, Multnomah Channel, and downstream reaches, and the range of values was much wider.

[8] For total dioxin/furan TEQ, concentrations greater than 0.02 ppb in sediment samples are considered elevated for the purposes of this discussion.
[9] Elevated DDx concentrations in surface sediments are defined here as those exceeding 200 ppb.
[10] Elevated total PAH concentrations in surface sediments are defined here as those exceeding 20,000 ppb.

2.2.2 Surface Water

Concentrations of PCBs, pesticides, dioxins/furans, and PAHs in surface water were reported in the draft final RI down to extremely low levels, parts per quadrillion in some cases, using high-volume sampling methods. Concentrations of these contaminants in surface water samples varied both spatially and with river flow. Concentrations of total PCBs and total PAHs in surface water were generally highest during low-flow conditions and lowest during high-flow conditions. Concentrations of total DDx in surface water were generally highest during high-flow conditions and lowest during stormwater-influenced conditions. Concentrations of dioxins/furans in surface water were generally lowest during high-flow conditions and highest during low-flow and stormwater-influenced conditions. Surface water summary statistics for contaminants potentially posing unacceptable risk are presented in Table 2.2-2.

Concentrations of total PCBs, total dioxins/furans, and total PAHs in surface water within the Study Area were generally higher than those entering the upstream limit of the Study Area under all flow conditions. The highest concentrations of DDx and total PAHs in surface water within the Site during low-flow conditions were found near known sources of these chemicals. The highest total PCB concentrations are associated with single-point samples collected at RM 6.7 within Willamette Cove during low-flow conditions. At RM 2, at the downstream end of the Study Area, concentrations of total PCBs, total dioxins/furans, DDx, and total PAHs in surface water were generally lower than the rest of the Study Area, potentially reflecting input of Columbia River water in this reach.

Concentrations of total PCBs and total PAHs in surface water tended to decrease with increasing flow rates due to the effect of dilution under higher flow conditions. No clear relationship was found between total dioxins/furans concentrations and river flow. DDx concentrations in surface water upstream of the Study Area were elevated in high-flow conditions, suggesting DDx is mobilized from upstream sources during high-flow conditions.

2.2.3 Transition Zone Water

A groundwater pathway analysis was performed during the RI to assess whether COIs associated with known upland groundwater plumes were discharging to the Study Area, thus creating a complete transport pathway for such COIs to reach the groundwater/ surface water transition zone in sediments. The transition zone is defined as the interval where both groundwater and surface water comprise some percentage of the water occupying pore space in the sediments (EPA 2008a). Samples of TZW (porewater) in surface and near surface sediments were collected offshore of nine upland locations where groundwater was suspected of potentially impacting sediment and/or porewater quality. The groundwater pathway was shown to potentially influence sediment/ porewater quality at four of these upland sites, which are all located in AOPCs 9U and 14 (see Section 5 for maps of AOPC locations). The recommended TZW COCs identified as having a known or likely complete pathway from upland groundwater to the river are 4,4'-DDT, total DDx, chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and trichloroethene (TCE). TZW COCs are different from sediment COCs; the methods by which recommended COCs were identified for use in the draft FS are discussed in Section 3. TZW summary statistics for contaminants potentially posing unacceptable risk are presented in Table 2.2-3.

There is considerable uncertainty as to whether some of the contaminants in TZW are truly associated with upland groundwater plumes. Concentrations of the DDx compounds were consistently higher in unfiltered samples than filtered and peeper samples, indicating that the DDx compounds are at least partly associated with solids in the transition zone. As discussed in the RI, it is possible that small amounts of hydrophobic compounds are transported to the transition zone via the groundwater pathway. However, the finding of detectable DDx in TZW appears to be largely an artifact of particulates present during sampling.

Similarly, concentrations of total PAHs were higher in unfiltered samples than filtered samples collected from the same locations, indicating the PAHs are adsorbed to solids in TZW. Unfiltered deep samples consistently exhibited higher concentrations than collocated shallow samples; however, the three filtered deep/shallow sample pairs did not exhibit this trend.

2.2.4 Biota

PCBs, dioxins/furans, DDx, and PAHs were detected in most samples of various fish and invertebrate species collected across the entire Study Area. Concentrations of these COCs varied greatly within and between species, with fish tissue concentrations generally greater than those in invertebrates. Concentrations of bioaccumulative compounds were often found at greater concentrations in organisms higher on the food chain. On a Site-wide scale, biological samples from within the Study Area exhibited greater concentrations of most contaminants than those seen in samples from upriver reaches and above Willamette Falls. Localized areas of elevated concentrations of some contaminants were found in resident species (e.g., sculpin), reflecting relatively high concentrations in nearby surface sediment and biological uptake by species with small home ranges.

2.2.5 Background Concentrations for Contaminants in Sediment and Surface Water

For bedded sediment, the upriver reach of the Lower Willamette River, extending from RM 15.3 to 28.4, was selected by EPA as the reference area for determining background conditions. This reach was chosen because it is considered broadly representative of the urban and suburban upland conditions along the banks of the river as it flows through Portland and its suburbs, but is upstream and uninfluenced by releases from the Study Area. The downtown reach between RM 15.3 and the Study Area contains several historical and active cleanup sites under State oversight and so was excluded from the sediment background reference area. The determination of background levels based on the upriver reach dataset following EPA directions is detailed in Appendix A, which is similar to the background information presented in the draft final RI. Background concentrations in upriver surface sediments are presented in Table 2.2-4 (dry-weight basis) and Table 2.2-5 (organic carbon [OC]-normalized). Background values are used in the draft FS for comparison to sediment preliminary remediation goals (PRGs) and the outcomes of various alternatives. In addition, a sensitivity/uncertainty analysis of the RI-determined background levels is provided in Section 4 of Appendix E.

Additional insight is provided to the background bedded sediment data by three related datasets: in-river sediment traps, surface water suspended sediment, and sediment cores from borrow pits and shoaling areas in the upstream portion of the Study Area. These are summarized in draft final RI Section 7. These data are used in various analyses in the draft FS to understand both incoming loads/concentrations of contaminants as well as the impact of those loads/concentrations on potential remedial alternatives within the Site. For example, the surface water background dataset was used to determine the incoming surface water contaminant concentrations and loads for contaminant fate modeling, and background sediment trap data were used to compare to model-predicted long-term bedded sediment concentrations. For surface water, the LWG and EPA agreed that samples collected from surface water transects at RM 11 and RM 16 would be the basis for the background dataset. Concentrations of contaminants entering the Site are less than the levels in surface and subsurface sediments and surface water existing within the Site. These observations, combined with the predominantly depositional nature of the Site (with localized exceptions), indicate that deposition of relatively cleaner sediment will occur within the Site, driving Site-wide surface sediment concentrations lower over time.

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2.3 BIOLOGICAL AND HABITAT DESCRIPTION

The information on the biological communities and habitat within the Study Area is based on available historical information about the species and habitats of the Lower Willamette River, as well as the investigations conducted by the LWG between 2001 and 2008 to support the Site characterization. In addition, as part of the BERA, the LWG worked with EPA to characterize the risks of chemical effects on the aquatic and aquatic-dependent species that might be found in the Study Area. The results of the biota sampling also support information about the species and habitat present within the Study Area.

The landscape of the Lower Willamette River watershed and the heavily industrialized condition of the Site are significant drivers of the biological communities and habitat found there. Upstream activities and introduced species have caused significant changes to the ecosystem and ecological processes through flood management and altered biological community structure. However, the Site includes some habitat areas that support fish and wildlife species as discussed more below.

Since the late 1800s, Portland Harbor has been extensively modified by wetland draining, channelization, and dredging for creation and maintenance of the federal navigation channel and ship berthing areas (Integral et al. 2011). The Lower Willamette River has also been deepened and narrowed through channelization, diking, and filling, and much of the shallow water habitat has been converted to deep water habitat. Over the last 100 years or so, approximately 79 percent of the shallow water habitat within the Lower Willamette River has been lost through historic channel deepening (WRI 2004) undertaken in support of waterfront based industrial and commercial activities. The habitats and biological communities present in the Study Area are described in more detail in Appendix M, which includes information on those parameters that contribute to habitat functions for fish and other aquatic species (i.e., the functional habitat parameters). These habitats and biological communities are summarized here.

As discussed more in Section 3.1, Site contaminants currently pose potentially unacceptable risks to ecological receptors (e.g., the benthic invertebrate community and fish and wildlife populations) as detailed in the draft final BERA (Windward 2011). The primary ecological risks are from bioaccumulation of PCBs and other persistent contaminants by wildlife and their prey, which occur in addition to the direct risks to benthic communities from contaminants. Anthropogenic background and upstream activities are important factors contributing to potentially unacceptable ecological risk in the Site, as indicated by the significant loads of PCBs and DDE entering the Site.

The presence of non-native species may have diverse impacts on overall ecosystem health. Invasive and non-native species are associated with the decline of many threatened and endangered species worldwide, as well as the overall degradation of rivers, lakes, marshes and other wetlands (Vitousek et al. 1996; Simberloff et al. 2005; MEA 2005). Sanderson et al. (2009) developed a database of known non-native species in the Pacific Northwest, and found that the Lower Willamette River watershed had among the highest number of non-native fishes (approximately 30 species) for the entire state of Oregon. Several studies have noted that the presence of non-native fish is one of the biggest threats to the health of native fish populations (Sanderson et al. 2009; Lassuy 1995; Richter et al. 1997; Rahel 2002); however, there are very few studies on predation from native or non-native species in the Lower Willamette River specifically. It is widely speculated that population declines of salmon throughout the Pacific Northwest are linked to food-web alterations, predation, and competition from non-native species (Ruckelshaus et al. 2002; Beechie et al. 1994; McClure et al. 2003; Sanderson et al. 2009); the high concentration of non-native introduced species at the Site have an unknown but generally hypothesized negative effect on native species in the river.

2.3.1 Biological Communities

The Lower Willamette River supports numerous aquatic and semi-aquatic organisms. These organisms can be divided into the following general groups: aquatic plants, invertebrates, fishes, amphibians, reptiles, birds, and mammals. Each group makes an important contribution to the ecological function of the river based on its trophic level, its abundance, and its interaction with the physical, chemical, and biological environment.

Riverine invertebrates are predominantly benthic, utilizing substrates such as sand and silt sediments, gravel and cobble, plant roots, or large woody debris. The benthic invertebrate community within the Lower Willamette River is dominated by small organisms that live on or in the sediment, many of which feed on and process organic material imported from upstream and upland areas. A 2009 study by SWCA Environmental Consultants conducted benthic macroinvertebrate sampling in downtown Portland. Similar to other studies (Windward 2011), they identified an abundance of oligochaetes, chironomids, amphipods, polychaetes, and clams. Exposed nearshore areas, particularly around berths, docks, and boat ramps are expected to have less robust benthic communities due to the greater physical disturbance in these areas, although the hard surfaces of the developed shoreline do provide habitat for an epibenthic community.

The Lower Willamette River is an important rearing and migration corridor for anadromous fish, such as salmon and lamprey. More detail on the use of the Site by salmon can be found in the *Preliminary Draft Site-wide Biological Assessment* (Preliminary Draft BA) (Anchor QEA 2012). The larger Willamette River basin is known to contain at least 31 native fish species and approximately 30 non-native introduced species, such as black crappie, large- and smallmouth bass, carp, and bullhead among others (Sanderson et al. 2009; PNERC 2002). The Lower Willamette River also provides habitat for more than 40 species of resident fish, both native and non-native (based on both historical and recent studies [Windward 2011]). In total, the fish species in the Lower Willamette River represent four major feeding guilds: omnivores/ herbivores, benthopelagic/benthic invertivores, piscivores, and detritivores. The riverbank types at the Site may influence fish species occurrence and use of a given area. The Oregon Department of Fish and Wildlife (ODFW 2005) found that in the Lower Willamette River, coho salmon preferred the water column overlying beaches and rock outcrops but avoided riprap and artificial fill; the abundance of all species was low at seawalls. The riprap and rocky substrates are the preferred habitats of sculpin and smallmouth bass (Farr and Ward 1993; SEA et al. 2003; Wydoski and Whitney 2003). More detailed information on fish species habitat requirements and use is presented in Appendix M, as well as the Preliminary Draft BA (Anchor QEA 2012).

Numerous aquatic-dependent bird species (more than 20 species commonly occur based on available information, including cormorants, spotted sandpiper, osprey and bald eagle) use habitats within the Lower Willamette River (Windward 2011). However, these avian habitats are largely fragmented due to urban development (ODFW 2005). The trophic representation of these birds is broad and includes herbivores, carnivores and omnivores, sediment-probing insectivores and omnivores, and piscivores. Six aquatic or semi-aquatic mammals have been identified that use or may use the Lower Willamette River, including opportunistic piscivores (Windward 2011).

Conditions within the Lower Willamette River provide limited habitat for amphibians and reptiles. Amphibians prefer undisturbed areas that offer ephemeral wetlands with emergent vegetation and shallow waters (Sparling et al. 2000). Reptiles prefer shallow, quiescent aquatic areas and wet vegetated terrestrial habitats. Current conditions in the Lower Willamette River prevent the widespread development of dense, submerged, and emergent plant communities along the riverbanks because of high turbidity and the presence of riprap and other bank modifications (Integral et al. 2011). See Section 2.4.2 on shoreline types for more detail on the conditions of the shoreline, as well as the Preliminary Draft BA (Anchor QEA 2012) and Appendix M for more detail on the influence of current conditions on the habitat in the Site.

2.3.2 Habitat Types

Habitat types in the Site are the result of extensive modifications in the Lower Willamette River, and existing habitat functions are impaired compared to historical, natural conditions. In support of the substantive compliance with the Clean Water Act (CWA) 404(b)(1) requirements as well as the Endangered Species Act (ESA), the LWG developed a functional habitat assessment framework utilizing both relative habitat values provided by National Oceanic and Atmospheric Administration (NOAA) Fisheries and functional habitat values developed specifically by the LWG for this purpose, to look at the existing habitat functions in the Site (Appendix M). Based on the functional assessment approach, habitat types and their function are influenced by water quantity, water depth, substrate type, and shoreline conditions, and each of these factors are summarized below. (Water quality also impacts habitat types and functions and this parameter is discussed more in Section 2.2.2, Appendix M, and the draft final RI.)

The Lower Willamette River is constrained by upstream management of flows (ODFW 2010; NMFS 2008). The 13 federal reservoirs on the Willamette River and its tributaries alter the timing and magnitude of flows resulting in downstream impacts to fish habitat (ODFW 2010; Fresh et al. 2005). The reduced occurrence of peak flows has resulted in decreased channel complexity and habitat diversity in the Lower Willamette River (Bottom et al. 2005; ODFW 2010).

An increase in global temperatures could lead to changes in temperature in Oregon, along with alterations to precipitation patterns, increase in sea levels, diminished water supplies, shifts in vegetation regimes, and alterations to ecosystems and species. The overall trend estimated by Oregon Climate Change Research Institute (OCCRI) shows warming for the entire Lower Willamette River basin by 2100, by as much as 10 to 15° Fahrenheit in the summer months under the highest emissions scenario (OCCRI 2009) and variability in precipitation trends. These predicted changes are likely to result in alterations to streamflow in the Willamette Basin and therefore within the Site.

Historically, the Lower Willamette River consisted of primarily shallow water habitat, and approximately 80 percent of the river had depths less than -20 feet CRD (approximately -15 feet North American Vertical Datum of 1988 [NAVD88]); however, dredging and anthropogenic alteration has reduced shallow water habitat to just 20 percent of the river (WRI 2004). The historical off-channel habitat has been significantly diminished by diking and filling the connected channels and wetlands. As a result of these habitat modifications, species including otter, mink, and juvenile salmonids that prefer the slower water velocities, foraging opportunities, and cover and refugia provided by shallow water and off-channel habitats are confined to relatively narrow strips of shallow water habitat between the shoreline and navigational channel. There are several shallow water habitat pockets remaining in the Lower Willamette River including Willamette Cove, the head of Swan Island Lagoon, the mouth and channel of Multnomah Channel, and the Sauvie Island shoreline (Integral et al. 2011). For the purposes of evaluating the draft FS alternatives in the Preliminary Draft Site-wide 404(b)(1) (Appendix M), as well as the Preliminary Draft BA (Anchor QEA 2012), habitat in the Site is divided into four different habitat zones based on water depths similar to those identified by the Portland Harbor Natural Resource Trustees Natural Resource Damage Assessment process (PHNRT 2008, 2010). These four zones are described more in Appendix M, and in summary, are:

- Active Channel Margin (ACM) – This zone is periodically available to aquatic species and extends from the regulatory-defined ordinary high water (OHW; approximately +20 feet NAVD88 or +15 feet CRD) elevation to the lower edge of persistent woody vegetation, approximately at the level of ordinary low water (OLW; +5 feet NAVD88; approximately 0 feet CRD). However, for the purposes of the draft FS, the vertical boundary of the ACM for purposes of evaluation of impacts is the Site boundary at +13 feet NAVD88 (+8 feet CRD).
- Shallow Water Zone – This zone extends from +5 to -4.9 feet NAVD88 (approximately 0 to -10 feet CRD), and the upper elevations of this zone are seasonally available to aquatic species while the lower elevations are continually available. This zone is rare in the Study Area but is important to the growth and survival of aquatic organisms.
- Main Channel Shallow Water Zone – This zone extends from -4.9 to -14.9 feet NAVD88 (approximately -10 to -20 feet CRD), which is continually available to aquatic species. This zone is important for various life stages of many aquatic species.
- Deep Water Zone – This zone is defined as the aquatic area deeper than -14.9 feet NAVD88 (deeper than -20 feet CRD). This zone is continually available to aquatic species and covers the largest amount of area in the Study Area.

Physical characteristics including substrate and water depth are important in defining habitat for benthic species. Figure 2.1-3 shows surface sediment grain size distribution within the Study Area, based on LWG's RI data. Fine-grained substrate provides habitat for macroinvertebrates and other benthic organisms, which are prey for some fish species.

Shallow water habitats with fine-grained substrates provide important foraging opportunities for aquatic species due to presence of benthic macroinvertebrates, zooplankton, and emergent insects (NMFS 2008). Overwater structures, which exist as mainly dock structures throughout the Study Area, may affect the primary and epibenthic productivity within the nearshore habitat. Overwater structures may limit light from penetrating the bottom of the river, thus restricting vegetation growth and the productivity of primary and epibenthic organisms (Nightengale and Simenstad 2001). The presence of structures within the Study Area is discussed more in Section 2.4.

Figure 2.3-1 and 2.3-2 show substrate, water depth and shoreline type, based on available information from the LWG FS database. The information is sufficient for the FS-level analysis, but should be reconsidered in more detail at the time of remedial design to confirm SMA-specific conditions. The ACM areas with benthic habitat suitable for juvenile salmonid forage based on substrate, water depth, and shoreline type (Figure 2.3-1 and 2.3-2), based on available information from the LWG FS database. The shallow water areas with benthic forage potential were determined as those areas characterized by small substrate size (silty sands, sands, and gravels) and no debris covering the substrate. Although these areas may have higher benthic forage potential based on the characteristics present, the areas may be impacted by the presence of contamination or overwater structures (discussed in Sections 2.2 and 2.4, respectively) that limit forage opportunities. Based on this mapping exercise, there are approximately 80 acres of ACM (+13 to +5 feet NAVD88) and 290 acres of shallow water (+5 to -4.9 feet NAVD88) areas within the Site that provide suitable forage opportunities. The deep water zone contributes to benthic production within the Lower Willamette River system and other species within the food web utilize this area for forage (e.g., crayfish, sturgeon, and carp).

2.4 SITE USES

This subsection summarizes the historical and current Site uses including ownership, shoreline conditions, structures, vessel traffic patterns, current and future navigation requirements, maintenance dredging history and status, environmental dredging and capping history, and potential future restoration uses. More detailed information is available in Section 3 of the draft final RI (Integral et al. 2011).

2.4.1 Historical and Current Site Use and Ownership

The Site is located within Portland Harbor, the deep-draft shipping channel and surrounding commercial, industrial, and transportation infrastructure from about the Broadway Bridge on the Willamette River (RM 11.65) to the confluence with the Columbia River, and includes Terminal 6 on the Columbia River. The Site, however, is limited to the Willamette River and ends at about RM 1.9. The current Site uses include public and private marine terminals, various manufacturing facilities, and commercial operations as well as public facilities, parks, and open spaces. Overwater structures to support maritime activity and shipping includes wharfs, piers, floating docks, and pilings.

Industrial and commercial development along the river began in the mid- to late-1800s in the cities of Portland, St. Johns, Linnton, and Macadam as the Portland area grew to be the major preferred trade port in the region due to its location at the confluence of the Columbia and Willamette Rivers. Portland Harbor remained largely undeveloped through the late 1800s, but urban development in the downtown area at the beginning of the 20th century pushed the shipping activity and industrial uses north to what is now Portland Harbor (Integral et al. 2011). Lumber and lumber products were the dominant cargo during the late 1800s. Cargo was diversified to include agricultural products such as grain, livestock, and woolen textiles at the turn of the century. Early industrial activities included sawmills, manufactured gas production, bulk fuel terminals, metal foundries, and smaller industrial facilities. Additional commercial and industrial development, including metals, manufacturing, and transportation equipment, emerged during the 20th century, making the Portland area a natural location for significant ship building efforts during World Wars I and II (Abott 2008).

Over time, the development of the harbor centered on several industrial sectors identified in the RI, including ship building, dismantling, and repair; wood products and wood treating; chemical manufacturing and distribution; metal recycling, production, and fabrication; manufactured gas production; electrical production and distribution; bulk fuel distribution and storage and asphalt manufacturing; steel mills, smelters, and foundries; commodities, maritime shipping and associated marine operations; and rail yards. Each sector is discussed in detail in Section 3.2.1 of the draft final RI and many of these operations continue today (Integral et al. 2011).

Today, Portland Harbor remains a gateway for importing goods to the region and exporting American-made and grown products to global markets. The public and private terminals handle breakbulk cargo, steel, bulk products, automobiles, grain, mineral bulks, petroleum products, and dry bulk products such as cement, alumina, sand and gravel, and limestone. Portland Harbor is the largest wheat export in the United States, the largest mineral bulks port on the west coast, and the largest automobile import gateway on the west coast and the sixth largest in the United States.

Oregon is the eleventh most trade-dependent state in the United States in terms of the overall economic activity. In recognition of Portland’s role in exports nationally, the greater Portland-Metropolitan area was selected as one of four cities for the Brookings Institute and Obama Administration’s national export initiative. Portland Harbor plays an important role in this initiative as Oregon’s largest seaport. The value of annual commerce related to international deep-draft shipping in Portland Harbor is $12.6 billion dollars for the last year of record (Port of Portland 2012). In 2010, the public and private Portland Harbor terminals handled nearly 24 million tons of cargo. This trade generates approximately 17,500 jobs in the greater Portland Metropolitan area and $1.4 billion of personal wage, salary, and consumption impact annually for the region (Martin Associates 2011). In addition to the terminal cargo activity, Portland Harbor is a leader in the metals, manufacturing and transportation industry, which are dependent upon the deep-draft shipping channel. The Portland Development Commission has estimated that all of the commercial and industrial businesses in Portland Harbor generate approximately 36,000 jobs for the region.

Portland Harbor also includes opens spaces, parks, and neighborhoods, and the area is home to wildlife and fish. In addition to shipping and industrial uses, the Lower Willamette River is used for fishing, recreational boating, sightseeing, and other recreation (Integral et al. 2011).

The ownership of the shoreline areas is shown in Figure 2.4-1, which illustrates current land use zoning along the Study Area shoreline. The State of Oregon owns certain submerged and submersible lands underlying navigable and tidally influenced waters. The ownership of submerged and submersible lands is complicated and has changed over time. The information shown on Figure 2.4-2 was provided by the Oregon Department of State Lands (DSL) and was used for FS-level evaluations only to estimate possible lease costs for constructing engineered caps (DSL 2011). It should be noted that this map contains inaccuracies; for example, at Terminal 2, the ownership boundary is up to OHW and not the harbor line as shown on Figure 2.4-2. DSL ownership should be verified during remedial design.

2.4.2 Shoreline Conditions and Structures

This section summarizes existing shoreline conditions and structures, which are discussed further in the draft final RI and Appendix M and are important for evaluating implementability of technologies.

The majority of upland area adjacent to the Study Area on both sides of the Lower Willamette River is zoned Heavy Industrial within the River Industrial Greenway Overlay Zone (City of Portland 2010 and 2011) (Figure 2.4-1). River-dependent uses cover an estimated 72 percent (1,704 acres) of the occupied riverfront (between the river and nearest street or railroad right-of-way) in the Study Area (City of Portland 2003). Little, if any, original shoreline or river bottom exists that has not been modified to some extent by human actions (Integral et al. 2011).

Much of the shoreline contains nearshore or overwater structures, such as wharfs, piers, floating docks, piling, bulkheads, and riprap revetments, and other engineered features that were built largely to accommodate or support shipping commerce, although structures supporting recreational vessels and other water-dependent uses also exist. Armoring covers approximately half of the harbor shoreline, which is integral to the operation of industrial activities that characterize the harbor. Numerous public and private outfalls, including stormwater and CSO outfalls, enter both shores of Portland Harbor and are described in detail in the draft final RI (Integral et al. 2011). These structures along the shoreline are shown in Figure 2.4-3.

The most common bank types along the shoreline in the Study Area are riprap, sandy and rocky beach, unclassified fill, and seawall (Figure 2.3-1). In 2009, the City of Portland reported that vegetated riprap (25 percent), non-vegetated riprap (12 percent), unclassified fill (21 percent), beach (23 percent), pilings limiting light (13 percent), bio-engineered (3 percent), rock outcrops (1 percent), and seawall (2 percent) were the representative bank types present in the North Reach (Broadway Bridge to the Columbia River; City of Portland 2009b). The bank types classified by the City were identified based on physical characteristics and were not associated with a specific range of shoreline elevations (City of Portland 2009b). The riprap or armored bank type is usually fairly steep with no or very narrow adjacent shallow water habitat present; there are localized exceptions to this such as Willamette Cove. The riprap areas create conditions that often suppress or preclude the establishment of riparian vegetation (Kaufmann et al. 1997), but some areas of vegetated riprap exist within the Study Area (City of Portland 2009b). The sandy bank type with little to no vegetation is characterized by gently sloped beaches (i.e., sand banks are rarely steep). However, this bank type is often adjacent to steep riprap shorelines or developed uplands that are frequently exposed to heavy wave action and faster moving water. The rocky or sandy bank types with a mix of native and invasive vegetation are common within the Study Area. These bank types range from gently to steeply sloped beaches and, similar to the sandy bank type without vegetation, are often adjacent to steep uplands, although the uplands are either of sandy or rocky substrate. The rocky or sandy bank types are generally located in areas with less development and a lack of bank hardening, the Multnomah Channel, Kelley Point Park, and Sauvie Island. Some riverbank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines due to relatively natural processes (Integral et al. 2011).

2.4.3 Vessel Traffic Patterns

Vessel traffic patterns vary widely throughout the river, due to the many types of vessel uses in the Lower Willamette River. Vessel traffic patterns are important for understanding effects of vessel traffic on bedded sediment stability. The river is authorized to a navigational depth of -43 feet CRD and maintained to -40 feet CRD by the USACE. However, maintenance dredging of the river is currently on hold due to the remedial investigation, with exceptions such as Post Office Bar in 2011and other parts that are dredged to different depths depending on individual site owner needs, which are detailed in the following section (Integral et al. 2011).

Information on waterway traffic was obtained from the USACE, Port of Portland, and correspondence with other harbor property owners (Table 2.4-1). Commercial vessels operating within the Study Area range from larger cargo vessels and tankers with drafts of less than 40 feet, to smaller push-boats, tugboats, and passenger ships/ferryboats with drafts of less than 18 feet. Overall, 51 percent of commercial vessel traffic consists of tugboats, tows, and push-boats; 44 percent consists of cargo ships; and only 5 percent consists of tankers. Large cargo vessels, tankers, and barges travel at 6 to 9 miles per hour (mph), while push-boats, tug-boats, and small passenger ships periodically travel at speeds up to 17 mph in the centerline of the navigational channel. Occasionally, the City of Portland uses fireboats that travel at 8 to 25 mph. Excursion jet boats operated by the Portland Spirit and Willamette Jetboat Excursions travel through the project reach several times daily during the summer season (approximately April through September). These boats can travel within the navigation channel at speeds up to 40 mph, as river vessel traffic conditions allow. No available count was found for smaller recreational boats.

The effects of vessel traffic on bedded sediment stability and movement in terms of propeller wash forces (propwash) and vessel wake generated waves on the shoreline is assessed in Appendices Fb and Hc. The implications of these forces for SMA development and feasibility of remedial technologies are discussed in Sections 5 and 6, respectively.

2.4.4 Current and Future Navigation Requirements

Current and future navigation requirements are used to evaluate implementability of remedial technologies.

Congress authorized the Lower Willamette River federal navigation project through the Act to Improve Rivers and Harbors of June 18, 1878. Its purpose was to deepen and maintain parts of the Columbia and Willamette Rivers to a 20-foot minimum depth. The USACE maintains the channel for both rivers, which have been deepened at various intervals since that time. Most significantly, the authorizations affecting the Lower Willamette River depth occurred as follows: -25 feet CRD in 1899, -30 feet CRD in 1912, -35 feet CRD between 1930 and 1935, and -40 feet CRD in 1962 (Integral et al. 2011). Most recently, in 1999 Congress authorized the Willamette River (and Columbia River) deepening to -43 feet CRD. Some areas of the channel are naturally deeper than -43 feet CRD.

Work on the -40-foot CRD channel from Portland and Vancouver to the Pacific was completed in 1976. The Willamette River channel from the Broadway Bridge (RM 11.7) to the mouth (RM 0) varies in width from 600 to 1,900 feet, with an average width of approximately 1,700 feet (Integral et al. 2011).

In November 2008, a site use survey was developed and distributed to LWG members whose shoreline properties along the Lower Willamette River are adjacent to AOPCs. The purpose of the site use survey was to gather information on existing and future activities at the locations along the Study Area to inform site use assumptions for purposes of the draft FS. The topics addressed in the survey include vessel activity, number and type of dock structures, shoreline characteristics, outfall locations, potential restoration areas, and potential future development or in-water construction.

Responses were received from seven LWG members (Table 2.4-1 and Figure 2.4-3). The detail of information varied among the survey responses. In all cases, general information on vessel activity was provided, and in a few cases detailed vessel information was also available. Information related to dock configuration and future site uses was usually specific and was used to develop estimates of likely future navigation depth requirements and potential future maintenance dredging depths near and around docks (Moore 2009).

2.4.5 Maintenance Dredging History and Status

Active maintenance dredging in the Lower Willamette River has occurred to create and maintain the authorized depth of the navigation channel, as well as to maintain operational depths at docks and wharfs outside the navigation channel. Each type of maintenance dredging is discussed more below. Environmental dredging and contaminated sediment remediation projects are discussed in the next section. Maintenance dredging discussions focus on the period since 1997, when the last major dredging of the harbor (federal navigation channel) was conducted, because these maintenance dredging projects have an impact on the sediment chemistry dataset used for the draft FS, which goes back to 1997.

With regards to channel maintenance, since 1888, most of the original channel has been deepened by at least 10 to 20 feet to reach a navigation channel depth of -40 feet CRD. Historically until 1998, the USACE has dredged between 500,000 to 750,000 cubic yards (cy) of sediment from the channel every three to five years (Port of Portland 2011). In particular, periodic dredging was needed to maintain this depth in two major shoaling areas, between RM 8 and 10, particularly in the western half of the channel, and from RM 2 to 2.5 in the eastern portion of the channel (known as Post Office Bar). In addition, there are several deep “borrow areas” in the channel that extend from -60 to -80 feet CRD that were dredged to create the adjacent uplands; the two most extensive ones are in the western portion of the channel from RM 4.3 to 5 and RM 9.2 to 10 (Integral et al. 2011).

Currently, maintenance dredging of the navigation channel has been mostly suspended until issues are resolved regarding dredging within the boundaries of the Site. The lack of maintenance dredging in the channel over the past 14 years has resulted in significant shoaling of the channel. Many areas of the channel are now less than 40 feet deep, which is a significant navigation hazard and impediment to large cargo ships that require a water depth of 40 feet or more. A critical area of shoaling in the river that needed immediate attention is Post Office Bar at RM 2 to 2.5. This area was dredged by the USACE in October 2011 and 52,292 cy of sediment was removed.

Ultimately, the remedial actions associated with the Site may require removal of sediments that would otherwise be dredged for navigation purposes. In these cases, the removal would be considered environmental dredging. However, in most instances where maintenance dredging is conducted on a routine basis, sediment contamination is present at very low levels, like the federal navigation channel and berthing areas. All maintenance dredging in the navigational channel and berthing areas is regulated through various federal and state laws. The USACE coordinates issuance of permits for individual maintenance dredging projects with other federal and state agencies. Navigational maintenance dredging methods used to remove sediments are designed and permitted (or authorized) to minimize environmental impacts (e.g., conservation measures such as environmental buckets used at berthing areas). This issue is further discussed in Section 6.2.7.

With regards to maintenance dredging projects outside of the navigation channel, projects that have been undertaken since 1997 by the Port of Portland, USACE, the City of Portland, and private parties are listed in Table 2.4-2. The dredging projects that are italicized in the table indicate recent projects for which a USACE public notice has been issued, but specific information about dredging dates and amounts was not available. Note that the issuance of a permit does not mean that the project was implemented or that the volume of dredged material indicated in the table was dredged. Furthermore, the table does not distinguish between single events and multi-year permits. Figure 2.4-4 shows the locations of dredging and capping operations between RM 1 and 11.8 since 1997.

Since 1997, the Port of Portland has performed maintenance dredging at its marine Terminals 2 and 4 (See Table 2.4-2). Maintenance dredging has also been performed after the listing of Portland Harbor on the NPL by Schnitzer Steel Industries, Inc. (Schnitzer berths in International Terminal Slip, RM 4), Chevron (Willbridge Terminal, RM 7.5), the City of Portland (Portland Fire Bureau Station 6 Dock, RM 9.7), the former Goldendale Aluminum Company (Goldendale Aluminum facility dock, RM 10), and Cargill (Irving Elevator Terminal, RM 11.6). Brief descriptions of these dredging projects are provided below:

- Schnitzer performed maintenance dredging of its berths located inside the International Terminal Slip in 2004 under two separate permits. Approximately 77,000 cy of material was dredged from Berths 1, 2, and 3 under Permit #199100099. Maximum target dredge depths were -42, -38, or -24 feet CRD, depending on the location within the slip. Outside the slip, Schnitzer dredged approximately 61,000 cy of material from Berths 4 (to -42 feet CRD) and 5 (to -36 feet CRD) under Permit #199200812. The permits for both projects allowed for biannual maintenance dredging through January 31, 2009 (USACE 2004a, b).
- In 2001, Chevron Products removed approximately 15,000 cy of material from both sides of its pier at Willbridge Terminal. The dredging was performed under a maintenance dredging permit issued in 1997. Sediments were removed to a target dredge depth of -40 feet CRD (PNG 2001).
- The former Goldendale Aluminum Company conducted maintenance dredging at its dock in 2000. Dredging volumes were not provided, but material was removed to -38 feet CRD (CH2M Hill 2000).
- The City of Portland performed maintenance dredging of the Portland Fire Bureau Station 6 Dock in 2005. The area approaching the dock was dredged to -12 feet CRD, and the area adjacent to the dock was dredged to -10 feet CRD. Altogether, 4,130 cy of dredged material was removed. In accordance with the permit, both areas were capped to bring the bottom grade to between -10 and -11 feet CRD. Approximately 1,190 cy of capping material was used (CH2M Hill 2005).

- CDL Pacific Grain last performed maintenance dredging at two separate locations at the Irving Elevator Terminal in October 2009 to a depth of -41 to -42 feet CRD and a 12-inch (or greater) sand cap was installed. The permit (NWP-2001-00031) states that the applicant [CLD Pacific Grain (aka Cargill)] proposed to remove up to 8,000 cy of sediments, but the actual dredge volume is unknown at this time.
- Two dock areas offshore of Glacier NW (RM 11.3) were dredged in August 2004. No as-built drawings are available to determine the exact dredge footprint and volume removed, but the authorized dredge depth for the main (upstream) dock and the barge (downstream) dock were -36 feet CRD and -21 feet CRD, respectively.
- As part of the Terminal 4 Early Action removal, approximately 13,000 cy of sediment was dredged from Slip 3 in 2008 (discussed further below).
- Kinder Morgan performed maintenance dredging at the Willbridge Terminal to remove sediment that had filled in the shipping channel and berthing zone on the upstream side of the existing Kinder Morgan dock. Dredging began on August 26, 2011, and was completed on October 25, 2011. A total of 26,105 cy of sediment was removed and disposed of at Wasco County Landfill, The Dalles, Oregon. Approximately 2,600 cy of clean Columbia River sand was placed across the dredged area as a cap.
- As of late 2011, maintenance dredging was planned for the dock areas offshore of Gunderson, the Portland Shipyard (Cascade General), and at ConocoPhillips and Chevron properties in the Willbridge complex (Integral et al. 2011). Maintenance dredging for ConocoPhillips and Chevron was completed in 2011 and approximate footprints are shown on Figure 2.4-4.
- The USACE completed dredging of the Post Office Bar area in October 2011; approximately 52,000 cy of material was removed.

Overall, the historical need to regularly dredge both the navigation channel and individual berthing areas further confirms the depositional nature of the Site as described previously.

2.4.6 Environmental Dredging and Capping History

This section discusses environmental dredging and capping (i.e., contaminated sediment remediation projects). Dredging and capping projects have been completed or are in process as part of contaminated sediment remedial actions at selected Portland Harbor locations. Table 2.4-2 and Figure 2.4-4 show these locations. Below is a brief description of environmental dredging and capping projects since 1997, which is the year of the oldest data in the FS database.

Interim removal action activities at Port of Portland's Terminal 4 are underway and are occurring in two phases. The first phase, which was completed in the fall of 2008, included remediation and maintenance dredging of approximately 13,000 cy of sediment. Remediation dredging consisted of dredging 6,315 cy of contaminated sediment and placement in an off-site disposal facility, isolating contaminated sediment in the back of Slip 3 with a cap made of an organoclay-sand mix, and stabilizing the bank along Wheeler Bay. The second phase of the Terminal 4 project will be implemented after the harbor-wide ROD (see Section 2.7.1).

At the ARCO BP terminal, a new steel sheetpile wall was installed in 2007 to stabilize the facility and prevent migration of contaminants to the river. The following year, the concrete revetment riverward of the new sheetpile wall was removed, along with 13,293 cy of underlying and nearshore contaminated sediment, which was disposed of off-site. Clean fill was placed in the excavated area (DEQ 2010a).

At the McCormick and Baxter site, a former wood treating facility, construction activities were completed in September 2005 to place a cap over contaminated sediments. (Subsequent modifications to the cap were performed in October 2005 and July 2007.) The boundaries of the cap are shown in Figure 2.4-4. Approximately 23 acres of contaminated sediment was capped with 2 feet of sand. More highly contaminated areas were capped with 5 feet of sand. In addition, multiple areas of the cap overlying seeps were constructed with a total of 600 tons of organoclay, a bentonite or hectorite clay altered to be hydrophobic. The cap design incorporated different types of armoring (i.e., articulating concrete block mats and rock) in the nearshore areas to reduce erosion (DEQ 2005).

At the Gasco site in 2005, approximately 15,300 cy of tar-like material and tar-like-contaminated sediment were removed by dredging from the riverbank and nearshore area adjacent to the Gasco facility and disposed of off-site. After the removal action, an organoclay mat was placed along an upper-elevation band of the shoreline dredge cut. This mat was secured with placement of overlying cap sand and quarry spalls. The remainder of the removal area (0.4 acres) received 1 foot of cap sand and 0.5 foot of erosion protection gravel. In addition, 2.3 acres of the area surrounding the removal area received 0.5 foot of “fringe cap” sand material. Construction activities took place between August and October 2005 (Parametrix 2006).

2.4.7 Potential Habitat Restoration Sites

Locations of potential habitat restoration activities constitute valid potential future uses of the Site that should be considered in evaluation of sediment remediation alternatives similar to commercial or industrial uses. In later sections, the draft FS considers whether sediment remediation could preclude potential habitat restoration in some cases. This section reviews locations that have been preliminarily identified as potentially suitable restoration areas within the Study Area.

Several entities, including the City of Portland, USACE, and the Portland Harbor Natural Resource Trustees (PHNRT), have identified a number of sites in the Lower Willamette River, some of which are within the Study Area, which may be suitable for restoration (City of Portland 2008; Tetra Tech 2008; PHNRT 2011). Some of the sites identified by the City and PHNRT are located on active industrial lands and may not be suitable with current or future proposed site uses. Approximately 20 potential restoration opportunities have been preliminarily identified or proposed by various entities within the Study Area (see Table 2.4-3). One potential restoration site located at the confluence of Multnomah Channel, the former site of the Alder Creek Lumber Mill, is in the early permitting stages for development of a restoration project; no other sites within the Study Area have been publicly identified for restoration as of March 2012. The preliminary list of potential restoration sites was obtained from publicly available information on restoration concepts from PHNRT Council, March 2011, Portland Harbor Natural Resource Restoration Portfolio.

The preliminary restoration concepts represented in this list of sites may require excavation in the nearshore area for the purposes of creating a shallower slope in the ACM, removing riprap and upland fill, creating new off-channel habitat through reconnection of the historic floodplain, and improved riparian zone vegetation. Sediment remedial alternatives that provide a suitable final substrate, shoreline slope, and appropriate water depth may be integrated into potential restoration concepts. In other cases, remedial alternatives that limit excavation for restoration purposes or require final surface substrate of large rock may be less compatible with the potential restoration concepts. This issue is considered for each remedial alternative in Section 9.3.7.

2.5 SOURCES AND SOURCE CONTROL STATUS

A successful overall Portland Harbor remedy includes the implementation of effective in-water remedies and upland source control measures. The sediment cleanup should consider and be compatible with upland and upstream source controls so the potential for sediment recontamination following cleanup is minimized. Upland source controls are regulated and determined by the Oregon Department of Environmental Quality (DEQ) working with individual parties along the river and are not part of the SOW for the Portland Harbor Site RI/FS. DEQ's work with these parties on source control is intended to reduce risk to in-water receptors and minimize the potential for the unacceptable recontamination of remediated sediments. Because ongoing sources via groundwater, stormwater, soil erosion, and overwater activities at and upstream from the Site could continue to impact sediment and in-water receptors following remediation, upland source control activities need to be implemented in a timeframe that is consistent with the Site remedy. EPA sediment remediation principles call for source control as a key precept. An important draft FS assumption is that sources will be controlled under the DEQ program at the time of the sediment remedy (EPA 2002b). Therefore, the draft FS does not attempt to determine acceptable levels of upland sources or source controls or targets for specific source control efforts. However, Section 8 of the draft FS evaluates the extent to which known ongoing sources, at a Site-wide scale, are expected to contribute to sediment recontamination.

This section reviews the existing status of sources and source controls within the Study Area and describes, where possible, how quantitative estimates of existing sources were made and the overall results of those estimates of existing sources. In later sections, this existing information is used in combination with the Site contaminant fate and transport model (described in Appendix Ha) to understand and predict the expected future impact of the existing sources on various sediment remedial alternatives. This includes an analysis of the potential future conditions after sediment remediation should sources be reduced by ongoing source control efforts by DEQ.

2.5.1 Source Control Inventory

A source control inventory was completed during the RI. The source control status and inventory tables were developed to summarize the status of source control evaluations, decisions, and measures for upland sites associated with the Study Area. These include sites and shared conveyance systems adjacent to or upstream of the AOPCs identified later in this draft FS as well as upland Oregon Environmental Cleanup Site Inventory (ECSI) sites within the shared conveyance system drainage that discharge to or upstream of these AOPCs. The purpose of these tables (see Appendix Q) is to provide a status of current and potential upland and overwater sources to Portland Harbor to support the potential recontamination assessment in the draft FS.

These tables focus on current sources and potential sources (those that are not yet evaluated) and are not an inventory of historical sources that may have adversely impacted sediment in a particular AOPC. The tables should not be used as a comprehensive inventory of current sources that may be impacting or may have adversely impacted sediments in a particular AOPC. Identification and evaluation of potential sources is an ongoing process.

The tables were created by identifying riverside upland ECSI sites and ECSI sites located within the shared conveyance drainages that discharge within AOPC footprints. The ECSI sites included in the tables rely upon information in the September 2010 DEQ Milestone Report Table 1 (DEQ 2010b), comments provided by EPA and DEQ on November 23, 2010, portions of draft final RI Tables 4.2-2 and 4.4-4, as well as LWG member understanding of their site status. The full tables are provided in Appendix Q, and the January 2012 DEQ Milestone Report is provided as Attachment 1 to Appendix Q. Generally, the tables incorporate current and potential sources from the ECSI sites to the river:

- Riverside sites located adjacent to an AOPC included in the Milestone Report
- Riverside sites located adjacent to an AOPC not listed in the Milestone Report but included in RI Table 4.2-2
- New riverside sites at RM 11.2 located adjacent to AOPC 25 not listed in the Milestone Report
- Sites draining to or upstream of an AOPC through a single or shared conveyance system included in the Milestone Report
- Sites draining to or upstream of an AOPC through a single or shared conveyance system not listed in the Milestone Report but included in RI Table 4.2-2

- Sites draining to or upstream of an AOPC through a single or shared conveyance system included in RI Table 4.4-4.

The tables primarily consist of ECSI sites and City of Portland outfalls within Portland Harbor. Some Toxic Substance Control Act (TSCA) sites and Oregon Department of Transportation (ODOT) outfalls are also included to provide identification of sources to Portland Harbor that is as comprehensive as possible. The tables summarize the status of DEQ source control evaluations, decisions, and measures for sites and shared conveyance systems.

The tables identify the adjacent or nearest downstream AOPC for each area with a potential upland (overland), overwater, stormwater, groundwater, and riverbank erosion source based on the available information for each facility. (The identification and delineation of AOPCs is discussed more in Section 5.1.) These facilities may or may not have pathways with known current sources. It is also possible that there are some currently unidentified sources to the Study Area; however, DEQ's source control program to identify such sources is ongoing. The status of the known pathways (e.g., pathway priority levels of none, low, medium, or high) are provided in the tables and are based on the findings within the September 2010 Milestone Report. The source control status and inventory tables have undergone numerous internal and external review stages including input from LWG members on their specific sites as well as DEQ input on all sites at several stages in the table development process.

2.5.2 Summary Review of Current Known Source Types and Status

This section summarizes current known source types and status based on detailed information contained elsewhere in this draft FS including the source control inventory tables in Appendix Q as well as evaluations of contaminant fate and loading (for some source types) conducted for remedial alternatives evaluation in Section 8 (and associated appendices) in this draft FS. External sources include upstream loading (via surface water and sediment bedload), "lateral" external loading such as stormwater runoff permitted discharges (point-source, non-stormwater), upland groundwater (contaminant plume transport to river), atmospheric deposition (to the river surface), direct upland soil and riverbank erosion, otherwise uncontaminated groundwater advection through contaminated subsurface sediments (chemical partitioning from subsurface sediment to pore water and advection to the surface sediment interval), and overwater releases. Internal sources include surface sediment loading to the surface water via sediment erosion (resuspension) and sediment porewater exchange (chemical partitioning from surface sediment to porewater and advection to surface water), as well as sinks.

The sources evaluated in the draft FS can be generally categorized into those qualitatively assessed versus those sources where quantitative estimates of source loads were possible and integrated into the overall remedial alternative analysis. The following two subsections discuss these two types of source evaluations.

2.5.2.1 Qualitatively Assessed Sources

This subsection summarizes the status of sources that were qualitatively assessed in the draft FS. Qualitative assessments were needed in these cases due to the general difficulty of quantifying such sources on a Site-wide scale. These sources include overwater discharges, overland transport, and riverbank erosion and atmospheric deposition. As discussed in the RI, although these sources have not been quantified, it appears likely that overland transport do not represent a large percentage of the source load to the Study Area. The relative importance of overwater discharges and bank erosion as an overall source is less clear and may be important at the SMA scale.

2.5.2.1.1 Overwater Discharge

Overwater discharges include activities related to overwater activities and marine operations (e.g., dock operations and material or marine fuel transfer). Per the Source Control Inventory in Appendix Q, a summary of the facilities where DEQ identified the potential for overwater sources and/or source controls of this pathway are (Section 5.1 discusses AOPC locations):

- AOPC 3:
  - Schnitzer Steel: general on-water activities
- AOPC 5:
  - Kinder Morgan: dock operations
- AOPC 9D:
  - US Moorings: vessel maintenance activities
  - NuStar (ST Services/Shore Terminal): marine fuel transfer and dock operations
- AOPC 16:
  - Willbridge Bulk Fuel Facilities: marine fuel transfer and dock operations
- McCall Oil: marine fuel transfer and dock operations
- AOPC 17S:
  - Cascade General (Portland Shipyard/Vigor Industrial OU1): overwater ship repair and maintenance operations (see DEQ Milestone Report in Appendix Q)
- AOPC 18:
  - McCall Oil: marine fuel transfer and dock operations

It is also possible that sporadic unintentional overwater sources may occur at other sites as well, but given current regulations and controls, these instances are considered to be infrequent and consequently of little significance in the draft FS but may need to be addressed during remedial design on a localized scale.

2.5.2.1.2 Overland Transport

Overland transport sources include sheetflow or runoff during a storm event from land in areas where contaminants are present in surface soils. A summary of the facilities where DEQ identified the potential for overland transport sources and/or need for source controls of this pathway are:

- AOPC 3:
  - Schnitzer Burgard Industrial Park: The potential for overland transport from this parcel is unknown. DEQ ranks the pathway as a high priority. The source control evaluation for overland transport was anticipated in the fourth quarter of 2010.
  - Schnitzer Steel: Auto shredder residue on ground surface. The source control evaluation for overland transport was anticipated in the fourth quarter of 2010.
  - Premier Edible Oils: Near surface contaminated soil areas in former NW Oil Company tank farm and Oregon Shipbuilding storage facilities southern shoreline, vicinity of former diesel underground storage tanks (USTs), wastewater treatment plant, and former process buildings and truck loading area. DEQ was scheduled to respond to the source control evaluation work plan in October 2010.
- AOPC 9D:
  - US Moorings: Former USTs, electrical transformers, routine vehicle/vessel maintenance activities, historic fill and stormwater outfalls.
  - NuStar (ST services/Shore Terminal): Terminal tank farm.
- AOPC 9U:
  - NW Natural "Gasco" Site: Potential runoff in eastern corner of site will be controlled by future bank remedial work.
- AOPC 11:
  - Mar Com South: Former sawmill, steel fabrication building, former warehouse, machine shop, compressor shed, paint booth, contaminated soil in knoll and southwest corner.
- AOPC 12:
  - Crawford Street Corporation: Historical and current manufacturing operations and site runoff; former UST, electrical transformer, and sandblast fill material
- AOPC 13:
  - Willamette Cove: Impacts to soil from historical industrial activities.
- AOPC 14:
  - GS Roofing: Finished products storage area and landfilled materials.

- AOPC 15:
  - Triangle Park: Contaminated soil entrained in stormwater and sheetflow. Site soils contaminated with PCBs, dioxin, lead, PAHs, and tributyltin (TBT) above Joint Source Control Strategy (JSCS) screening levels.
- AOPC 17D:
  - Triangle Park: Contaminated soil entrained in stormwater and sheetflow. Site soils contaminated with PCBs, dioxin, lead, PAHs, and TBT above JSCS screening levels.
- AOPC 17S:
  - Cascade General (Portland Shipyard/Vigor Industrial OU1): Current shipyard operations.
- AOPC 21:
  - Cascade General (Portland Shipyard) OU2: Impacts to soil from historical operations such as electrical substations, module fabrication/paining, and sandblasting grit storage.

2.5.2.1.3 Riverbank Erosion

Riverbank erosion sources consist of areas where contaminants present in bank soil are a known pathway or have the potential to erode into the river. These contaminated materials may then become a source to downstream and adjacent surface sediments, potentially causing recontamination after remediation. Riverbank erosion of contaminated soils has been determined by DEQ to be a potential concern in the following areas as shown in the CSM (Figure 2.6-2):

- AOPC 1:
  - Evraz Oregon Steel: A source control evaluation completed in May 2006 determined that source control measures for PCBs and metals in riverbank soil are warranted. Source control measures involve targeted removal and bank stabilization. Source control is needed to protect adjacent surface sediment following remediation. Evraz Oregon Steel is working with DEQ on the design and permitting of a remedial action.
- AOPC 3:
  - Schnitzer Steel: A source control evaluation was ongoing for bank erosion as of the fourth quarter 2010. Site COIs include PAHs, total petroleum hydrocarbons (TPH), PCBs, metals, and pesticides. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
  - Premier Edible Oils: As of October 2010, DEQ was to respond to the source control evaluation for bank erosion at this site. Site COIs include metals, volatile organic compounds (VOCs), PAHs, TPH, and pesticides.

- AOPC 5:
  - Kinder Morgan Bulk Terminals: A source control evaluation was ongoing for riverbank erosion as of the fourth quarter of 2010. Site COIs include metals, PAHs, and pesticides. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 6:
  - Port of Portland Terminal 4, Slip 3: A source control evaluation completed in July 2007 and July 2008 determined that source control measures for PAHs in riverbank soil are warranted. Source control measures include excavation, stabilization, and capping. One of three areas was completed in June 2009. The two remaining areas are planned to be implemented with the Terminal 4 Phase II Removal Action, which includes adjacent sediment remediation.
- AOPC 9D:
  - US Moorings: This is an EPA-led upland source control site. A source control evaluation was completed in winter of 2010. The findings were to be determined pending an FS that was recently issued. Until results of the source control evaluation are assessed, it is assumed by DEQ that this bank may be a current source.
  - Foss Maritime/Brix Marine: A source control evaluation was ongoing as of the fourth quarter 2010. Site COIs include metals, TBT, PAHs, and VOCs. DEQ has preliminarily indicated that riverbank erosion is believed not to be a complete pathway. The outcome of the source control evaluation should be reviewed when available to determine if this continues to be an incomplete pathway.
- AOPC 9U:
  - NW Natural Gasco Manufactured Gas Plant (MGP) and Siltronic Sites: A source control evaluation for riverbank erosion is ongoing for the shoreline in this area. It has been broken into three separate segments based on current bank conditions: 1) Segment 2, which is the most downstream section of the Gasco property, 2) Segment 1, which is the upstream portion of the Gasco property and some of the downstream portion of the Siltronic property, and 3) Segment 3, which is an upstream section of the Siltronic property. The COIs in Segments 1 and 2 soils are primarily PAHs and cyanide, although other contaminants have exceeded some JSCS screening levels. Source control measures for bank erosion for Segments 1 and 2 will be designed and implemented as part of in-water sediment remediation under EPA authority. Pursuant to the 2009 Administrative Order on Consent among EPA, NW Natural, and Siltronic (the 2009 Gasco/Siltronic AOC), riverbank remediation along Segments 1 and 2 will take place concurrently with the construction phase of the NW Natural/Siltronic in-water sediment action, both to be overseen by EPA (see Section 2.9 for more information on this process). The

Segment 3 source control evaluation includes characterization of contamination along the Siltronic shoreline. Available data from source control evaluation findings for Segment 3 indicate exceedances of JSCS values in shoreline soils for several contaminants. DEQ is currently evaluating shoreline soil data screening results, and bank erosion source control measures and source control decisions for Segment 3 are still to be determined.

- AOPC 11:
  - Mar Com North: The source control evaluation for riverbank erosion has not begun. The investigation has been deferred to Mar Com South Parcel and DEQ requested the South Parcel owner to conduct this work. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
  - Mar Com South: The site has been divided into operable units. DEQ is awaiting response from Mar Com South site property owner on bank investigation. Site COIs including VOCs, semivolatile organic compounds (SVOCs), PAHs, TPH, PCBs, and metals. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 12:
  - Crawford Street Corp.: The source control evaluation for riverbank erosion was anticipated during second quarter of 2011. In October 2001, black sand was removed from beach and bank, and clean fill was replaced on the bank. Residual contamination existing on the beach could include VOCs, PAHs, TPH, PCBs, and metals. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 13:
  - Willamette Cove: A source control evaluation is ongoing for the bank erosion pathway. Source control evaluation sampling was completed in September 2010. Site COIs include PAHs, PCBs, and metals. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 14:
  - NW Natural Siltronic MGP Site: Source control evaluation is ongoing for Segment 3 (see AOPC 9U description above). Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
  - Arkema: A source control evaluation determined that source control measures for metals and pesticides in riverbank soil are warranted. A draft Riverbank Remedial Alternatives Summary was submitted in October 2009 to DEQ, with

comments received April 2010. A review of riverbank remedial alternatives is to be coordinated with EPA.

- GS Roofing: A source control evaluation work plan for riverbank erosion was in progress as of October 2010. Site COIs include metals and PAHs. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- Willbridge Bulk Fuel Facilities: An assessment report including a source control evaluation was submitted on February 27, 2008. Site COIs include PAHs, pesticides/herbicides, and metals. It is still being determined if source control measures will be needed to protect sediment following remediation, but DEQ has determined this pathway priority as low. The outcome of DEQ’s source control measure decision should be reviewed when available to determine if this is a possible ongoing source.

- AOPC 15:
  - Triangle Park: This is an EPA-led upland source control site. Findings thus far include contaminated soil entrained in stormwater and sheetflow and site soil contaminated with PCBs, dioxin, lead, PAHs, and TBT above JSCS screening levels. An Engineering Evaluation/Cost Analysis (EE/CA) is anticipated to be completed during summer of 2011. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 16:
  - Willbridge Bulk Fuel Facilities: An assessment report including a source control evaluation was submitted on February 27, 2008. Site COIs include PAHs, pesticides/herbicides, and metals. It is still being determined if source control measures will be needed to protect sediment following remediation, but DEQ has determined this pathway priority as low. The outcome of DEQ’s source control measure decision should be reviewed when available to determine if this is a possible ongoing source.
  - McCall Oil: A source control evaluation for bank erosion is ongoing. Completion was anticipated for the first quarter of 2011. Site COIs include SVOCs, PAHs, and metals. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 17D:
  - Triangle Park: This is an EPA led upland source control site. Findings thus far include contaminated soil entrained in stormwater and sheetflow and site soil contaminated with PCBs, dioxin, lead, PAHs, and TBT above JSCS screening levels. An EE/CA is anticipated to be completed during summer of 2011. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.

- AOPC 17S:
  - Cascade General (Portland Shipyard/Vigor Industrial) OU1: A source control evaluation is ongoing for bank erosion, and completion is anticipated in the first quarter of 2012. Site COIs include PCBs and butyltins. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 18:
  - McCall Oil: A source control evaluation is ongoing for bank erosion. Completion was anticipated in the first quarter of 2011. Site COIs include SVOCs, PAHs, and metals. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
  - Front Avenue LP Properties: A source control evaluation was anticipated during the second quarter of 2010. Site COIs are metals. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 19:
  - Gunderson: Source control evaluations are ongoing for bank erosion at areas 1, 2, and 3. Site COIs include VOCs, PAHs, PCBs, and metals. Final source control measures were submitted in August 2011 and are being negotiated between Gunderson and DEQ. Portions of the bank, primarily in Area 3, will need to be remediated to achieve source control.
- AOPC 21:
  - Cascade General (Portland Shipyard) OU 2: A source control evaluation was completed in April 2010. Additional sampling was completed in October 2011. An addendum to the source control evaluation is anticipated in first quarter 2012. Until results of the source control evaluation are known, it is assumed by DEQ that this bank may be a current source.
- AOPC 23:
  - UPRR Albina Railroad: The final RI/Source Control Evaluation was submitted in November 2010 with approval from DEQ in May 2011. Site COIs are metals and total PCBs. DEQ considers this pathway incomplete and its pathway priority as low. The outcome of DEQ's source control decision should be reviewed when available to confirm these conclusions.
- AOPC 24:
  - Sulzer Pumps: A source control evaluation for bank erosion is ongoing. Completion was anticipated in the fourth quarter of 2010. Site COIs include metals and total PCBs. Until results of the evaluation are known, it is assumed by DEQ that this bank may be a current source.

2.5.2.1.4 Atmospheric Deposition

Atmospheric deposition was assessed both qualitatively and semi-quantitatively in the draft final RI. A qualitative summary is included below. See Section 4 of the draft final RI for a more specific evaluation.

As discussed in the RI, air pollution comes from both natural and anthropogenic sources and can be in the form of either gasses or particulates. Similar to historical sources, current regional sources include automotive emissions, pesticide applications, and energy generation. Air pollution (e.g., vehicle and industrial emissions, other combustion products, fugitive dust, etc.) can enter the river directly through the processes of dry and wet deposition.

Chemicals emitted to the air may be transported over long distances, generally in the direction of the prevailing winds. They can be deposited from the atmosphere to land and water surfaces through wet deposition (precipitation) or dry deposition (as particles). Air pollutants can be deposited to waterbodies through either direct or indirect deposition. Direct deposition occurs when chemicals are deposited onto the surface of a waterbody. Indirect deposition occurs when chemicals are first deposited on land and then transported to the waterbody via surface water or stormwater runoff.

Chemicals commonly acknowledged to play an atmospheric source role in urban river settings within the broader geographic region of the Pacific Northwest include PCBs, dioxin/furans, PAHs, and mercury (Integral et al. 2011).

2.5.2.2 Current Known Sources Quantitatively Assessed

This subsection summarizes the status of current known sources that were quantitatively assessed in the draft FS. For these sources, quantitative estimates were made of the source loads currently input to the Study Area based on existing data. Given the size of the Study Area and the many potential specific sources, it is not possible to sample, measure, and directly quantify all inputs for any source. Thus, various methods are used to extrapolate and estimate Study Area loads based on the subset of available data. Also, the quantification was conducted for a subset of contaminants (total PCBs, BaP, and DDE). Selection of these contaminants for this analysis is described in Sections 3 and 4. These estimates are then used later in the draft FS to help quantitatively evaluate the remedial alternatives using the contaminant fate and transport model (see Appendix Ha).[11]

The quantified source types include watershed/upstream, groundwater, stormwater, and National Pollution Discharge Elimination System (NPDES) discharges. Each of these sources is discussed separately in the subsections below. Estimates of these sources have been developed for the 7-year fate and transport model calibration period, and are

[11] Additional contaminants were quantitatively modeled, but not summarized here, and the selection of these contaminants for modeling purposes is described in Section 3 and Appendix C. Thus, some other contaminants (naphthalene, DDD, and DDT) are referred to in this discussion although only results for total PCBs, BaP, and DDE are presented here.

summarized on an annual basis on Figure 2.5-1 (a through c) for the select contaminants. Note that these figures present a comprehensive mass balance for the Study Area developed from the calibrated fate and transport model, as described in Appendix Ha. As such, these figures provide a comprehensive accounting of contaminant sources, including the external sources described above (upstream, groundwater, stormwater, and NPDES process water) and other internal sources such as sediment porewater exchange and sediment erosion, as well as sinks (see Section 2.5.2 for a more detailed definition of external and internal sources). A brief description of the methods used to quantify these various external source terms for the model based on the Study Area data is provided in the subsections below, while a more detailed description is provided in Appendix Ha.

In summary, Figure 2.5-1 shows that for total PCBs and DDE, the loads entering the Study Area from upstream represent a much larger contribution than the other external sources. Internal sediment sources such as erosion and porewater exchange generally represent the next largest source load, while groundwater and process water discharge loads are relatively small in comparison. By contrast, for BaP, internal transport processes (primarily sediment erosion and sediment porewater exchange) represent the largest source of this contaminant to the Study Area. Stormwater discharge loads are comparable to internal sediment loads for total PCBs and to a lesser extent for DDE, but stormwater loading is highly influenced by several specific industrials sites for these chemicals (see Figures 6.1-30 and 6.1-25 in the draft final RI). Generally, much smaller external sources such as stormwater and groundwater should not be a major factor that would cause existing contaminant concentrations within sediments to stay the same or increase over time on a Site-wide basis[12] (see Section 2.6.3 for more discussion on this).

For total PCBs and DDE, the loads entering the Study Area from upstream represent a much larger contribution than the other external sources.

The following subsections describe the general process of identifying and calculating the loads summarized in Figure 2.5-1.

2.5.2.2.1 Watershed/Upstream

River surface water entering the Study Area at RM 11.8 has measurable levels of many of the contaminants found at the Site. These contaminants are sourced from a variety of upstream activities in the watershed that eventually enter the river and make their way downstream to the Study Area. This process and the surface water concentrations measured upstream of the Study Area are described more in the RI. Quantification of this source was conducted in context of the draft FS contaminant fate and transport model using the empirical data from the RI. In summary, contaminant loads entering the Study Area from upstream were characterized in the RI by water column transect sampling data collected at RMs 11 and 16; therefore, this same water column dataset was used to establish the upstream boundary condition in the Portland Harbor contaminant fate model (see Appendix Ha). The general approach used to specify the contaminant concentrations upstream of the Study Area for the model was based upon relationships between

[12] These external sources may have impacts on a localized scale.

contaminant concentrations and river flow rate. Specifically, concentrations of each contaminant were plotted against flow measured on the date of sampling, and regressions were performed. These regression results were reviewed, and if a relatively strong, positive relationship existed between flow and concentration, the regression equation was used to calculate daily contaminant concentrations at the upstream boundary as a function of river flow. For those contaminants that demonstrated relatively poor relationships with flow, average concentrations measured during high and low flow were used to represent the upstream concentration for these contaminants. Once these relationships were defined, they were used to estimate upstream contaminant concentrations for any given flow rate in the river; from this, upstream contaminant loads were calculated over the 7-year model calibration period by multiplying daily flows and concentrations, and then summing. Additional detail regarding the calculation of upstream contaminant loads is provided in Section 3.2.1.1 of Appendix Ha.

2.5.2.2.2 Groundwater

An analysis of groundwater flows into the river near currently known or suspected upland contaminated groundwater plumes was conducted during the RI to identify where such upland groundwater plumes might be discharging to the river at measurable levels. Where discharges to the river were found and determined to impact TZW, these are referred to as “complete” upland contaminated plume pathways in the RI (see RI Appendix C2). Contaminated groundwater discharge areas with complete flowpaths were found on the west side of RM 6 to 8. In these areas, the average expected groundwater COI concentrations were calculated based on filtered trident and peeper data (discussed more in the RI Section 5.4 and Appendix C2) collected from TZW in sediments offshore of these areas. In areas of complete upland groundwater plume flowpaths, contaminant concentrations were combined with estimates of groundwater flow rates up through the bottom of the river (Figure 2.1-7) to provide loading estimates of each contaminant in these areas. Groundwater loading estimates were input to the Portland Harbor fate and transport model for naphthalene, BaP, DDD, and copper, which have groundwater-related upland plumes. The rationale for selection of contaminants for modeling is described in Appendix C. (Modeling to address whether several other groundwater sourced contaminants could be effectively remediated using sediment technologies after upland source controls were in place was also conducted and described in Appendix Hc.) The groundwater loads specified in the fate model were developed based on multiplying the measured concentrations in plume areas (as discussed in Section 2.2.3) by estimates of spatially varying groundwater flow (Figure 2.1-7). Additional detail regarding specification of groundwater loading in the fate and transport model is provided in Section 3.2.3.3 of Appendix Ha. It should be noted that the groundwater source term shown on Figure 2.5-1 (labeled as “Groundwater” on this figure) includes contributions from both upland groundwater plume sources described here, but also includes an internal groundwater advection source (i.e., loading to the system resulting from movement of groundwater through contaminated sediments). The contaminant contribution from groundwater (both upland groundwater and internal groundwater advection) is relatively small and does not affect the relative comparison of source loads discussed in this section.

2.5.2.2.3 Stormwater

Loads associated with current known stormwater inputs from the Study Area shorelines were estimated according to the *Stormwater Loading Calculation Methods Report* submitted to EPA in April 2011 (Anchor QEA 2011a). These estimates were approved by EPA for use in the draft FS and fate and transport model (EPA 2010d). A land-use-based contaminant loading approach was used to estimate loads across the entire Study Area. This approach used land use characteristics and acreages (e.g., areas of types of land use such as heavy industrial, light industrial, residential, major transportation corridors, and open space as well as percent impervious surface) in upland areas draining stormwater to the Study Area to estimate land-use-specific stormwater concentrations and flow rates, which were multiplied together to produce loadings. The Study Area shoreline was broken into segments for the purpose of estimating the stormwater loads (Figure 2.5-2). The abbreviation "FT" on the figure designates the basin draining to that segment of the river and its corresponding input into the fate and transport model. For each segment of shoreline, the total amount of each land-use type draining to each segment, and its associated load, was determined and combined across all land use types draining to each segment to provide an overall stormwater load estimate for each segment.

The stormwater concentration assigned to each land use type, which was then multiplied by flow to produce a loading per the above process, was determined by sampling 31 select outfalls or locations, each of which predominantly drains one of the land use types or specific industrial location. The stormwater sampling, analysis, and loading rate determination is described more in the RI and *Stormwater Loading Calculation Methods Report* (Anchor QEA 2011a). For each of the modeled contaminants, the resulting loads for each shoreline segment were input to the in-river contaminant fate and transport model on a time-varying basis consistent with expected seasonal variations in stormwater runoff flow.

As described in Anchor QEA (2011a), stormwater loads were computed using two types of measurements (composite water samples and sediment trap samples). For each of these datasets, stormwater loads were calculated using several different statistics in order to represent a range of central tendencies. Ultimately, composite water loads based on statistics averaged by site and then weighting by the amount of runoff (i.e., basin-weighted average) were selected for use in the contaminant fate model (a discussion of the rationale for this selection is provided in Section 3.2.3.1 of Appendix Ha). Additional detail regarding specification of stormwater loads in the fate and transport model is provided in Section 3.2.3.1 of Appendix Ha.

2.5.2.2.4 Process Water Discharges (NPDES)

As described in the RI, there are 14 NPDES-permitted industrial process water discharge permits in the Study Area. These process water permits and discharge monitoring reports were reviewed to estimate potential loading rates from these process water discharges for the contaminants on the modeling list. Most of the permits do not call for monitoring of the specific contaminants on this list, and therefore, do not have any permit limits or other information for those contaminants. The Koppers facility has an NPDES permit that includes monitoring and permit limits for one of the contaminants (BaP) on the modeling list. For this facility, the annual load of BaP was estimated at 0.05 kg/yr based on the NPDES discharge monitoring report (DMR) data obtained for the facility.[13] This load was entered into the contaminant fate and transport model cell located at the facility's discharge location, assuming the discharge takes place constantly and continuously over each model year. [14]

2.5.2.2.5 Quantitative Source Loading Summary

Table 2.5-1 summarizes the estimated annual contaminant mass loadings to the Site over the 7-year model calibration period for the various sources and contaminants discussed in this section.

2.6 CONCEPTUAL SITE MODEL SUMMARY

The CSM integrates the information gathered through extensive physical, chemical, and biological characterizations to provide a coherent hypothesis of the Site relevant to development of the draft FS including current Site conditions, potentially unacceptable risks posed, and currently known or suspected ongoing sources. It is a refinement of the CSM presented in the draft final RI. These refinements include some changes to certain technical information based on draft FS analyses as well as a condensation of RI CSM features so that the CSM is more focused and useable for the draft FS. The draft FS CSM is summarized visually through three key figures:

- Figure 2.6-1, from the RI, provides an overall visual summary of currently known or suspected contaminant sources, fate and transport processes, and contaminant interactions with humans and ecological receptors that result in potentially unacceptable risk.
- Figure 2.6-2 provides a visual summary of the major Site physical and contaminant conditions most relevant to the draft FS as described in Sections 2.6.1 and 2.6.2.
- Figure 2.5-1, already presented above, provides a visual summary of currently known or suspected contaminant source loads and the fate and transport of contaminants (in terms of loads) within and exiting from the Site as described in Section 2.6.3.

[13] Since October 2008, flows have been diverted to the municipal wastewater treatment plant.

[14] In addition to BaP, NPDES process and stormwater discharge loads were also calculated for arsenic, copper, and mercury; loads for these contaminants are summarized in Section 3.2.3.2 of Appendix Ha.

2.6.1 Physical Setting

This physical configuration and the associated hydrodynamic interactions result in deposition and accumulation of sediments in much of the Study Area (i.e., bathymetry measurements indicate 88 percent of the Study Area is depositional or shows no substantial change over the period measured).

The Site is in a relatively low-energy depositional reach of the Lower Willamette River and the entire Willamette River Watershed. The sections of the river upstream (from approximately RM 11 to the Willamette Falls at RM 26) and downstream of the Study Area (RM 1.9 to the Columbia River) are narrower than the Study Area, and the Multnomah Channel exits the Lower Willamette River at RM 3, reducing the Lower Willamette River discharge downstream of this point. This physical configuration and the associated hydrodynamic interactions result in deposition and accumulation of sediments in much of the Study Area (i.e., bathymetry measurements indicate 88 percent of the Study Area is depositional or shows no substantial change over the period measured). This creates prominent channel shoals from RM 2 to 3 and RM 8 to 10 (Figure 2.6-2). Some channel segments are more dynamic, and localized areas in these regions exhibit both net erosion as well as net deposition (Figure 2.6-2). Nearshore and off-channel areas are generally depositional. Some of the nearshore areas where vessels transit to nearshore docks are subject to anthropogenic sediment resuspension (e.g., vessel propwash); removal of sediments through maintenance dredging may also occur in these areas (indicated by Future Maintenance Dredge areas in Figure 2.6-2). Since 1997, selective maintenance dredging has been performed in the federal navigation channel. Very close to shore in shallower water, sediment resuspension from wind and vessel wake generated waves occurs (Figure 2.6-2). These off-channel areas tend to have a higher incidence of debris in and on the surface sediment. Shoreline areas have numerous structures and other anthropogenic features, which are important factors in determining remedial alternative feasibility (Figure 2.6-2).

2.6.2 Chemical Distribution

Elevated concentrations of contaminants in the Study Area are typically associated with areas near currently known or likely historical and/or existing sources. Figure 2.6-2 shows the surface sediment areas (i.e., AOPCs; see draft FS Section 5) that most often exceed a range of sediment PRGs that were developed for the draft FS (and described more in Section 3). Although the highest sediment concentration levels for the bounding ICs are found in nearshore areas, somewhat elevated levels of the bounding ICs are found in the higher energy portion of the channel in the middle of the Study Area (RM 5 to 7). This may reflect past or current dispersal of material away from nearshore source areas. Throughout the Study Area, contaminant concentrations are generally higher in subsurface sediments than in surface sediments, indicating both higher historical contaminant inputs and improving sediment quality over time (see draft final RI and draft FS Section 6.2.2 for more detail on sediment trends over time). Localized exceptions to the pattern of higher subsurface sediment concentrations exist in a few areas for some contaminants, likely reflecting more recent releases and/or disturbances of bedded sediments. Also, the depth of subsurface contamination is generally greater in nearshore areas as compared to the navigation channel (see Section 5.6).

Areas with elevated contaminant concentrations in surface sediments generally correspond to areas of elevated subsurface sediment contaminant concentrations, particularly in nearshore areas. Areas where only surface or subsurface sediments exhibited elevated concentrations of contaminants point to spatially and temporally variable inputs and sources, or to different influences from sediment transport mechanisms. Per the RI, the PCB distributions in areas of elevated PCB concentrations are generally distinct from those in surrounding areas of lower PCB concentrations. Within areas of elevated PCB concentrations, the PCB patterns in surface and subsurface sediment, sediment traps, and in the particulate portion of the surface water samples are often similar. A similar pattern and similar composition across media was observed to a lesser degree for PAHs, but was less apparent for dioxins/furans or DDx compounds.

Most areas of elevated contaminant concentration in bedded sediment are located in relatively stable nearshore areas, and large-scale downstream migration/dispersal of concentrated contaminants from these areas is not indicated by the bedded sediment data. Much larger historical direct discharges from upland and overwater sources, rather than reworking of bedded sediments, are believed to have produced some of the observed patterns (e.g., elevated levels in subsurface sediments downstream of the source areas). Limited ongoing downstream dispersal of contaminants in sediments is suggested based on bedded sediment concentration gradients downstream of areas with elevated sediment concentrations.

Most areas of elevated contaminant concentration in bedded sediment are located in relatively stable nearshore areas, and large-scale downstream migration/dispersal of concentrated contaminants from these areas is not indicated by the bedded sediment data.

2.6.3 Sources, Fate, and Transport

Most of the sediment contamination at the Site is associated with known or suspected historical sources and practices that have largely been discontinued or otherwise controlled. As discussed previously, historical industrial activities and facilities in the Site and upriver areas date back to the late 1800s and include ship building, repair, and dismantling; wood treatment operations and lumber mills; bulk fuel facilities and manufactured gas plants; chemical plants; steel mills; metal recycling; rail yards; electricity generation and distribution; and other urban and industrial activities. These activities have primarily contributed to the current contaminants observed in sediments and associated risks discussed in the next section. However, more important than the history of contaminant sources to conducting a sediment FS is determining the current locations of unacceptable contaminant concentrations and current ongoing sources that may either: 1) maintain unacceptable in-river contaminant levels;

Most of the sediment contamination at the Site is associated with known or suspected historical sources and practices that have largely been discontinued or otherwise controlled.

and/or 2) potentially contribute to unacceptable sediment or water recontamination after sediment remedies are performed. The RI/FS has catalogued or estimated historical and current sources of contaminants to the Study Area; however, not all sources have been identified.

For PCBs and DDx, the main external ongoing sources quantified for the draft FS are upstream surface water inputs encompassing all upstream watershed sources, and at the Study Area, local stormwater (Figures 2.5-1a-c and Table 2.5-1). This association is likely true for other persistent bioaccumulative compounds that were not quantified here, some of which, like dioxin/furans, are substantial contributors to potential Site risks discussed in the next section. Although the mass of PCBs and similar compounds entering the Site from upstream is relatively large (due to the large flow volume of the river), the concentration of these contaminants in upstream suspended sediments in surface water entering the Site is relatively low compared to current bedded sediment concentrations in portions of the Site posing the greatest risks (see below as well as Section 6.2). The concept of high loads, relative to other sources, and simultaneously low in-river concentrations in the Study Area appears to be true for both the upstream surface water and within Study Area stormwater inputs. Model results indicate that the influence of stormwater loads on surface water concentrations is quickly attenuated across and downstream through the Study Area due to the large volume of flows in the river (modeling in Appendix Ha and the discussion of the modeling in Section 8 and 9 helps to further describe and quantify this effect). However, stormwater sources may have localized impacts on bedded sediment concentrations, although this effect is difficult to quantify on the scale of the entire Site. Some unquantified source terms, e.g., bank erosion, may also be important in localized areas.

The high load/low concentration inputs, particularly of upstream surface water and stormwater, likely account for the low concentrations of PCBs, DDx, and dioxins/furans in bedded sediments (which are comparable to upriver bedded sediment levels; Appendix A) seen across much of the Study Area, while the distribution of elevated concentrations of these contaminants in sediments in several nearshore portions of the Study Area appears to reflect more significant historical localized lateral inputs. The spatial correlation between elevated levels of PCBs in tissues with elevated concentrations in sediments suggests that bottom sediments are an ongoing source of PCB contamination to biota, and this may be true for some other persistent bioaccumulative contaminants such as DDx and dioxin/furans.

The high load/low concentration inputs, particularly of upstream surface water and stormwater, likely account for the low concentrations of PCBs, DDx, and dioxins/furans in bedded sediments seen across much of the Study Area, which are comparable to upriver bedded sediment levels, while the distribution of elevated concentrations of these contaminants in sediments in several nearshore portions of the Study Area appears to reflect more significant historical localized lateral inputs.

For PAHs, model results for naphthalene and BaP represent sources, fate, and transport for low molecular weight PAHs (LPAHs) and high molecular weight PAHs (HPAHs), respectively. External sources differ substantially for LPAHs and HPAHs. Both these contaminants (i.e., naphthalene and BaP) are modeled and discussed more in Appendix Ha. For LPAHs, the main external ongoing sources are advection from subsurface sediment to surface sediment, upstream surface water inputs encompassing all upstream watershed sources, and local groundwater plumes (Appendix Ha). For HPAHs (i.e., BaP), the external ongoing sources quantified for the draft FS are all relatively minor, with upstream surface water inputs being the largest. For BaP, the model results indicate that internal transport processes (primarily sediment erosion and sediment porewater exchange with the water column) represent the largest sources of BaP to the Study Area (Figure 2.5-1).

Patterns of bedded surface sediment contamination suggest some redistribution of contaminants over time from past source areas, but this is limited by ongoing burial of much of the source area contamination (as indicated by higher subsurface sediment concentrations in these areas).

The magnitude of various internal fate and transport processes for contaminants within the Study Area is generally summarized in Figure 2.5-1. The major internal fate and transport processes are erosion from the sediment bed, deposition to the sediment bed, dissolved flux from the sediment bed (porewater exchange), groundwater advection, degradation for some contaminants, volatilization to the air, and downstream transport of either particulate or dissolved phase associated contaminants. These processes interact to create potentially complex patterns of contaminant redistribution within the Study Area that are not easily described because they vary over space, time, and by contaminant. However, they can be estimated through the contaminant fate and transport modeling for different classes of contaminants (see Appendix Ha). As noted above, patterns of bedded surface sediment contamination suggest some redistribution of contaminants over time from past source areas, but this is limited by ongoing burial of much of the source area contamination (as indicated by higher subsurface sediment concentrations in these areas). It should be noted that there is little in the empirical information from sediment contaminant profiles or fate and transport modeling results to suggest that buried contamination is a substantial or ongoing source to surface sediment contamination, through dissolved phase advection or any other process, over the vast majority of the Study Area. In some limited cases, periodic erosion may have the potential to temporarily expose buried contamination, as discussed more in Section 5.6. Specifically, most evidence supports that the generally Site-wide (with localized exceptions) burial process acts like a natural cap to much of the buried contamination. As noted above, groundwater plume advection and release has been observed in a few areas, and appears to be a relatively important process for certain LPAHs (e.g., naphthalene) in some locations along with dissolved phase flux from surface sediments to the water column. Also, per the RI some other groundwater sourced contaminants have the potential to create in-river risk in specific localized areas, which indicates the need for upland groundwater source controls at those specific sites. In addition, RI surface water data suggest that resuspension and/or dissolved phase flux from the sediment bed are contributing to elevated contaminant levels in surface water, particularly in quiescent areas where surface water mixing and dilution is reduced. Loading estimates presented in Figure 2.5-1 are consistent with this concept, indicating the mass flux of contaminants exiting the downstream end of the Study Area in surface water (either directly to the Columbia River or via Multnomah Channel) is greater than the flux entering the Study Area. Stormwater inputs appear to be a relatively minor factor in determining in-river surface water concentrations except at RM 3 to 4 (International Slip) in the case of PCBs (see Appendix Ha, Table 6.2-1a). Stormwater loading for PCBs at RM 3 to 4 east is primarily responsible for the increased surface water flux due to stormwater that occurs throughout the Site (see Appendix Ha, Figures 3.3-43b to 3.3-43c, and Figure 6.2-1).

The food web model projects that fish tissue concentrations will decline over time as sediment concentrations decline.

Finally, empirical tissue contaminant data and food web modeling (described more in Appendix Hb) indicate that persistent contaminants (particularly PCBs and dioxin/furans) in sediments and surface water is bioaccumulated into aquatic species tissue. This process occurs into and through the food chain from contaminants present in both sediment and surface water matrices. Given the contribution of sediment contaminants to surface water contaminant levels within the Site, as noted above, determining the exact contribution of sediment versus surface water contaminants to tissue is a complex exercise. The food web modeling runs project that fish tissue concentrations will decline over time as sediment concentrations decline. Active sediment remediation is projected to yield lower tissue concentrations than natural recovery in some segments of the Site. This is explored further in Section 8 and 9 of the draft FS. These tissue levels are discussed in the next section in terms of the risk they are estimated to potentially pose to human health and ecological receptors.

2.6.4 Current and Likely Future Risk

Figure 2.6-1 depicts how people and ecological receptors in the Site may interact with the contaminants discussed in the previous sections resulting in potentially unacceptable risks that exceed EPA target levels in some cases. Total PCBs were found to account for more than 90 percent of the potentially unacceptable risk posed to human health from fish consumption, which is the scenario resulting in the highest risks of those evaluated in the BHHRA.

Human Health

The BHHRA identified a total of 29 contaminants (as individual chemicals, intermediate sums, or totals) that pose potentially unacceptable risk to human health across all potential exposure routes (i.e., direct contact with sediments/water and fish/shellfish consumption, breast feeding), including metals, PAHs, PCBs, dioxins and furans, DDT and other pesticides, polybrominated diphenyl ethers (PBDEs), and single phthalate, SVOC, phenol, and herbicide compounds.

Fish consumption is the exposure scenario accounting for the majority of risks to human health in the Study Area. PCBs contribute the majority of the total cancer risk for the fish tissue consumption pathway (both whole body and fillet tissue) on a Study Area-wide exposure area basis and are the primary contributor to risk under this exposure scenario. Dioxins and furans are the secondary contributor to risk. PCBs contribute approximately 93 percent of the cumulative cancer risk, and dioxins/furans contribute approximately 5 percent of the cumulative cancer risk for Study Area-wide whole body fish tissue consumption. For fillet tissue consumption, PCBs contribute approximately 97 percent of the cumulative cancer risk, and dioxins/furans contribute approximately 2 percent for Study Area-wide exposure. The remaining contaminants of potential concern (COPCs) for Study Area-wide fish consumption account for less than 2 percent of the cumulative cancer risk. PCBs and dioxins/furans also resulted in the highest hazard quotients (HQs) for Study Area-wide fish tissue consumption. In some cases in the Portland Harbor, contaminants contributing most to cumulative risks differ between localized exposure areas.

Direct contact with sediment, surface water, or seeps in the Site was found to not result in potential cancer risks exceeding EPA's target range of 1×10^{-6} to 1×10^{-4} (between one in a million and one in ten thousand chance of getting cancer beyond normal cancer risks) with the exception of two half-river-mile segments for direct contact with sediment by a Tribal fisher (potential cumulative cancer risks from the reasonable maximum exposure scenario are 2×10^{-4} and 3×10^{-4} at RMs 6 west and 7 west, respectively), and one exposure area for hypothetical domestic water use (potential cumulative cancer risks range from 3×10^{-4} to 9×10^{-4} for various receptors at RM 6). These potentially unacceptable risks were primarily from cPAHs (RM 6 west) and dioxins/furans (RM 7 west). The direct contact scenarios were also found to not result in noncancer hazards above the EPA target hazard index (HI) of 1, with the exception of one half-river mile segment for in-water sediment and two locations for hypothetical use of untreated surface water as a drinking water source.

For fish consumption, the potential cancer risks were estimated to be in the range of 3×10^{-6} to 7×10^{-2} and the noncancer HI ranged up to 5,000. However, regional tissue concentrations of PCBs also were found to result in potential human health risks above EPA target levels through fish consumption under the assumptions made in the BHHRA to calculate risks. In addition, concentrations of contaminants in upstream surface water entering the Site, even in the absence of any contaminants in Site sediments, were calculated to result in potential human health risks above EPA target levels via fish consumption due to PCBs, dioxin/furans, and several other contaminants.

PCBs are also the most significant contributor to the estimated ecological risks, with the mink population being the receptor most at risk from PCB exposure, with a Site HQ ranging up to 33. PCB risks to spotted sandpiper and bald eagle are elevated, but not as high as for mink. Along with PCBs, a relatively large number of other chemicals (e.g., PAHs and DDTs) were correlated with toxicity to benthic (i.e., bottom-dwelling) invertebrates in areas ranging across the Site and constituting approximately 5 percent of the Site. The potentially unacceptable risks to fish from PCBs and other Site-related contaminants were estimated to be negligible.

Ecological

The BERA identified a total of 89 contaminants (as individual chemicals, sums, or totals) that pose potentially unacceptable risk. The likelihood and ecological significance of the potentially unacceptable risk varies across COPCs and lines of evidence from very low to high. Therefore, the potentially unacceptable risks range from negligible to significant. The primary risk of ecologically significant adverse effects on ecological receptors in the Study Area is from four groups of contaminants: PCBs, dioxins and furans, PAHs, and DDx compounds. The identification of the primary contributors to risk is consistent with EPA risk assessment guidance and is not intended to suggest that other contaminants in those areas, and generally in the Study Area, do not also present potentially unacceptable risk.

Potentially unacceptable PCB risks occur throughout the Study Area for mink and for river otter, indicating possible population-level effects expressed as reduced reproductive success. Reproductive success in spotted sandpiper, bald eagle, and osprey might also be reduced because of PCB exposure throughout the Study Area for spotted sandpiper and bald eagle and, over a smaller area, for osprey. The potential for adverse effects in fish due to exposure to total PCBs is low. Overall, a greater degree of uncertainty is associated with PCB risk estimates for birds than for mammals because of uncertainty about both exposure and the effects data. Uncertainty is higher for otter than for mink because otter-specific effects data are not available.

The combined toxicity of dioxins/furans and dioxin-like PCBs, expressed as TEQ, poses the potential risk of reduced reproductive success in mink, river otter, sandpiper, bald eagle, and osprey. Dioxin-like PCBs are responsible for the majority of the potentially unacceptable TEQ risk, but dioxins and furans contribute as well in some locations of the Study Area. As was the case for total PCBs, a greater degree of uncertainty is associated with TEQ risk estimates for birds and otter than for mink.

DDx compounds pose low to negligible risk of reduced reproductive success to individual bald eagles and Pacific lamprey ammocoetes and only within limited portions of the Study Area. DDx risk to sculpin and spotted sandpiper populations was assessed to be negligible based on the weight of evidence.

Contaminant concentrations in TZW were compared to surface water effects thresholds to predict risk to benthic invertebrates, fish, amphibians, and aquatic plants. TZW risks were evaluated in a focused study of only nine locations in the Study Area with known or likely pathways for discharge of contaminated upland groundwater to the Study Area. Fifty-eight COPCs measured in TZW have baseline HQs greater than or equal to 1. TZW exceedances are localized, indicating that none of the TZW COPCs is likely to pose risk to Study Area benthic invertebrate communities or fish populations. Risks to amphibians and plants are even lower because the species in the Study Area are unlikely to use the habitats where contaminated groundwater discharges. Thirty-eight TZW COPCs, including 6 metals, 16 PAHs, 2 SVOCs, 2 pesticides, 10 VOCs, cyanide, and perchlorate, pose potentially unacceptable risk to Pacific lamprey ammocoetes in localized areas. However, compared to other aquatic species, lamprey ammocoetes have average or lower sensitivity to chemicals that cause toxicity across several different modes of action; the water TRVs are thus conservative for lamprey ammocoetes. Given their feeding habits and the low oxygen levels at the depths represented by the TZW samples, lamprey ammocoetes have relatively low exposure to TZW compared with surface water in the hyporheic zone; thus, the exposure estimates, too, are conservative.

COPCs occur at concentrations that are projected to pose unacceptable benthic risks for about 7 percent of the Study Area. Unlike other ecological receptors, for which risk was evaluated on a chemical-specific basis, risk to the benthic invertebrate community was evaluated in large part by considering exposure to the mixture of chemicals present in the Study Area sediments. The COPCs in sediment that are spatially associated with locations of potentially unacceptable risk to the benthic community or populations are PAHs, PCBs, and DDx compounds.

2.7 DESCRIPTION AND STATUS OF OTHER PORTLAND HARBOR REMEDIAL ACTION OR REMOVAL ORDERS

Within Portland Harbor, separate removal or remedial action orders have been executed by EPA with individual LWG members for three specific sites or AOPCs. As discussed in the *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005a), such orders can help expedite and inform Site-wide sediment cleanup and result in cleanup of some locales earlier in the overall CERCLA process prior to, during, or immediately after execution of a Site-wide ROD. The specific AOPCs or portions of AOPCs under these separate orders are:

1. AOPC 6 – Terminal 4 (conducted by the Port of Portland)
2. AOPC 9U – Gasco and Siltronic (conducted by NW Natural and Siltronic)
3. AOPC 14 – Arkema (conducted by Arkema)

The locations and extents of these AOPCs are described more in Section 5.

These projects are currently in various stages of completion, as described below. In addition, as part of draft FS scoping, EPA clarified in a February 25, 2011 letter (EPA 2011b) regarding "Schedule for Remedial Investigation (RI) and Feasibility Study (FS)" that:

> "*As a reminder, it is LWG's responsibility to include all areas under early action evaluation in the draft Feasibility Study, including Terminal 4, Gasco/Siltronic, and Arkema. We expect that each LWG member working under an AOC is providing all information to the LWG for incorporation into the draft FS. The Harbor-wide FS must weigh alternatives wherever COCs are above acceptable risk levels. Specific information should also be solicited from each project...The early action work should*

help the LWG produce more robust alternatives analysis for these areas, and better cost estimates."

Consequently, this draft FS includes each of these three AOPCs or portions of those AOPCs covered by these separate orders in the development and detailed evaluation of alternatives. The draft FS evaluation was conducted using the most recent information available for each of these areas and was performed using methods that were consistent with the Site-wide evaluation. The situations for each of the individual orders vary somewhat as described below. To the extent that detailed designs were available for these areas at the time the draft FS was being prepared, such design features were carried forward into the draft FS evaluation. However, the Gasco and Terminal 4 projects specifically contemplate alternatives so that: 1) the scope of such actions are consistent with the draft FS evaluations; and 2) the designs selected by EPA can be described as a component of the remedy in the Portland Harbor-wide ROD, allowing construction of the approved separate order designs to proceed after the ROD is executed. Each of the actions under separate orders is described in more detail below in the context of this process.

2.7.1 Terminal 4

The Port of Portland has been implementing a removal action at Terminal 4 pursuant to an AOC. The Terminal 4 removal action selected by EPA includes a combination of MNR, capping, and dredging, with placement of contaminated sediment in a CDF to be built in this area. EPA consulted with its federal, state, and tribal partners in making its non-time critical removal action decision under its CERCLA authorities. Implementation of the removal action is occurring in two phases, because the CDF is linked to the overall Portland Harbor-wide FS and ROD. A majority of the Terminal 4 CDF capacity is anticipated to be reserved for non-Terminal 4 sediments. Thus, many of the CDF design items are dependent upon harbor-wide decisions that will be made by EPA in the ROD.

A Phase I Abatement Measure was completed in 2008 (see Section 2.4.6). The post-construction sediment data collected in this area were included in the draft FS database, and this area was evaluated in the draft FS using methods similar to all other Site-wide areas to determine if any additional remediation may be necessary in this area under the ROD. In January 2010, EPA made the decision to implement Phase II after the harbor-wide ROD, including the final CDF design, construction, and remaining actions at Terminal 4. A primary reason the EPA realigned the Phase II schedule was to provide better integration of the CDF design with the harbor-wide FS to allow the EPA to better evaluate the protectiveness and cost-effectiveness of the CDF alternative and select or change this alternative in the harbor-wide ROD. The Terminal 4 CDF 60 Percent Design document has been completed, and this information was used in this draft FS. The Terminal 4 CDF is included as a specific disposal site option in a number of draft FS alternatives to allow EPA to evaluate and select the final remedial action at Terminal 4 consistent with the harbor-wide ROD (Anchor QEA 2011c). Alternatives not involving a CDF in this area are also evaluated in the draft FS for comparative purposes, and in these cases remediation of this area is evaluated consistent with the rest of Portland Harbor in accordance with EPA's direction on this draft FS (EPA 2011b) and the Terminal 4 order.

2.7.2 Gasco and Siltronic

NW Natural and Siltronic are preparing remedial design documents for sediments adjacent to the Gasco and Siltronic facilities under the 2009 Gasco/Siltronic AOC. The remedial design for the Gasco and Siltronic facilities is being developed to be consistent with the harbor-wide FS, and will ultimately be directly incorporated into the harbor-wide remedy decision to be identified in the ROD. To achieve the desired consistency and integration of these actions, the analysis of remedial alternatives in this draft FS includes a detailed evaluation of sediments near the Gasco and Siltronic facilities. Under the Gasco and Siltronic order, an EE/CA is being developed simultaneously with the development of this draft FS, and is thus generally consistent with this draft FS for the Portland Harbor Site. However, as discussed in more detail in Section 2.8, Gasco and Siltronic collected additional data after the harbor-wide FS database was locked down. Therefore, areas and volumes of this SMA in the EE/CA for this site and this draft FS will vary, potentially causing variation in the evaluation of alternatives across the two documents. It is expected that this new Gasco and Siltronic data will be reflected in EPA's Proposed Plan as well as the final FS for Portland Harbor. Development of the Gasco and Siltronic remedy design will proceed after EPA comments on the project-specific EE/CA, and that design will consider and integrate EPA comments on this draft FS as well. The end result of this process will be a remedial design in the harbor-wide Proposed Plan, final FS, and ROD that is consistent with the Gasco and Siltronic-specific final design. The remedial action to be selected in EPA's ROD for the Gasco and Siltronic sediments will subsequently be implemented pursuant to a consent decree following completion of any necessary upland Gasco and Siltronic source control work being managed by DEQ and after completion of upstream remedial actions necessary to prevent recontamination.

2.7.3 Arkema

Under an AOC with EPA, Arkema is performing site characterization and initial design evaluations for an EE/CA, which will evaluate alternative non-time critical removal action (NTCRA) responses to address DDx detected in sediments adjacent to the Arkema facility. The EE/CA is being performed pursuant to EPA's removal authority. In this draft FS, the area inside the prospective Removal Action Area boundary was evaluated using methods consistent with the Site-wide evaluation approach. However, specific features of the evolving Arkema EE/CA design that were available at the time of writing this draft FS were carried forward in this document. This includes an Arkema CDF option in some draft FS alternatives. For the areas outside the prospective Removal Action Area boundary, the draft FS evaluates these areas using methods consistent with those for other areas of the Portland Harbor Site. Similar to the rest of the Portland Harbor Site, these sediments will ultimately be remediated according to ROD requirements, as necessary. The final remedial action identified for this AOPC in the ROD will be constructed pursuant to a consent decree following issuance of the ROD, completion of appropriate Pre-remedial Engineering Design Studies, and following the demonstration of adequate upland source control for groundwater, soil, and stormwater discharges. Source control efforts associated with the specific, yet to be determined, AOPC are being managed by DEQ.

2.8 DESCRIPTION OF FS DATABASE

As discussed in detail in the draft final RI (Integral et al. 2011), environmental data have been collected within the Portland Harbor Site during numerous LWG sampling events since the inception of the Portland Harbor RI/FS process in 2001. These data, along with data from historical and concurrent studies by other parties in the Lower Willamette River constitute the Portland Harbor Site Characterization and Risk Assessment (SCRA) database. The Portland Harbor SCRA database consists of over 1 million analytical results representing a variety of sample matrices dating back to 1969. The most recent data in the FS database were collected in March 2010 and were added to the SCRA database on February 4, 2011.

Environmental datasets in the SCRA database have undergone rigorous data quality review and meet the data quality objectives established for the project in the Programmatic Work Plan (Integral et al. 2004; see RI). The SCRA database is the basis for defining the nature and extent of the contaminants and provides foundational information from which decisions are made regarding human health and ecological risk within the Site, as well as the development of remedial alternatives for the draft FS. For the RI, the BERA, BHHRA, and draft FS, a date of May 1, 1997 was used to define the initiation of the sediment dataset to follow the last major flood of the Willamette River in the winter of 1996.

The Portland Harbor SCRA database was transmitted to members of the LWG RI and risk assessment teams on June 2, 2008. These data were used in the draft and revised draft final RI and risk assessments. The RI, BERA, and BHHRA database managers separately queried the Portland Harbor SCRA database to derive subsets of data to support their respective efforts as described in the RI.

Additional sediment and tissue data were obtained subsequent to the June 2008 transmittal and were incorporated into an updated SCRA database, which is presented in Appendix H of the draft final RI report. This update included all available data obtained by February 4, 2011 and is the dataset used in this draft FS, although tissue data are not directly evaluated in the draft FS. Additional selections and data reduction steps were applied to the updated SCRA datasets to fulfill specific data evaluation and presentation needs of the draft FS, and this subset of data is referred to as the draft FS database.

Other than the update of data as of February 4, 2011, the draft FS dataset is identical to the RI dataset. Data used for the Comprehensive Benthic Approach to delineate benthic areas of concern are detailed in Table 4-2 of the BERA. The fate and transport model only includes data added to the SCRA database as of September 10, 2009 and does not include additional data added on February 4, 2011.

An additional subset of data was selected for the *Stormwater Loading Methods Report* (Anchor QEA 2011a) from a subset of the SCRA stormwater data. This database was defined as the "draft FS stormwater database," which was submitted to EPA with the *Stormwater Loading Methods Report*.

The entire draft FS Sediment Database was submitted to EPA on June 27, 2011. Data evaluation, selection, totaling, and other rules and procedures for the draft FS are described in more detail in Appendix R.

2.8.1 Consistency of Datasets with Sites under Separate Orders

Instances where additional data have as been collected as part of other Portland Harbor Orders, but not included in the draft FS database are described below:

- Terminal 4 – No additional data have been collected as part of the Terminal 4 AOC process that is not included in the draft FS database.
- Gasco – As part of an EE/CA data gaps sampling, additional data were collected by NW Natural and Siltronic in the summer of 2011, which was after the February 4, 2011 draft FS database lockdown. Data collection at this site included additional sediment core chemistry, sediment core visual observations, surface sediment chemistry, surface sediment bioassays, Toxicity Characteristic Leaching Procedure (TCLP) tests, and Dredge Elutriate (DRET) tests throughout AOPC 9U.
- Arkema – EE/CA sediment sampling data was collected in 2010 and was not available before the draft FS database lockdown on February 4, 2011 (Integral and Arcadis 2010).

2.9 SITE SEGMENTATION FOR DRAFT FS PURPOSES

The Study Area covers 10 river miles, spanning a variety of physical and contaminant conditions. The draft FS contains numerous evaluations of these conditions to identify SMAs, develop alternatives, and assess remedial alternatives. Consequently, the development of alternatives and evaluation of those alternatives can be conducted on a variety of relevant engineering spatial scales that result in an almost infinite variety of potential discussions (e.g., by SMA, Site-wide, by river mile, by shoreline, by physical areas like slips vs. open water, etc.). Therefore, to simplify draft FS evaluations, regions or segments of the Site have been defined that are relevant to engineering concepts addressed in draft FS discussions.

One important engineering concept considered relates to how remedial alternatives might actually be designed and implemented post-ROD. Given the variety of SMAs and parties likely involved, the commitment of resources (e.g., construction equipment needed, EPA oversight staffing, etc.), and the limited fish window, it would be impossible for every SMA in the Site to be constructed simultaneously under one order. Rather, the cleanup (both at the design and construction phases) will need to proceed in some type of sequence, perhaps with a certain number of projects (but not all projects) proceeding simultaneously.

Thus, for draft FS purposes, some assumptions are needed as examples of a post-ROD process for implementation of cleanup design and construction. One such possible approach is that the Site would be split into regions or segments. The segments proposed later in this section are offered as an example to help develop and evaluate draft FS alternatives in some reasonable manner. Other equally reasonable proposals for Site segmentation and/or sequence of Site construction could be devised and implemented.

Another related engineering concept involves how work might proceed across any segments. Such segments could be implemented sequentially, simultaneously, or in some other combination of work. Clearly, the exact sequence and overlap of work in segments cannot be predicted in advance and involves many factors such as the numbers and ability of parties available to conduct cleanups, the availability and distance to disposal sites and transfer facilities, and the other staff and equipment resource factors noted above. These factors in turn impact the duration of remedial alternatives, which can be an important factor in comparative alternative evaluations. The segmentation framework also allows some reasonable draft FS assumptions to be made with regards to sequence and duration that, again, are only examples for draft FS purposes, but allow the draft FS to proceed.

Finally, the segmentation concept allows for some summarization of alternative evaluation results within the draft FS at a spatial scale that is relevant to these engineering concepts. Thus, results relevant to engineering decisions may best be viewed at a segment spatial scale rather than Site-wide or by SMA. It should be noted that any such evaluations are not intended to supplant or replace determinations of effectiveness on spatial scales that are relevant to the potentially unacceptable risks in question, per the exposure assumptions in the risk assessment. The segment scale is also used in some cases to simplify discussions by comparing against several risk-related exposure scales at once given that a segment scale is intermediate between relatively small exposures scales (e.g., river mile) and large exposure scales (e.g., Site wide). Viewing results on a segment scale also helps understand the potential uncertainty associated with some of the smaller exposure scales (e.g., smallmouth bass that may migrate over areas larger than one river mile).

Given the above, two criteria were used to develop reasonable example segments for the draft FS evaluations:

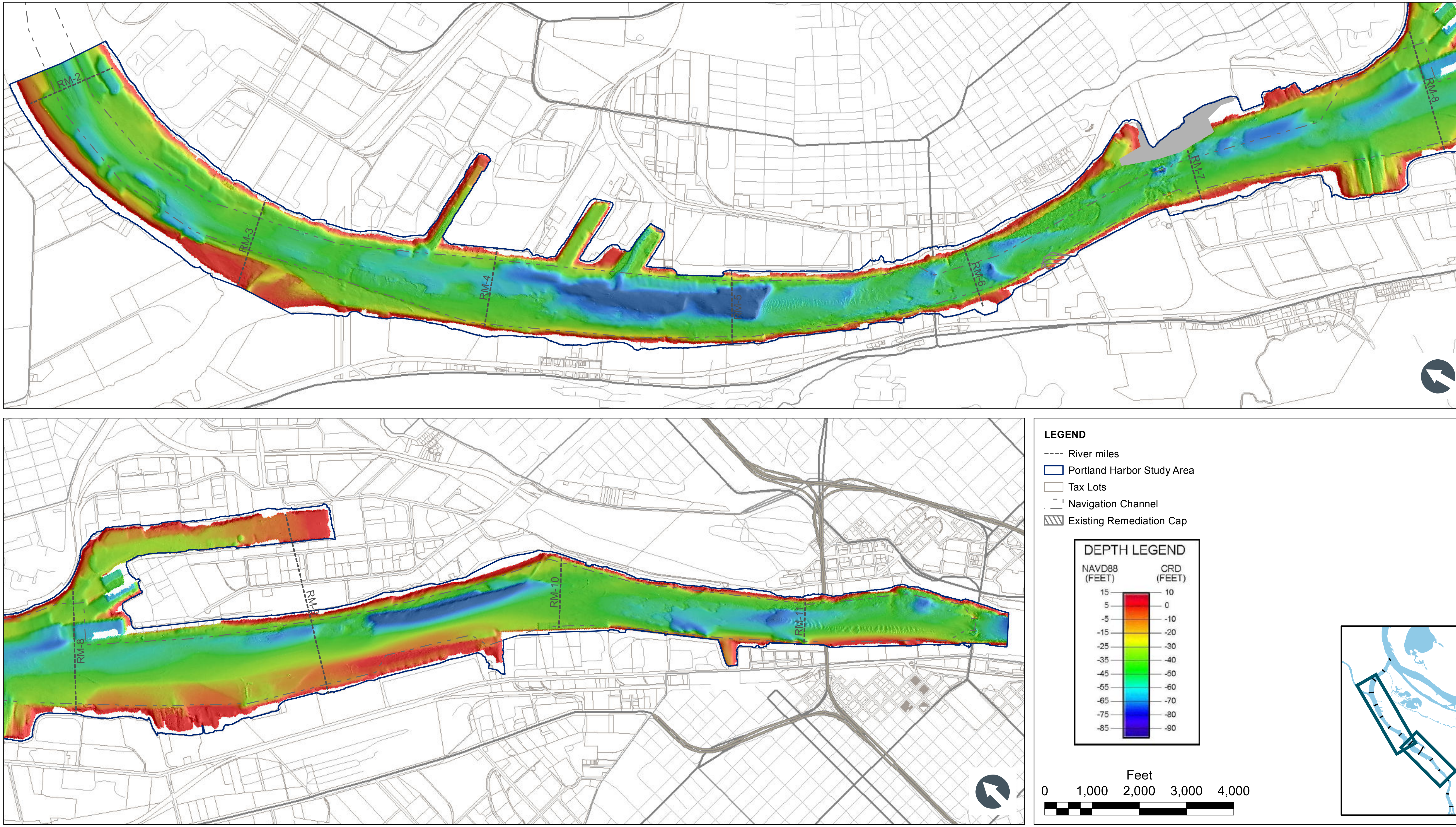
- Develop segments consistent with the most important physical conditions affecting draft FS evaluations, which are long-term sedimentation/erosion patterns. Sediment transport dynamics are important to determination of existing sediment contamination patterns, future sediment contamination and recontamination patterns, affect the stability of remedy components, and are a key determinant to MNR processes.

- Develop relatively even-sized segments to avoid evaluating one area at an entirely different spatial scale than another area.

Figure 2.9-1 shows the draft FS example segments developed based on the above concepts and criteria. The Site is split into four relatively equal-sized segments, per the second criteria. Each segment is about 2.5 to 3 RMs in size, counting Swan Island Lagoon as approximately one river mile in size. This spatial scale is relevant to engineering considerations such as barge travel times, proximity to transfer facilities, and proximity to disposal sites. Transportation distance of a few miles is a reasonable estimate of where transportation costs may become important in draft FS evaluations. As shown in the figure, these segments are also relatively consistent in terms of the sediment transport processes. The figure shows the net sedimentation/erosion predicted over a 30-year evaluation period of the sediment transport model (discussed more in Appendix La). Segment 1 (the upstream segment) is primarily a depositional environment, with one major exception being the navigation channel in RM 11.8 to about 11. However, within this area, the shoreline areas are also primarily depositional, and this is where most of the contamination in this area resides (see Section 5 for more details). Segment 2 is also mostly depositional including quiescent areas such as Swan Island Lagoon. Segment 3 represents a more dynamic environment within the Site, where both erosional and depositional processes exist concurrently. Finally, Segment 4 represents the downstream end of the Site, which is also mostly depositional.

2.10 CONCLUSIONS

A large body of available information and data fully support the detailed evaluation of alternatives for the draft FS. The physical/chemical/biological system, site uses, and ongoing source control efforts are sufficiently understood to fully evaluate and compare alternatives against the NCP FS evaluation criteria. This information has been combined into a CSM that focuses on those issues that are most important to draft FS development. This information is used in the following sections to develop RALs and SMAs, screen technologies, and assemble and evaluate comprehensive remedial alternatives.



Note:
1. Bathymetry data from David Evans and Associates, Inc., as displayed in the Por land Harbor RI/FS, Remedial Investigation Report, Integral Consulting, Inc.
2. Willamette River Channel Surveyed 2009.

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Figure 2.1-1
Portland Harbor RI/FS
Draft Feasibility Study
Site Bathymetry

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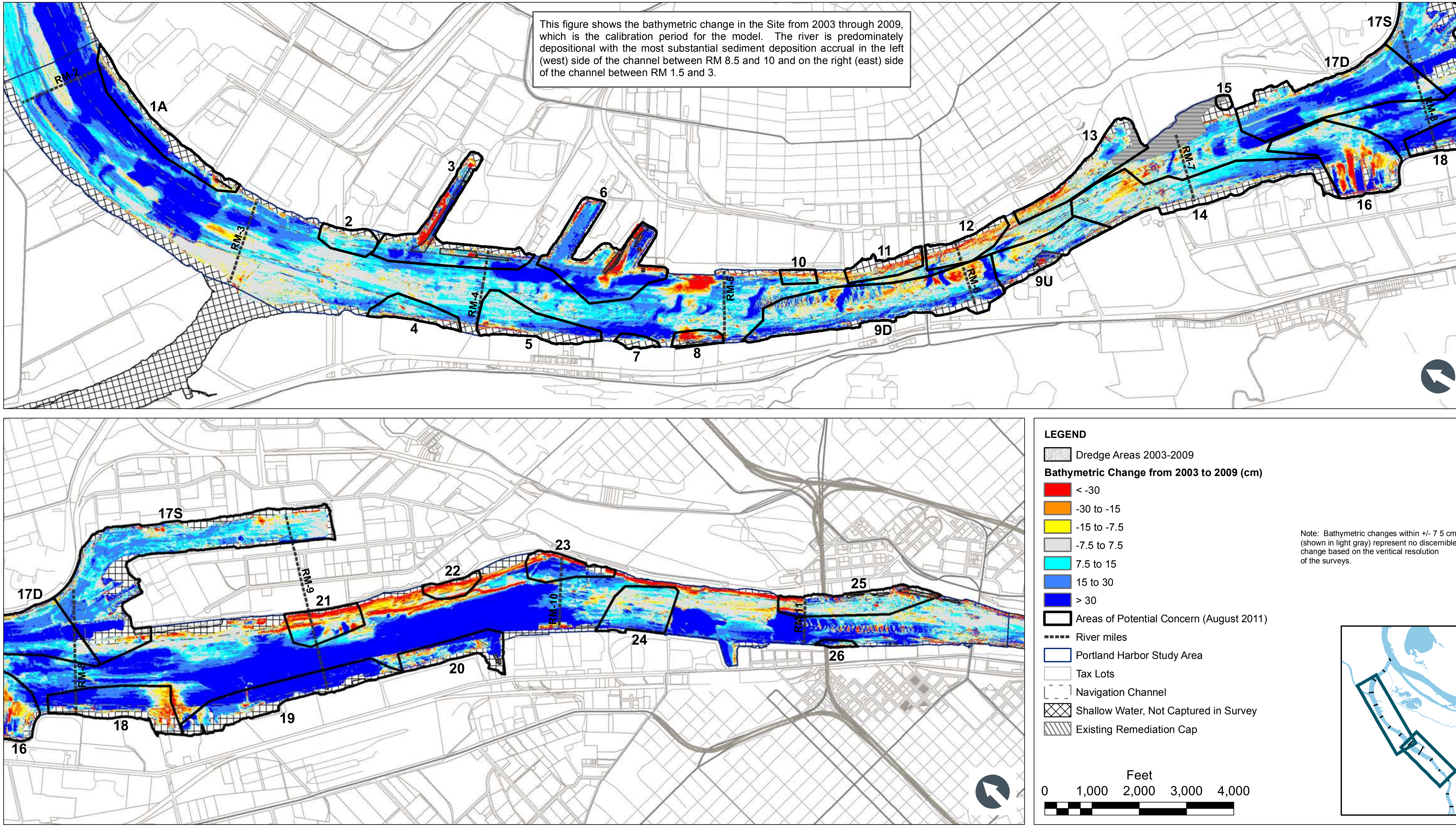

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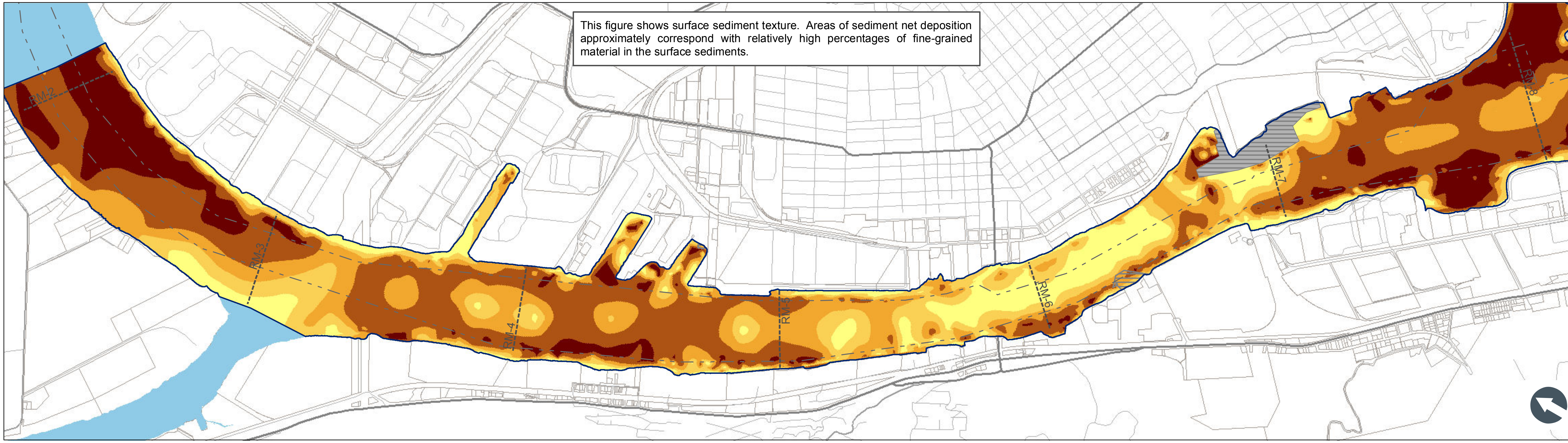
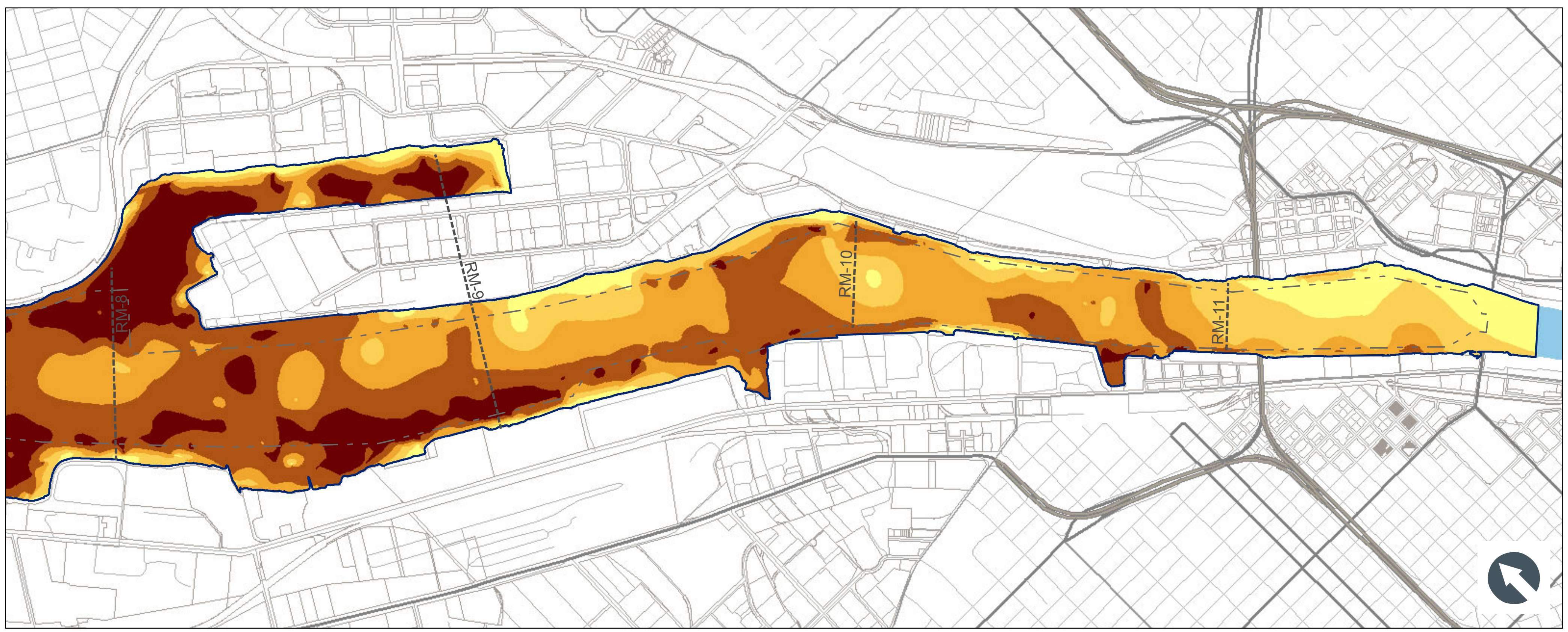
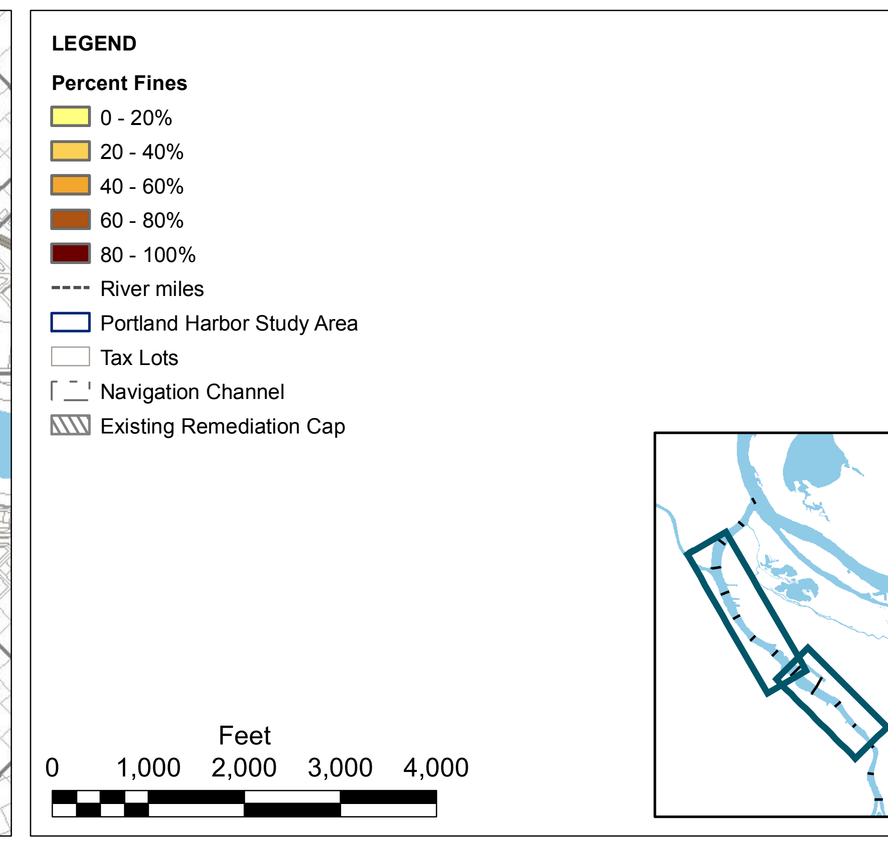
Figure 2.1-2
Portland Harbor RI/FS
Draft Feasibility Study
Bathymetric Change - July 2003 to January 2009







ANCHOR QEA

LWG LOWER WILLAMETTE GROUP

NOTE
Existing condition data shown on this figure is based on available LWG-RI data. Site- specific studies conducted during remedial design may draw differing conclusions as to the characteristics of the existing habitat.

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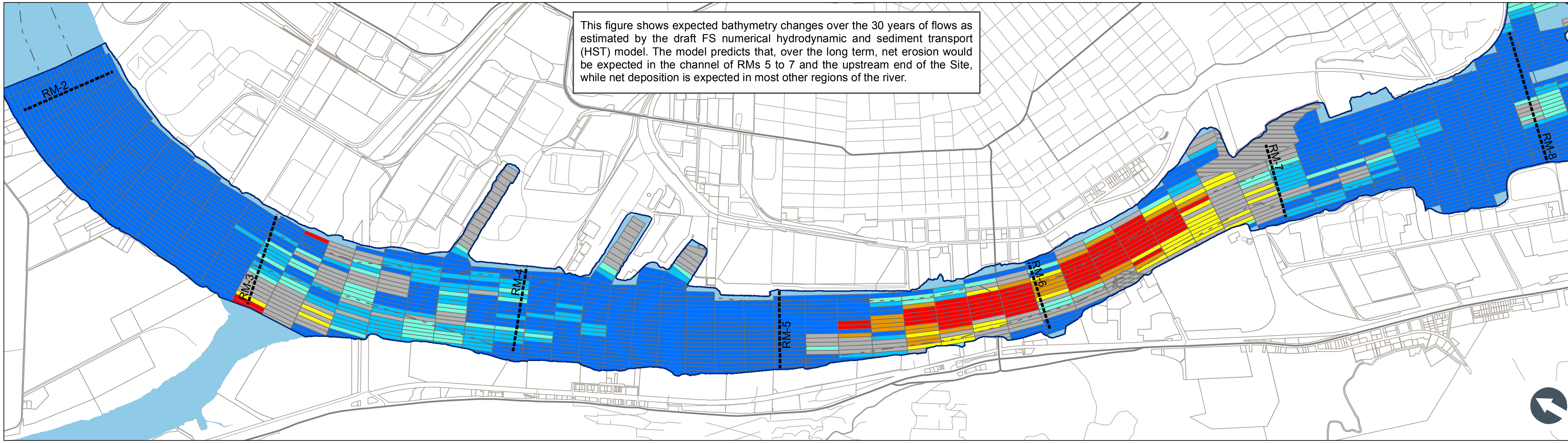
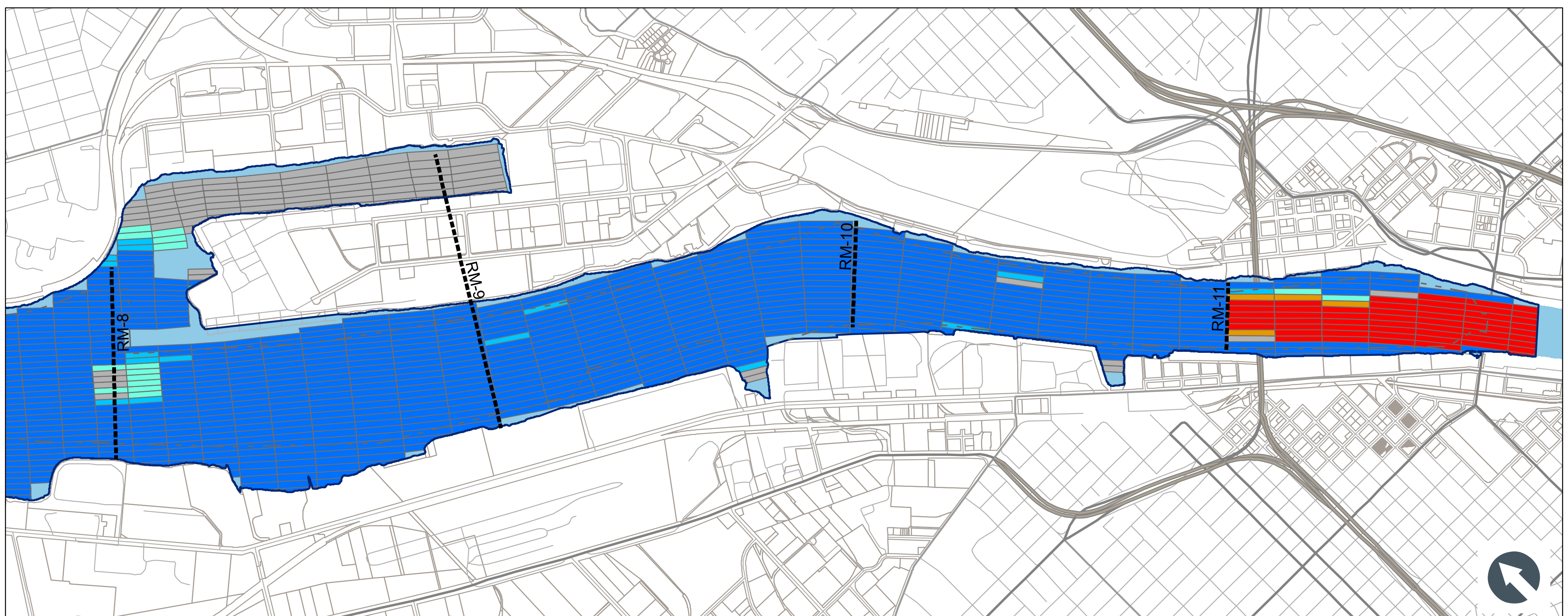
Figure 2.1-3
Portland Harbor RI/FS
Draft Feasibility Study
Contoured Surface Sediment Texture, Percent Fines





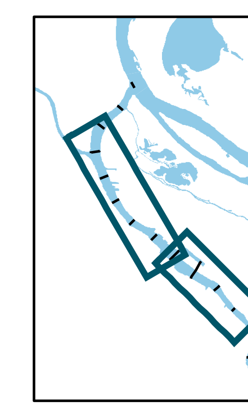
LEGEND

Bed Elevation Change (cm)

- < -30
- -30 to -15
- -15 to -7.5
- -7.5 to 7.5
- 7.5 to 15
- 15 to 30
- \> 30
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Feet

0 1,000 2,000 3,000 4,000



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Note:
Bed elevation change calculated for the time period 1/1/1979 - 1/31/2009.

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Figure 2.1-4
Portland Harbor RI/FS
Draft Feasibility Study
Predicted Riverbed Elevation Net Change (High Flow Scenario)
2003 to 2009 Calibration Period

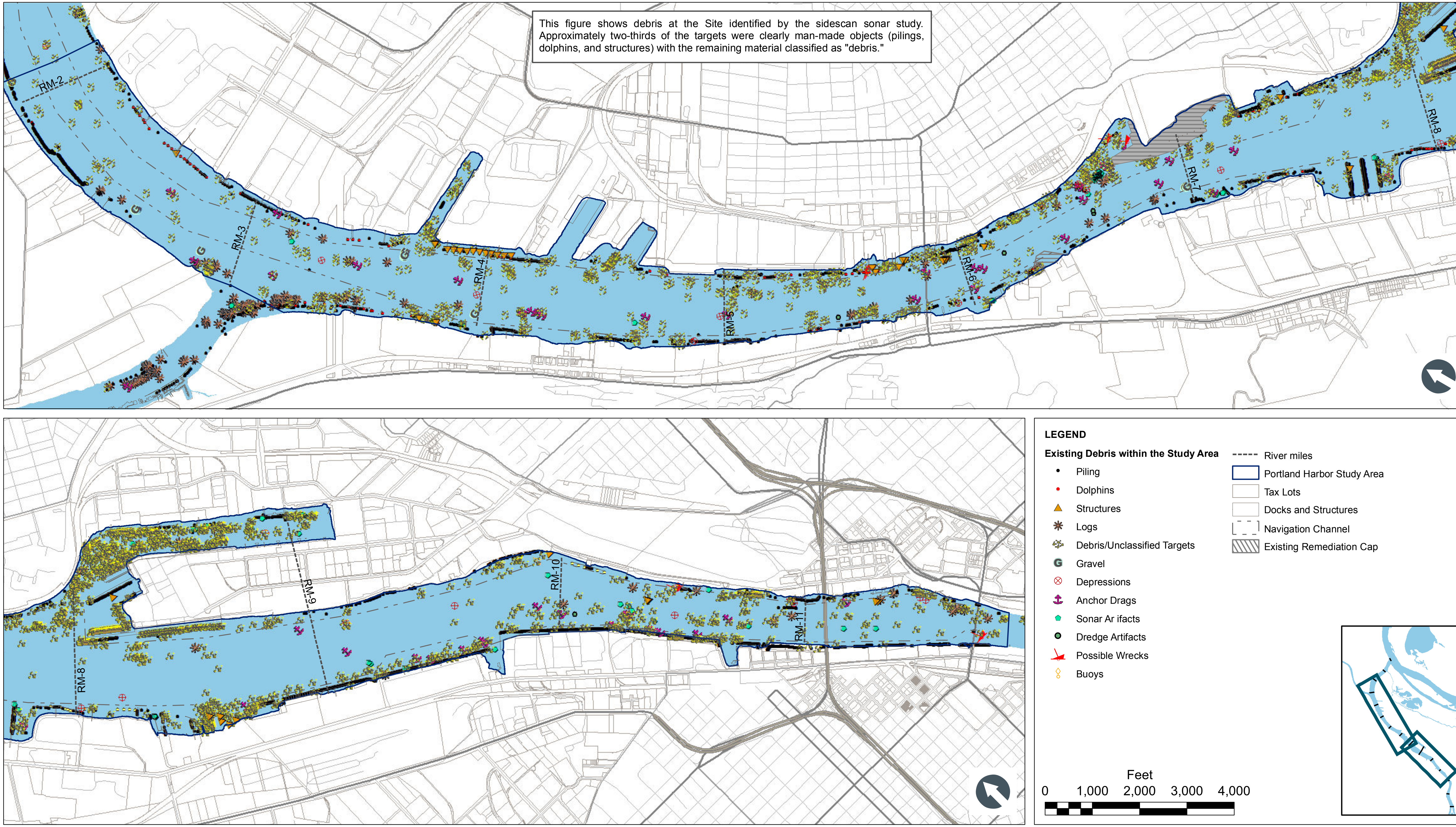

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Figure 2.1-5
Portland Harbor RI/FS
Draft Feasibility Study
Existing Debris within the Site

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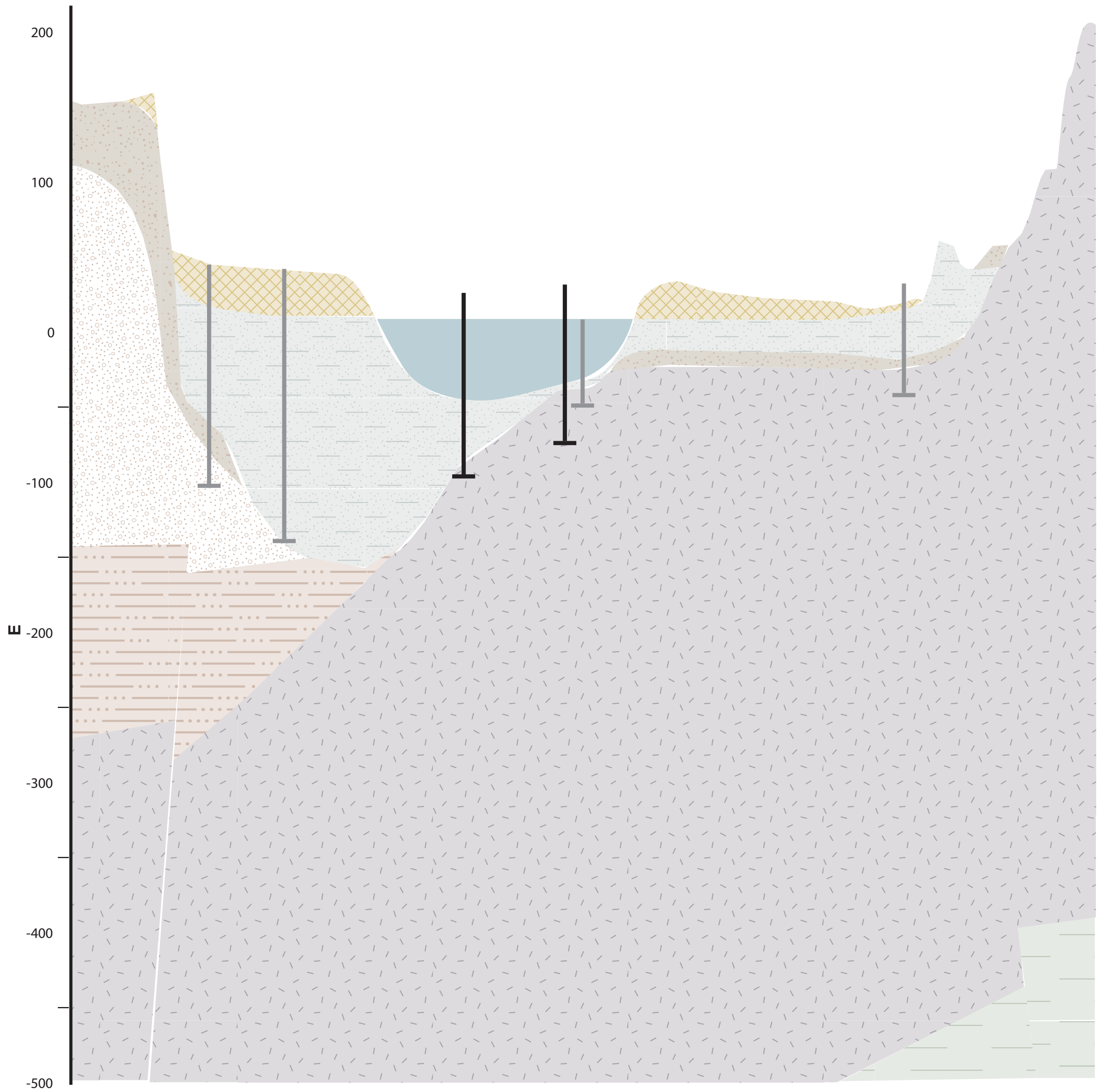

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_1_6_GeologicCrossSection.mxd jolivet 3/12/2012 12:23:25 PM

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Figure 2.1-6
Portland Harbor RI/FS
Draft Feasibility Study
Generalized Geologic Section

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Figure 2.1-7
Portland Harbor RI/FS
Draft Feasibility Study
Estimated Groundwater Flux to Site

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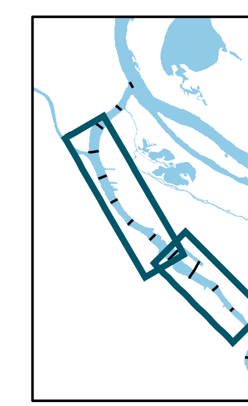
LEGEND

Total PCBs (µg/kg)

- < 50
- 50 - 75
- 75 - 200
- 200 - 500
- 500 - 750
- 750 - 1,000
- > 1,000
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Note:
Natural neighbor gridding is approximate and some artifacts have not been removed.

Feet
0 1,000 2,000 3,000 4,000



Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_2_1_SedChem_Surf_tot_pcb.mxd jolivert 3/12/2012 2:01:36 PM

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Figure 2.2-1
Portland Harbor RI/FS
Draft Feasibility Study
Surface Sediment Chemistry
Total PCBs

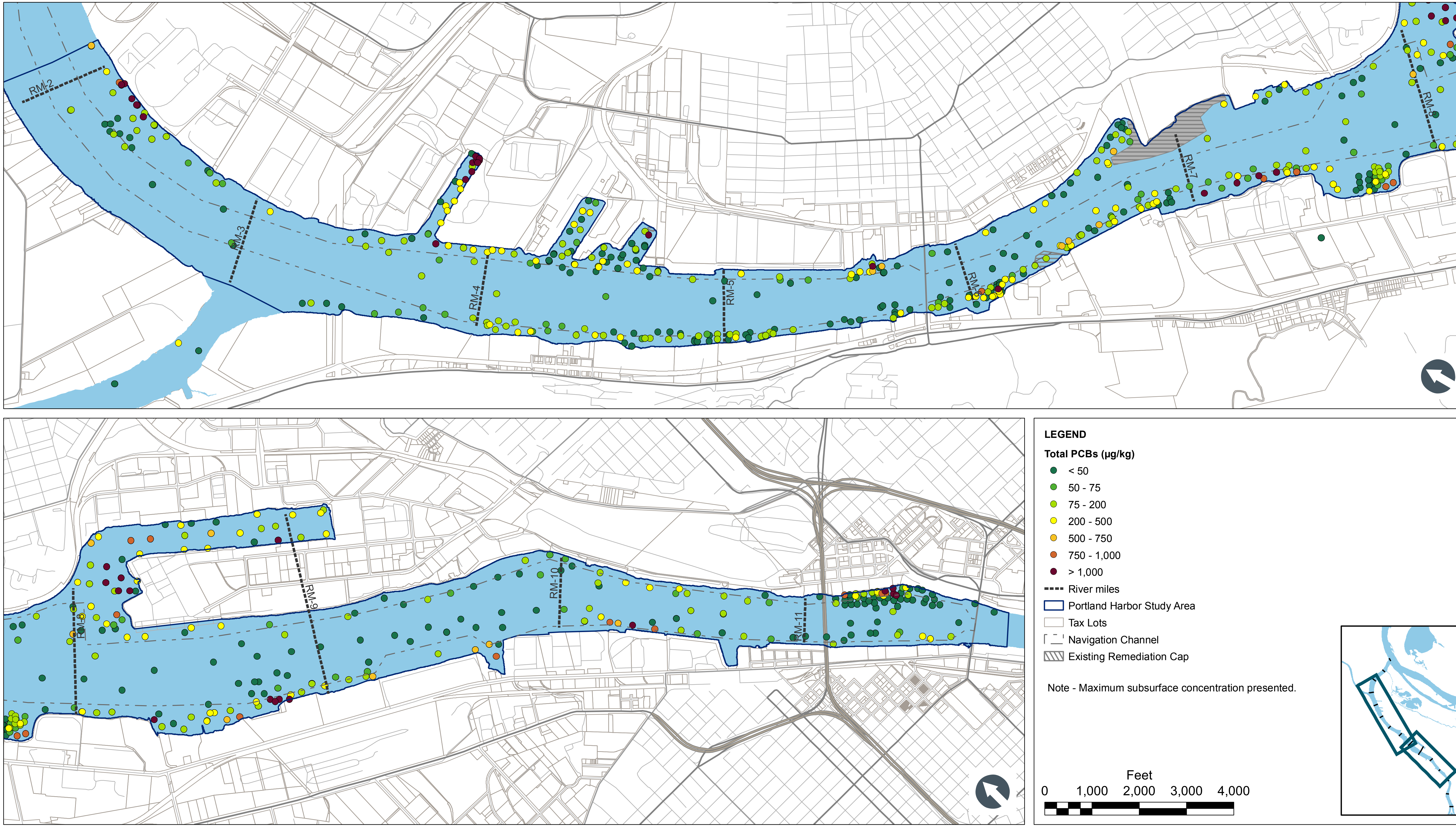

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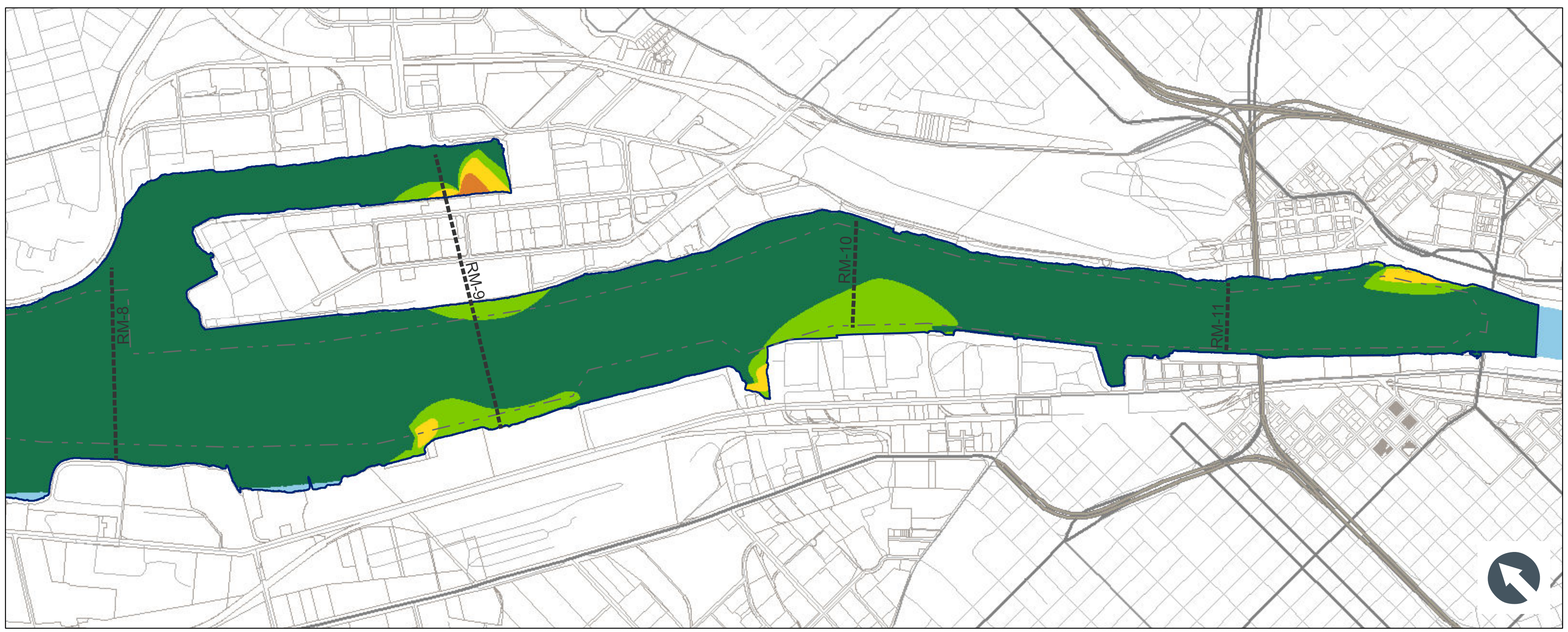
Figure 2.2-2
Portland Harbor RI/FS
Draft Feasibility Study
Subsurface Sediment Chemistry
Total PCBs



LEGEND

Total Dioxin/Furan TEQ (µg/kg)

- < 0.005
- 0.005 - 0.01
- 0.01 - 0.02
- 0.02 - 1
- > 1
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Note:
Natural neighbor gridding is approximate and some artifacts have not been removed.

Feet

0 1,000 2,000 3,000 4,000

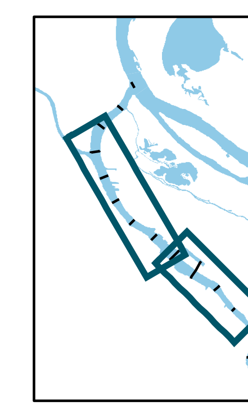


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Figure 2.2-3
Portland Harbor RI/FS
Draft Feasibility Study
Surface Sediment Chemistry
Total Dioxin/Furan TEQ (2005 Mammalian TEFs)

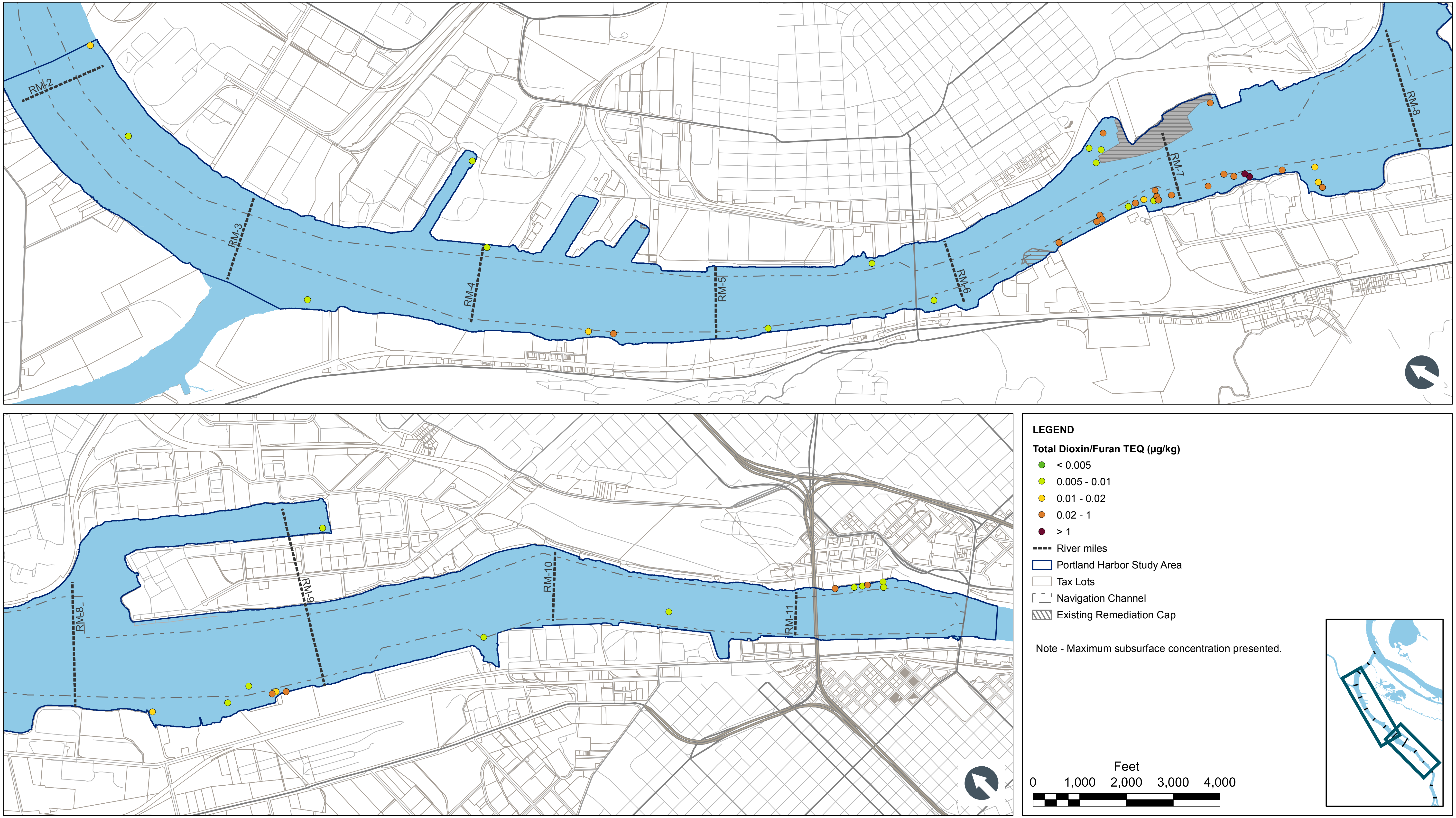

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Figure 2.2-4
Portland Harbor RI/FS
Draft Feasibility Study
Subsurface Sediment Chemistry
Total Dioxin/Furan TEQ (2005 Mammalian TEFs)

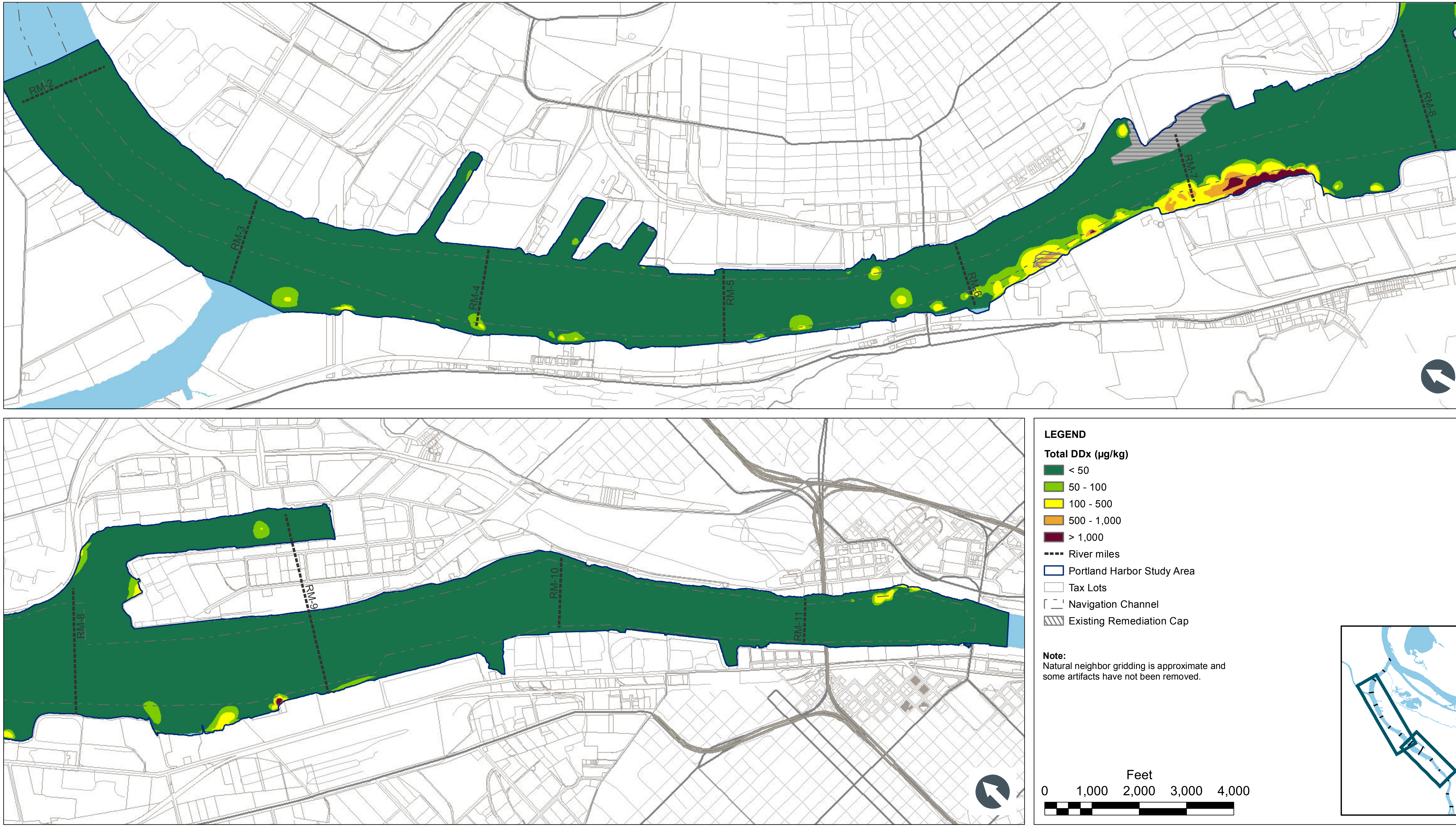

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Figure 2.2-5
Portland Harbor RI/FS
Draft Feasibility Study
Surface Sediment Chemistry
Total DDx

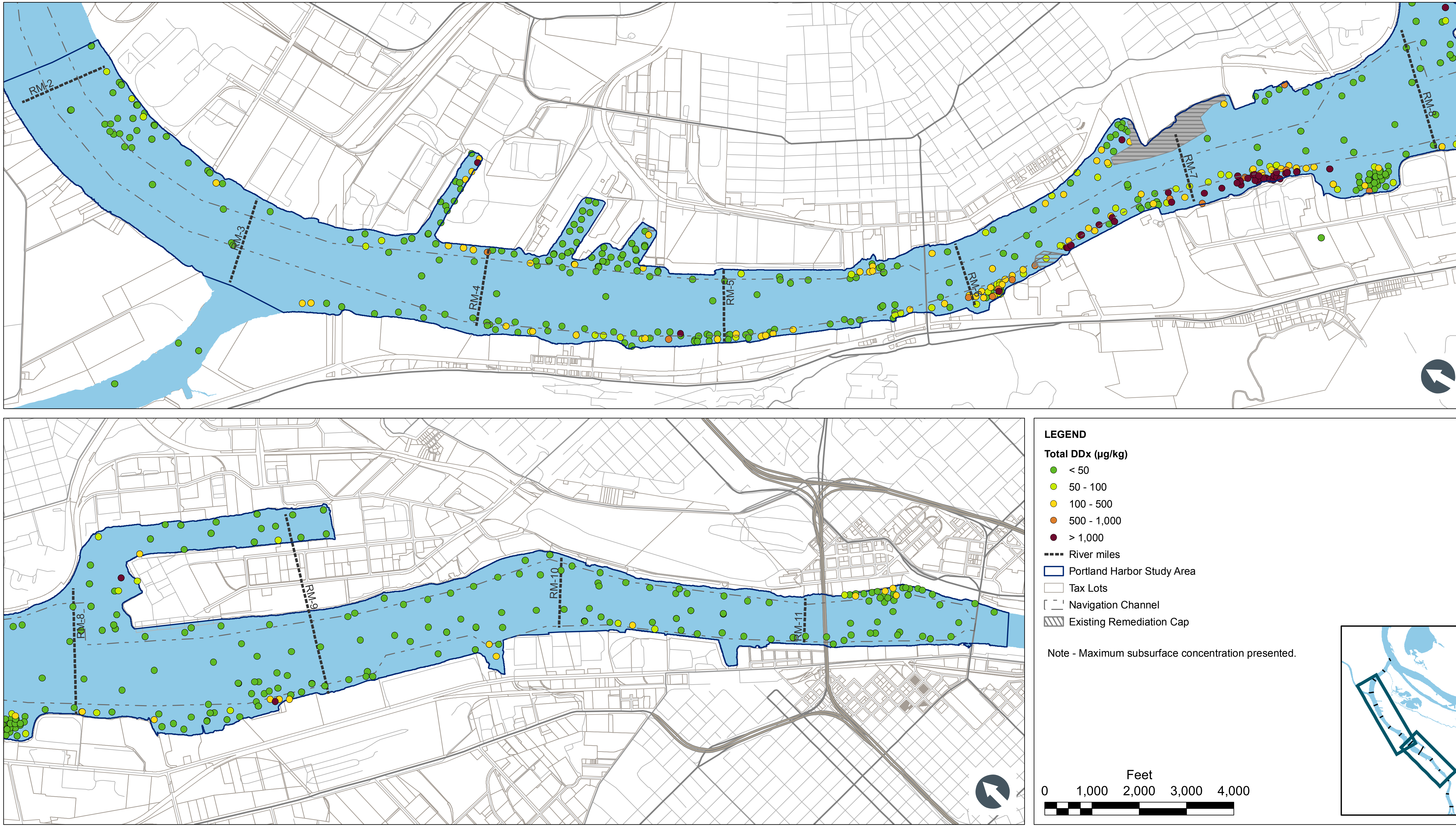

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Figure 2.2-6
Portland Harbor RI/FS
Draft Feasibility Study
Subsurface Sediment Chemistry
Total DDx

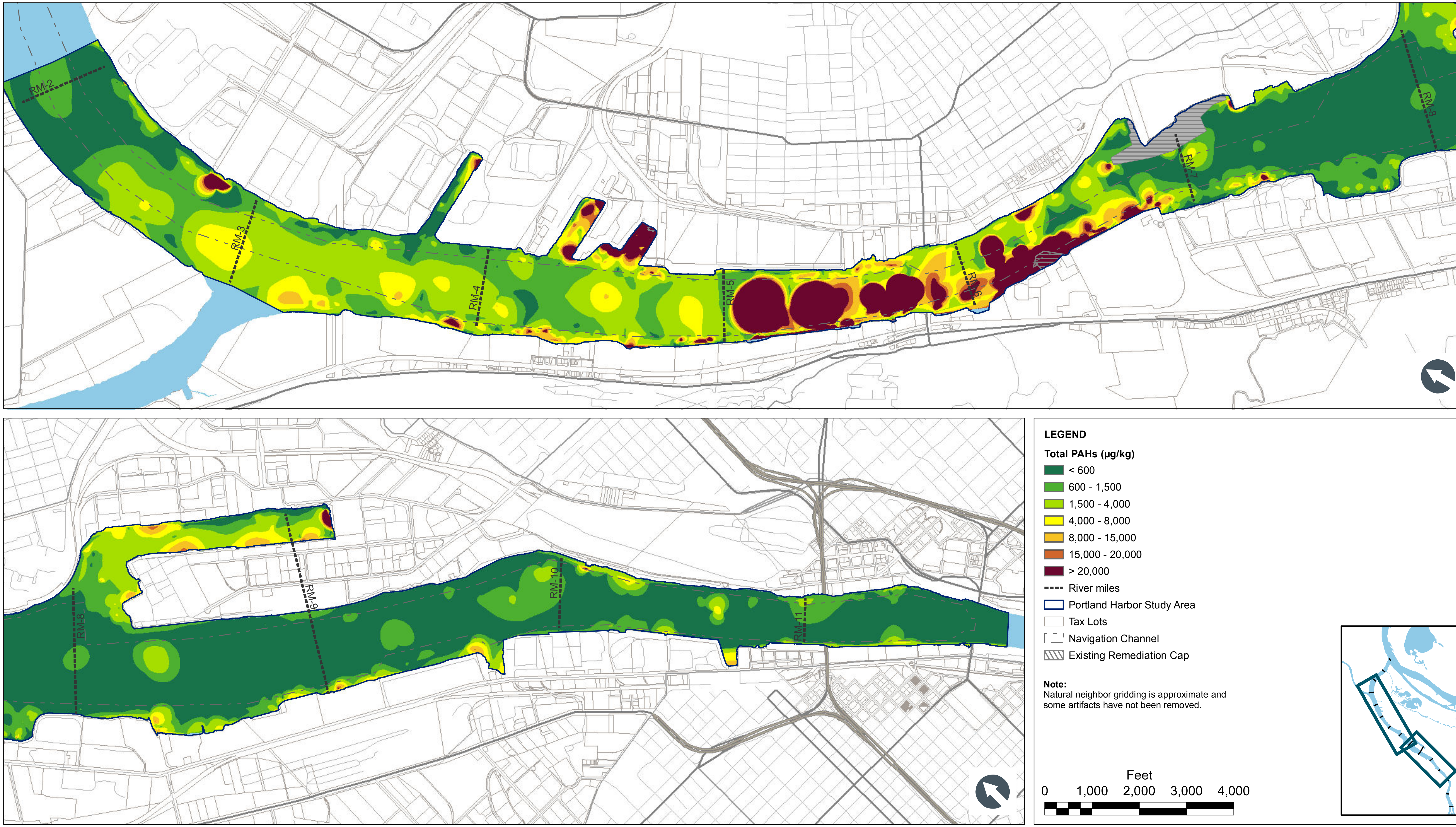

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Figure 2.2-7
Portland Harbor RI/FS
Draft Feasibility Study
Surface Sediment Chemistry
Total PAHs

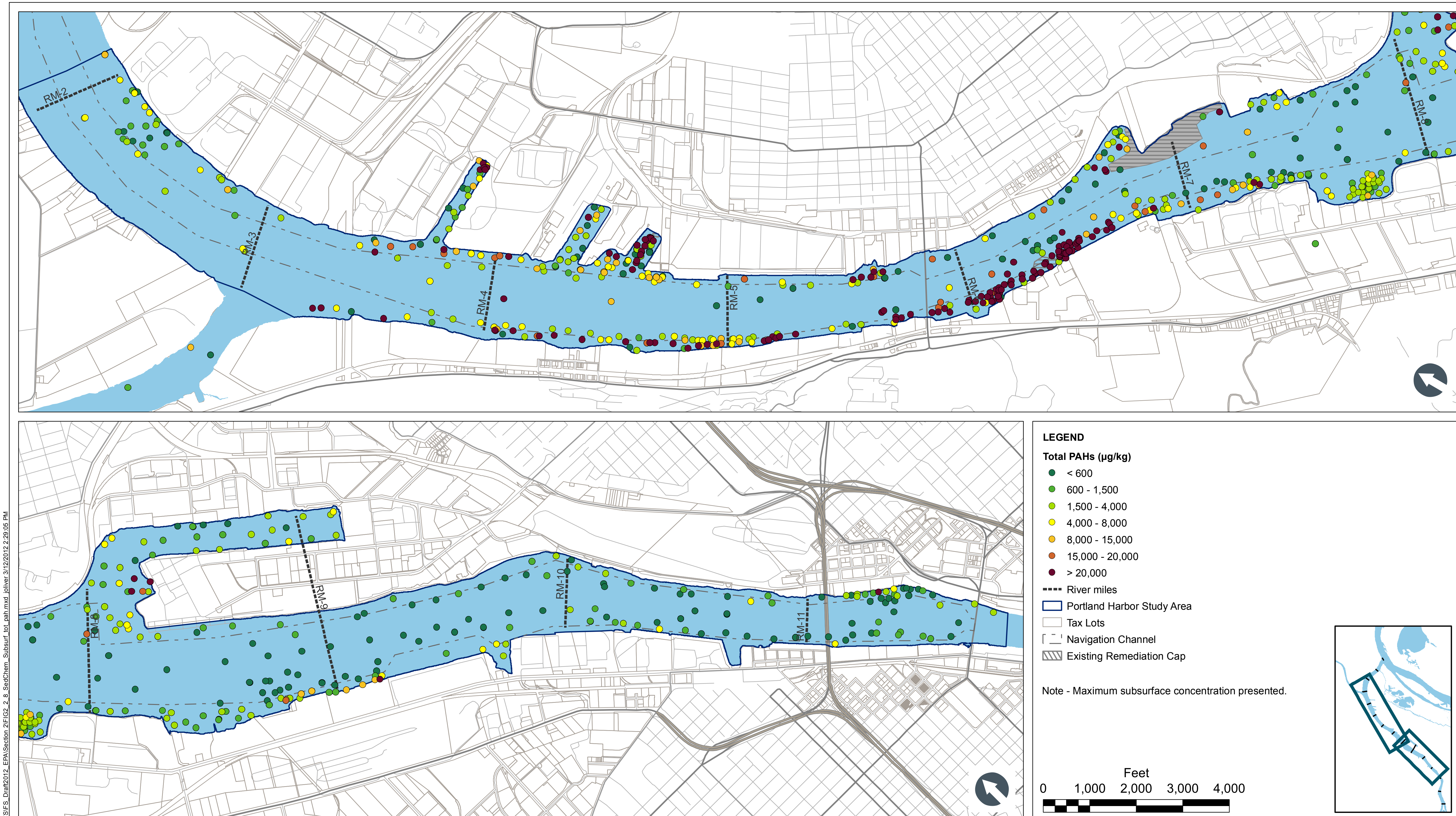

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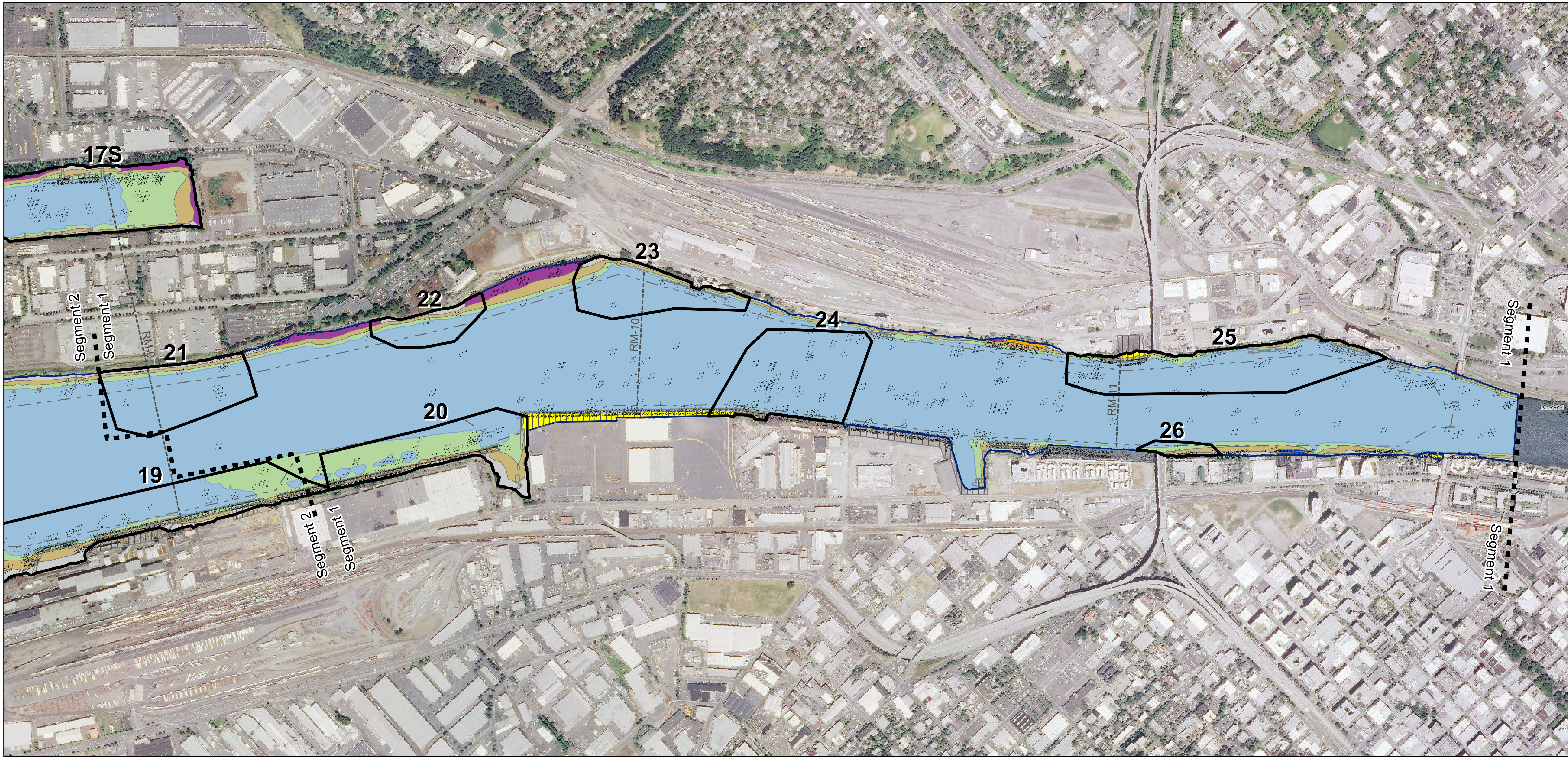
Figure 2.2-8
Portland Harbor RI/FS
Draft Feasibility Study
Subsurface Sediment Chemistry
Total PAHs



LEGEND

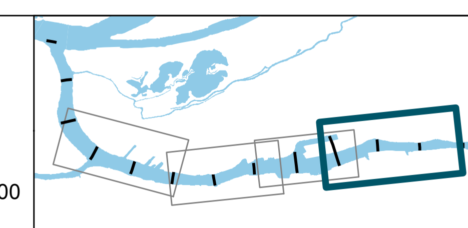
Active Channel Margin Shoreline Type

- Beach
- Bio-Engineered
- Pilings - Allowing Light
- Pilings - Limiting Light
- Rip Rap
- Rock
- Seawall
- Shallow Water Nearshore (5.1 to -4.9 ft NAVD88)
- Shallow Main Channel (-4.9 to -14.9 ft NAVD88)
- Deep Water (> -14.9 ft NAVD88)
- Debris (See Figure 2.1-5)
- Over Water Structures
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

AERIAL PHOTO: NAIP 2011.

Feet

0 550 1,100 1,650 2,200



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NOTES

1. The active channel margin shoreline type is derived from the LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.
2. Existing condition data shown on this figure is based on available LWG-RI data. Site- specific studies conducted during remedial design may draw differing conclusions as to the characteristics of the existing habitat.

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Figure 2.3-1a
Portland Harbor RI/FS
Draft Feasibility Study
Functional Habitat Assessment Existing Shoreline and Water Depth Conditions within the Site
Segment 1: AOPCs 20-26

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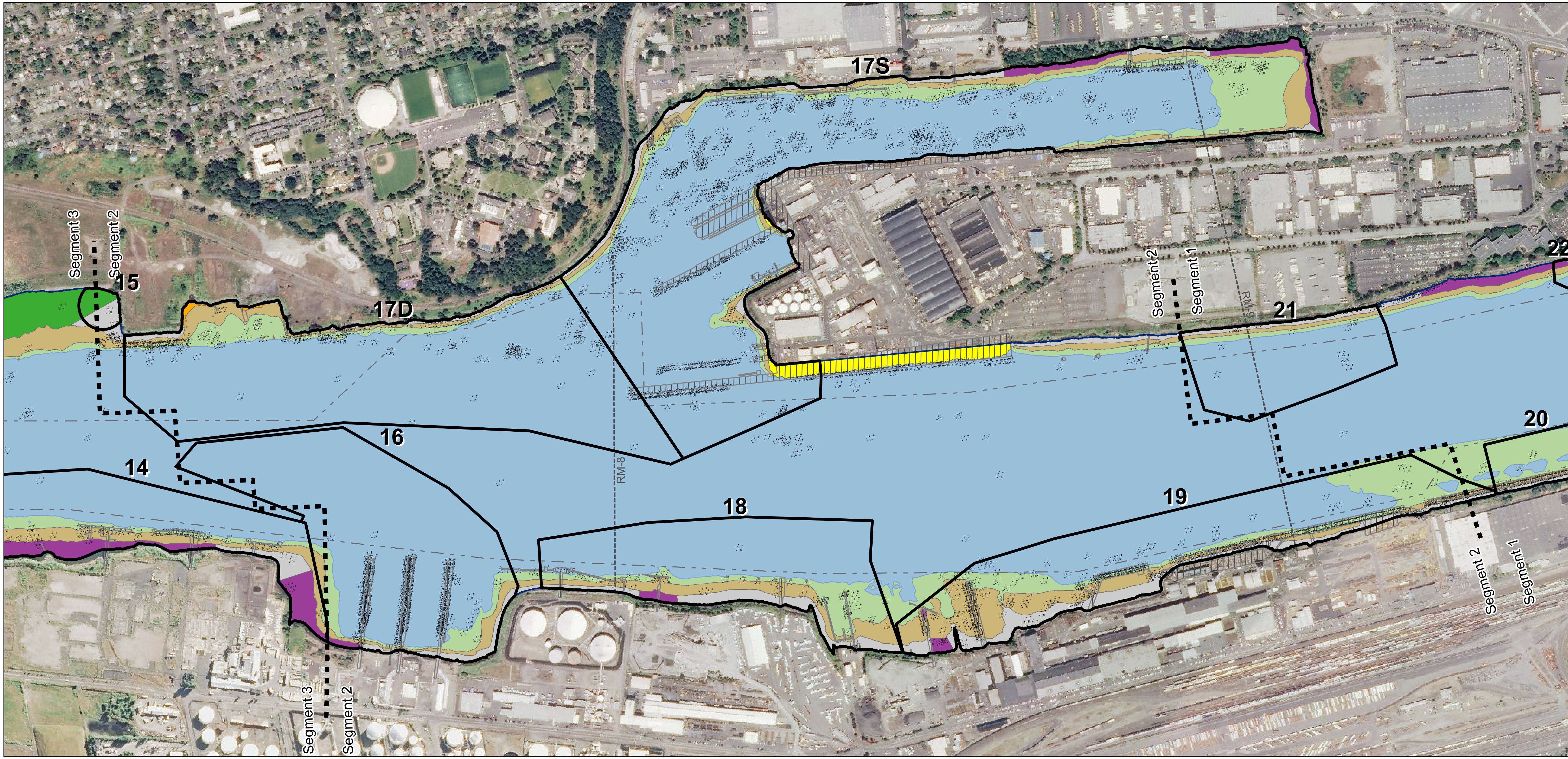

LEGEND

Active Channel Margin Shoreline Type

- Beach
- Bio-Engineered
- Pilings - Allowing Light
- Pilings - Limiting Light
- Rip Rap
- Rock
- Seawall
- Shallow Water Nearshore (5.1 to -4.9 ft NAVD88)
- Shallow Main Channel (-4.9 to -14.9 ft NAVD88)
- Deep Water (> -14.9 ft NAVD88)
- Debris (See Figure 2.1-5)
- Over Water Structures
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

Feet

0 400 800 1,200 1,600

AERIAL PHOTO: NAIP 2011.

ANCHOR QEA

LWG LOWER WILLAMETTE GROUP

NOTES
1. The active channel margin shoreline type is derived from the LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.
2. Existing condition data shown on this figure is based on available LWG-RI data. Site- specific studies conducted during remedial design may draw differing conclusions as to the characteristics of the existing habitat.

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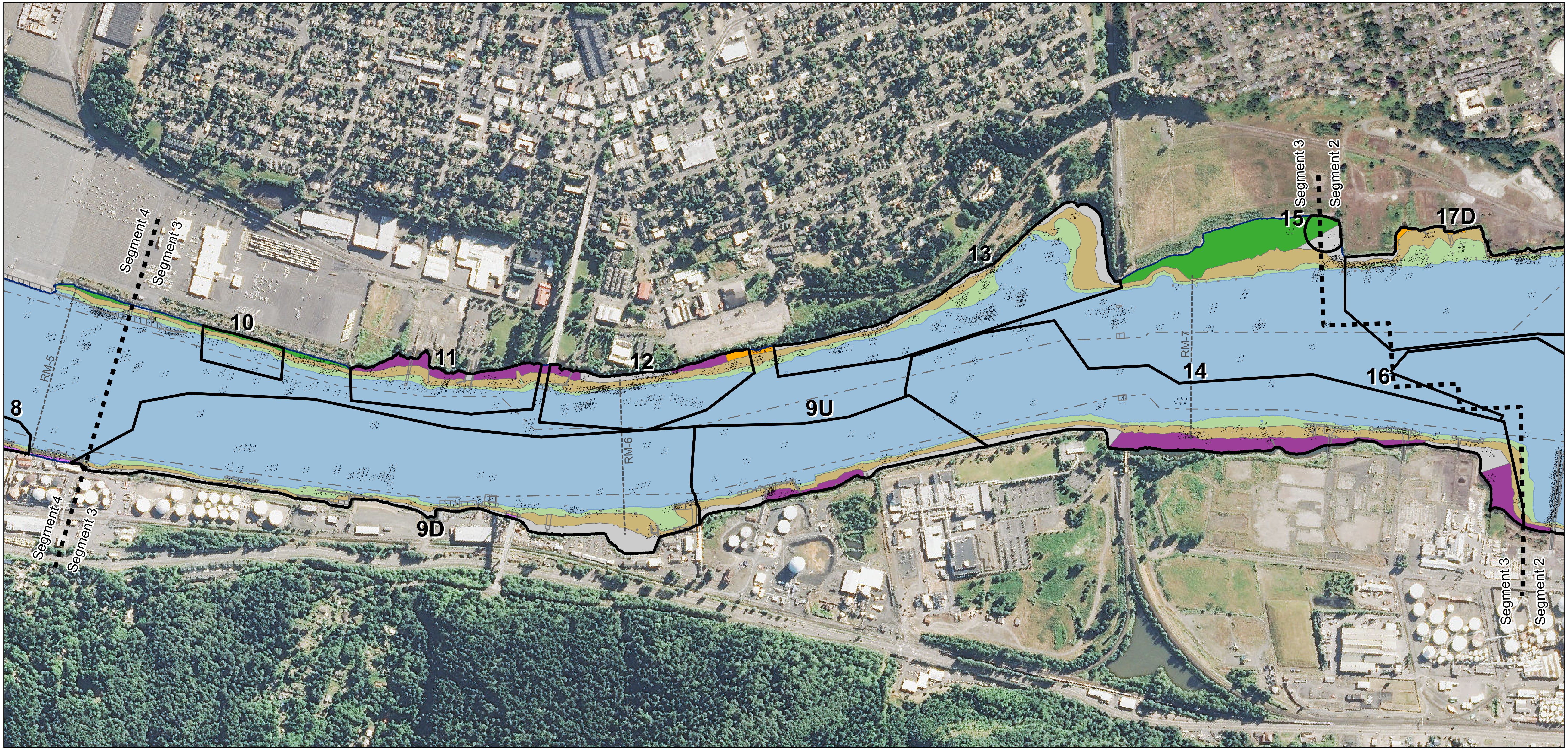
Figure 2.3-1b
Portland Harbor RI/FS
Draft Feasibility Study
Functional Habitat Assessment Existing Shoreline and Water Depth Conditions within the Site
Segment 2: AOPCs 15-19



LEGEND

Active Channel Margin Shoreline Type

- Beach
- Bio-Engineered
- Pilings - Allowing Light
- Pilings - Limiting Light
- Rip Rap
- Rock
- Seawall
- Shallow Water Nearshore (5.1 to -4.9 ft NAVD88)
- Shallow Main Channel (-4.9 to -14.9 ft NAVD88)
- Deep Water (> -14.9 ft NAVD88)
- Debris (See Figure 2.1-5)
- Over Water Structures
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

Feet

0 450 900 1,350 1,800

AERIAL PHOTO: NAIP 2011.

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LWG LOWER WILLAMETTE GROUP

NOTES

1. The active channel margin shoreline type is derived from the LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.
2. Existing condition data shown on this figure is based on available LWG-RI data. Site- specific studies conducted during remedial design may draw differing conclusions as to the characteristics of the existing habitat.

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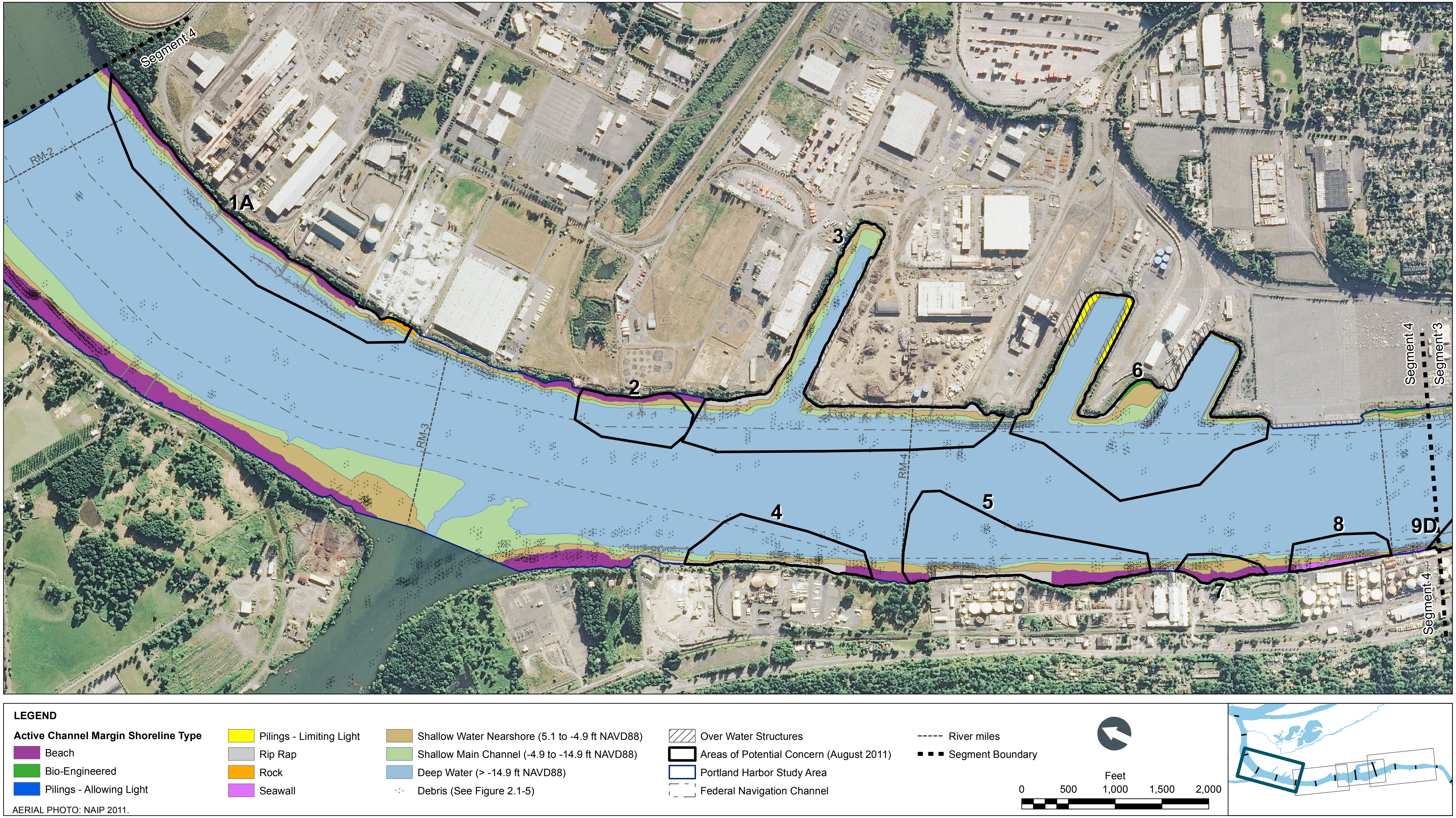
Figure 2.3-1c
Portland Harbor RI/FS
Draft Feasibility Study
Functional Habitat Assessment Existing Shoreline and Water Depth Conditions within the Site
Segment 3: AOPCs 9D - 14



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NOTES
1. The active channel margin shoreline type is derived from the LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.
2. Existing condition data shown on this figure is based on available LWG-RI data. Site- specific studies conducted during remedial design may draw differing conclusions as to the characteristics of the existing habitat.

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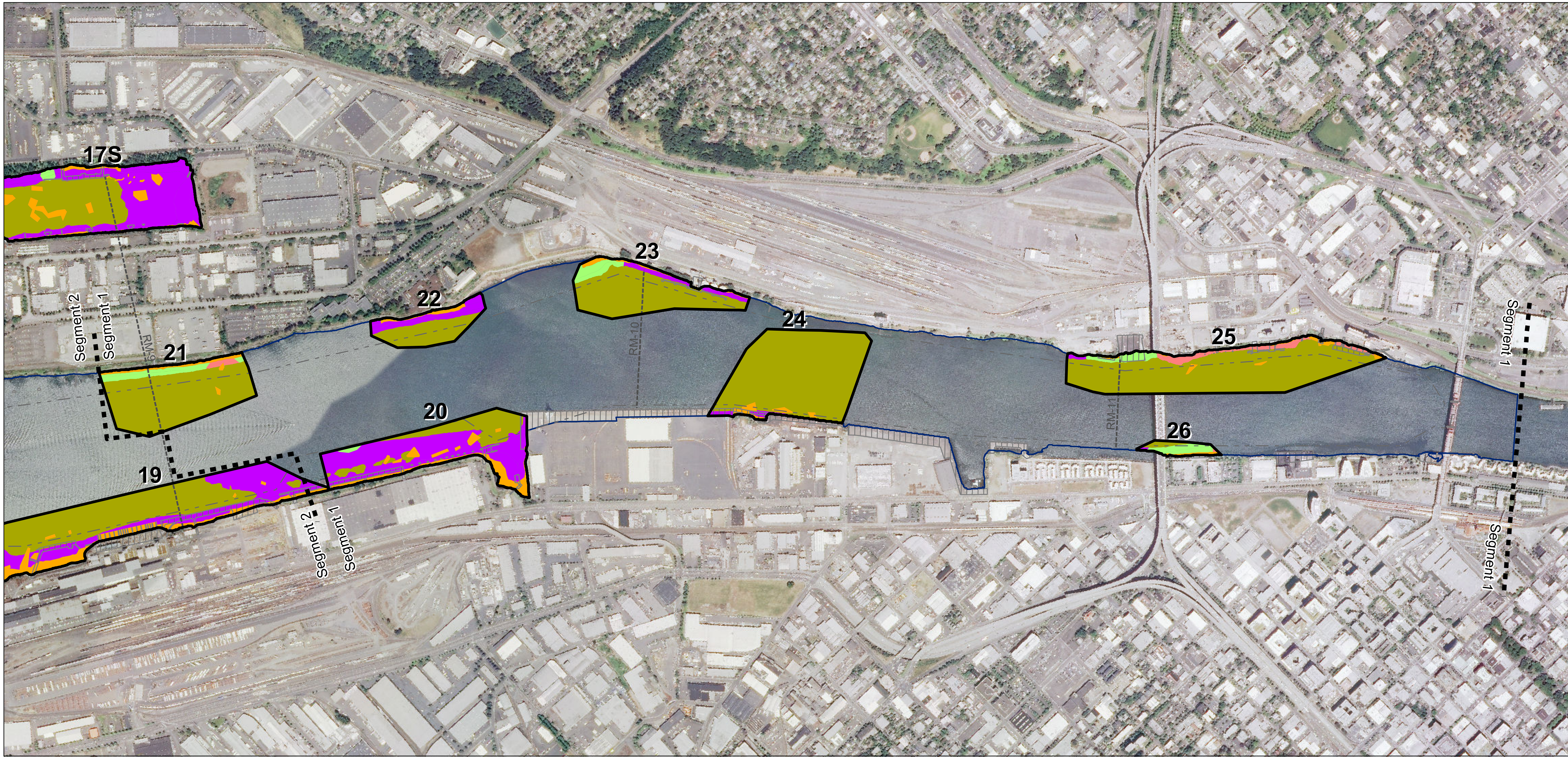
Figure 2.3-1d
Portland Harbor RI/FS
Draft Feasibility Study
Functional Habitat Assessment Existing Shoreline and Water Depth Conditions within the Site
Segment 4: AOPCs 1-8



LEGEND

Substrate
- 0-40% fines
- 40-60% fines
- 60-100% fines
- Deep Water - All Substrates
- Riprap/Debris
- No data
- Over Water Structure
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

AERIAL PHOTO: NAIP 2011.

Feet

0 550 1,100 1,650 2,200

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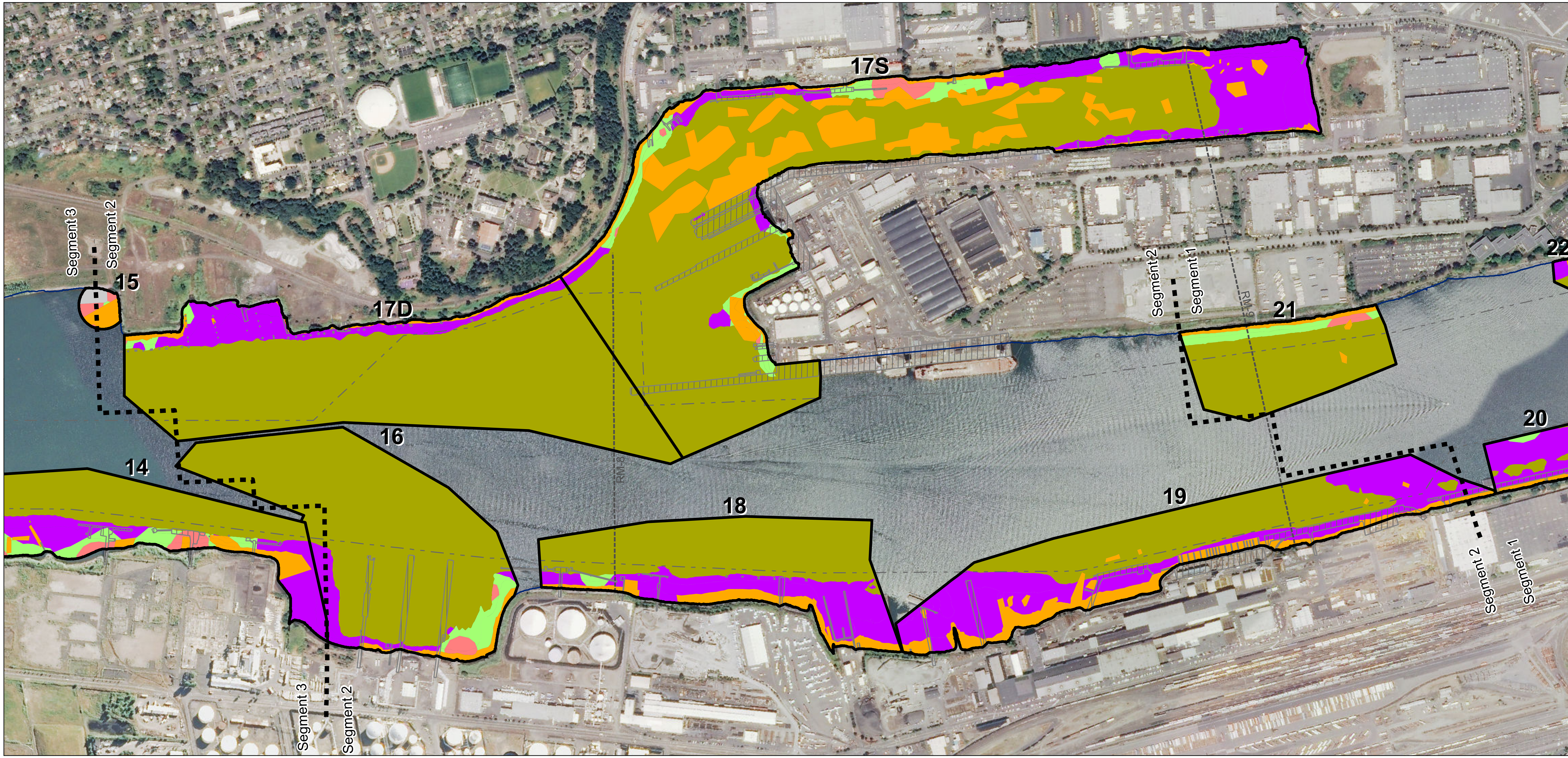
Figure 2.3-2a
Portland Harbor RI/FS
Draft Feasibility Study
Substrate Types within the Site
Segment 1: AOPCs 20-26



LEGEND

Substrate
- 0-40% fines
- 40-60% fines
- 60-100% fines
- Deep Water - All Substrates
- Riprap/Debris
- No data
- Over Water Structure
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

AERIAL PHOTO: NAIP 2011.

Feet
0 400 800 1,200 1,600

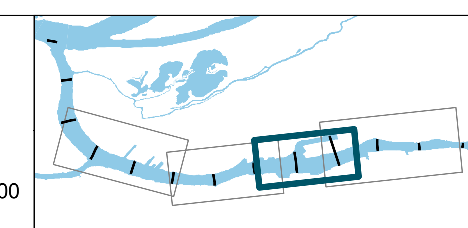


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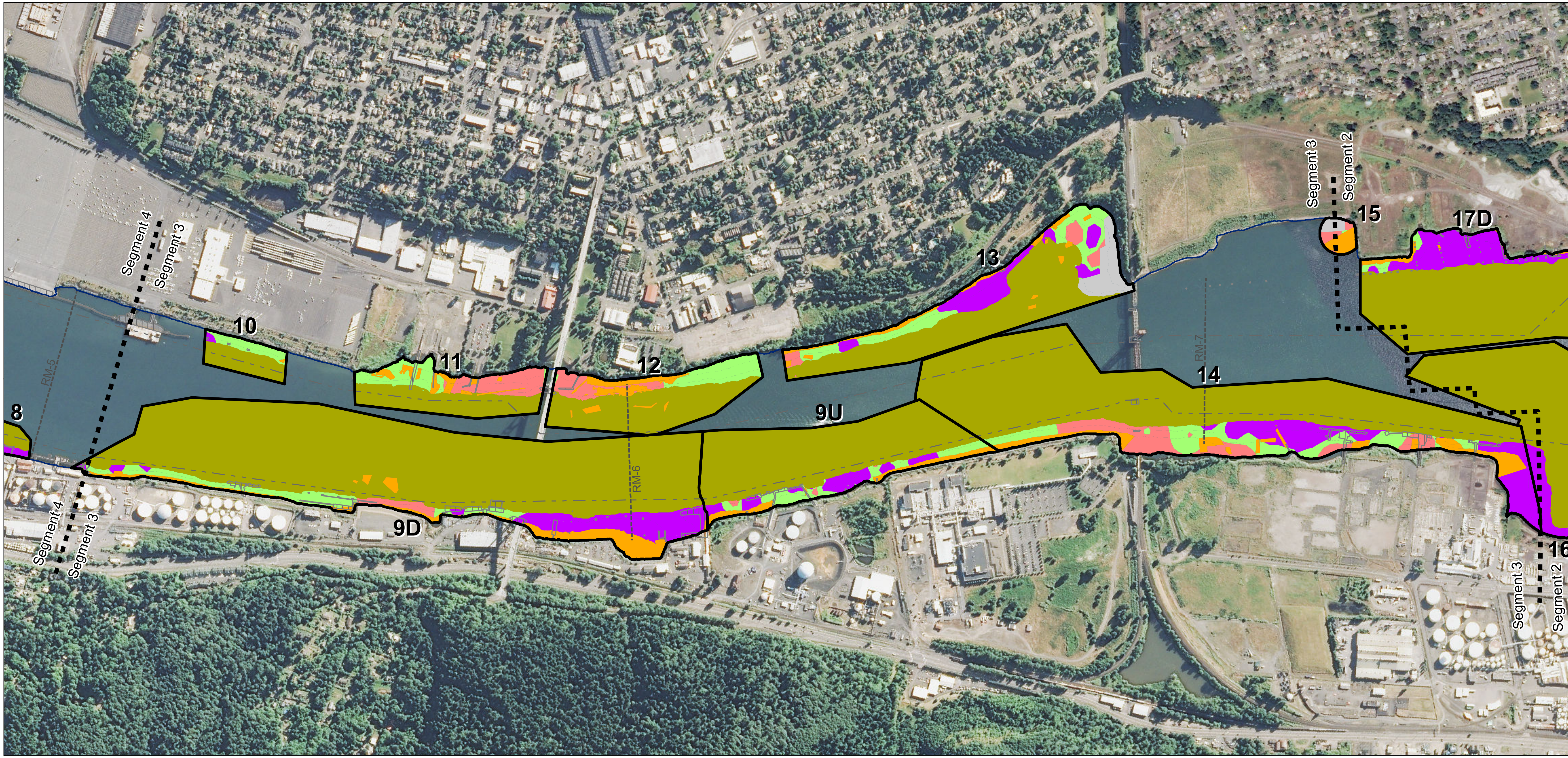
Figure 2.3-2b
Portland Harbor RI/FS
Draft Feasibility Study
Substrate Types within the Site
Segment 2: AOPCs 15-19

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_3_2_Substrate_Types_Within_SA.mxd joliver 3/12/2012 12:46:27 PM



LEGEND

Substrate

- 0-40% fines
- 40-60% fines
- 60-100% fines
- Deep Water - All Substrates
- Riprap/Debris
- No data
- Over Water Structure
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

AERIAL PHOTO: NAIP 2011.

Feet
0 450 900 1,350 1,800

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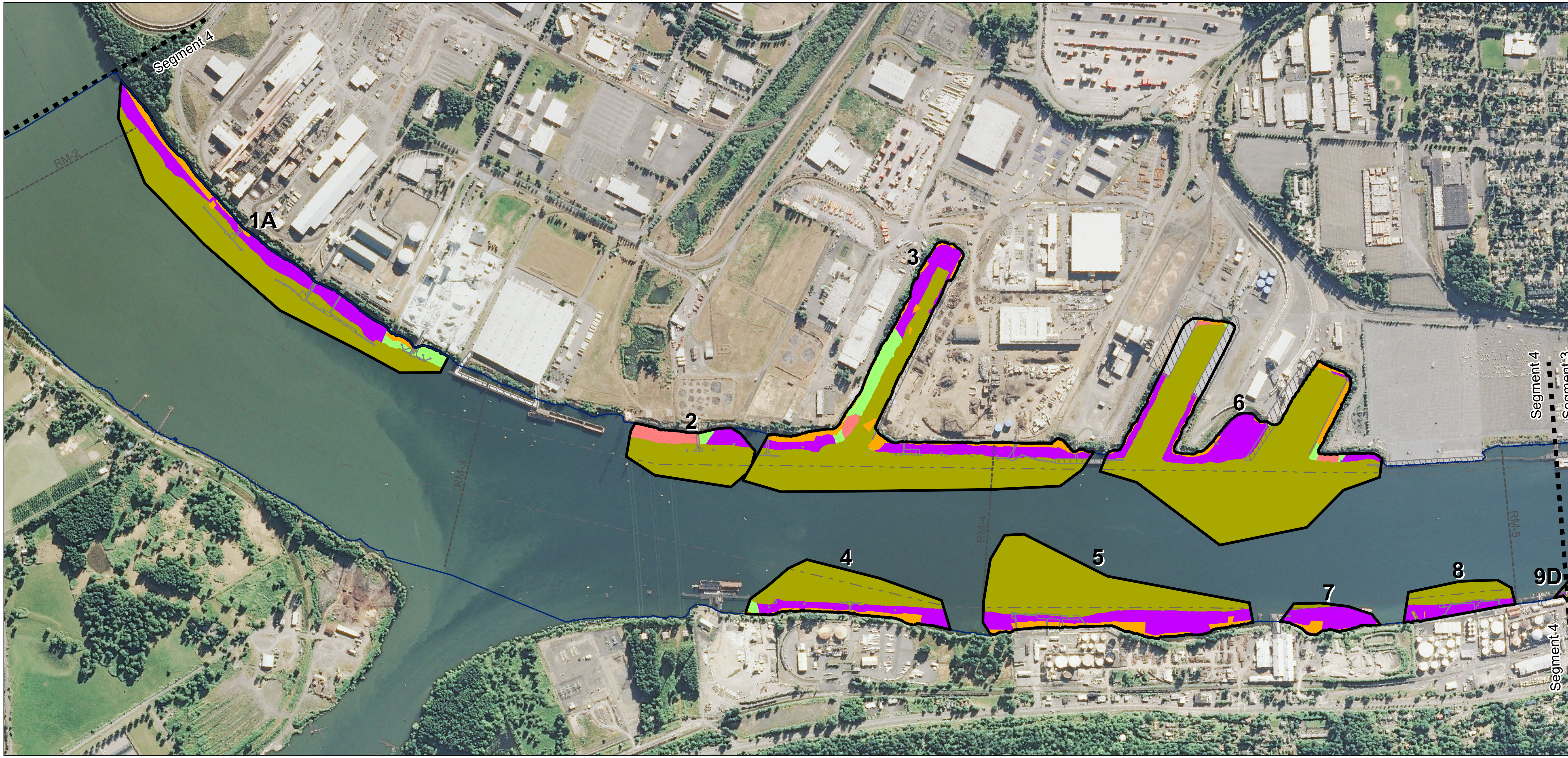
Figure 2.3-2c
Portland Harbor RI/FS
Draft Feasibility Study
Substrate Types within the Site
Segment 3: AOPCs 9D - 14



LEGEND

Substrate
- 0-40% fines
- 40-60% fines
- 60-100% fines
- Deep Water - All Substrates
- Riprap/Debris
- No data
- Over Water Structure
- Areas of Potential Concern (August 2011)
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

AERIAL PHOTO: NAIP 2011.

Feet
0 500 1,000 1,500 2,000

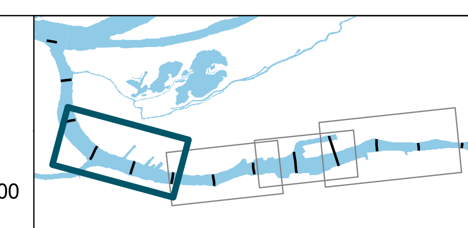


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Figure 2.3-2d
Portland Harbor RI/FS
Draft Feasibility Study
Substrate Types within the Site
Segment 4: AOPCs 1-8

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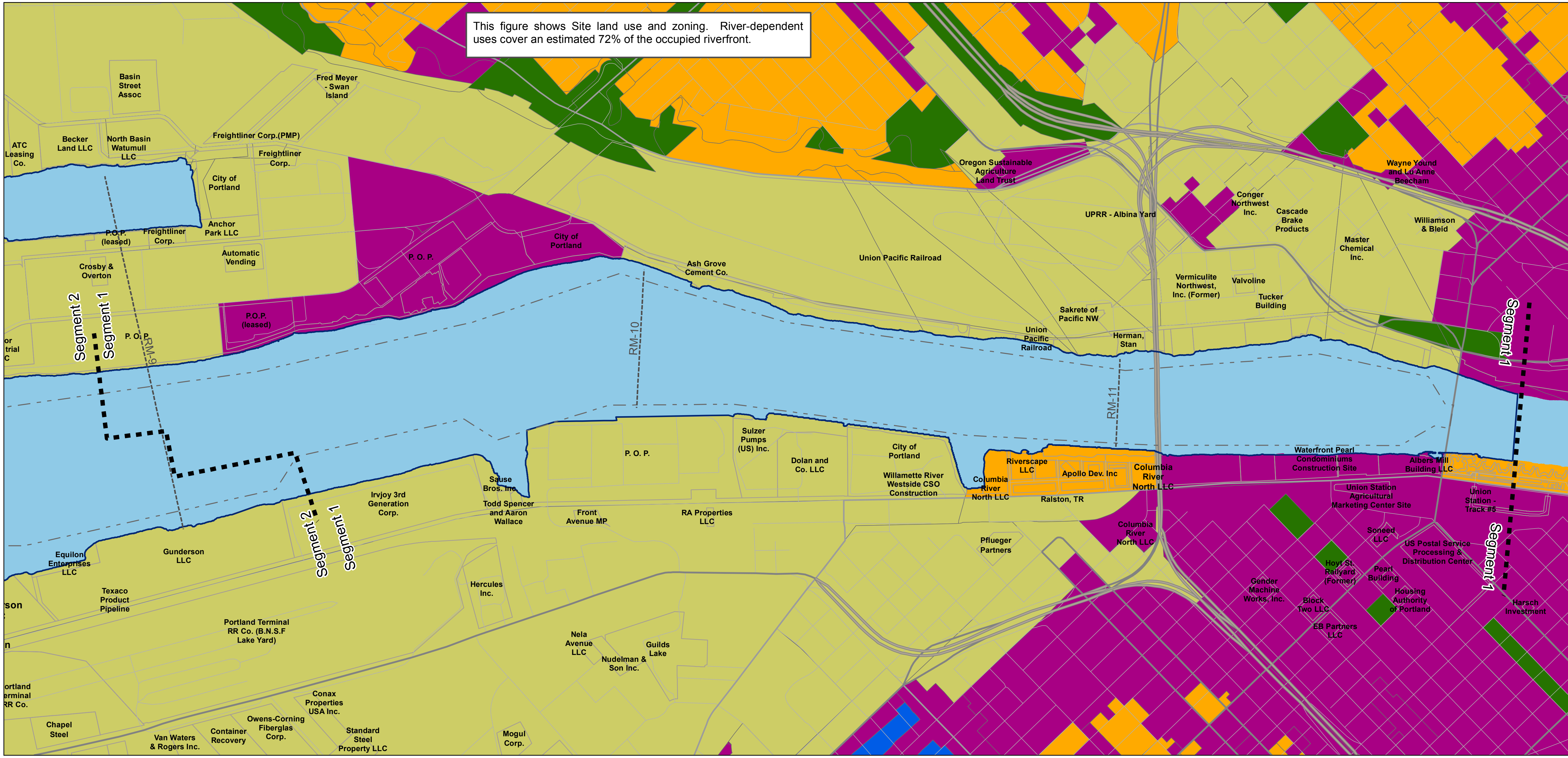


LEGEND

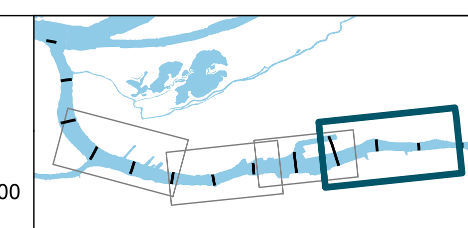
Generalized Zoning

- Commercial
- Mixed
- Industrial
- Open Space
- Residential
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

Notes:
1. Zoning data acquired from City of Portland, January 23, 2012.
2. Ownership layer per draft Final RI (August 2011).

Feet

0 550 1,100 1,650 2,200



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NOTE:
The active channel margin shoreline type is derived from he LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.

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Figure 2.4-1a
Portland Harbor RI/FS
Draft Feasibility Study
Site Land Use and Zoning
Segment 1: AOPCs 20-26

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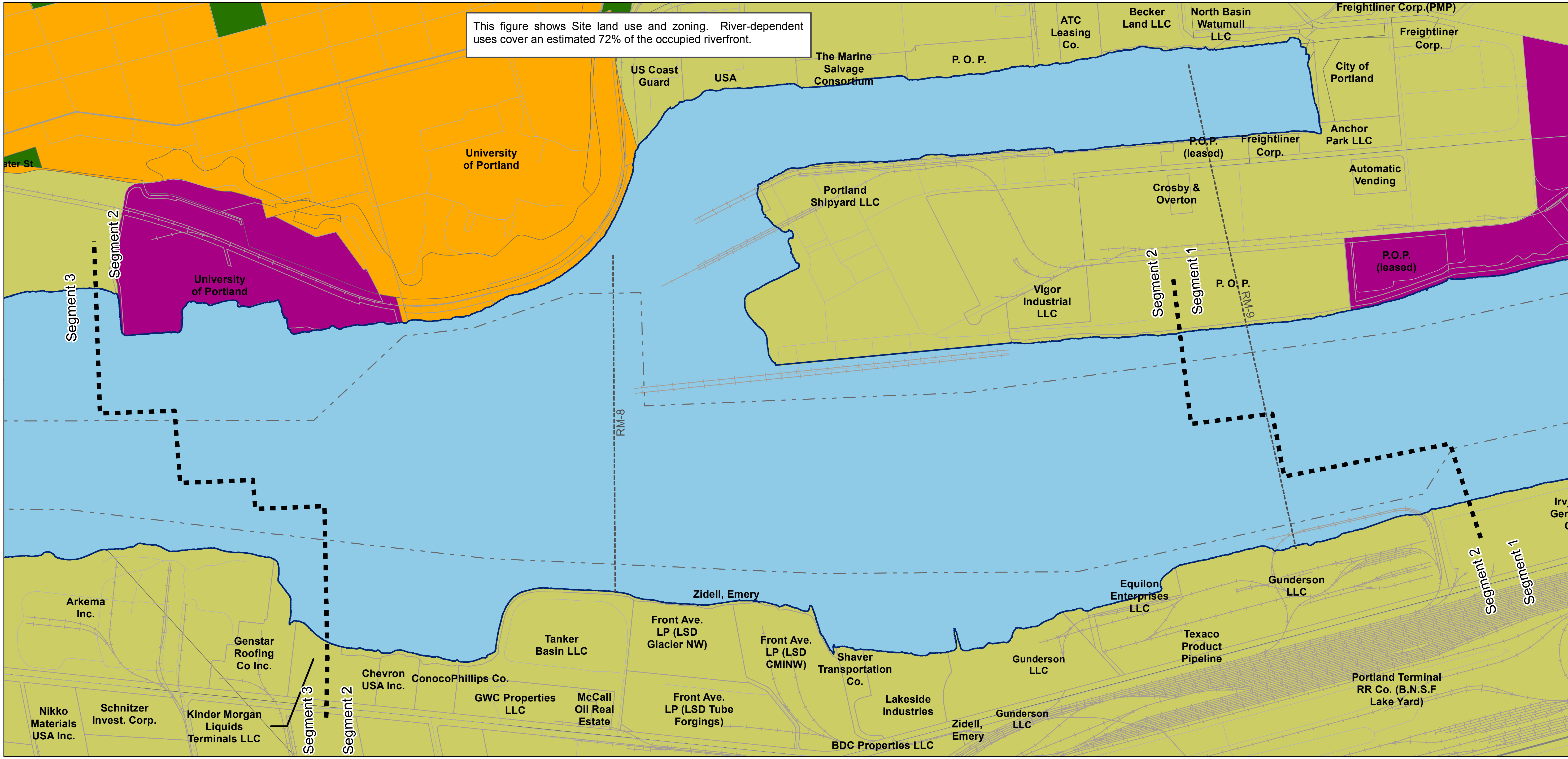


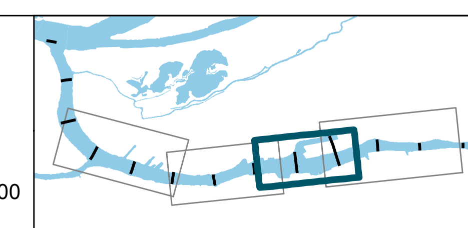
LEGEND

Generalized Zoning

- Commercial
- Mixed
- Industrial
- Open Space
- Residential
- Portland Harbor Study Area
- Federal Navigation Channel
- River miles
- Segment Boundary

Notes:
1. Zoning data acquired from City of Portland, January 23, 2012.
2. Ownership layer per draft Final RI (August 2011).

Feet: 0 400 800 1,200 1,600



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LWG LOWER WILLAMETTE GROUP

NOTE:
The active channel margin shoreline type is derived from he LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.

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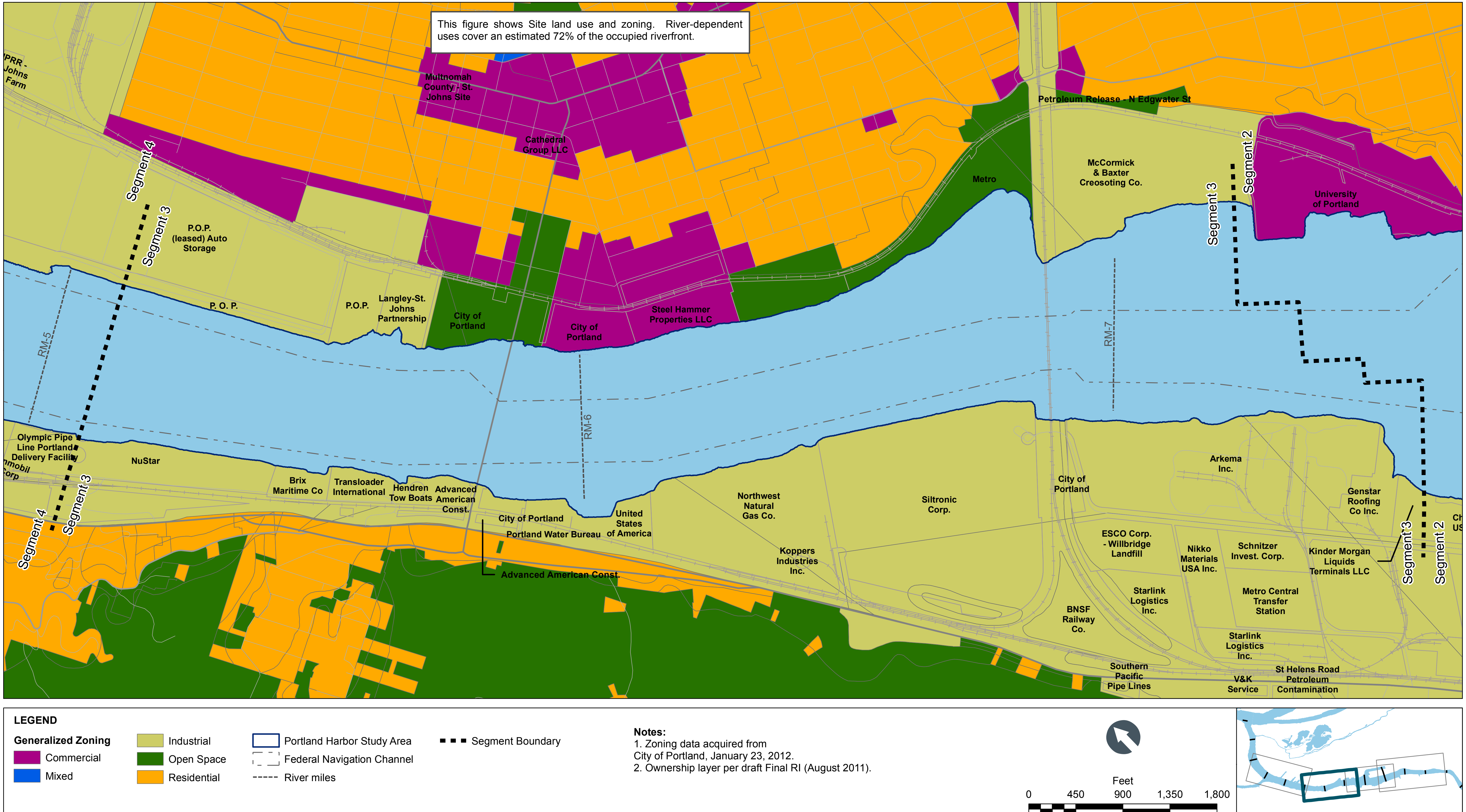
Figure 2.4-1b
Portland Harbor RI/FS
Draft Feasibility Study
Site Land Use and Zoning
Segment 2: AOPCs 15-19

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_4_1_Site_Land_Use_Zoning.mxd nkochie 3/13/2012 12:35:14 PM



Notes:
1. Zoning data acquired from City of Portland, January 23, 2012.
2. Ownership layer per draft Final RI (August 2011).

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LWG LOWER WILLAMETTE GROUP

NOTE:
The active channel margin shoreline type is derived from he LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.

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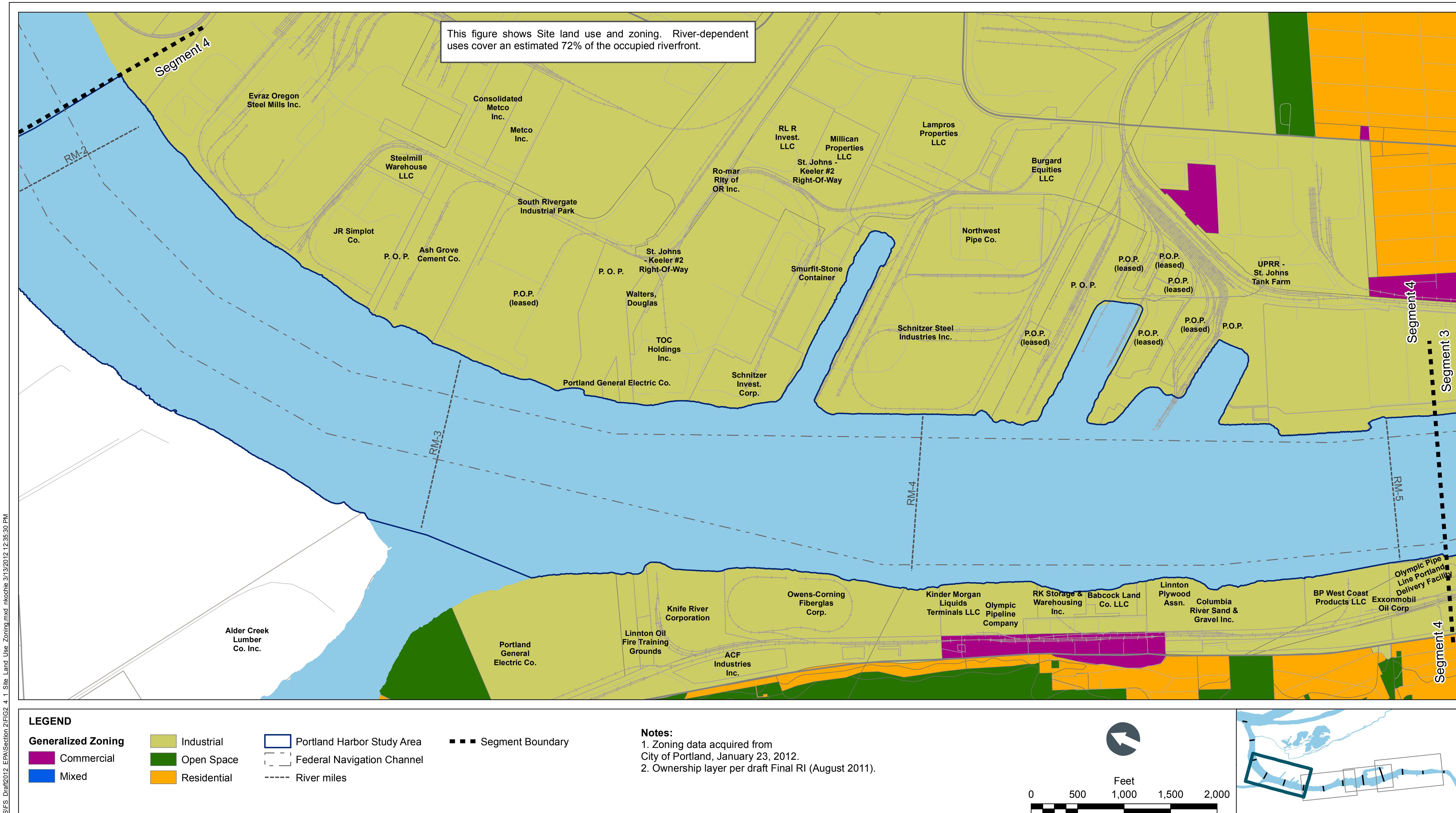
Figure 2.4-1c
Portland Harbor RI/FS
Draft Feasibility Study
Site Land Use and Zoning
Segment 3: AOPCs 9D - 14

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_4_1_Site_Land_Use_Zoning.mxd nkochie 3/13/2012 12:35:22 PM



Notes:
1. Zoning data acquired from City of Portland, January 23, 2012.
2. Ownership layer per draft Final RI (August 2011).

Q:\Jobs\010142-01 AQ LWG\Maps\FS\FS Draft2012 EPA\Section 2\FIG2 4 1 Site Land Use Zoning.mxd nkochie 3/13/2012 12:35:30 PM

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LWG LOWER WILLAMETTE GROUP

NOTE:
The active channel margin shoreline type is derived from he LWG shoreline condition line dataset, created in 2007 and updated in 2010, and assumes the shoreline condition extends throughout the active channel margin zone.

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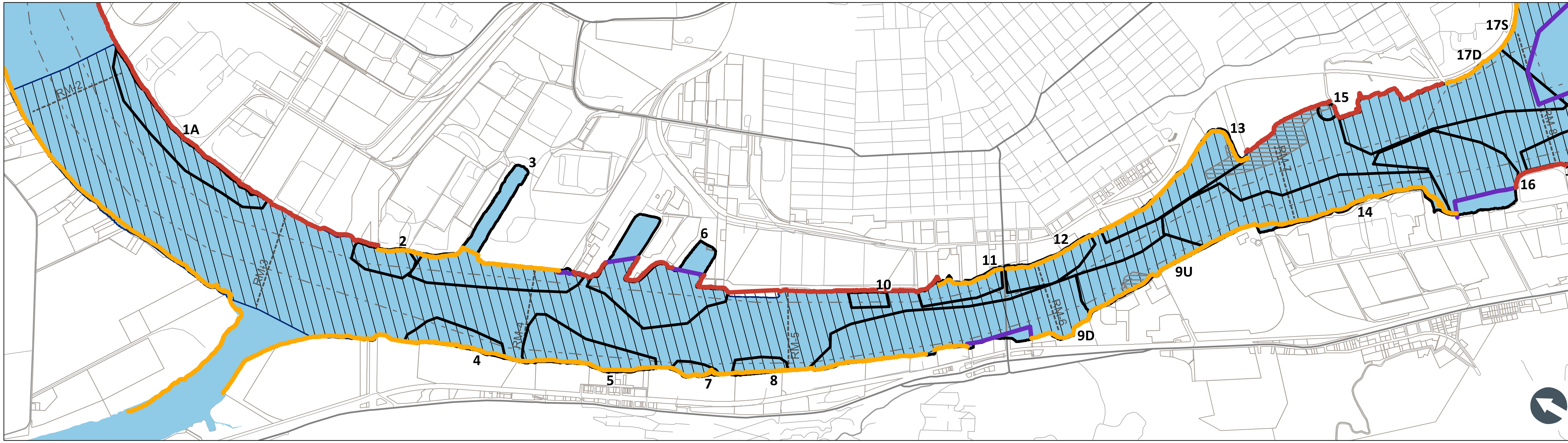
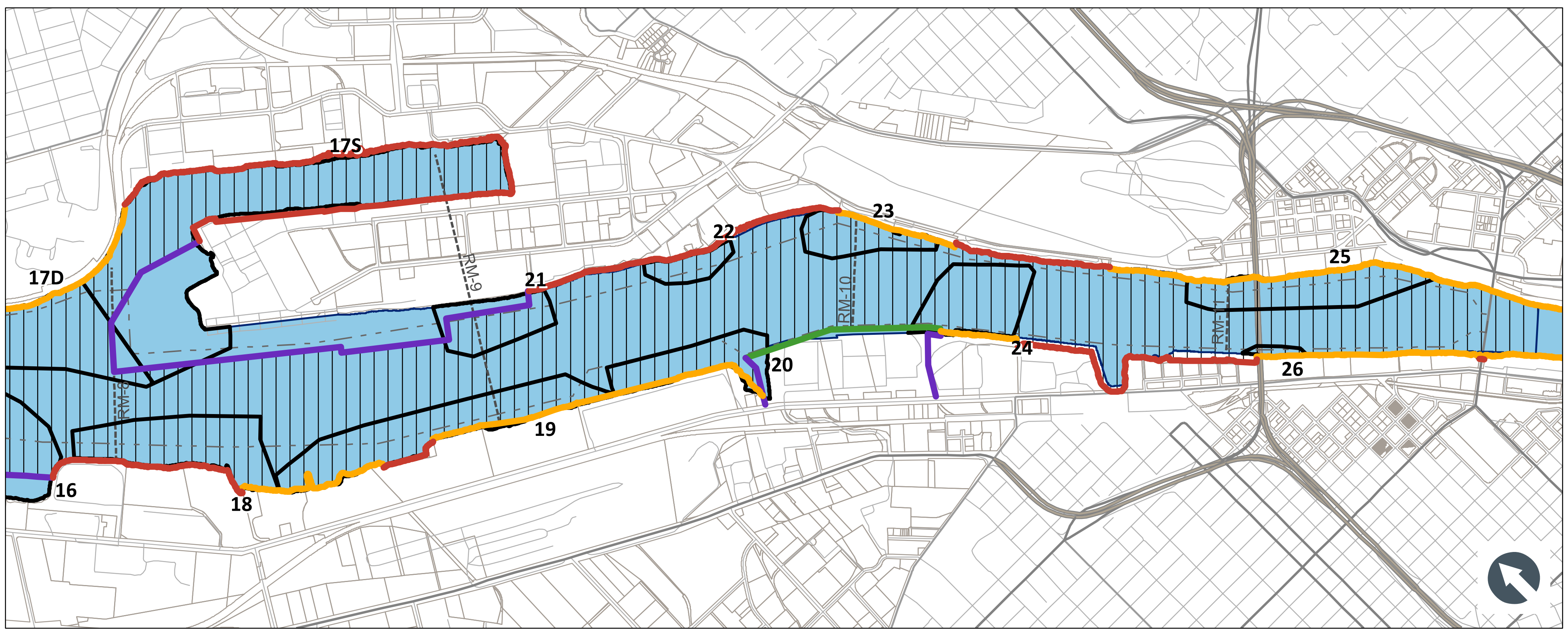
Figure 2.4-1d
Portland Harbor RI/FS
Draft Feasibility Study
Site Land Use and Zoning
Segment 4: AOPCs 1-8





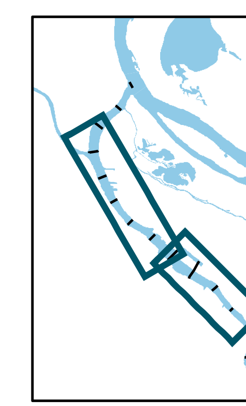
LEGEND

DSL Land Ownership

- Deed Lines
- Harbor Line
- Ordinary High Water
- Ordinary Low Water
- DSL Land Ownership Area
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Feet

0 1,000 2,000 3,000 4,000



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LWG LOWER WILLAMETTE GROUP

Note:
1. DSL Land Ownership layer provided by DSL 5/10/2011
2. This information may change based on deed settlements.
3. It should be noted that this map contains inaccuracies; for example, at Terminal 2, the ownership boundary is up to ordinary high water and not the harbor line as shown.

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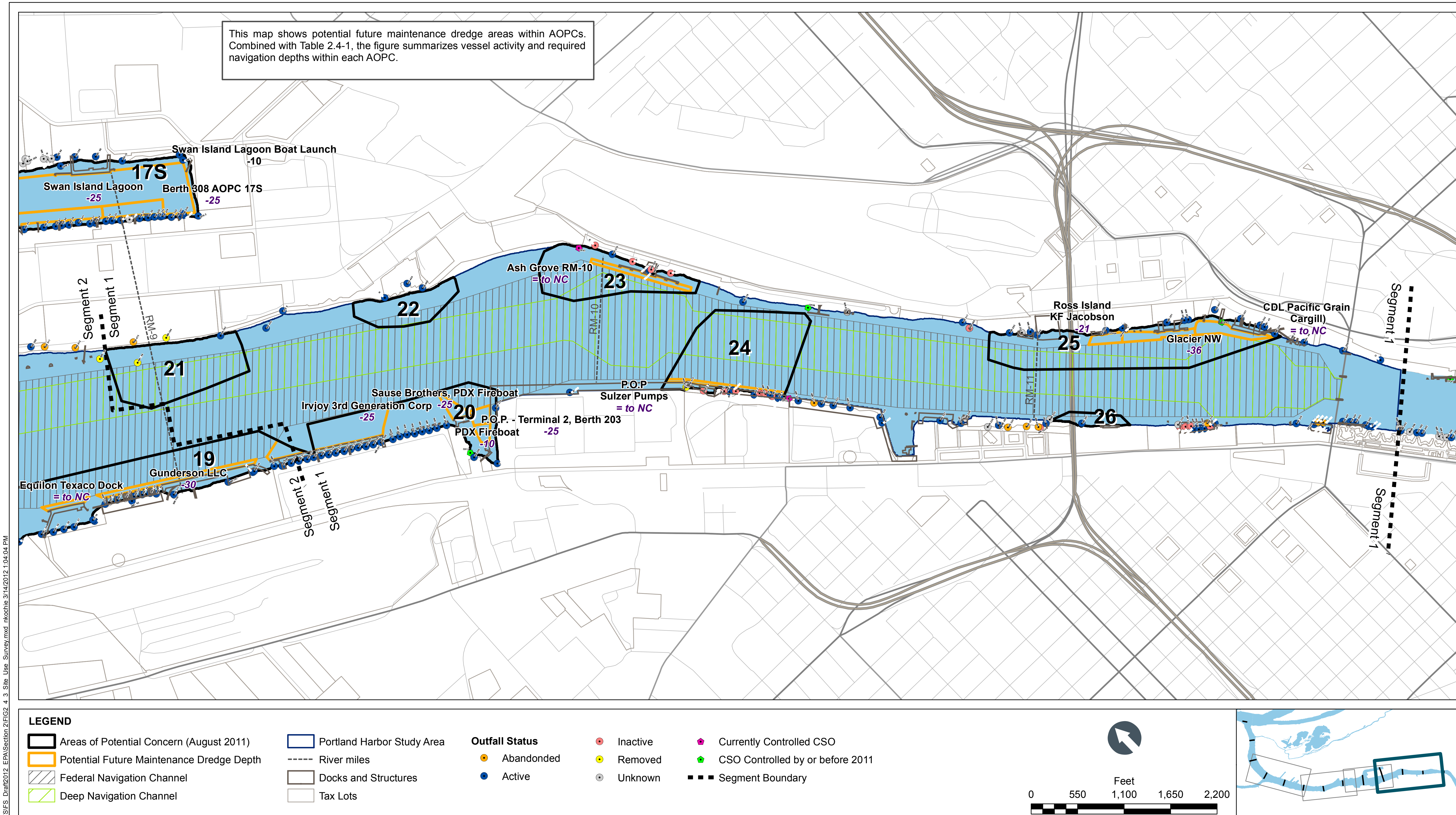
Figure 2.4-2
Portland Harbor RI/FS
Draft Feasibility Study
DSL Land Ownership

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_4_2_DSL_Land_Ownership.mxd jloliver 3/13/2012 12:59:31 PM



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LWG LOWER WILLAMETTE GROUP

Note:
1. Elevation in CRD.
2. Elevation "= to NC" - depth is equal to navagation channel.
3. Elevation in purple italics.
4. Future maintenance dredge areas were identified inside of AOPCs only.

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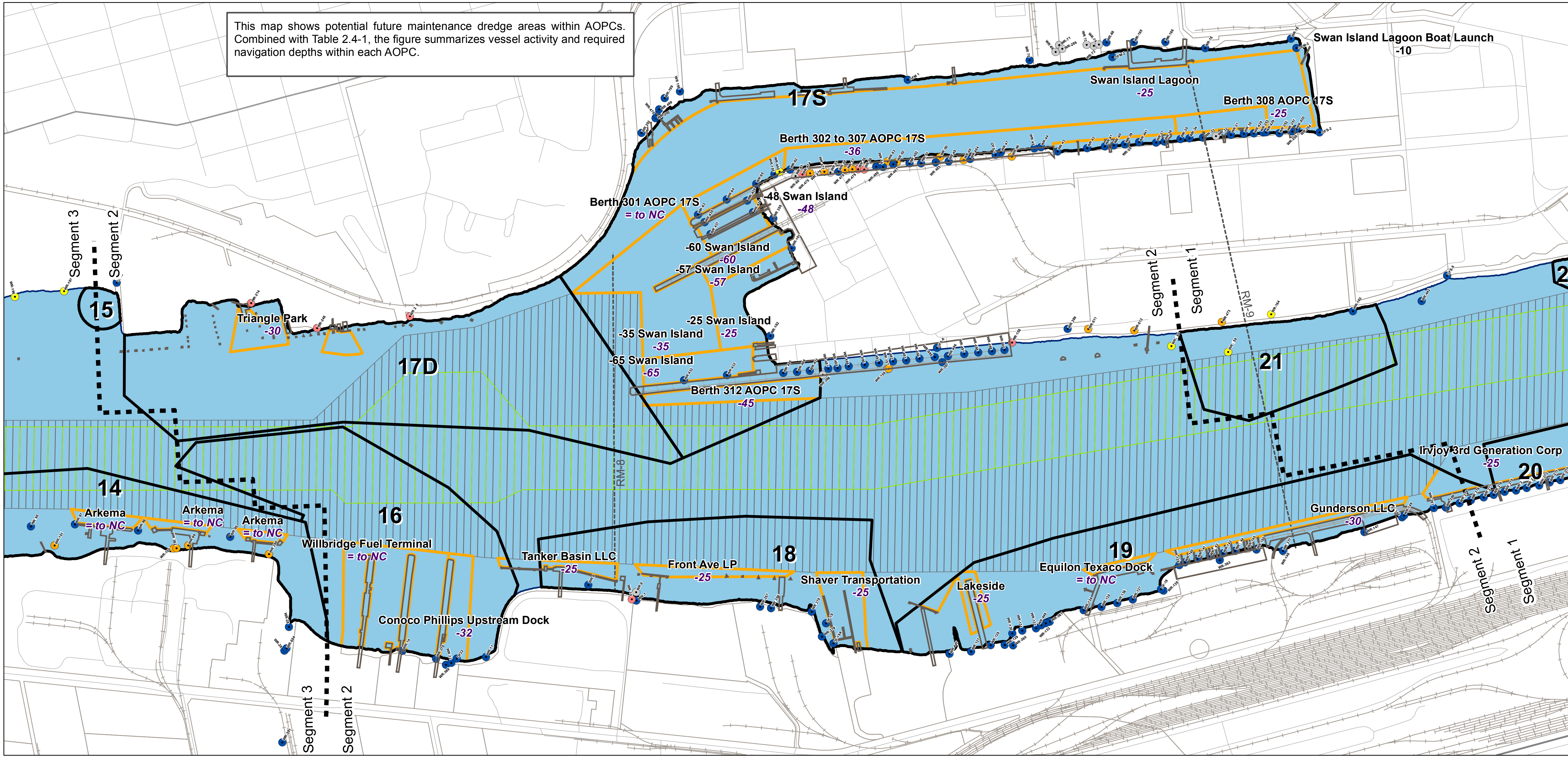
Work Product Prepared in Anticipation of Litigation

Figure 2.4-3a
Portland Harbor RI/FS
Draft Feasibility Study
Site Use Survey
Segment 1: AOPCs 20-26



LEGEND

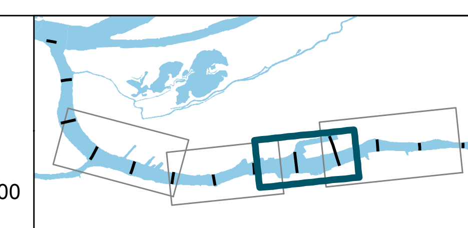
- Areas of Potential Concern (August 2011)
- Potential Future Maintenance Dredge Depth
- Federal Navigation Channel
- Deep Navigation Channel
- Portland Harbor Study Area
- River miles
- Docks and Structures
- Tax Lots

Outfall Status

- Abandonded
- Active
- Inactive
- Removed
- Unknown
- Currently Controlled CSO
- CSO Controlled by or before 2011
- Segment Boundary

Feet

0 400 800 1,200 1,600



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LWG LOWER WILLAMETTE GROUP

Note:
1. Elevation in CRD.
2. Elevation "= to NC" - depth is equal to navagation channel.
3. Elevation in purple italics.
4. Future maintenance dredge areas were identified inside of AOPCs only.

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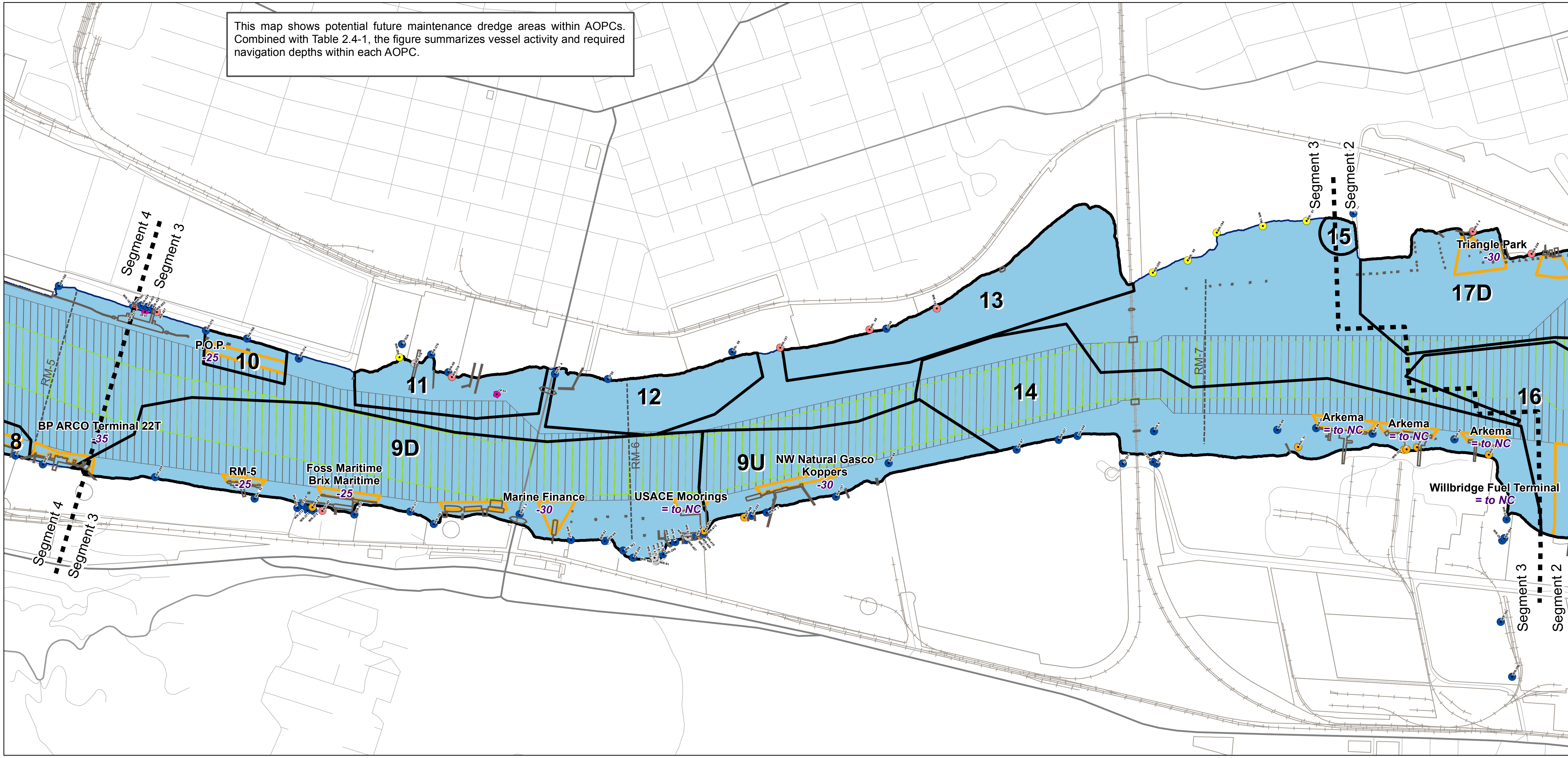
Figure 2.4-3b
Portland Harbor RI/FS
Draft Feasibility Study
Site Use Survey
Segment 2: AOPCs 15-19

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_4_3_Site_Use_Survey.mxd nkochie 3/14/2012 1:04:16 PM



LEGEND

- Areas of Potential Concern (August 2011)
- Potential Future Maintenance Dredge Depth
- Federal Navigation Channel
- Deep Navigation Channel
- Portland Harbor Study Area
- River miles
- Docks and Structures
- Tax Lots

Outfall Status

- Abandoned
- Active
- Inactive
- Removed
- Unknown
- Currently Controlled CSO
- CSO Controlled by or before 2011
- Segment Boundary

Feet

0 450 900 1,350 1,800

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LWG LOWER WILLAMETTE GROUP

Note:
1. Elevation in CRD.
2. Elevation "= to NC" - depth is equal to navagation channel.
3. Elevation in purple italics.
4. Future maintenance dredge areas were identified inside of AOPCs only.

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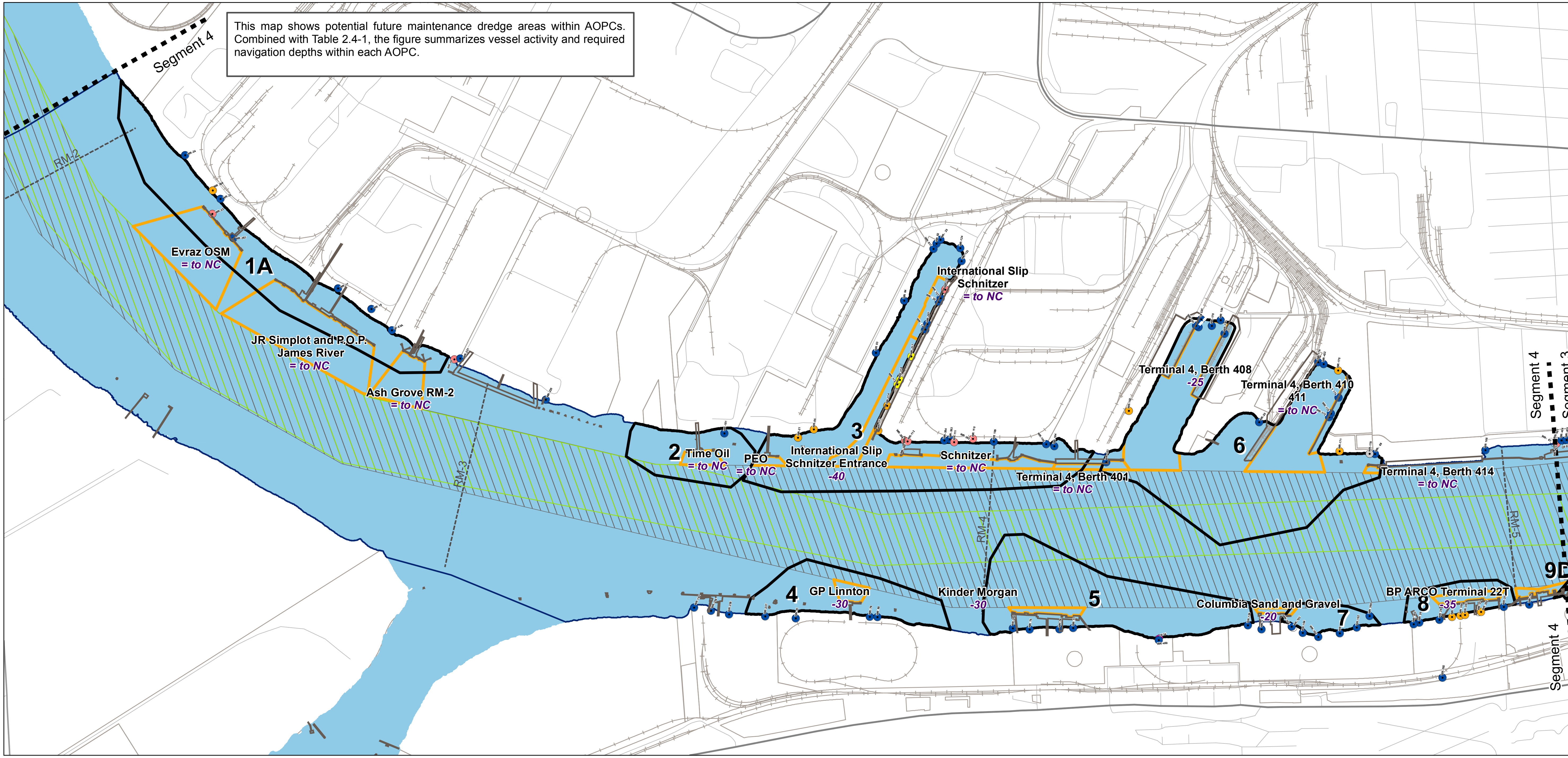
Figure 2.4-3c
Portland Harbor RI/FS
Draft Feasibility Study
Site Use Survey
Segment 3: AOPCs 9D - 14



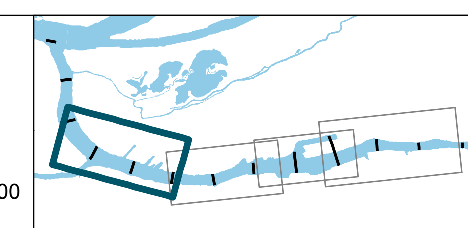
LEGEND

- Areas of Potential Concern (August 2011)
- Potential Future Maintenance Dredge Depth
- Federal Navigation Channel
- Deep Navigation Channel
- Portland Harbor Study Area
- River miles
- Docks and Structures
- Tax Lots

Outfall Status

- Abandonded
- Active
- Inactive
- Removed
- Unknown
- Currently Controlled CSO
- CSO Controlled by or before 2011
- Segment Boundary

Feet
0 500 1,000 1,500 2,000



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Note:
1. Elevation in CRD.
2. Elevation "= to NC" - depth is equal to navagation channel.
3. Elevation in purple italics.
4. Future maintenance dredge areas were identified inside of AOPCs only.

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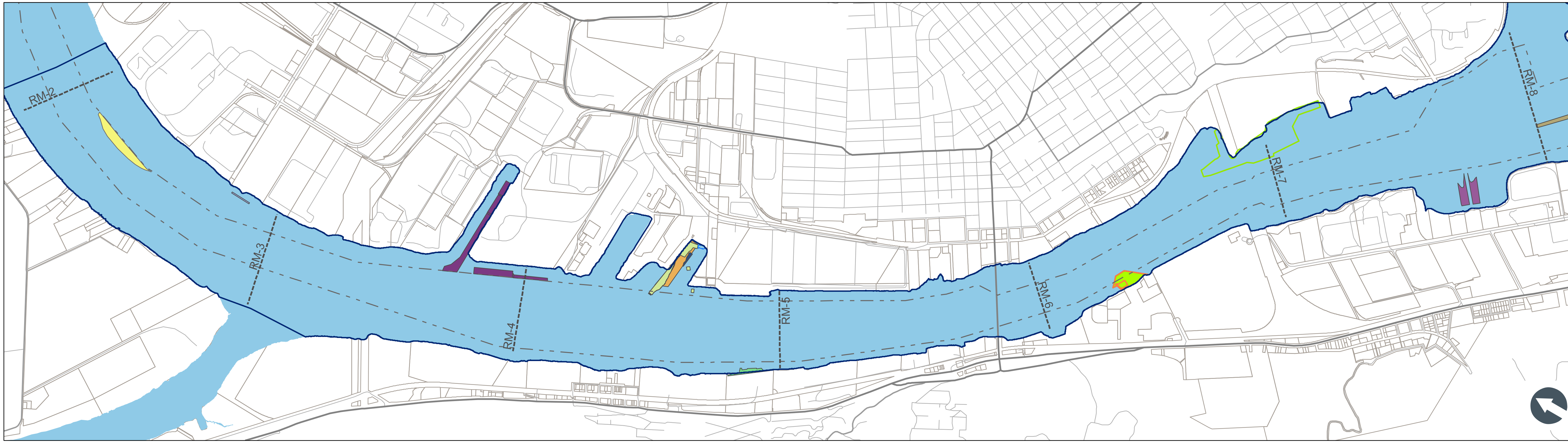
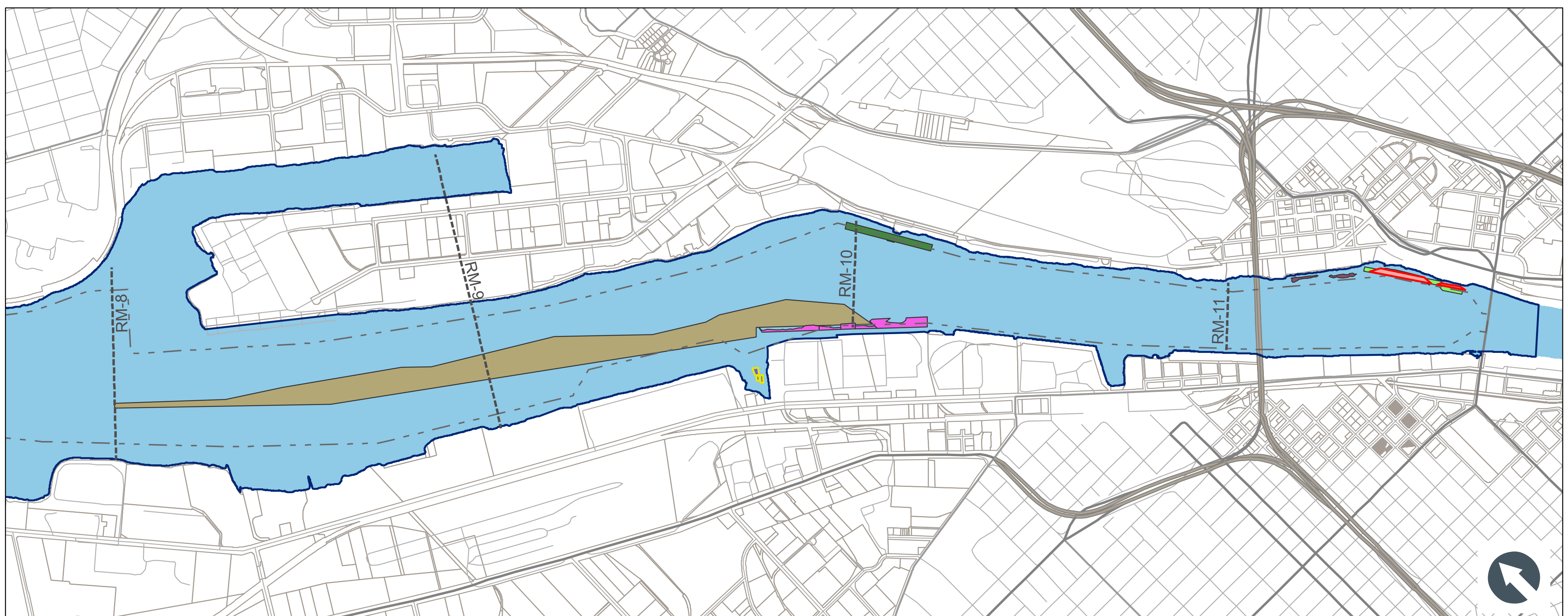
Figure 2.4-3d
Portland Harbor RI/FS
Draft Feasibility Study
Site Use Survey
Segment 4: AOPCs 1-8

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_4_3_Site_Use_Survey.mxd nkochie 3/14/2012 1:04:35 PM





LEGEND

Capping Areas
- 10/3/2009, CLD Pacific/Cargill
- 10/29/2005, GASCO
- 1/21/2005, Portland Fire Bureau
- 10/28/2004, McCormick and Baxter
- 2008, Terminal 4, Slip 3

Dredging Areas
- Ash Grove Cement (2005)
- BP West Coast Products LLC (2008)
- CLD Pacific Grain, Inc. (2009)
- Cargill Incorporated (2002)
- Chevron Products Company (2001)
- Chevron Products Company (2001)
- City of Portland Fire Bureau Station 6 Dock (2005)
- FY 97 Corps by Great Lakes #53 Clam (1997)
- Gasco (2005)
- Glacier Northwest (2004)
- Goldendale Aluminum (former) (2000)
- POP Willamette River Dredging (1997, Berth 410, 411)
- POP Willamette River Dredging (2005; Berth 410,411)
- POP Willamette River Dredging (2004, Berth 410, 411)
- POP Willamette River Dredging (2002; 205, 206)
- POP Willamette River Dredging (2008; Slip 3, Berth 410, 411)
- Schnitzer Steel Industries (2004)
- USACE Post Office Bar (2011)

- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel

Feet
0 1,000 2,000 3,000 4,000

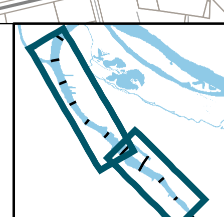


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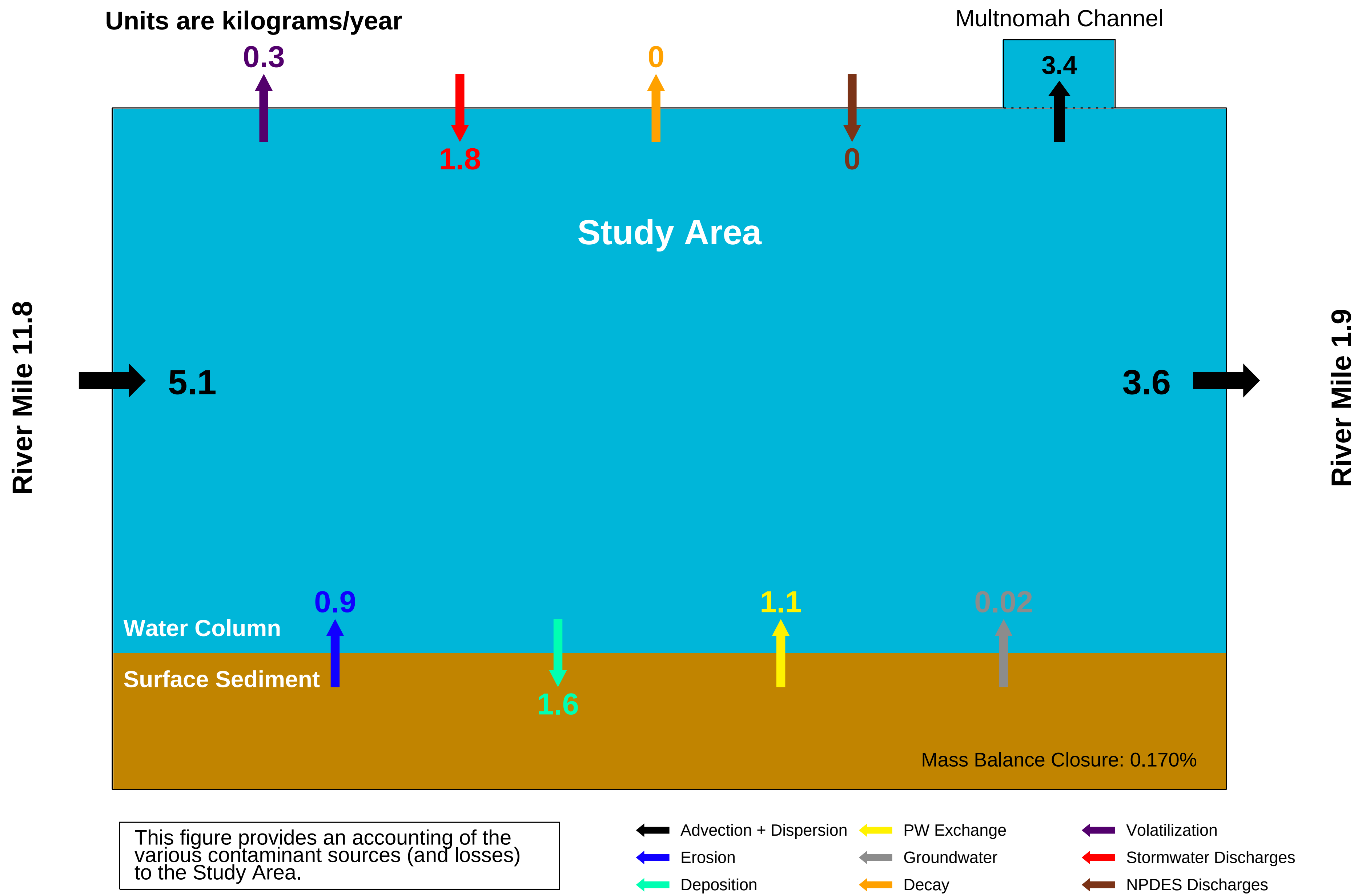
Figure 2.4-4
Portland Harbor RI/FS
Draft Feasibility Study
Site Dredging and Capping Activities

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_4_4_SiteDredgeCap.mxd jpliver 3/19/2012 7:25:01 AM



This figure provides an accounting of the various contaminant sources (and losses) to the Study Area.

Figure 2.5-1a

Portland Harbor RI/FS

Draft Feasibility Study

Model Mass Balance for Total PCB over 2002-2008 (Site-wide).

Run id: LWG_BC_chemfate_PCB-TOT_1012-01

RRM - H:\010142-01_LWG-Willamette\model\EFDC\Post_process\Mass_Balance\plot\Mass_Balance_Box_Diagram_bat_fs_120127.pro Tue Mar 13 11:51:00 2012

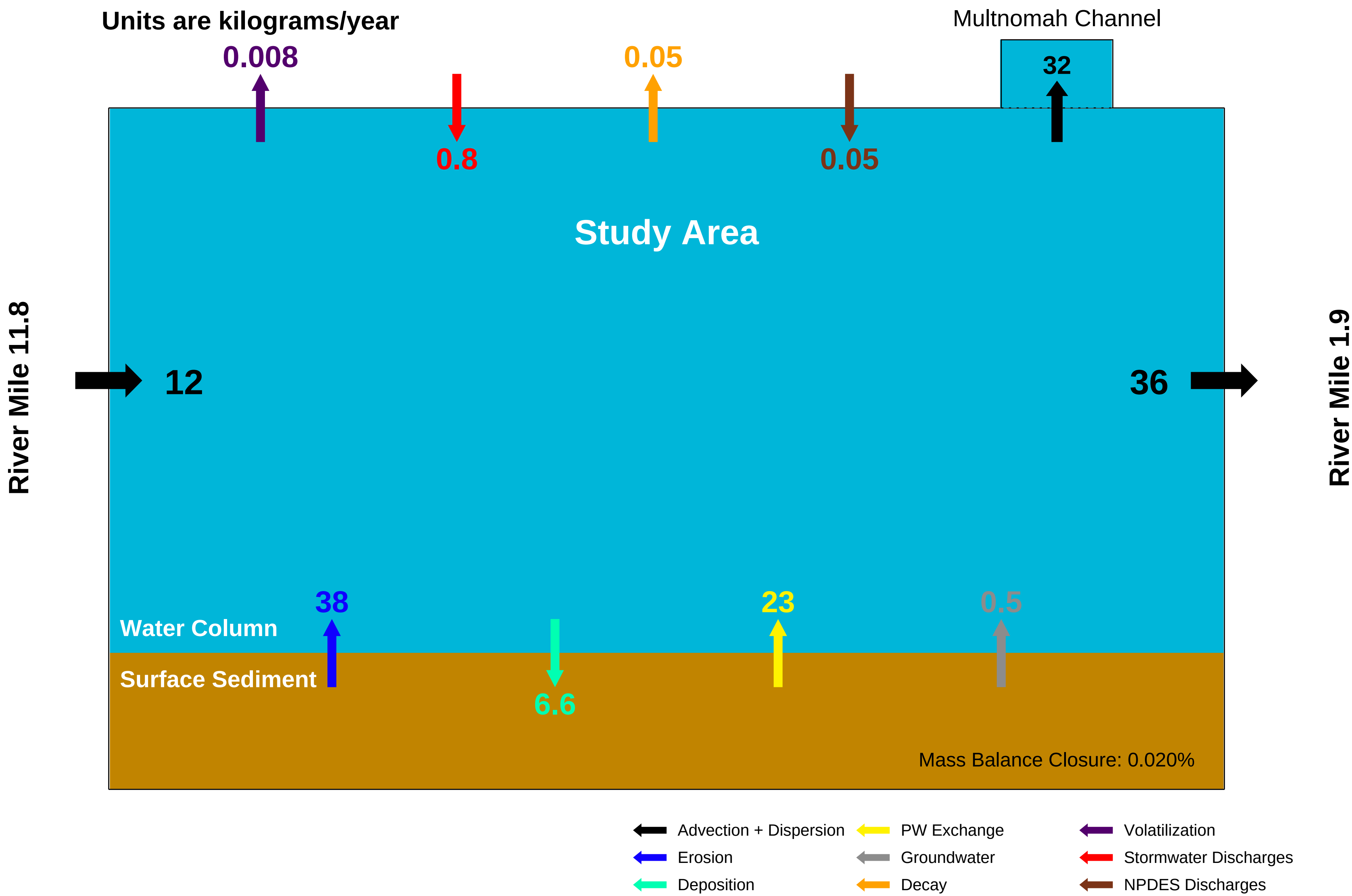


Figure 2.5-1b

Portland Harbor RI/FS

Draft Feasibility Study

Model Mass Balance for BaP over 2002-2008 (Site-wide).

Run id: LWG_cal_chemfate_BaP_1010-118

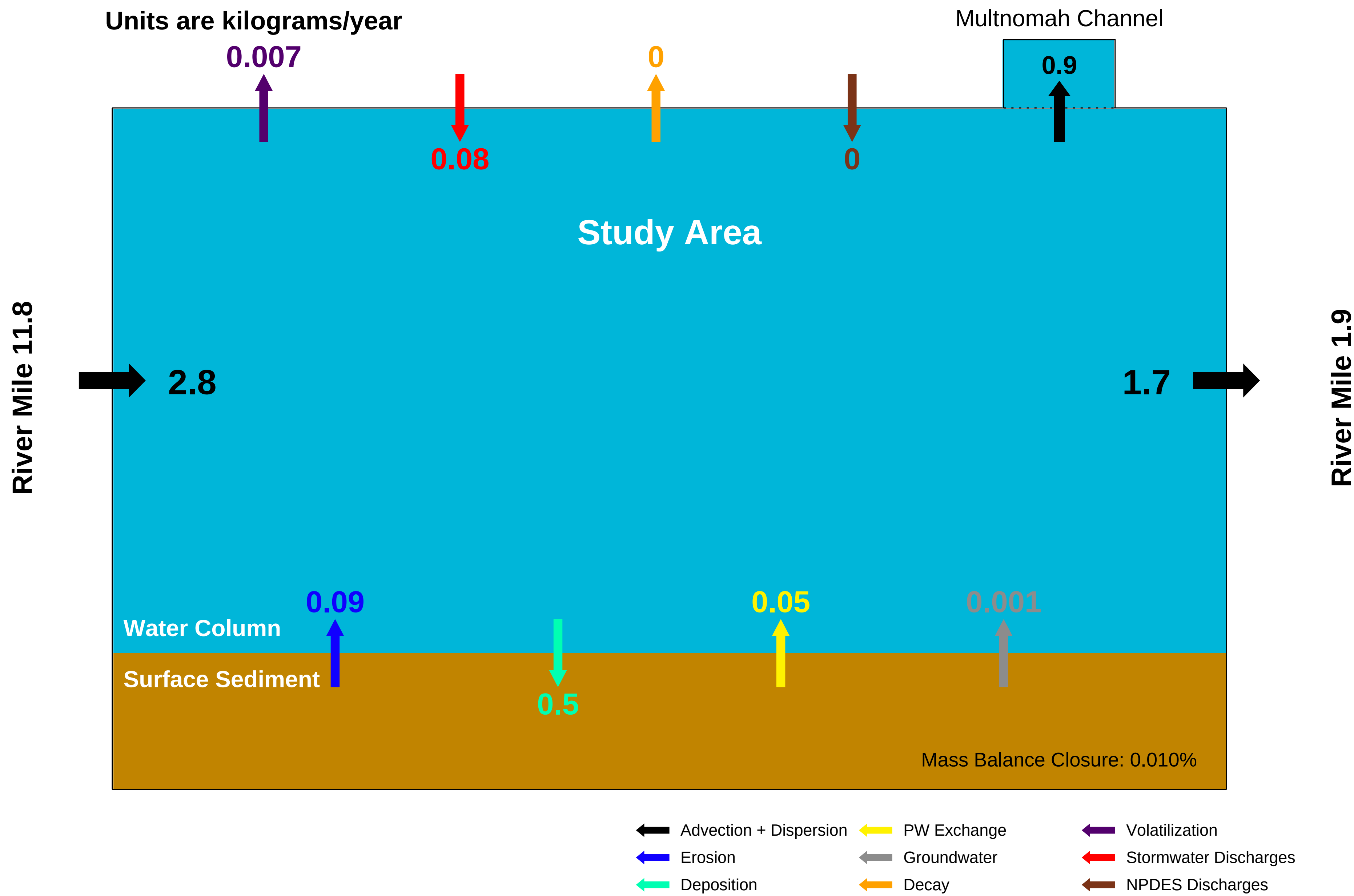


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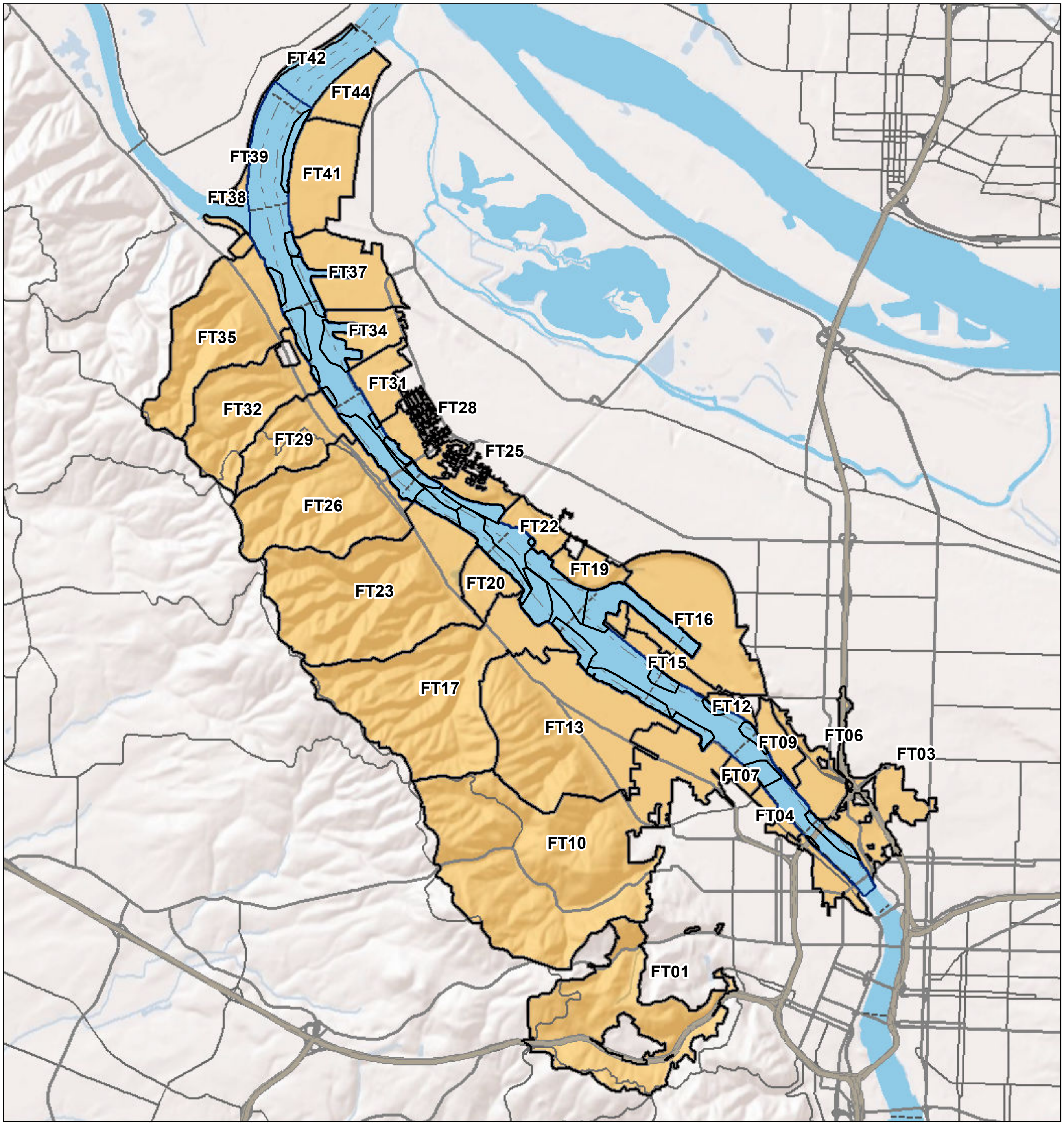
Figure 2.5-1c

Portland Harbor RI/FS

Draft Feasibility Study

Model Mass Balance for DDE over 2002-2008 (Site-wide).

Run id: LWG_cal_chemfate_DDE_1010-113



LEGEND

- Stormwater Basins
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Study Area
- Navigation Channel

Miles
0 0.3 0.6 0.9 1.2

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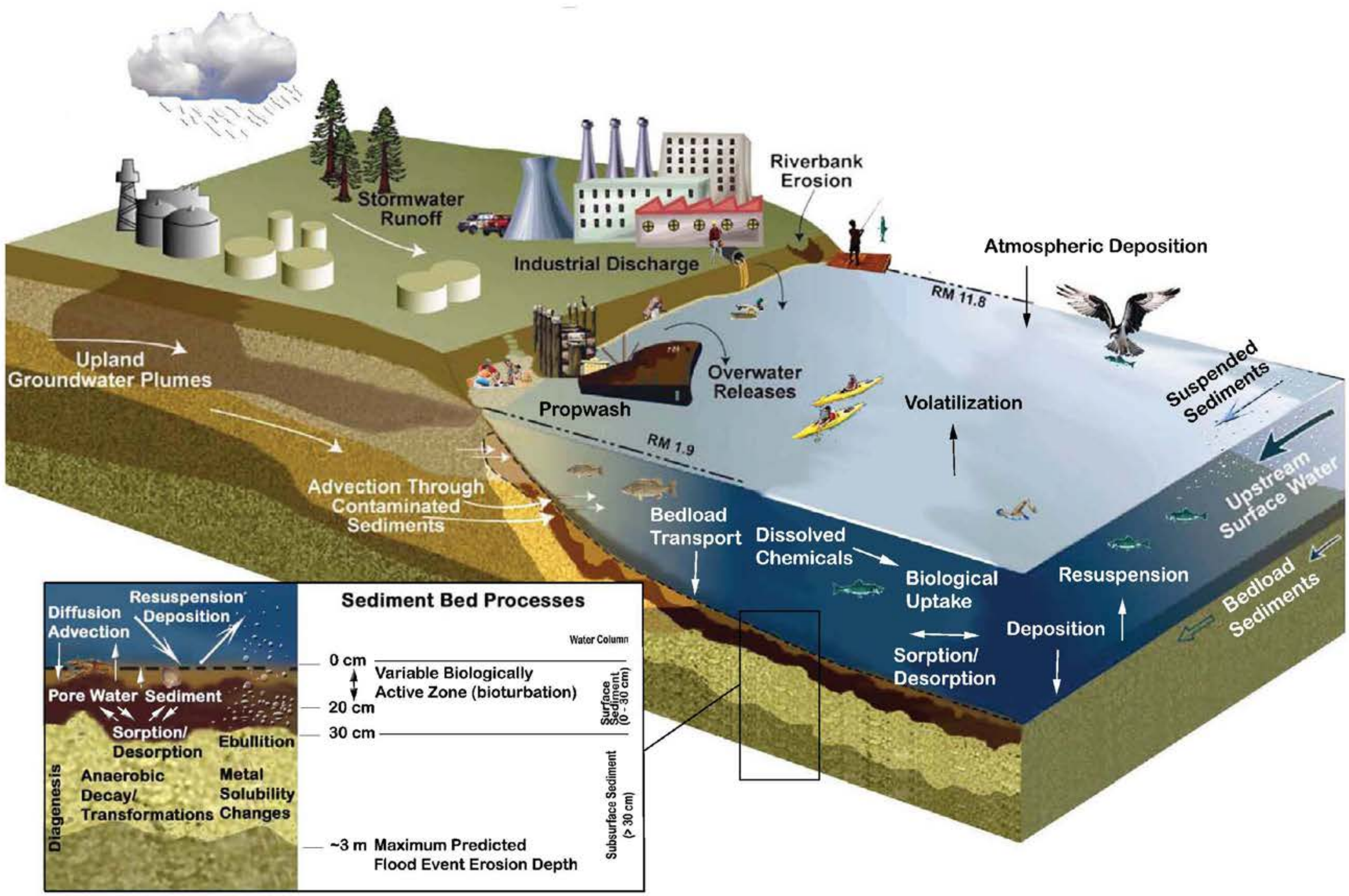
Figure 2.5-2
Portland Harbor RI/FS
Draft Feasibility Study
Site Stormwater Drainage Basins

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_5_2_StormwaterWatershed.mxd joliver 3/12/2012 12:52:44 PM



Mar 13, 2012 8:41am heriksen K:\Jobs\010142-Lower_Williamette_Group\01014201\LWG-01014201-25.dwg 2.6-1

SOURCE: Figure created from PDF provided by Integral Consulting, Inc.

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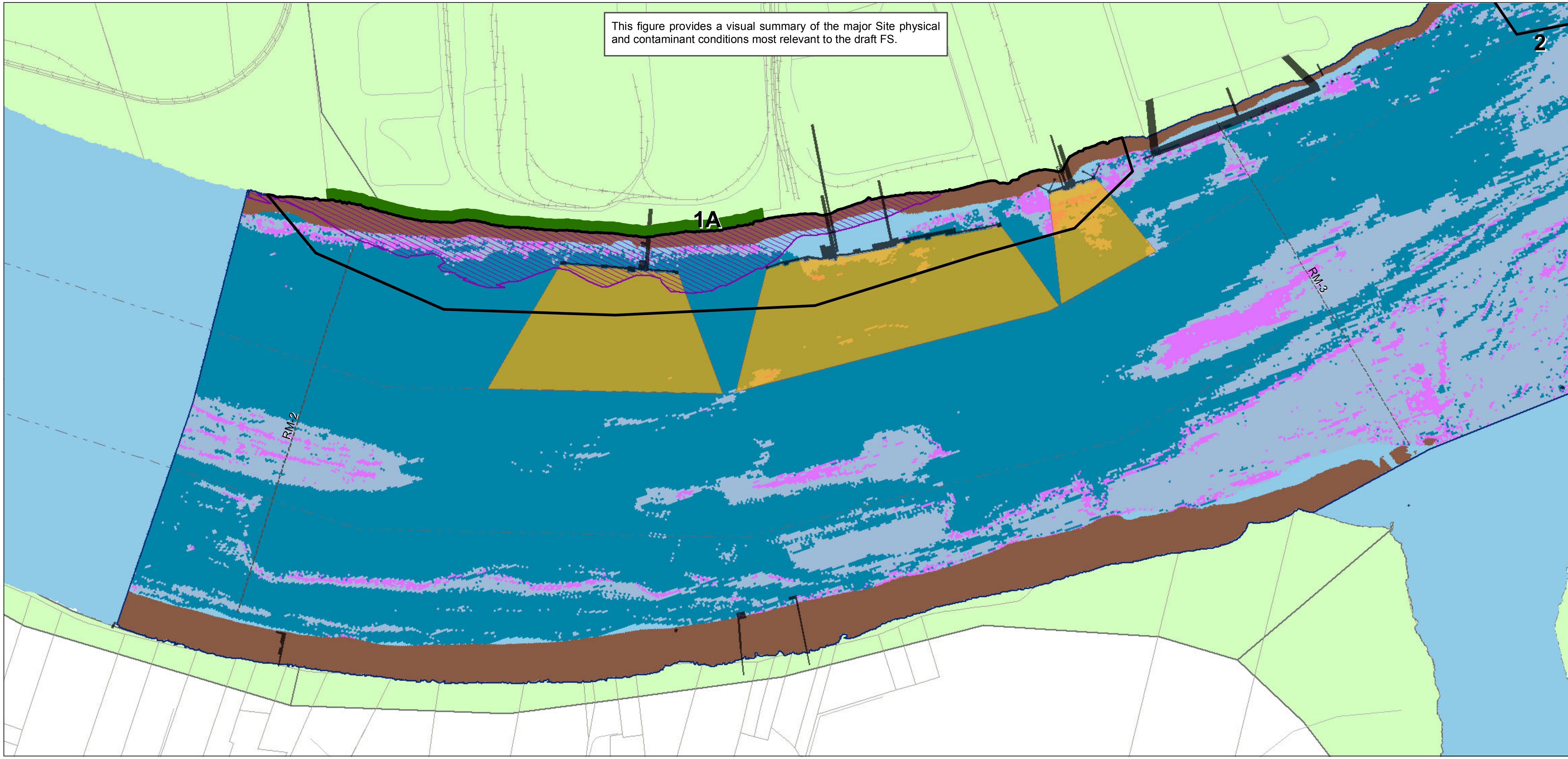
Figure 2.6-1
Portland Harbor RI/FS
Draft Feasibility Study
Major Elements of the Portland Harbor CSM



LEGEND

- Areas of Potential Concern (August 2011)
- Docks and Structures
- Areas Exceeding More Than 10 PRGs
- Potential Future Maintenance Dredge Areas
- Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based Basin Weighted Mean Annual Load by Model Cell (kg/yr)

- 0 - 0.100
- 0.101 - 1.00
- 1.01 - 1.04

Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009

- Net Erosion
- No Discernable Change
- Net Sedimentation
- Wave/Wake Areas

- Potential Riverbank Erosion Area
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap
- River miles

Feet
0 250 500 750 1,000

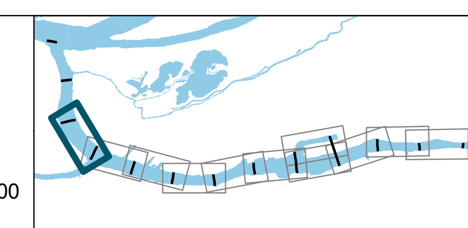


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Figure 2.6-2a
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 1.9 to 3

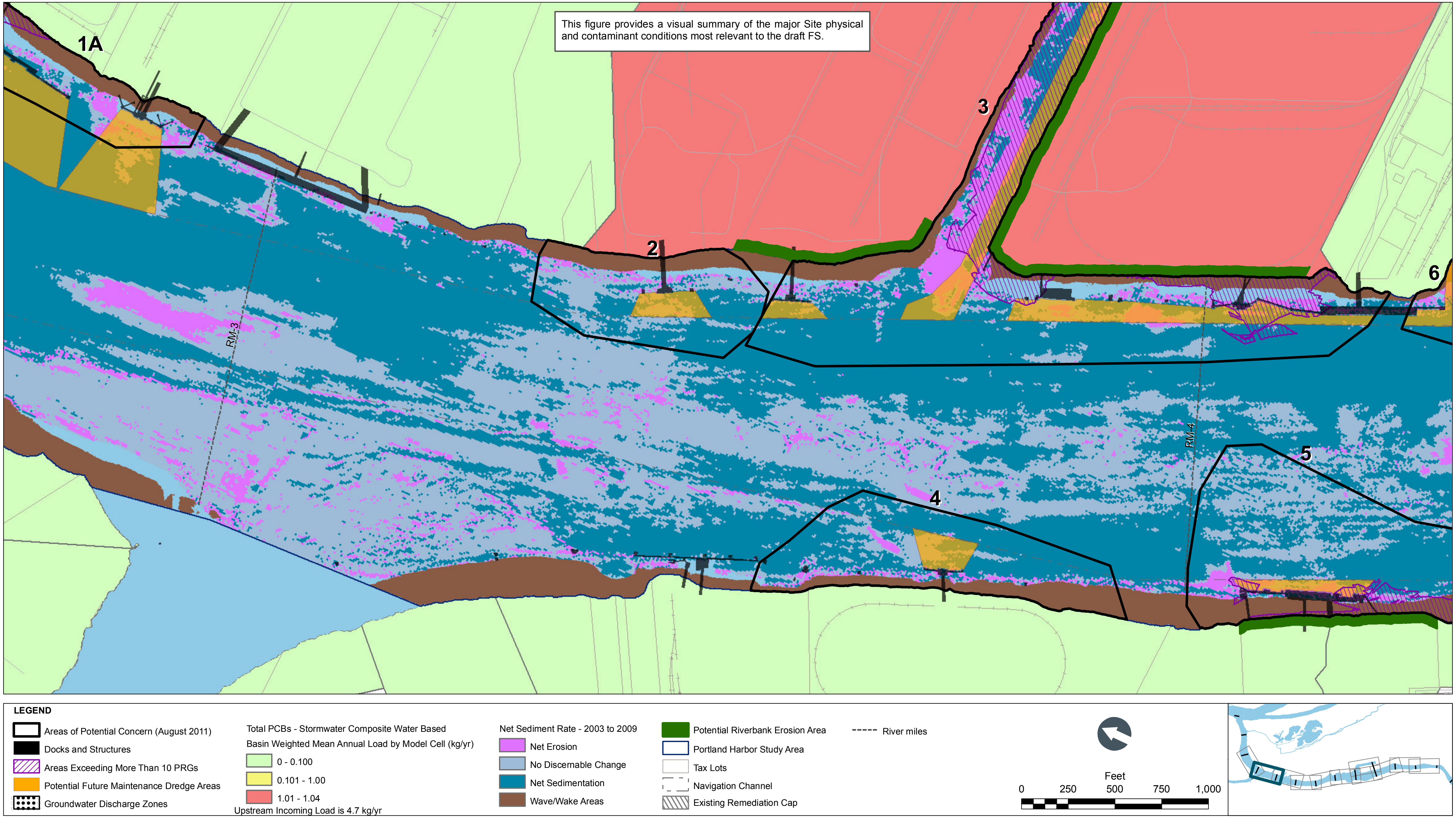

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Figure 2.6-2b
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 3 to 4

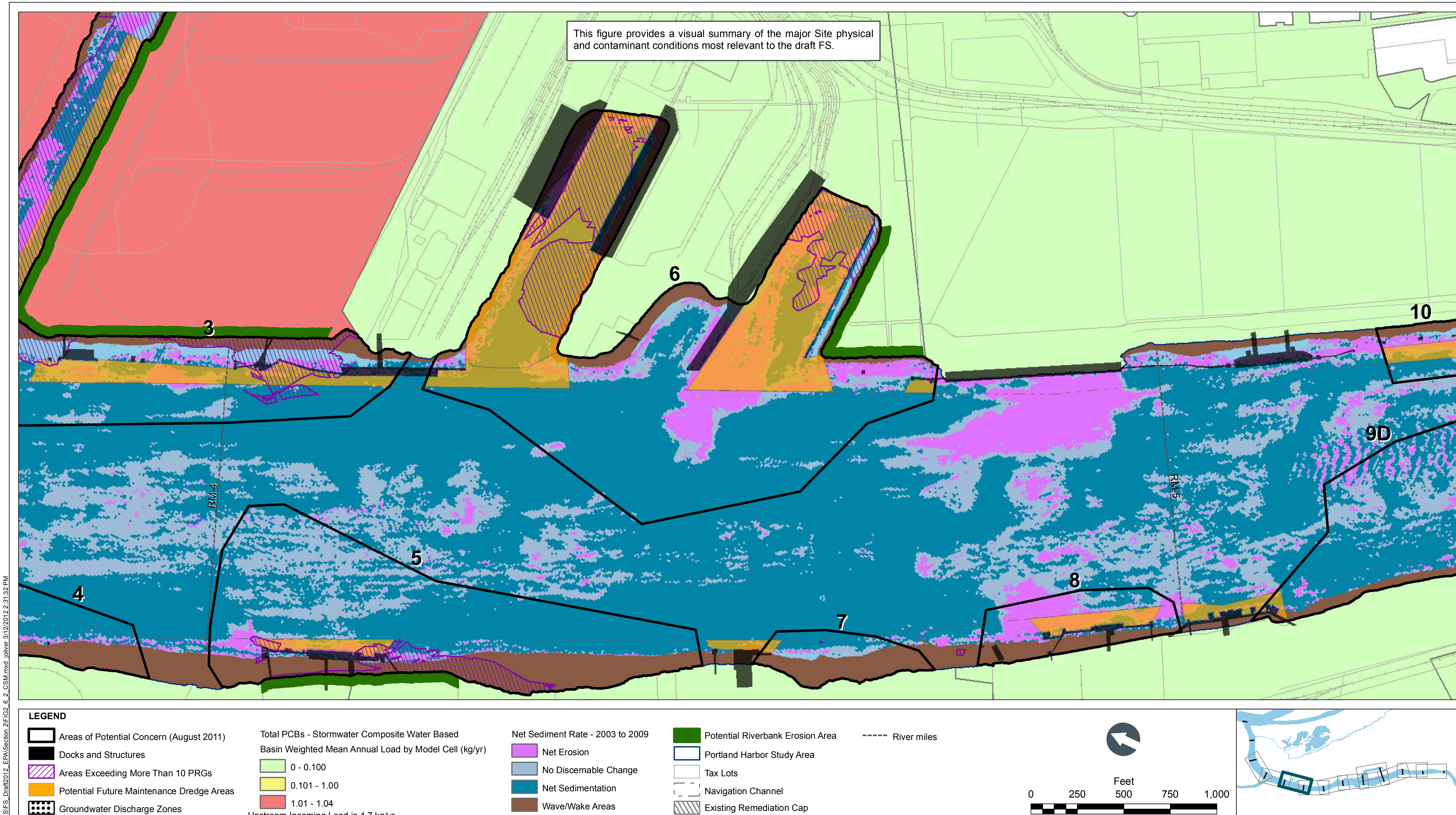

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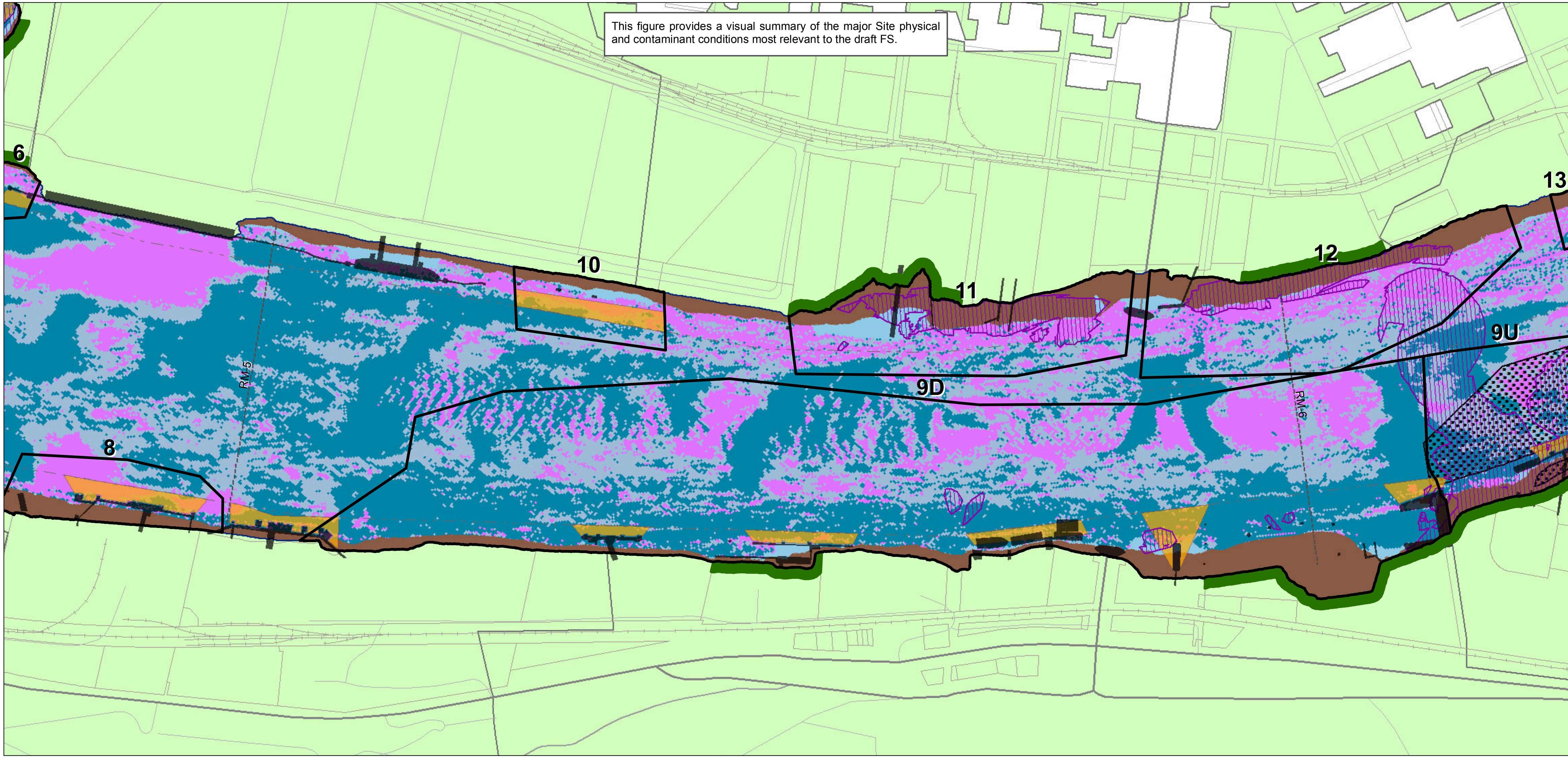
Figure 2.6-2c
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 4 to 5



LEGEND

- Areas of Potential Concern (August 2011)
- Docks and Structures
- Areas Exceeding More Than 10 PRGs
- Potential Future Maintenance Dredge Areas
- Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based Basin Weighted Mean Annual Load by Model Cell (kg/yr)
- 0 - 0.100
- 0.101 - 1.00
- 1.01 - 1.04

Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009
- Net Erosion
- No Discernable Change
- Net Sedimentation
- Wave/Wake Areas

- Potential Riverbank Erosion Area
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

- River miles

Feet
0 250 500 750 1,000

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_6_2_CSM.mxd joliver 3/12/2012 2:31:39 PM

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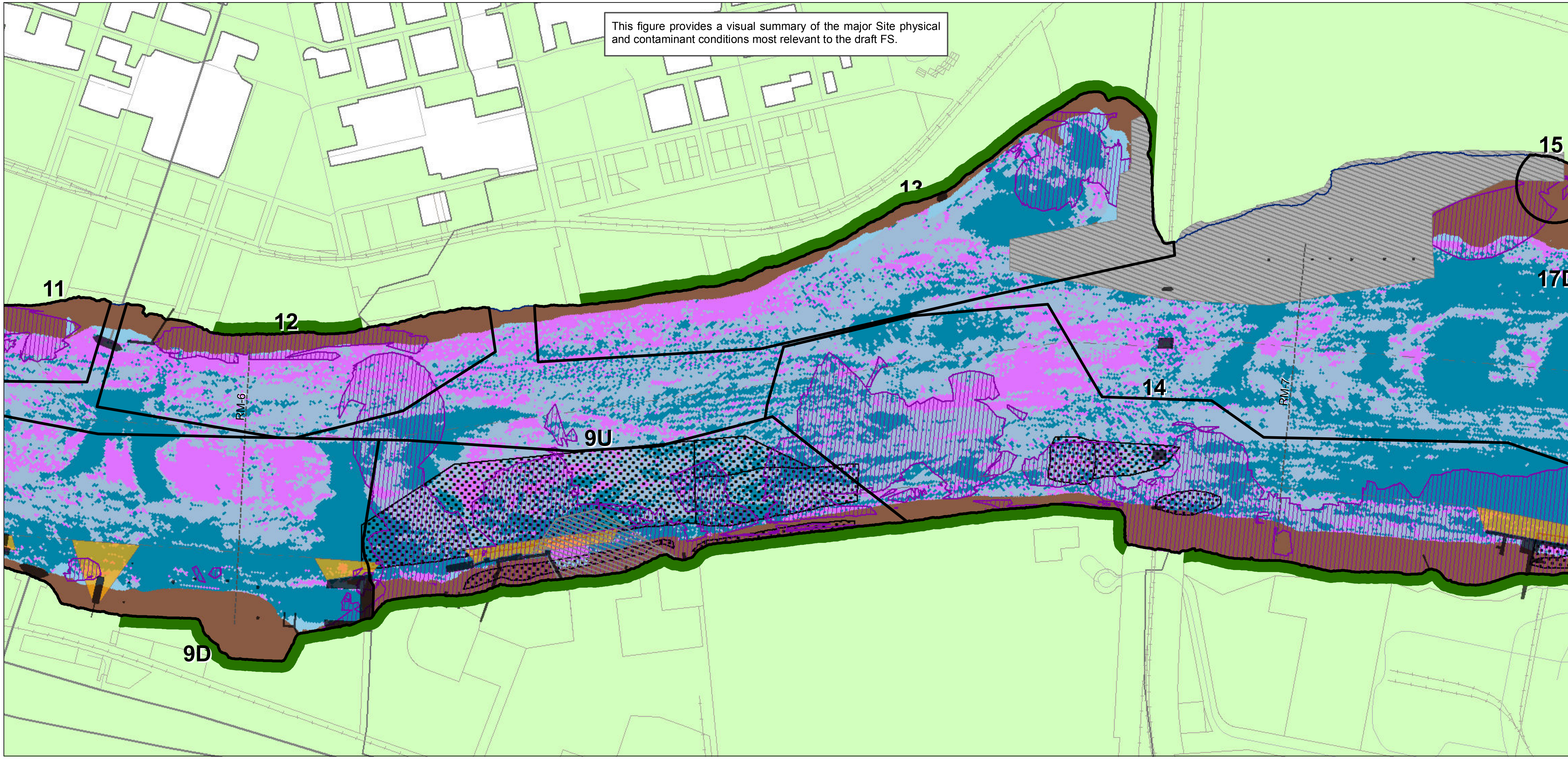
Figure 2.6-2d
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 5 to 6



LEGEND

Areas of Potential Concern (August 2011)
Docks and Structures
Areas Exceeding More Than 10 PRGs
Potential Future Maintenance Dredge Areas
Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based Basin Weighted Mean Annual Load by Model Cell (kg/yr)
0 - 0.100
0.101 - 1.00
1.01 - 1.04
Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009
Net Erosion
No Discernable Change
Net Sedimentation
Wave/Wake Areas

Potential Riverbank Erosion Area
Portland Harbor Study Area
Tax Lots
Navigation Channel
Existing Remediation Cap

River miles

Feet
0 250 500 750 1,000

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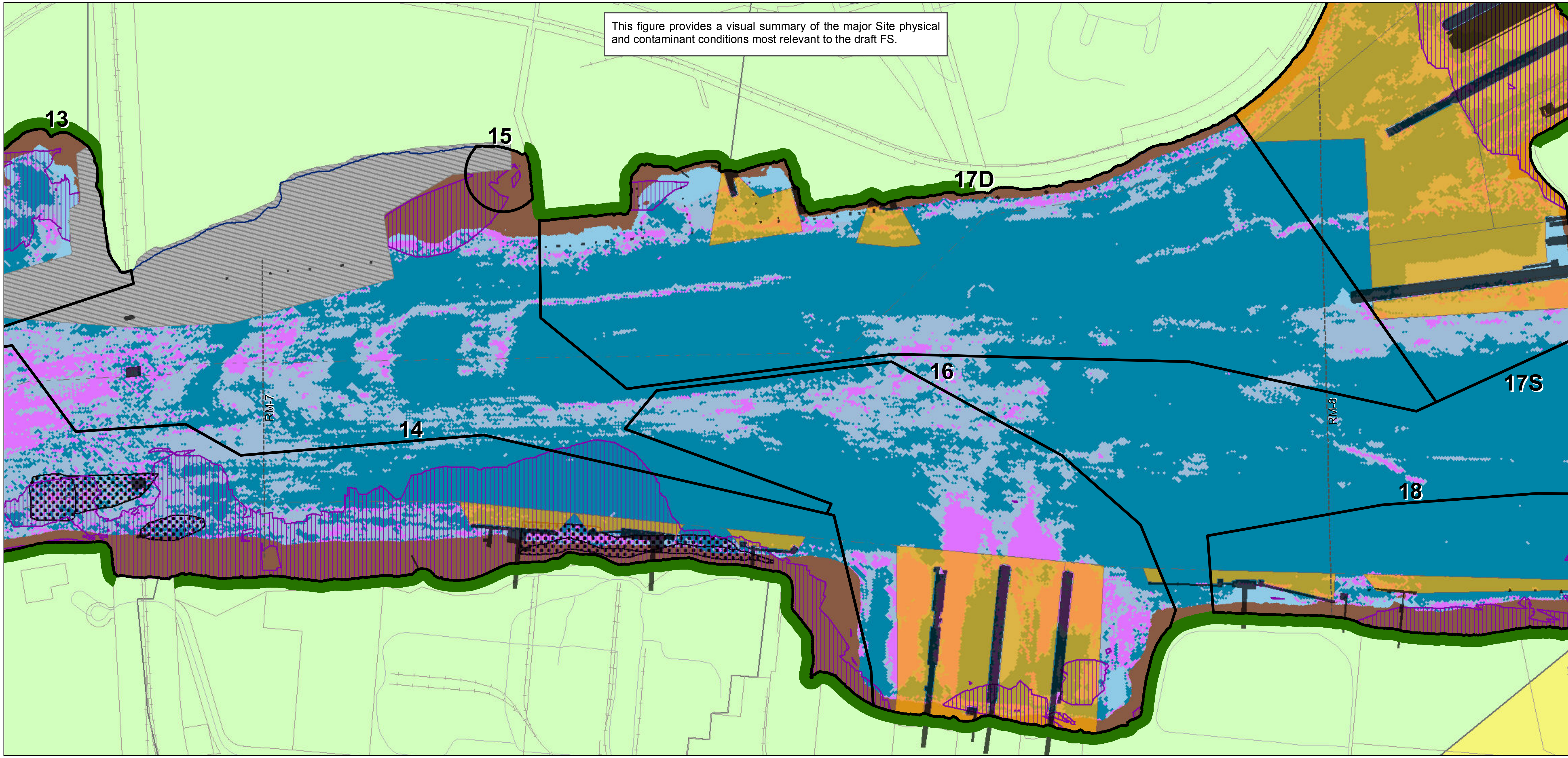
Figure 2.6-2e
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 6 to 7

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_6_2_CSM.mxd joliver 3/12/2012 2:31:50 PM



LEGEND

Areas of Potential Concern (August 2011)
Docks and Structures
Areas Exceeding More Than 10 PRGs
Potential Future Maintenance Dredge Areas
Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based
Basin Weighted Mean Annual Load by Model Cell (kg/yr)
0 - 0.100
0.101 - 1.00
1.01 - 1.04
Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009
Net Erosion
No Discernable Change
Net Sedimentation
Wave/Wake Areas

Potential Riverbank Erosion Area
Portland Harbor Study Area
Tax Lots
Navigation Channel
Existing Remediation Cap

River miles

Feet
0 250 500 750 1,000

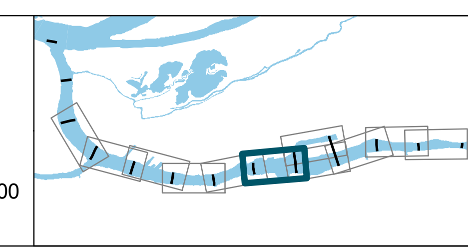


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Figure 2.6-2f
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 7 to 8

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 2\FIG2_6_2_CSM.mxd joliver 3/12/2012 2:31:58 PM

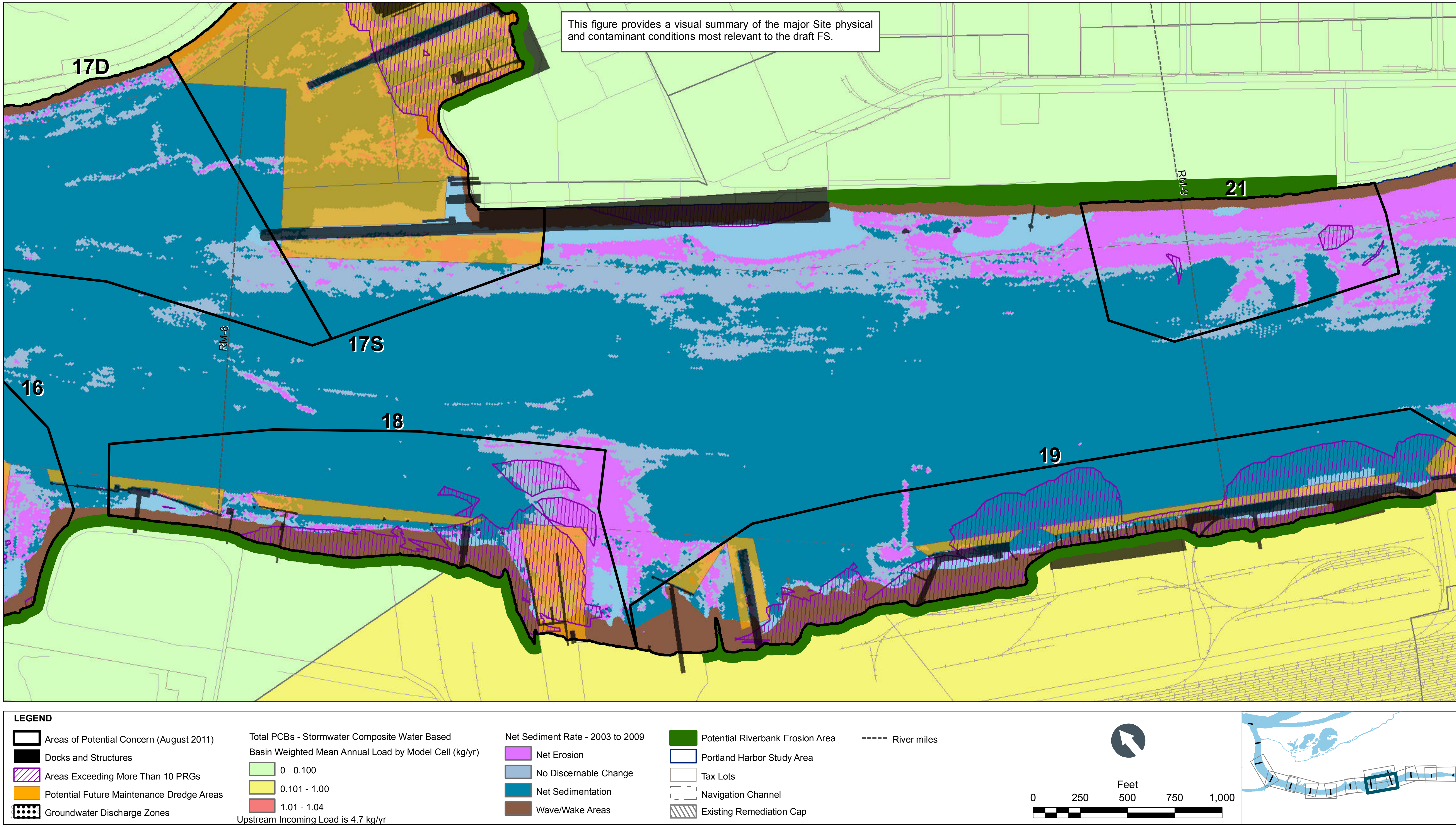

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Figure 2.6-2g
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 8 to 9

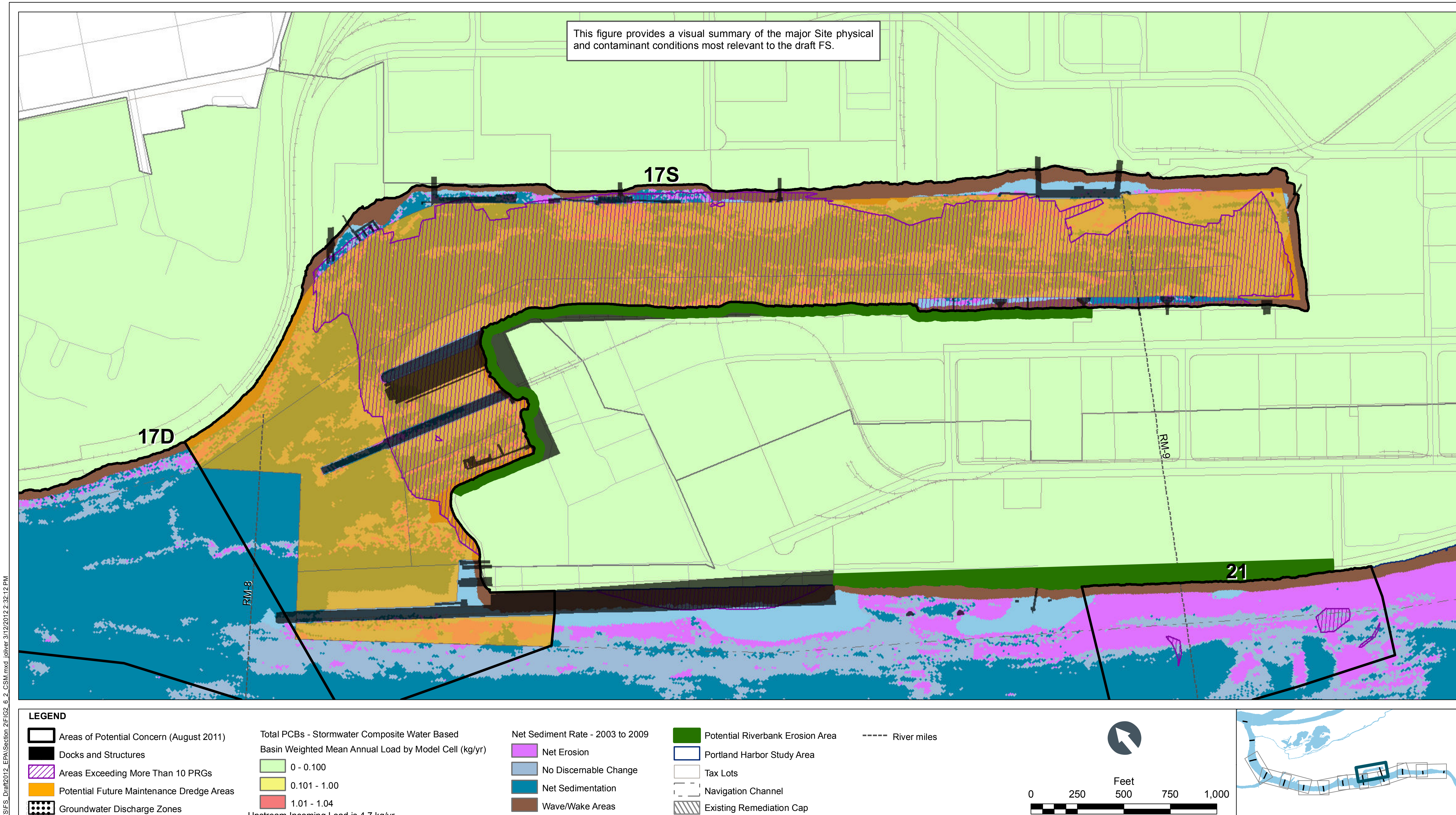

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Figure 2.6-2h
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 8 to 9 - Swan Is.

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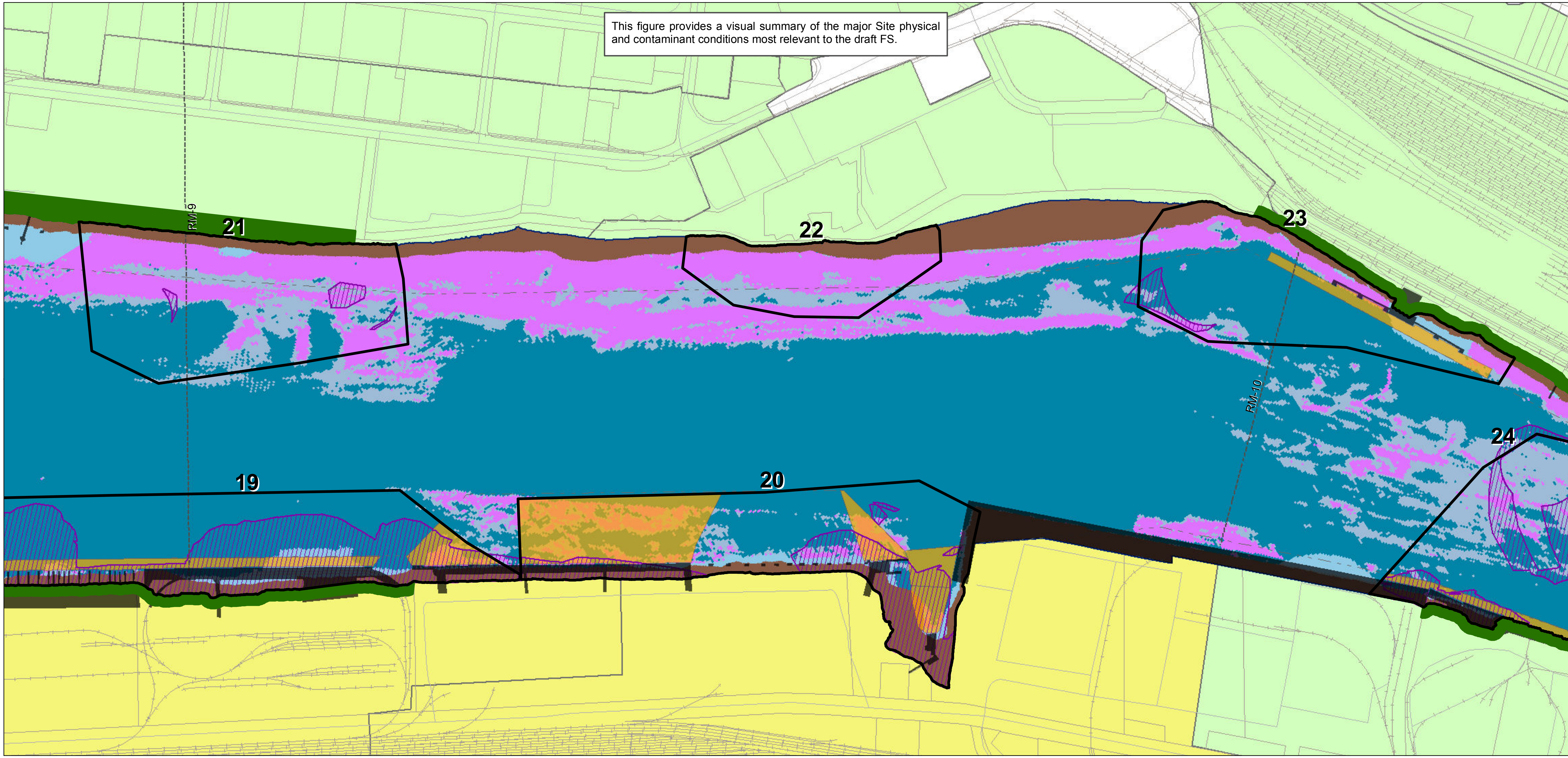

LEGEND

- Areas of Potential Concern (August 2011)
- Docks and Structures
- Areas Exceeding More Than 10 PRGs
- Potential Future Maintenance Dredge Areas
- Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based Basin Weighted Mean Annual Load by Model Cell (kg/yr)

- 0 - 0.100
- 0.101 - 1.00
- 1.01 - 1.04

Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009

- Net Erosion
- No Discernable Change
- Net Sedimentation
- Wave/Wake Areas

- Potential Riverbank Erosion Area
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap
- River miles

Feet

0 250 500 750 1,000

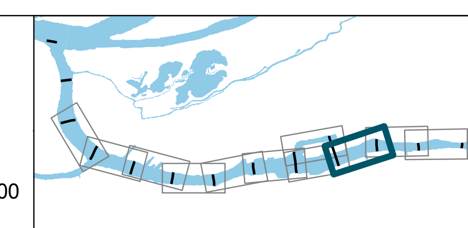

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Figure 2.6-2i
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 9 to 10

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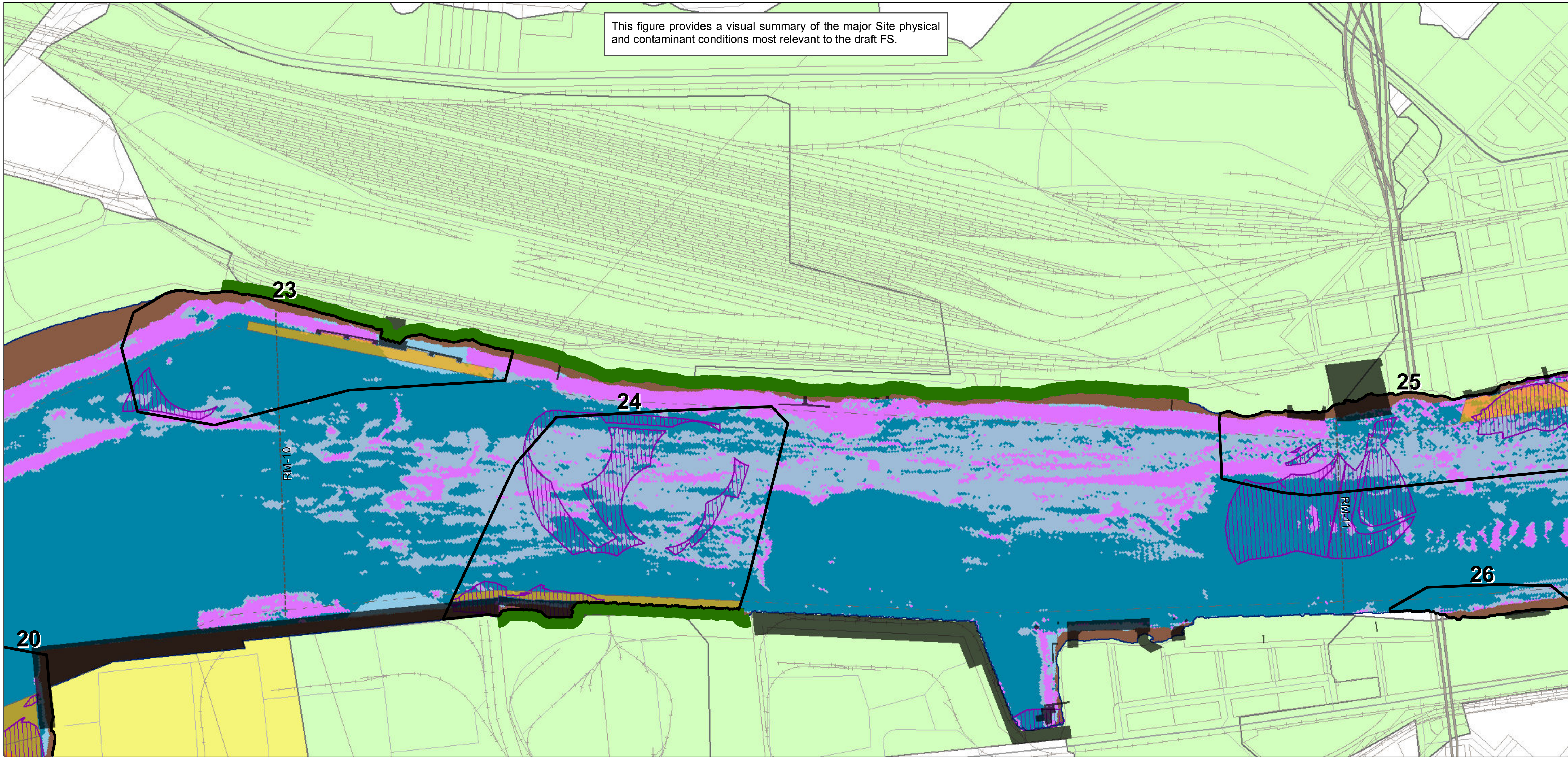

LEGEND

- Areas of Potential Concern (August 2011)
- Docks and Structures
- Areas Exceeding More Than 10 PRGs
- Potential Future Maintenance Dredge Areas
- Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based Basin Weighted Mean Annual Load by Model Cell (kg/yr)

- 0 - 0.100
- 0.101 - 1.00
- 1.01 - 1.04

Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009

- Net Erosion
- No Discernable Change
- Net Sedimentation
- Wave/Wake Areas

- Potential Riverbank Erosion Area
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

- River miles

Feet

0 250 500 750 1,000

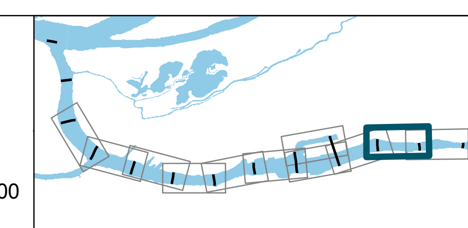

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Figure 2.6-2j
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 10 to 11

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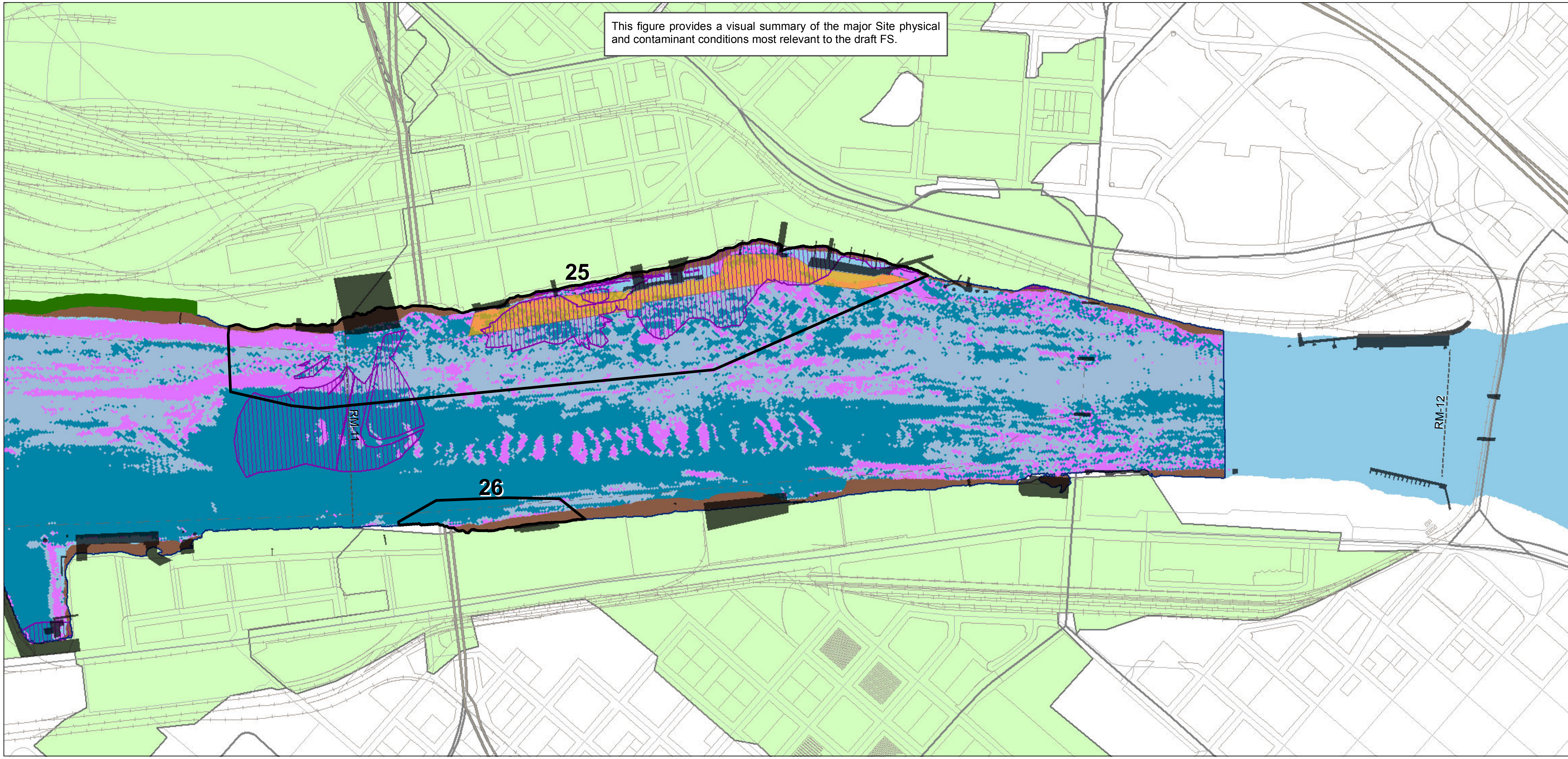

LEGEND

- Areas of Potential Concern (August 2011)
- Docks and Structures
- Areas Exceeding More Than 10 PRGs
- Potential Future Maintenance Dredge Areas
- Groundwater Discharge Zones

Total PCBs - Stormwater Composite Water Based Basin Weighted Mean Annual Load by Model Cell (kg/yr)

- 0 - 0.100
- 0.101 - 1.00
- 1.01 - 1.04

Upstream Incoming Load is 4.7 kg/yr

Net Sediment Rate - 2003 to 2009

- Net Erosion
- No Discernable Change
- Net Sedimentation
- Wave/Wake Areas

- Potential Riverbank Erosion Area
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

- River miles

Feet

0 250 500 750 1,000

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Figure 2.6-2k
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Site Model
River Mile 11 to 11.8

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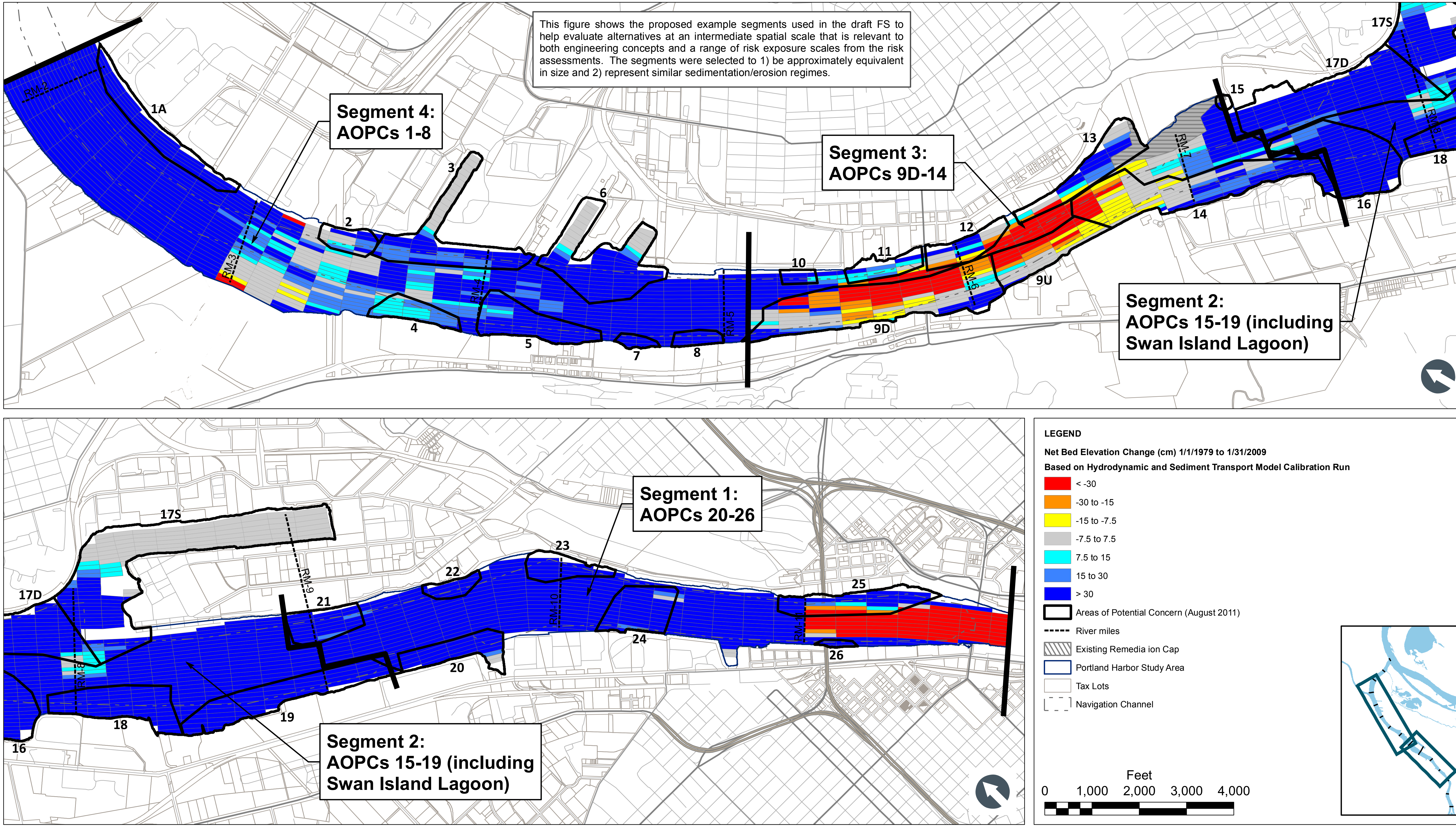

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Figure 2.9-1
Portland Harbor RI/FS
Draft Feasibility Study
Proposed Site Segmentation for Comprehensive Alternatives

Table 2.1-1. Percentage of Erosional/Deposition Areas Measured by Bathymetric Change and Projected by HST Model from 2003 to 2009

Object	Percent Site Area Estimated Erosional/Depositional as Measured by Bathymetric Elevation Changes Over the Period 2003 to 2009	Percent Site Area Projected to Be Erosional/Depositional Using the HST Model Over the 2003 to 2009 Calibration Period
Erosion (<-7.5cm)	12%	10%
Neutral - No significant change (-7.5 to 7.5 cm)	25%	12%
Deposition (>7.5cm)	63%	78%
Total	100%	100%

Table 2.1-2. Summary of Sonar Target Contacts

Object	Number of Contacts
Piling	4,519
Dolphins	148
Structures	39
Logs	193
Debris/Unclassified Targets	2,176
Gravel	21
Depressions	24
Anchor Drags	56
Sonar Artifacts	64
Dredge Artifacts	9
Possible Wrecks	7
Buoys	1
Total	7,257

Table 2.2-1. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface and Subsurface Sediment, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Conventionals (mg/kg)							
Ammonia							
Surface Sediment	459	99	0.07 U	481	98	87	220
Subsurface Sediment	215	100	1.4	775	210	200	460
Sulfide							
Surface Sediment	462	87	0.07 UJ	1830 J	26	4.7 JV	65 JV
Subsurface Sediment	208	85	0.4 UJ	796 J	25	6.1 JV	110 JV
Cyanide (Total)							
Surface Sediment	38	87	0.08 UJ	39.4 J	3.9	0.40 JV	20
Subsurface Sediment	125	73	0.03 J	1410	21	0.25 J	24
Perchlorate							
Surface Sediment	11	27	0.022 UJ	274	58	0.011 UT	270
Subsurface Sediment	NA	NA	NA	NA	NA	NA	NA
Metals (mg/kg)							
Aluminum							
Surface Sediment	1190	100	1630	47400	23000	24000	40000
Subsurface Sediment	1037	100	5730	45900	23000	24000	36000
Antimony							
Surface Sediment	1306	74	0.02 J	47.7	1.1	0.20 JV	5.4 UV
Subsurface Sediment	1189	71	0.02 J	55.1	0.69	0.17 JT	2.5 JV
Arsenic							
Surface Sediment	1476	92	0.7	132	4.7	3.6 JV	8.9
Subsurface Sediment	1492	96	0.5 J	51.4	4.0	3.5 JV	7.1
Barium							
Surface Sediment	232	100	58.9 J	5950	200	180	240
Subsurface Sediment	129	100	45.3	637	170	160	250
Beryllium							
Surface Sediment	233	86	0.22 U	1.31	0.59	0.60 T	0.70
Subsurface Sediment	89	91	0.279	1.05 U	0.51	0.52	0.70
Cadmium							
Surface Sediment	1476	90	0.00159 U	10.1	0.39	0.25 JV	1.2
Subsurface Sediment	1469	94	0.008 UJ	43.7	0.40	0.26 T	0.84 JV
Chromium							
Surface Sediment	1461	100	4.07 J	819 J	35	30 J	58 JV
Subsurface Sediment	1469	100	6.41 J	464	29	27	46 JV
Cobalt							
Surface Sediment	145	100	11.1 T	55.5	18	18 J	20
Subsurface Sediment	37	100	16.2	24.6	18	18 T	21
Copper							
Surface Sediment	1477	100	6.19 J	2830	61	39 J	170
Subsurface Sediment	1481	100	9.42 J	3290	56	36 J	110
Hexavalent Chromium							
Surface Sediment	60	45	0.1 UJT	2.1 J	0.43	0.30 JV	1.4 JV
Subsurface Sediment	39	13	0.2 JT	0.3 J	0.12	0.10 UJ	0.21
Iron							
Surface Sediment	164	100	19100	84900	42000	42000	53000
Subsurface Sediment	81	100	18900	53900	36000	36000	46000
Lead							
Surface Sediment	1500	99	1.1 J	13400 T	50	16 JV	120 JV
Subsurface Sediment	1536	99	1.54	3330 J	47	20	130
Magnesium							
Surface Sediment	145	100	3710	14500	6700	6900	7700
Subsurface Sediment	88	100	2280 J	8510	5500	5800	7600
Manganese							
Surface Sediment	281	100	236 T	2220	670	660	1000
Subsurface Sediment	136	100	206	2330	570	530 JV	880
Mercury							
Surface Sediment	1452	92	0.00189 U	65.2 T	0.13	0.063 JV	0.25
Subsurface Sediment	1395	94	0.004 J	16.8	0.18	0.083 T	0.53
Nickel							
Surface Sediment	1438	99	6.22 J	594	26	23 JV	38
Subsurface Sediment	1462	100	5.99 J	716	26	24 JV	33 JV
Potassium							
Surface Sediment	145	100	540	50000	1700	1300	1600
Subsurface Sediment	88	93	321 J	1550	890	840	1400
Selenium							
Surface Sediment	1148	45	0.03 J	20	1.4	0.12 JV	12
Subsurface Sediment	1056	39	0.02 J	14	0.47	0.065 JV	1.1
Silver							
Surface Sediment	1438	93	0.014 J	14.8	0.35	0.21 JV	1.1
Subsurface Sediment	1456	93	5.8E-05 U	4.32 J	0.32	0.25 JV	0.88
Sodium							
Surface Sediment	145	100	352	49000	1800	1100	2400
Subsurface Sediment	88	100	167 J	57800 J	1400	610 JV	1300 JV
Thallium							
Surface Sediment	251	73	0.031 J	27	5.9	3.0 U	22
Subsurface Sediment	89	69	0.041	12	2.0	0.34 UT	8.2
Vanadium							
Surface Sediment	145	100	63	152	100	100	120

Table 2.2-1. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface and Subsurface Sediment, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Subsurface Sediment	37	100	89.9	136	100	100	110
Zinc							
Surface Sediment	1506	100	3.68 J	4220	150	110 JV	380
Subsurface Sediment	1521	100	24	9000	150	110 JV	340
Butyltins (µg/kg)							
Monobutyltin							
Surface Sediment	310	68	0.042 U	740 J	10	1.8 JV	31
Subsurface Sediment	332	53	0.034 U	540 J	7.5	0.50 JV	18
Tributyltin ion							
Surface Sediment	342	94	0.079 U	47000	450	17 JV	710
Subsurface Sediment	397	54	0 U	90000	790	1.5 J	1300
PCBs (µg/kg)							
Total PCBs (congeners or Aroclors)[a]							
Surface Sediment	1228	79	1 UT	35000 T	200	29	710
Subsurface Sediment	1447	62	0.0097 UT	150000 UT	300	33	630
Total PCBs (TEQ) - mammalian WHO 2005 TEFs [a]							
Surface Sediment	331	85	3.9E-06 UT	0.22 T	0.0040	0.00046 JT	0.016
Subsurface Sediment	153	95	4.2E-05 JT	0.35 JT	0.010	0.0017 JT	0.021
PCDD/Fs (µg/kg)							
2,3,7,8-TCDD[e]							
Surface Sediment	222	21	4.1E-06 U	0.111091	0.00072	0.000022 UV	0.0010
Subsurface Sediment	251	29	2E-06 U	0.0836 JT	0.00090	0.000028 UV	0.0021
Total PCDD/Fs [a]							
Surface Sediment	222	100	0.0037 JT	200 JT	1.9	0.32 JTV	3.6 JTV
Subsurface Sediment	251	93	0.00035 JT	210 T	2.9	0.24 JT	6.4
TCDD TEQ - mammalian WHO 2005 TEFs [a]							
Surface Sediment	222	100	2.9E-05 JT	14 JT	0.071	0.0015 JTV	0.039 JTV
Subsurface Sediment	251	93	4E-06 UT	9.67 JT	0.082	0.0012 JT	0.049
Organochlorine Pesticides (µg/kg)							
2,4'-DDD							
Surface Sediment	1047	65	0.0272 U	710	7.9	0.95 J	25 JV
Subsurface Sediment	1115	57	0.0277 U	19300 NJ	55	1.1 NJ	54
4,4'-DDD							
Surface Sediment	1179	83	0.041 U	11000	36	1.9 J	77
Subsurface Sediment	1298	75	0.0415 U	690000	1900	2.5 JV	230
4,4'-DDE							
Surface Sediment	1176	82	0.027 U	2240 J	14	2.0 NJV	32
Subsurface Sediment	1298	65	0.027 U	24000	61	2.4 JV	46
4,4'-DDT							
Surface Sediment	1165	69	0.0478 U	81000	180	1.3 J	140 JV
Subsurface Sediment	1279	59	0.049 UJ	3500000	5500	1.5 NJ	270
Total of 2,4' and 4,4'-DDD (Sum DDD) [a]							
Surface Sediment	1179	85	0.041 UT	11000 T	43	1.3 NJT	2.5 AJT
Subsurface Sediment	1298	77	0.0415 UT	690000 T	1900	0.65 JV	3.2
Total of 2,4' and 4,4'-DDE (Sum DDE)[a]							
Surface Sediment	1176	82	0.038 UT	2530 JNT	16	1.3 NJT	2.2
Subsurface Sediment	1298	68	0.0389 UT	24000 T	63	0.25 JV	2.4
Total of 2,4' and 4,4'-DDT (Sum DDT)[a]							
Surface Sediment	1178	75	0.0441 AUJT	81000 T	190	0.72 JV	1.7
Subsurface Sediment	1297	66	0.0427 AUT	3500000 T	5400	0.23 AT	1.8
Total of 2,4' and 4,4'-DDD, -DDE, -DDT[a]							
Surface Sediment	1179	91	0.054 UT	85000 T	240	3.7 AJT	7.0
Subsurface Sediment	1298	82	0.049 UJT	3600000 T	7400	1.4 JV	9.1
Aldrin							
Surface Sediment	1081	23	0.00333 J	691 J	2.0	0.18 U	5.0 JV
Subsurface Sediment	1102	12	0.0269 UJ	3800 U	9.8	0.11 JV	9.0 JV
cis-Chlordane							
Surface Sediment	1101	35	0.00955 J	203 J	1.5	0.17 J	4.9 JV
Subsurface Sediment	1103	24	0.0286 U	3800 UJ	7.0	0.17 J	14 JV
Total Chlordanes [a]							
Surface Sediment	1103	66	0.0351 UT	700 UT	5.6	1.1 JNT	20 JTV
Subsurface Sediment	1103	55	0.0359 UT	3800 UJT	19	1.2 JNT	51 JV
Dieldrin							
Surface Sediment	1121	21	0.00834 J	356 J	2.0	0.19 UJ	4.0 JV
Subsurface Sediment	1134	6	0.03 U	7500 U	7.9	0.17 UJV	5.0
Total Endosulfan [a]							
Surface Sediment	1115	29	0.027 JT	270 T	2.0	0.32 NJT	5.0
Subsurface Sediment	1076	21	0.0393 AUJT	38000 UT	27	0.32 JTV	10.0
Endrin							
Surface Sediment	882	9	0.00984 J	200 U	1.8	0.15 UV	7.5 JV
Subsurface Sediment	870	14	0.0367 U	22000 U	24	0.18 JV	20
Endrin ketone							
Surface Sediment	1101	17	0.00208 UT	200 U	1.6	0.18 U	5.0 JV
Subsurface Sediment	1053	11	0.0253 U	7500 UJ	9.6	0.13 U	8.5
Heptachlor							
Surface Sediment	1126	6	0.00141 U	99 U	0.80	0.095 UJV	1.8 JV
Subsurface Sediment	1145	5	0.0262 U	3800 U	5.4	0.10 UJ	4.5 UV
Heptachlor Epoxide							
Surface Sediment	1114	8	0.00189 J	360 U	1.1	0.11 UJV	2.9

Table 2.2-1. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface and Subsurface Sediment, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations: Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Subsurface Sediment	1086	11	0.0341 U	3800 U	6.0	0.15 UJV	5.5 JV
beta-Hexachlorocyclohexane							
Surface Sediment	1115	38	0.00112 U	99 U	1.8	0.55 U	6.6
Subsurface Sediment	1076	31	0.0291 U	3800 U	7.0	0.49 JV	9.5
delta-Hexachlorocyclohexane							
Surface Sediment	1112	13	0.00116 U	99 U	0.87	0.12 JV	2.2
Subsurface Sediment	1057	4	0.0615 UJ	3800 UJ	5.8	0.16 U	5.2
gamma-Hexachlorocyclohexane							
Surface Sediment	1126	18	0.0031 J	430	1.6	0.22 JV	5.7 NJV
Subsurface Sediment	1145	10	0.051 UT	3800 U	6.2	0.22 U	8.0 JV
MCPP							
Surface Sediment	200	1	0.115 UT	91000 U	900	0.89 UV	1800 UV
Subsurface Sediment	171	2	0.6 U	3100 U	28	0.82 UV	8.5
2,4,5-TP (Silvex)							
Surface Sediment	200	1	0.11 U	44 U	1.1	0.75 UJV	2.2 UV
Subsurface Sediment	182	1	0.45 U	21 U	1.5	0.63 UV	8.0 UV
Polycyclic Aromatic Hydrocarbons (µg/kg)							
2-Methylnaphthalene							
Surface Sediment	1432	80	0.37 J	52000	210	9.5 JV	250
Subsurface Sediment	1582	79	0.3 J	3800000	13000	14 JV	2900
Acenapthene							
Surface Sediment	1580	83	0.18 U	430000	1100	12 JV	1200 JV
Subsurface Sediment	1620	83	0.18 U	3900000	15000	23	13000
Acenapthylene							
Surface Sediment	1580	76	0.27 J	54000	140	9.5 UV	230
Subsurface Sediment	1620	76	0.2 J	1500000 J	3100	10	1100 JV
Anthracene							
Surface Sediment	1580	87	0.24 U	390000	1000	22	1400 JV
Subsurface Sediment	1620	84	0.22 J	1310000	7600	27 JV	12000
Benzo(a)anthracene							
Surface Sediment	1580	95	0.5 J	320000	1500	74	4000
Subsurface Sediment	1620	89	0.17 J	772000	5300	67 JV	13000
Benzo(a)pyrene							
Surface Sediment	1580	95	0.24 U	340000	1800	85	4900
Subsurface Sediment	1620	88	0.14 UT	1010000	6400	79 JV	18000
Benzo(b)fluoranthene							
Surface Sediment	1474	96	0.72 U	300000	1500	94	4100
Subsurface Sediment	1620	88	0.19 J	850000	5000	79	14000
Benzo(b+k)fluoranthene							
Surface Sediment	482	90	3.8 T	108000 T	2600	210 TV	12000 TV
Subsurface Sediment	433	85	0.21 T	157000 T	2400	93 TV	13000
Benzo(g,h,i)perylene							
Surface Sediment	1580	93	0.5 J	180000	1200	65 JV	3700
Subsurface Sediment	1619	88	0.15 J	730000	4500	64	14000
Benzo(k)fluoranthene							
Surface Sediment	1442	95	0.36 U	100000	800	43	2900
Subsurface Sediment	1620	85	0.15 UT	540000	2600	42	8400
Chrysene							
Surface Sediment	1580	96	0.45 U	370000	1700	100 JV	4500 JV
Subsurface Sediment	1620	88	0.17 J	980000	6100	93 JV	16000
Dibenzo(a,h)anthracene							
Surface Sediment	1580	82	0.22 J	25000	200	12 JV	670 JV
Subsurface Sediment	1620	76	0.22 J	88000	580	11 JV	1900
Fluoranthene							
Surface Sediment	1588	98	0.8 J	1200000	4000	180 JV	10000
Subsurface Sediment	1620	90	0.24 J	3500000	20000	180 JV	44000
Fluorene							
Surface Sediment	1580	83	0.21 U	220000	610	11 JV	830
Subsurface Sediment	1620	82	0.21 U	1500000	7600	19	7900
Ideno(1,2,3-cd) pyrene							
Surface Sediment	1580	93	0.26 U	210000	1300	63	3800
Subsurface Sediment	1620	86	0.16 UT	610000	4100	60	12000
Naphthalene							
Surface Sediment	1518	71	0.27 J	73000 J	310	16 JV	370 UV
Subsurface Sediment	1499	78	0.27 J	20000000	61000	32 J	2000 U
Phenanthrene							
Surface Sediment	1580	95	0.53 J	1700000	4000	86	5600 JV
Subsurface Sediment	1620	90	0.24 J	8500000	42000	130 JV	54000
Pyrene							
Surface Sediment	1580	98	0.54 U	1300000	4400	180	10000
Subsurface Sediment	1620	91	0.15 J	4700000	25000	200 JV	48000
Total HPAHs [a]							
Surface Sediment	1580	99	3.9 JT	4300000 T	18000	970 JTV	49000 JV
Subsurface Sediment	1620	94	0.53 UT	13000000 T	79000	930 JV	190000 TV
Total LPAHs [a]							
Surface Sediment	1580	95	1.55 UJT	2900000 T	7300	190 JV	10000 JT
Subsurface Sediment	1620	93	0.39 UT	40000000 T	140000	280 JTV	99000 TV
Total PAHs [a]							
Surface Sediment	3160	99	6.3 JT	7300000 T	26000	340 JV	1000 JV
Subsurface Sediment	3240	96	0.7 UT	53000000 T	220000	200 JTV	1100 TV

Table 2.2-1. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface and Subsurface Sediment, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations: Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Total Carcinogenic PAHs [a]							
Surface Sediment	1580	97	0.42 JT	450000 T	2400	130 TV	7000 TV
Subsurface Sediment	1620	92	0.26 JT	1300000 T	8400	110 JTV	25000 TV
Phthalates (µg/kg)							
Bis(2-ethylhexyl) phthalate							
Surface Sediment	1438	61	2 U	440000 J	750	93 JV	1700
Subsurface Sediment	1496	40	2 U	40000 U	230	40 JV	770
Butylbenzyl phthalate							
Surface Sediment	1429	31	1.6 U	10000 U	46	9.5 JT	160
Subsurface Sediment	1494	17	1.7 U	11800	48	6.5 JV	110
Dibutyl phthalate (Di-n-butyl phthalate)							
Surface Sediment	1428	33	2.9 U	20000 U	71	10 JV	140 UJV
Subsurface Sediment	1496	24	3 U	20000 U	67	9.9 JV	130
Diethyl phthalate							
Surface Sediment	1425	11	1.3 U	10000 U	32	5.0 UJ	100
Subsurface Sediment	1488	7	1.3 J	8800 U	48	5.5 JV	150 UT
Semivolatile Organic Compounds (µg/kg)							
Benzyl Alcohol							
Surface Sediment	1288	13	2.1 U	6600 U	34	7.5 JV	110 UJV
Subsurface Sediment	1232	13	2.1 UT	11700 U	99	6.5 JV	280
Carbazole							
Surface Sediment	1220	59	1.3 U	32000	160	8.3 JV	290 JV
Subsurface Sediment	1109	54	0.6 J	520000	2300	6.9 JV	1200
Dibenzofuran							
Surface Sediment	1416	77	0.19 U	31000	110	7.8 UJV	250
Subsurface Sediment	1383	76	0 U	230000	1200	9.2	1900
1,2-Dichlorobenzene							
Surface Sediment	139	2	0.092 U	322 UJ	22	0.50 UV	140
Subsurface Sediment	1135	2	1.5 U	3720 U	27	2.1	60
1,4-Dichlorobenzene							
Surface Sediment	311	1	0.14 U	322 U	10	0.13 UT	110 UJV
Subsurface Sediment	793	6	2.1 U	4800 U	36	3.4 UJ	75
Hexachlorobenzene							
Surface Sediment	1266	32	0.0122 J	10000 UJ	20	1.3 JV	13 JV
Subsurface Sediment	1270	17	0.0162 U	14000	45	1.1 JV	77
Phenols (µg/kg)							
4-Methylphenol							
Surface Sediment	1309	49	1.5 U	10000 U	84	14 J	460
Subsurface Sediment	1159	54	1.5 UT	7300 U	68	19 J	210
Phenol							
Surface Sediment	1340	29	2 U	10000 U	36	10 JV	100 UJV
Subsurface Sediment	1287	24	2 U	7100	58	9.0 J	160 UV
Pentachlorophenol							
Surface Sediment	238	39	0.2 U	72 U	4.0	1.2 JV	11 UJV
Subsurface Sediment	274	49	0.18 U	1300 U	12	1.9 JV	15
Volatile Organic Compounds (µg/kg)							
1,1-Dichloroethene							
Surface Sediment	290	0	0.08 U	322 U	11	0.085 UJV	120
Subsurface Sediment	570	0	0.069 U	8400 U	40	0.075 UV	57
1,2-Dichloroethane							
Surface Sediment	290	1	0.038 U	322 U	11	0.032	120
Subsurface Sediment	570	1	0.035 U	8000 U	39	0.029 UV	55
1,2-Dichloropropane							
Surface Sediment	290	0	0.043 U	322 U	11	0.036 UJV	120
Subsurface Sediment	559	0	0.04 U	8700 U	37	0.032 U	55
1,1,2-Trichloroethane							
Surface Sediment	290	0	0.072 U	322 U	11	0.060 UV	120
Subsurface Sediment	560	0	0.067 U	7000 U	34	0.055 UV	76 UV
1,2,4-Trimethylbenzene							
Surface Sediment	47	2	2 UJ	322 U	73	50 U	150 UV
Subsurface Sediment	96	18	0.18 U	13100	480	15 UJV	1900
1,3,5-Trimethylbenzene							
Surface Sediment	47	0	2 UJ	322 U	71	50 U	150 UV
Subsurface Sediment	96	16	0.077 U	7530 U	210	8.9 UV	760
Acrolein							
Surface Sediment	40	0	0.7 U	560 U	38	0.60 UV	130 UV
Subsurface Sediment	94	2	0.63 U	89000 UJ	1200	65 UJV	7700
Benzene							
Surface Sediment	346	12	0.01 U	720 J	13	0.048 UV	99
Subsurface Sediment	599	32	0.01 U	270000	1600	0.12 J	290
Bromochloromethane							
Surface Sediment	290	0	0.073 U	322 U	11	0.065 UJV	120
Subsurface Sediment	559	0	0.068 U	8900 U	34	0.055 U	55 U
Bromodichloromethane							
Surface Sediment	290	0	0.051 U	322 U	11	0.070 UJV	120
Subsurface Sediment	559	0	0.047 U	6000 U	26	0.060 U	37
Carbon disulfide							
Surface Sediment	287	9	0.085 U	3220 U	99	0.14 UJ	1200 UV
Subsurface Sediment	559	21	0.069 U	12000 U	49	0.13 U	76
Chlorobenzene							
Surface Sediment	299	16	0.072 U	35000	300	0.075 UJ	130

Table 2.2-1. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface and Subsurface Sediment, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations: Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Subsurface Sediment	570	10	0.062 U	80000	240	0.065 UV	86
Chloroethane							
Surface Sediment	293	0	0.26 U	500 U	14	0.28 UJ	130
Subsurface Sediment	559	0	0.24 U	13000 U	45	0.24 U	64
Chloroform							
Surface Sediment	290	4	0.068 U	322 U	11	0.060 UJV	120
Subsurface Sediment	570	4	0.063 U	6700 U	36	0.055 UV	64
cis-1,2-Dichloroethene							
Surface Sediment	121	2	0.076 U	322 U	24	0.085 U	140 UV
Subsurface Sediment	204	4	0.12 U	2300 U	45	5.3 UV	170
Ethylbenzene							
Surface Sediment	362	9	0.009 U	322 U	11	0.085 UV	62 UJV
Subsurface Sediment	589	19	0.009 U	140000	1400	0.065 U	1600
Isopropylbenzene							
Surface Sediment	293	14	0.054 U	643 U	23	0.055 U	250
Subsurface Sediment	563	26	0.05 U	19000 J	180	0.080 U	450 JV
Methylene chloride							
Surface Sediment	290	1	0.37 U	1610 U	52	0.90 JV	590
Subsurface Sediment	560	8	0.17 U	14000 U	100	1.8 UV	420 UV
MTBE							
Surface Sediment	270	4	0.048 U	322 U	9.8	0.040 UJV	120
Subsurface Sediment	555	16	0.044	5200	27	0.074 J	52
Tetrachloroethene							
Surface Sediment	337	1	0.11 U	322 U	9.6	0.11 UT	70
Subsurface Sediment	587	3	0.092 U	7700 U	43	0.085 U	82 UJV
Toluene							
Surface Sediment	337	5	0.02 U	3800	31	0.17 UT	120
Subsurface Sediment	589	20	0.01 U	190000	710	0.15 U	200 JV
trans-1,2-Dichloroethene							
Surface Sediment	287	0	0.075 U	322 U	10	0.19 U	120
Subsurface Sediment	559	0	0.068 U	9800 U	37	0.17 U	60 U
Trichloroethene							
Surface Sediment	337	2	0.076 U	322 U	9.6	0.070 UT	70
Subsurface Sediment	587	17	0.07 U	1900000	3800	0.090 U	80 UJV
Vinyl chloride							
Surface Sediment	290	1	0.11 U	500 U	13	0.090 UJV	130
Subsurface Sediment	571	2	0.096 U	15000 U	62	0.080 U	84
m,p-Xylene							
Surface Sediment	337	8	0.02 U	643 U	18	0.15 U	140
Subsurface Sediment	589	19	0.02 U	200000	1100	0.12 U	700 JV
o-Xylene							
Surface Sediment	337	12	0.008 U	322 U	9.9	0.090 UJT	100
Subsurface Sediment	589	25	0.008 U	80000	560	0.14 J	670 UV
Total xylenes [a]							
Surface Sediment	337	12	0.02 UT	643 UT	19	0.16 UT	210
Subsurface Sediment	589	28	0.02 UT	280000 T	1700	0.23 UT	1300 UTV
Petroleum (TPH) (mg/kg)							
Diesel-Range Hydrocarbons							
Surface Sediment	807	92	0.046 J	20000 J			JV
Subsurface Sediment	1087	81	0.045 J	190000 J	1100	130 J	2000 JV
Gasoline-Range Hydrocarbons							
Surface Sediment	429	14	0.02 U	140 J	4.4	1.3 UJ	19 JV
Subsurface Sediment	817	27	0.02 U	21000 J	89	1.7 J	54
Residual-Range Hydrocarbons							
Surface Sediment	645	96	0.29	18000 J	630	400 J	1500 JV
Subsurface Sediment	999	84	0.1 U	110000 J	990	430 JT	2400 JT
Total Petroleum Hydrocarbons							
Surface Sediment	836	94	0.35 JT	33000 JT	810	500 JTV	1900
Subsurface Sediment	1185	82	0.1 UT	320000 JT	2100	500 JT	4500 JTV

Notes

When a statistic matched more than one sample, preference was given to qualifiers in the following order: A, J, N, T, V, No Flag, U.

Duplicates not included
a - Calculated U = 1/2 DL
Total PCBs are total PCB congeners whenever available and total Aroclors if not (on a per sample basis).
NA - Not Analyzed
DL - Detection Limit
ND - non-detect
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
RM - river mile
TEQ - toxic equivalent concentration

Reason codes for qualifiers:

A - Total value based on limited number of analytes.
J - The associated numerical value is an estimated quantity.
T - The associated numerical value was mathematically derived (e.g., from summing multiple analyte results such as Aroclors, or calculating the average of multiple results for a single analyte). Also indicates all results that are selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods) for Round 2 data.
U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.
V - Median or 95th percentile obtained through interpolation.
N -The identity of the analyte is presumptive and not definitive, generally as a result of the presence in the sample of an analytical interference, such as hydrocarbons or, in the case of pesticides, PCBs. Data that are N-qualified meet the primary identification criteria of the method; however, the confirmation criteria are not met and the identification is potentially a false positive.

Table 2.2-2. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations					
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Conventionals (mg/L)							
Ammonia	11	100	0.083	0.13	0.11	0.10	0.13
Sulfide	191	0	0.002 U	0.05 UT	0.0026	0.0020 U	0.025
Cyanide	181	6	0.003 J	0.11	0.0030	0.0015 U	0.0040 JV
Perchlorate	13	15	0.0002 U	0.00325 JT	0.00057	0.00020 U	0.0023
Metals - Total (µg/L)							
Aluminum	137	100	41	1860	320	160	730
Antimony	159	48	0.02 J	0.2 UT	0.034	0.030 JT	0.10 UT
Arsenic	178	82	0.257	5 U	0.54	0.44 JV	1.0
Barium	NA	NA	NA	NA	NA	NA	NA
Beryllium	NA	NA	NA	NA	NA	NA	NA
Cadmium	159	19	0.008 T	0.2 UT	0.021	0.010 UJT	0.10 UT
Chromium	178	60	0.2 JT	1700	64	0.33 J	350
Cobalt	NA	NA	NA	NA	NA	NA	NA
Copper	178	94	0.65	20	1.7	1.2	3.9
Hexavalent Chromium	13	31	0.6 UJT	20 UT	3.7	0.90	10
Iron	192	100	167	438	270	260	360
Lead	159	93	0.077	1.8	0.30	0.24	0.56
Magnesium	12	100	2430	2670	2500	2500	2600
Manganese	12	100	18.4	22.7	21	20	23
Mercury	160	4	0.02 J	0.403	0.023	0.020 JV	0.050 UTV
Nickel	159	93	0.2	2.19	0.82	0.73	1.5
Potassium	12	75	900 U	1540 J	1000	1300 JV	1400
Selenium	153	52	0.1 JT	0.8 J	0.24	0.20 JT	0.50
Silver	159	2	0.003 UT	0.2 UT	0.011	0.0045 UT	0.10 UT

Table 2.2-2. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Sodium	12	100	6840	7770	7400	7400	7800
Thallium	24	25	0.004 J	0.2 UT	0.013	0.0020 JV	0.090 JV
Vanadium	NA	NA	NA	NA	NA	NA	NA
Zinc	178	73	1.65 T	57.9	3.5	2.8	6.1
Butyltins (µg/L)							
Monobutyltin	148	8	0.0017 UJ	0.085	0.0042	0.0019	0.018 UV
Tributyltin ion	NA	NA	NA	NA	NA	NA	NA
PCBs							
Total PCBs (congeners or Aroclors) (µg/L) a	43	12	0.0025 JT	0.017 JT	0.0023	0.0013	0.71
Total PCBs (TEQ) - mammalian WHO 2005 TEFs (ng/L	11	18	0.00066 JT	0.0022 UT	0.00075	0.00070 UT	0.0010
PCDD/Fs (ng/L)							
2,3,7,8-TCDD	4	0	0.00112 U	0.00135 UT	0.00061	0.00060 UV	0.00067 UV
Total PCDD/Fs [a]	4	75	0.018 UT	0.051 JT	0.032	0.035 JTV	0.049 JTV
TCDD TEQ - mammalian WHO 2005 TEFs [a]	4	75	0.002 UT	0.0025 JT	0.0021	0.0024 JTV	0.0025 JTV
Herbicides (µg/L)							
Silvex ™	148	0	0.042 U	0.21 U	0.026	0.023 UV	0.028 UV
Organochlorine Pesticides µg/L							
2,4'-DDD	87	0	0.000472 UJ	0.01 U	0.00092	0.00026 U	0.0050 UV
4,4'-DDD	87	10	0.00016 UJ	0.01 U	0.00088	0.00026 U	0.0050 UV
4,4'-DDE	87	11	0.00016 UJ	0.01 U	0.00083	0.00025 U	0.0050 JV
4,4'-DDT	87	16	0.00033 U	0.01 U	0.0012	0.00025 U	0.0050 JV
Total of 2,4' and 4,4'-DDD (Sum DDD) [a]	87	10	0.000472 UJT	0.01 UT	0.00097	0.00026 UJT	0.0050 UTV
Total of 2,4' and 4,4'-DDE (Sum DDE) [a]	87	11	0.00025 UJT	0.01 UT	0.00085	0.00025 UT	0.0050 JV
Total of 2,4' and 4,4'-DDT (Sum DDT) [a]	87	17	0.00033 UT	0.019 NJT	0.0014	0.00026 UJT	0.0050 JV
Total DDX LWG RA Total DDx [a]	87	31	0.000472 UJT	0.02 NJT	0.0018	0.00047 UJT	0.0050 JV

Table 2.2-2. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Aldrin	87	1	0.000057 U	0.0058	0.00063	0.00025 U	0.0025 UV
cis-Chlordane	87	6	0.000072 UJ	0.005 U	0.00052	0.00025	0.0025 JV
Total Chlordanes [a]	87	6	0.000472 UJT	0.01 UT	0.0010	0.00026 UT	0.0050 JV
Dieldrin	87	3	0.0004 UJ	0.01 U	0.00087	0.00025 U	0.0050 JV
Total Endosulfan [a]	87	11	0.00014 UT	0.01 UT	0.00090	0.00025 UT	0.0050 JV
Endrin	87	1	0.000083 U	0.01	0.00089	0.00025 UJ	0.0050 UV
Endrin ketone	87	0	0.00015 UJ	0.01 U	0.00079	0.00024 U	0.0050 UJV
Heptachlor	87	2	0.0001 U	0.005 U	0.00063	0.00025 U	0.0025 JV
Heptachlor Epoxide	87	1	0.000065 UJ	0.005 U	0.00049	0.00024 UJ	0.0025 UJV
beta-Hexachlorocyclohexane	87	1	0.00038 UJ	0.005 U	0.00060	0.00025 U	0.0025 UV
delta-Hexachlorocyclohexane	87	6	0.00018 U	0.005 U	0.00055	0.00025 U	0.0025 JV
gamma-Hexachlorocyclohexane	87	10	0.000092 U	0.005 U	0.00054	0.00025 U	0.0025 UV
MCPP	146	3	6 U	110 U	10	3.5 UV	55 UV
Polycyclic Aromatic Hydrocarbons (µg/L)							
2-Methylnaphthalene	161	7	0.0027 U	1 U	0.032	0.0042 U	0.22
Acenapthene	175	10	0.002 U	0.21	0.0067	0.0031	0.014
Acenapthylene	175	15	0.0018 U	0.043	0.0039	0.0023	0.012
Anthracene	175	11	0.0011 J	0.48	0.0073	0.0039 U	0.012
Benzo(a)anthracene	167	11	0.0021 U	0.27	0.0072	0.0039	0.012 JV
Benzo(a)pyrene	175	5	0.00033 U	0.19	0.0063	0.0043 U	0.012
Benzo(b)fluoranthene	175	6	0.00083 U	0.13	0.0060	0.0046 U	0.012
Benzo(b+k)fluoranthene	175	6	0.00083 UT	0.26 T	0.0087	0.0055 UT	0.012
Benzo(g,h,i)perylene	175	4	0.0037 U	0.14	0.0069	0.0041 U	0.012
Benzo(k)fluoranthene	175	6	0.00015 U	0.13	0.0060	0.0055 U	0.012
Chrysene	167	18	0.0013	0.37	0.0090	0.0055 U	0.012 UV

Table 2.2-2. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Dibenzo(a,h)anthracene	175	3	0.0017	0.094	0.0048	0.0036 U	0.020
Fluoranthene	175	39	0.0024	0.81	0.017	0.0047 U	0.040
Fluorene	175	10	0.0026	0.31	0.014	0.0036 U	0.077
Ideno(1,2,3-cd) pyrene	175	6	0.0021	0.12	0.0059	0.0033 U	0.012
Naphthalene	175	10	0.0014 U	0.77	0.014	0.0065 J	5.8
Phenanthrene	175	13	0.0032 U	2.2	0.0200	0.0032 UJ	0.023
Pyrene	175	39	0.0023 U	1.3	0.019	0.0047 J	0.037
Total HPAHs [a]	175	50	0.0037 UT	3.5 T	0.068	0.018 JT	0.11
Total LPAHs [a]	175	35	0.0032 UT	3.9 T	0.082	0.0065 UT	0.51
Total PAHs [a]	175	58	0.0065 UT	7.4 T	0.15	0.044 JT	0.53
Total carcinogenic PAHs [a]	175	22	0.0017 UT	0.27 T	0.0095	0.0043 UT	0.024
Phthalates (µg/L)							
Bis(2-ethylhexyl) phthalate	159	12	0.098 U	64 J	1.2	0.22 U	2.1
Butylbenzyl phthalate	159	19	0.013 U	0.32	0.031	0.015	0.13 U
Dibutyl phthalate	159	1	0.039 U	0.32 UJ	0.064	0.050	0.14 UJ
Diethyl phthalate	159	11	0.015 UJ	0.26 J	0.036	0.023	0.13 U
Semivolatile Organic Compounds (µg/L)							
Benzyl Alcohol	159	0	0.98 UJ	5 U	0.65	0.49 UJ	2.5 U
Carbazole	148	3	0.013 UJ	0.16 J	0.0083	0.0065	0.0070 UJV
Dibenzofuran	161	2	0.0038 U	0.076	0.0064	0.0038	0.015 UV
1,2-Dichlorobenzene	159	0	0.015 UJ	1 UJ	0.042	0.0075 UJ	0.50 UJV
1,4-Dichlorobenzene	159	1	0.014 UJ	1 UJ	0.041	0.0070 UJ	0.50 UJ
Hexachlorobenzene	159	8	0.000014 U	0.017 U	0.0048	0.0075 UJ	0.0076
Phenols (µg/L)							
4-Methylphenol	159	0	0.051 U	1 UJ	0.059	0.026 UJ	0.50 UJ

Table 2.2-2. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Phenol	159	6	0.02 UJ	1 UJ	0.050	0.010 UJ	0.50 UJ
Pentachlorophenol	165	0	0.029 UJ	0.25 U	0.026	0.015 UJ	0.13 UV
Volatile Organic Compounds (µg/L)							
1,1-Dichloroethene	23	4	0.2 U	0.51	0.12	0.10 U	0.10 UV
1,2-Dichloroethane	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
1,2-Dichloropropane	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
1,1,2-Trichloroethane	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
1,2,4-Trimethylbenzene	23	13	1 U	2.92	0.69	0.50 U	1.8
1,3,5-Trimethylbenzene	23	13	0.3 U	0.44	0.18	0.15 U	0.39
Acrolein							
Benzene	23	35	0.2 U	31.4	1.8	0.10 U	3.9
Bromochloromethane	23	0	1 U	1 U	0.50	0.50 U	0.50 UV
Bromodichloromethane	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
Carbon disulfide	23	0	1 U	1 U	0.50	0.50 U	0.50 UV
Chlorobenzene	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
Chloroethane	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
Chloroform	23	0	0.2 U	0.2 U	0.10	0.10 U	0.10 UV
cis-1,2-Dichloroethene	23	22	0.2 U	279	18	0.10 U	120
Ethylbenzene	23	35	0.2 U	11.4	1.1	0.10 U	3.5
Isopropylbenzene	23	0	0.3 U	0.3 U	0.15	0.15 U	0.15 UV
Methylene chloride	23	0	20 U	20 U	10	10 U	10 UV
MTBE	23	0	0.5 U	0.5 U	0.25	0.25 U	0.25 UV
Tetrachloroethene	23	0	0.5 U	0.5 U	0.25	0.25 U	0.25 UV
Toluene	23	35	0.2 U	4.12	0.42	0.17 U	0.93
trans-1,2-Dichloroethene	23	4	0.3 U	1.46	0.21	0.15 U	0.15 UV

Table 2.2-2. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Surface Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Trichloroethene	23	9	0.2 U	194	8.6	0.10 U	0.56
Vinyl chloride	23	65	0.2 U	73.2	4.00	0.46	6.7
m,p-Xylene	23	17	0.4 U	3.93	0.40	0.20 U	0.53
o-Xylene	23	9	0.2 U	1.97	0.20	0.10 U	0.40
Total xylenes [a]	23	17	0.4 UT	5.9 T	0.51	0.20 UT	0.88 TV
Petroleum (TPH) mg/L							
Diesel-Range Hydrocarbons	11	0	0.25 U	0.25 U	0.13	0.13 U	0.13

Notes

When a statistic matched more than one sample, preference was given to qualifiers in the following order: A, J, N, T, V, No Flag, U.

Duplicates not included

a - Calculated U = 1/2 DL

Total PCBs are total PCB congeners whenever available and total Aroclors if not (on a per sample basis).

NA - Not Analyzed

DL - Detection Limit

ND - non-detect

PAH - polycyclic aromatic hydrocarbon

PCB - polychlorinated biphenyl

RM - river mile

TEQ - toxic equivalent concentration

Reason codes for qualifiers:

A - Total value based on limited number of analytes.

J - The associated numerical value is an estimated quantity.

T - The associated numerical value was mathematically derived (e.g., from summing multiple analyte results such as Aroclors, or calculating the average of multiple results for a single analyte). Also indicates all results that are selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods) for Round 2 data.

U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

V - Median or 95th percentile obtained through interpolation.

N - The identity of the analyte is presumptive and not definitive, generally as a result of the presence in the sample of an analytical interference, such as hydrocarbons or, in the case of pesticides, PCBs. Data that are N-qualified meet the primary identification criteria of the method; however, the confirmation criteria are not met and the identification is potentially a false positive.

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Conventionals (mg/L)							
Ammonia							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA	NA	NA
Sulfide							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	62	8	0.002 U	2 U	0.61	0.50 JV	1.0 UV
Cyanide							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	46	89	0.003 U	23.1 J	0.68	0.12 JV	0.67
Perchlorate							
Dissolved	5	40	0.01 UJ	75.2 J	25	0.0050 UJ	70 JV
Total	29	48	0.0004 U	210	34	1.1	160
Metals (µg/L)							
Aluminum							
Dissolved	55	31	1.2 UJ	555 T	31	2.8 U	160
Total	95	80	10.8	50300	4800	830	26000
Antimony							
Dissolved	55	33	0.03 J	2.7 J	0.21	0.075 UJ	0.88
Total	108	46	0.02 J	25.2	1.6	0.050 JV	10 UV
Arsenic							
Dissolved	63	94	0.21 U	77.3 T	12	8.3	31
Total	120	85	0.2 U	74.9	10	8.6	27
Barium							
Dissolved	55	100	5.39	2120	200	85	710
Total	95	99	4.06	4390	330	150	850
Beryllium							
Dissolved	55	16	0.005 J	0.06 J	0.0078	0.0060 U	0.018
Total	95	65	0.006	1.63 J	0.17	0.053	0.71
Cadmium							

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Dissolved	55	65	0.002 U	0.52	0.070	0.040	0.29
Total	95	66	0.004 U	36	0.56	0.091 J	0.71
Chromium							
Dissolved	60	55	0.09 U	95.9	3.3	0.43	7.2
Total	116	70	0.14 U	147	11	3.1 JV	49
Cobalt							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	13	62	5 UT	82	17	9.4	50
Copper							
Dissolved	55	29	0.02 UJ	3.63	0.42	0.23 UT	1.3
Total	105	53	0.17 UJ	182	14	5.0 UT	58
Iron							
Dissolved	55	100	30.8 J	122000	34000	26000	100000
Total	126	100	173	252000	50000	44000	120000
Lead							
Dissolved	63	43	0.01 J	1.61	0.12	0.027	0.59
Total	120	56	0.11 U	166	12	5	55
Magnesium							
Dissolved	71	100	1900	743000	61000	17000	330000
Total	140	100	814 J	1720000	63000	22000	150000
Manganese							
Dissolved	71	100	23 J	33500 J	4700	2500	16000
Total	146	100	72.3 J	66200 T	5100	3200	12000
Mercury							
Dissolved	55	9	0.08 J	0.36	0.053	0.040 UT	0.11
Total	95	21	0.08 J	0.495	0.067	0.040 UT	0.20
Nickel							
Dissolved	55	93	0.4 J	25.5	5.1	2.9 J	16
Total	108	81	0.2 J	142	13	6.9 JV	53
Potassium							
Dissolved	71	100	881 J	88500	8000	3700	25000
Total	127	96	133 J	197000 JT	10000	4200	33000

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Selenium							
Dissolved	55	65	0.1 JT	3.5 J	0.58	0.20 JT	2.3
Total	108	56	0.1 JT	20	1.9	0.50 JV	10 UV
Silver							
Dissolved	55	16	0.002 U	0.049 U	0.0063	0.0035 U	0.024
Total	108	35	0.004 U	10 UT	0.71	0.031 UV	5.0 UV
Sodium							
Dissolved	71	99	6150	56380000	2400000	19000	10000000
Total	127	98	580	58650000	2500000	18000 T	14000000
Thallium							
Dissolved	55	53	0.0005 U	0.171	0.010	0.0064 U	0.026
Total	95	42	0.002 U	0.655	0.040	0.011 JT	0.16
Vanadium							
Dissolved	NA	NA	NA U	NA	NA	NA	NA
Total	13	69	10 UT	379	65	16	230
Zinc							
Dissolved	63	56	0.78 UJ	526	12	2.0 U	11
Total	120	68	1.51 UJ	983	67	19 JV	240
PCDD/Fs ng/L							
2,3,7,8-TCDD							
Dissolved	2	0	0.00023 U	0.002139 U	0.00059	0.00059 UV	0.0010 UTV
Total	2	0	0.000247 U	0.00258 U	0.00071	0.00071 UV	0.0012 UV
Total PCDD/Fs [a]							
Dissolved	2	0	0.0004 UT	0.0043 UT	0.0012	0.0012 UTV	0.0021 UTV
Total	2	50	0.0166 UT	0.0226 JT	0.015	0.015 JV	0.022 JV
TCDD TEQ - mammalian WHO 2005 TEFs							
Dissolved	2	0	0.000056 UT	0.00061 UT	0.00017	0.00017 UTV	0.00029 UTV
Total	2	50	0.000652 UT	0.0018 JT	0.0011	0.0011 JV	0.0017 JV
Herbicides µg/L							
Silvex ™							
Dissolved	6	17	0.06 U	0.76	0.20	0.096 UV	0.61

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Total	9	33	0.063 U	22	3.1	0.043 U	15
Organochlorine Pesticides µg/L							
2,4'-DDD							
Dissolved	4	100	0.011 J	0.16	0.088	0.090 JV	0.16
Total	12	75	0.0034 UJ	1.1 J	0.27	0.12 JV	0.86
4,4'-DDD							
Dissolved	7	14	0.0019 U	0.077 U	0.013	0.0040 U	0.034
Total	18	50	0.0015 U	1.8 J	0.38	0.024 JV	1.7
4,4'-DDE							
Dissolved	7	0	0.0015 U	0.024 U	0.0029	0.0020	0.0091 UV
Total	18	39	0.0012 U	0.93 U	0.073	0.013 JV	0.27
4,4'-DDT							
Dissolved	7	0	0.0042 U	0.035 U	0.0067	0.0029 U	0.017 UV
Total	18	44	0.0056 U	2.7	0.48	0.013 JV	1.9
Total of 2,4' and 4,4'-DDD (Sum DDD) [a]							
Dissolved	7	57	0.0019 AUT	0.16 T	0.062	0.036 JT	0.16 TV
Total	18	61	0.0015 AUT	2.5 JT	0.56	0.15 JV	2.4
Total of 2,4' and 4,4'-DDE (Sum DDE) [a]							
Dissolved	7	0	0.0015 AUT	0.024 UT	0.0029	0.0020 UT	0.0091 UTV
Total	18	39	0.0012 AUT	0.93 UT	0.073	0.013 JV	0.27
Total of 2,4' and 4,4'-DDT (Sum DDT) [a]							
Dissolved	7	29	0.0042 AUT	0.035 AUT	0.011	0.010 NJT	0.021 UV
Total	18	56	0.0075 AJT	3.2 T	0.52	0.013 JTV	2.1
Total of 2,4' and 4,4'-DDD, -DDE, -DDT [a]							
Dissolved	7	57	0.0042 AUT	0.19 JT	0.074	0.049 JT	0.18 JV
Total	18	78	0.008 UJT	5.7 JT	1.1	0.20 JTV	3.9
MCPP							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	1	0	17 U	17 U	8.5	8.5	8.5
Polycyclic Aromatic Hydrocarbons µg/L							
2-Methylnaphthalene							

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Dissolved	38	18	0.004 U	44	1.3	0.0090 UV	1.1
Total	78	42	0.0034 U	1000	63	0.019 UV	580
Acenapthene							
Dissolved	38	92	0.0024 U	64	6.4	0.41	40
Total	91	96	0.0034 U	680	60	8.4	350
Acenapthylene							
Dissolved	38	50	0.0022 U	0.41	0.055	0.013 UV	0.23
Total	91	69	0.0032 U	12	0.83	0.087	4.5
Anthracene							
Dissolved	38	76	0.0013 U	1.1	0.13	0.010 JV	0.83
Total	91	79	0.0019 U	97	6.8	0.13 U	34
Benzo(a)anthracene							
Dissolved	38	24	0.0024 U	0.17	0.0077	0.0020 UV	0.011
Total	91	59	0.0026 U	59	3.1	0.035 J	16
Benzo(a)pyrene							
Dissolved	38	13	0.0018 U	0.075	0.004	0.0012 UV	0.0063
Total	91	58	0.0025 J	75	3.7	0.024 J	19
Benzo(b)fluoranthene							
Dissolved	38	8	0.0022 U	0.087	0.0059	0.0015 UV	0.014
Total	91	49	0.0023 U	65	3.2	0.017 U	17
Benzo(b+k)fluoranthene							
Dissolved	38	8	0.0022	0.0022 T	0.0084	0.0015 UTV	0.023
Total	91	49	0.0025	0.0025 T	4.2	0.021 UTV	23
Benzo(g,h,i)perylene							
Dissolved	38	5	0.0041 U	0.021 J	0.0033	0.0025 UV	0.0073
Total	91	60	0.0029 U	54	2.7	0.030 J	15
Benzo(k)fluoranthene							
Dissolved	38	8	0.0015 U	0.071	0.004	0.0011 UV	0.0089
Total	91	43	0.0017 U	20	1.0	0.013 U	5.3
Chrysene							
Dissolved	38	21	0.0014	0.24	0.011	0.0018 UV	0.025
Total	91	64	0.0022	70	3.6	0.051	17

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations: Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Dibenzo(a,h)anthracene							
Dissolved	38	5	0.0018 U	0.0066 U	0.0018	0.0013 UV	0.0033
Total	91	44	0.0019 U	6.7	0.34	0.0047	2.0
Fluoranthene							
Dissolved	38	50	0.0042 U	2.1	0.24	0.016 UV	1.1
Total	91	78	0.013 J	310	15	0.69	76
Fluorene							
Dissolved	38	76	0.0031 U	17	2.0	0.074	12
Total	91	82	0.0038 U	170	17	1.8	81
Ideno(1,2,3-cd) pyrene							
Dissolved	38	5	0.0023 U	0.019 J	0.0025	0.0016 UV	0.0056
Total	91	59	0.0026 U	53	2.3	0.024 UT	12
Naphthalene							
Dissolved	38	16	0.015	1100	29	0.035 UV	1.3
Total	57	26	0.003 J	15000	280	0.47 JV	6700
Phenanthrene							
Dissolved	38	58	0.004 U	21	2.2	0.12	12
Total	91	77	0.0066 U	790	48	1.6	270
Pyrene							
Dissolved	38	55	0.0071 U	2.7	0.25	0.028	0.92
Total	91	80	0.017 J	310	17	0.90 U	81
Total HPAHs [a]							
Dissolved	38	58	0.0071 UT	5.5 JT	0.52	0.049 UV	2.0
Total	91	89	0.036 UT	1000 T	51	1.9 JT	270
Total LPAHs [a]							
Dissolved	38	95	0.042 UT	1200 T	41	0.88 JTV	79
Total	91	96	0.016 UT	18000 T	370	12 JT	1300
Total PAHs [a]							
Dissolved	38	95	0.042 UT	1200 JT	42	0.94 JTV	81
Total	91	97	0.036 UT	19000 T	420	13 JT	1500
Total Carcinogenic PAHs [a]							

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

			Detected and Nondetected Concentrations				
Analyte	# Analyzed	% Detected	Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Dissolved	38	34	0.0018 UT	0.1 JT	0.0060	0.0032 UV	0.0099
Total	91	79	0.0029 UT	99.67 T	4.9	0.035 JT	26
Semivolatile Organic Compounds µg/L							
1,2-Dichlorobenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	222	9	0.12 UJ	640	6.9	0.15 JV	6.0 UJV
1,4-Dichlorobenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	217	8	0.12 UJ	240	3.1	0.15 UT	6.0
Volatile Organic Compounds µg/L							
1,1-Dichloroethene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	14	0.082 U	283	3.7	0.10 UV	7.0
1,2-Dichloroethane							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	5	0.031 U	770	6.3	0.10	2.9 UV
1,2-Dichloropropane							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	2	0.035 U	70 U	0.83	0.10 JV	2.9 UV
1,1,2-Trichloroethane							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	4	0.059 U	400	4.2	0.085 UV	3.8
1,2,4-Trimethylbenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	97	44	1 UT	69.9	8.2	0.50 U	44
1,3,5-Trimethylbenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	97	43	0.3 UT	21.6	2.3	0.15 UT	11
Acrolein							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	131	4	0.51 UJ	1400 UJ	120	700	700
Benzene							

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	231	55	0.14 J	5490	220	0.30	2000
Bromochloromethane							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	1	0.06 U	1800	8.9	0.085 UJV	3.4 UV
Bromodichloromethane							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	2	0.068 U	290	1.7	0.10 UV	2.3 UV
Carbon disulfide							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	4	0.15 J	800	4.6	0.45 UV	4.0 UV
Chlorobenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	22	0.07 U	30000	250	0.10 UV	52
Chloroethane							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	6	0.2 UT	160	1.7	0.12 UJV	6.0 UV
Chloroform							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	11	0.056 U	820000	7100	0.10 UV	41
cis-1,2-Dichloroethene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	195	41	0.12 J	574000	3700	0.10 UT	3200
Ethylbenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	231	40	0.071 U	690	31	0.10 UT	260
Isopropylbenzene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	31	0.044 U	53 U	1.7	0.15 JV	10
Methylene chloride							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	8	0.2 UJ	520000	2800	2.5 UV	29 JV

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
MTBE							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	13	0.039 U	99 U	1.3	0.25 JV	8.8
Tetrachloroethene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	9	0.096 U	12000	60	0.25 JV	5.9
Toluene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	231	54	0.11 UJ	821	11	0.69 U	39
trans-1,2-Dichloroethene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	13	0.15 UJ	1760	11	0.15 JV	14
Trichloroethene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	23	0.062 U	585000	3100	0.10 UV	40
Vinyl chloride							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	228	45	0.042 UJ	28900	200	0.11 JV	530
m,p-Xylene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	231	41	0.2 J	380	16	0.20 J	76
o-Xylene							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	231	45	0.11 J	210	10	0.11 J	73
Total xylenes [a]							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	231	48	0.22 JT	590 T	26	0.24 JT	140
Petroleum (TPH) (mg/L)							
Diesel-Range Hydrocarbons							
Dissolved	38	76	0.026 J	3.6 J	0.63	0.37 JV	2.9
Total	60	70	0.022 U	6.1 J	0.89	0.44 JV	3.3 JV

Table 2.2-3. Summary Statistics for Contaminants Potentially Posing Unacceptable Risks in Transition Zone Water, Study Area (RM 1.9-11.8)

Analyte	# Analyzed	% Detected	Detected and Nondetected Concentrations				
			Minimum (full DL)	Maximum (Full DL)	Mean (Half DL)	Median (Half DL)	95th Percentile (Half DL)
Gasoline-Range Hydrocarbons							
Dissolved	NA	NA	NA	NA	NA	NA	NA
Total	65	49	0.013 JT	4 J	0.3	0.048	1.1 JV
Residual-Range Hydrocarbons							
Dissolved	38	53	0.034 U	0.71 J	0.16	0.11 UV	0.44
Total	60	50	0.038 U	4.9 J	0.39	0.15 JV	0.94 JV

Notes

When a statistic matched more than one sample, preference was given to qualifiers in the following order: A, J, N, T, V, No Flag, U.

Duplicates not included

a - Calculated U = 1/2 DL

Total PCBs are total PCB congeners whenever available and total Aroclors if not (on a per sample basis).

NA - Not Analyzed

DL - Detection Limit

ND - non-detect

PAH - polycyclic aromatic hydrocarbon

PCB - polychlorinated biphenyl

RM - river mile

TEQ - toxic equivalent concentration

Reason codes for qualifiers:

A - Total value based on limited number of analytes.

J - The associated numerical value is an estimated quantity.

T - The associated numerical value was mathematically derived (e.g., from summing multiple analyte results such as Aroclors, or calculating the average of multiple results for a single analyte). Also indicates all results that are selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods) for Round 2 data.

U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

V - Median or 95th percentile obtained through interpolation.

N - The identity of the analyte is presumptive and not definitive, generally as a result of the presence in the sample of an analytical interference, such as hydrocarbons or, in the case of pesticides, PCBs. Data that are N-qualified meet the primary identification criteria of the method; however, the confirmation criteria are not met and the identification is potentially a false positive.

Table 2.2-4. Upriver Surface Sediment Background Values (Dry Weight)

Analyte	Units	Distribution (ND = ROS)	Kaplan-Meier Statistics KM Mean	Kaplan-Meier Statistics KM SD	Upper Threshold Statistics 95-UPL Type	Upper Threshold Statistics 95-UPL UPL	Upper Threshold Statistics 95-Percentile Percentile	Central Tendency Statistics 95-UCL Type	Central Tendency Statistics 95-UCL UCL	Central Tendency Statistics Mean (ND = DL)
PCB-77	pg/g	Lognormal	7.67	10.2	95% KM UPL (t)	25.2	26.9	95% KM (t) UCL	10.8	7.93
PCB-81	pg/g	Normal	0.454	0.256	95% KM UPL (t)	0.932	1.28	95% KM (t) UCL	0.621	0.659
PCB-105	pg/g	Lognormal	44.1	68.9	95% KM UPL (t)	163	171	97.5% KM (Chebyshev) UCL	121	44.9
PCB-118	pg/g	Gamma	73.9	87.7	95% KM UPL (t)	231	393	95% KM (Chebyshev) UCL	167	74.3
PCB-126	pg/g	Lognormal	1.51	1.40	95% KM UPL (t)	3.92	6.47	95% KM (t) UCL	2.01	1.99
PCB-156	pg/g	Lognormal	19.3	28.5	95% KM UPL (t)	68.5	108	95% KM (Chebyshev) UCL	41.8	22.2
PCB-157	pg/g	Lognormal	12.2	21.2	95% KM UPL (t)	48.6	65.6	97.5% KM (Chebyshev) UCL	36.1	15.3
PCB-169	pg/g	N/A	N/A	N/A	N/A	N/A	26.5	N/A	N/A	3.89
Total PCBs (Congeners + Aroclors)	µg/kg	Approx. Gamma	5.44	6.87	95% KM UPL (t)	17.0	18.7	95% KM (Percentile Bootstrap) UCL	6.85	5.76
Total PCBs (Aroclors only) - LWG case	µg/kg	Non-parametric	8.48	8.91	95% KM UPL (t)	23.5	33.0	95% KM (t) UCL	10.4	8.77
Total PCBs (Aroclors only) - EPA case	µg/kg	Lognormal	6.41	2.93	95% KM UPL (t)	11.3	13.7	95% KM (t) UCL	7.07	6.72
Total PCBs (Congeners only)	pg/g	Lognormal	5380	6700	95% KM UPL (t)	16900	24800	95% KM (Chebyshev) UCL	10600	5380
Total PCBs (TEQ) - mammalian WHO 2005 TEFs	pg/g	Non-parametric	0.179	0.248	95% KM UPL (t)	0.606	0.723	95% KM (Chebyshev) UCL	0.376	0.179
1,2,3,4,7,8 HCDF	pg/g	Gamma	0.0976	0.120	95% KM UPL (t)	0.301	1.14	95% KM (t) UCL	0.134	0.419
1,2,3,6,7,8 HCDD	pg/g	Lognormal	0.440	0.580	95% KM UPL (t)	1.42	2.51	97.5% KM (Chebyshev) UCL	0.814	0.667
1,2,3,7,8 PCDD	pg/g	Approx. Gamma	0.0319	0.0271	95% KM UPL (t)	0.0777	1.17	95% KM (t) UCL	0.0404	0.393
2,3,4,7,8 PCDF	pg/g	Non-parametric	0.0644	0.257	95% KM UPL (t)	0.500	1.04	95% KM (BCA) UCL	0.148	0.375
2,3,7,8 TCDD	pg/g	N/A	N/A	N/A	N/A	N/A	0.228	N/A	N/A	0.0899
2,3,7,8 TCDF	pg/g	Gamma	0.132	0.182	95% KM UPL (t)	0.441	0.686	95% KM (t) UCL	0.177	0.166
TCDD TEQ - mammalian WHO 2005 TEFs	pg/g	Non-parametric	0.720	0.848	95% KM UPL (t)	2.16	2.38	95% KM (Chebyshev) UCL	1.25	0.720
Total TEQ-mammalian WHO 2005 TEFs	pg/g	Non-parametric	0.917	1.03	95% KM UPL (t)	2.65	2.83	95% KM (Chebyshev) UCL	1.55	0.917
4,4'-DDD	µg/kg	Gamma	0.447	0.307	95% KM UPL (t)	0.964	1.20	95% KM (t) UCL	0.518	0.620
4,4'-DDE	µg/kg	Gamma	0.760	0.494	95% KM UPL (t)	1.59	1.80	95% KM (Percentile Bootstrap) UCL	0.866	0.908
4,4'-DDT	µg/kg	Gamma	0.304	0.385	95% KM UPL (t)	0.953	1.20	95% KM (t) UCL	0.394	0.581
Sum DDD	µg/kg	Gamma	0.594	0.426	95% KM UPL (t)	1.31	1.56	95% KM (t) UCL	0.689	0.753
Sum DDE	µg/kg	Gamma	0.836	0.525	95% KM UPL (t)	1.72	1.80	95% KM (Percentile Bootstrap) UCL	0.951	0.976
Sum DDT	µg/kg	Approx. Gamma	0.462	0.378	95% KM UPL (t)	1.10	1.30	95% KM (t) UCL	0.544	0.591
Total DDx - LWG case	µg/kg	Non-parametric	1.56	1.21	95% KM UPL (t)	3.59	3.04	95% KM (BCA) UCL	1.85	1.71
Total DDx - EPA case	µg/kg	Normal	1.43	0.947	95% KM UPL (t)	3.03	2.94	95% KM (t) UCL	1.64	1.59
alpha-Hexachlorocyclohexane	µg/kg	N/A	N/A	N/A	N/A	N/A	0.610	N/A	N/A	0.228
beta-Hexachlorocyclohexane	µg/kg	Gamma	0.357	0.411	95% KM UPL (t)	1.05	1.47	95% KM (t) UCL	0.446	0.470
delta - Hexachlorocyclohexane	µg/kg	Normal	0.220	0.0126	95% KM UPL (t)	0.242	0.253	95% KM (t) UCL	0.224	0.126
gamma-Hexachlorocyclohexane	µg/kg	--	--	--	--	--	--	--	--	0.117
Chlordanes (Total)	µg/kg	Gamma	0.331	0.218	95% KM UPL (t)	0.698	0.788	95% KM (t) UCL	0.380	0.408
Aldrin	µg/kg	Normal	0.254	0.0499	95% KM UPL (t)	0.339	0.480	95% KM (t) UCL	0.267	0.242
Dieldrin	µg/kg	Normal	0.122	0.0546	95% KM UPL (t)	0.215	0.320	95% KM (t) UCL	0.137	0.119
Endrin	µg/kg	N/A	N/A	N/A	N/A	N/A	1.20	N/A	N/A	0.470
Endrin ketone	µg/kg	Normal	0.0913	0.00699	95% KM UPL (t)	0.103	0.110	95% KM (t) UCL	0.0933	0.0630
Heptachlor	µg/kg	N/A	N/A	N/A	N/A	N/A	0.480	N/A	N/A	0.175
Heptachlor epoxide	µg/kg	N/A	N/A	N/A	N/A	N/A	0.630	N/A	N/A	0.260
MCPP	µg/kg	N/A	N/A	N/A	95% KM UPL (t)	N/A	2500	N/A	N/A	1460

Table 2.2-4. Upriver Surface Sediment Background Values (Dry Weight)

			Kaplan-Meier Statistics		Upper Threshold Statistics			Central Tendency Statistics		
		Distribution			95-UPL		95-Percentile	95-UCL		Mean
Analyte	Units	(ND = ROS)	KM Mean	KM SD	Type	UPL	Percentile	Type	UCL	(ND = DL)
Total PAHs	µg/kg	Gamma	71.2	69.2	95% KM UPL (t)	187	187	95% KM (Chebyshev) UCL	108	77.0
cPAH BaPEq	µg/kg	Gamma	8.16	7.94	95% KM UPL (t)	21.5	25.8	95% KM (BCA) UCL	9.86	9.41
Total LPAHs	µg/kg	Normal	10.1	8.08	95% KM UPL (t)	23.6	25.2	95% KM (t) UCL	11.7	11.6
Benzo(a)anthracene	µg/kg	Lognormal	5.56	6.18	95% KM UPL (t)	15.9	20.0	95% KM (BCA) UCL	6.93	6.61
Benzo(a)pyrene	µg/kg	Gamma	5.10	5.69	95% KM UPL (t)	14.7	19.0	95% KM (t) UCL	6.26	6.72
Benzo(b)fluoranthene	µg/kg	Approx. Gamma	7.44	7.60	95% KM UPL (t)	20.2	25.0	95% KM (Percentile Bootstrap) UCL	9.08	9.01
Benzo(k)fluoranthene	µg/kg	Non-parametric	3.57	4.10	95% KM UPL (t)	10.5	14.0	95% KM (BCA) UCL	4.78	4.10
Chrysene	µg/kg	Lognormal	7.79	10.2	95% KM UPL (t)	24.9	25.0	95% KM (BCA) UCL	10.2	9.03
Dibenzo(a,h)anthracene	µg/kg	Approx. Gamma	1.48	1.02	95% KM UPL (t)	3.20	10.0	95% KM (Percentile Bootstrap) UCL	1.70	2.05
Indeno(1,2,3-cd)pyrene	µg/kg	Gamma	4.60	4.02	95% KM UPL (t)	11.4	14.0	95% KM (BCA) UCL	5.66	4.98
Bis(2-ethylhexyl) phthalate	µg/kg	Gamma	40.8	46.0	95% KM UPL (t)	118	120	95% KM (BCA) UCL	50.1	73.9
Diethyl phthalate	µg/kg	Gamma	3.12	0.954	95% KM UPL (t)	4.70	6.80	95% KM (t) UCL	3.44	4.59
Benzyl alcohol	µg/kg	Gamma	7.02	3.87	95% KM UPL (t)	13.6	15.0	95% KM (t) UCL	8.04	8.19
Carbazole	µg/kg	Lognormal	1.58	0.359	95% KM UPL (t)	2.20	2.80	95% KM (t) UCL	1.69	1.95
Hexachlorobenzene	µg/kg	Lognormal	0.260	0.253	95% KM UPL (t)	0.691	0.869	95% KM (t) UCL	0.328	0.346
Pentachlorophenol	µg/kg	Gamma	2.54	2.01	95% KM UPL (t)	5.92	6.40	95% KM (t) UCL	2.97	2.38
4-Methylphenol	µg/kg	Non-parametric	6.84	6.99	95% KM UPL (t)	18.6	33.0	95% KM (t) UCL	8.38	14.4
Phenol	µg/kg	Normal	4.19	0.816	95% KM UPL (t)	5.70	6.20	95% KM (t) UCL	4.64	4.35
Aluminum	mg/kg	Non-parametric	20600	7890	95% KM UPL (t)	33800	32300	95% KM (Chebyshev) UCL	24900	20600
Antimony	mg/kg	Non-parametric	0.154	0.208	95% KM UPL (t)	0.503	0.690	95% KM (t) UCL	0.197	0.163
Arsenic	mg/kg	Approx. Gamma	2.87	0.657	95% KM UPL (t)	3.97	3.75	95% KM (BCA) UCL	3.01	2.87
Cadmium	mg/kg	Gamma	0.117	0.0504	95% KM UPL (t)	0.201	0.210	95% KM (BCA) UCL	0.129	0.119
Chromium	mg/kg	Normal	22.6	5.69	95% KM UPL (t)	32.1	32.7	95% KM (t) UCL	23.8	22.6
Copper	mg/kg	Normal	24.3	7.72	95% KM UPL (t)	37.3	38.0	95% KM (t) UCL	25.9	24.3
Lead	mg/kg	Non-parametric	8.40	4.15	95% KM UPL (t)	15.4	14.3	95% KM (Chebyshev) UCL	10.6	8.40
Mercury	mg/kg	Normal	0.0307	0.0134	95% KM UPL (t)	0.0532	0.0540	95% KM (t) UCL	0.0337	0.0313
Nickel	mg/kg	Normal	20.7	3.24	95% KM UPL (t)	26.1	26.1	95% KM (t) UCL	21.4	20.7
Selenium	mg/kg	Gamma	0.136	0.0968	95% KM UPL (t)	0.302	0.350	95% KM (Percentile Bootstrap) UCL	0.168	0.137
Silver	mg/kg	Approx. Gamma	0.121	0.0944	95% KM UPL (t)	0.281	0.660	95% KM (BCA) UCL	0.143	0.144
Zinc	mg/kg	Normal	74.7	21.1	95% KM UPL (t)	110	105	95% KM (t) UCL	79.0	74.7
Tributyltin ion	µg/kg	N/A	N/A	N/A	N/A	N/A	1.10	N/A	N/A	0.636

Notes:

For bedded surface sediment, the upriver reach of the Lower Willamette River, extending from RM 15.3 to 28.4, was selected by EPA as the reference area for determining background concentrations.

Sediment statistics are based on datasets with primary outliers removed. See Appendix A for background value statistical methods and rationale.

-- Indicates not applicable or data not available

BaPEq - benzo(a)pyrene equivalent
cPAH - carcinogenic polycyclic aromatic hydrocarbon
DDx - total of 2,4' and 4,4'- DDD, -DDE, -DDT
DL - detection limit
EPA - U.S. Environmental Protection Agency
KM - Kaplan-Meier
LWG - Lower Willamette Group
N/A - not available
ND - non-detect
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
ROS - regression on order statistics (Helsel 2005)
SD - standard deviation
TEF - toxicity equivalency factor
TEQ - toxic equivalent concentration
UPL - upper prediction limit
UCL - upper confidence limit
WHO - World Health Organization

Table 2.2-5. Upriver Surface Sediment Background Values (OC-Normalized)

					Upper Threshold Statistics			Central Tendency Statistics		
		Distribution	Kaplan-Meier Statistics		95-UPL		95-Percentile	95-UCL		Mean
	Units	(ND = ROS)	KM Mean	KM SD	Type	UPL	Percentile	Type	UCL	(ND = DL)
PCB-77	pg/g	Non-parametric	749	828	95% KM UPL (t)	2170	2300	95% KM (t) UCL	1010	869
PCB-81	pg/g	Normal	27.4	24.3	95% KM UPL (t)	72.4	108	95% KM (t) UCL	42.9	62.1
PCB-105	pg/g	Non-parametric	4940	6040	95% KM UPL (t)	15300	17300	95% KM (Chebyshev) UCL	9680	5310
PCB-118	pg/g	Normal	9520	6080	95% KM UPL (t)	20400	27000	95% KM (t) UCL	12200	9890
PCB-126	pg/g	Non-parametric	128	134	95% KM UPL (t)	363	527	95% KM (t) UCL	181	181
PCB-156	pg/g	Non-parametric	1800	2120	95% KM UPL (t)	5450	11200	95% KM (Chebyshev) UCL	3530	2890
PCB-157	pg/g	Non-parametric	1140	1400	95% KM UPL (t)	3550	8670	97.5% KM (Chebyshev) UCL	2800	2320
PCB-169	pg/g	N/A	N/A	N/A	N/A	N/A	13300	N/A	N/A	1280
Total PCBs (Congeners + Aroclors)	µg/kg	Gamma	558	609	95% KM UPL (t)	1580	2280	95% KM (Percentile Bootstrap) UCL	694	625
Total PCBs (Aroclors only) - LWG case	µg/kg	Non-parametric	660	743	95% KM UPL (t)	1910	4100	95% KM (t) UCL	825	1060
Total PCBs (Aroclors only) - EPA case	µg/kg	Lognormal	494	342	95% KM UPL (t)	1070	4100	95% KM (t) UCL	577	933
Total PCBs (Congeners only)	pg/g	Lognormal	661000	669000	95% KM UPL (t)	1810000	2620000	95% KM (Chebyshev) UCL	1190000	661000
Total PCBs (TEQ) - mammalian WHO 2005 TEFs	pg/g	Non-parametric	22.0	19.4	95% KM UPL (t)	55.5	55.6	95% KM (Chebyshev) UCL	37.7	22.0
1,2,3,4,7,8 HCDF	pg/g	Gamma	11.4	13.8	95% KM UPL (t)	34.9	565	95% KM (t) UCL	15.6	112
1,2,3,6,7,8 HCDD	pg/g	Approx. Gamma	43.2	43.9	95% KM UPL (t)	118	540	95% KM (Percentile Bootstrap) UCL	56.3	121
1,2,3,7,8 PCDD	pg/g	Gamma	3.28	3.50	95% KM UPL (t)	9.26	84.9	95% KM (t) UCL	4.39	14.0
2,3,4,7,8 PCDF	pg/g	Normal	2.65	3.06	95% KM UPL (t)	7.83	520	95% KM (t) UCL	3.62	97.0
2,3,7,8 TCDD	pg/g	N/A	N/A	N/A	N/A	N/A	27.3	N/A	N/A	5.35
2,3,7,8 TCDF	pg/g	Gamma	12.5	19.4	95% KM UPL (t)	45.4	114	95% KM (t) UCL	17.7	29.8
TCDD TEQ - mammalian WHO 2005 TEFs	pg/g	Lognormal	149	234	95% KM UPL (t)	545	673	97.5% KM (Chebyshev) UCL	362	149
Total TEQ-mammalian WHO 2005 TEFs	pg/g	Lognormal	178	285	95% KM UPL (t)	660	728	97.5% KM (Chebyshev) UCL	432	178
4,4'-DDD	µg/kg	Non-parametric	38.8	20.8	95% KM UPL (t)	73.9	97.6	95% KM (BCA) UCL	44.7	45.1
4,4'-DDE	µg/kg	Gamma	67.5	28.3	95% KM UPL (t)	115	124	95% KM (BCA) UCL	74.1	72.3
4,4'-DDT	µg/kg	Normal	20.3	28.5	95% KM UPL (t)	68.4	97.6	95% KM (t) UCL	27.6	41.4
Sum DDD	µg/kg	Gamma	52.3	30.8	95% KM UPL (t)	104	134	95% KM (Percentile Bootstrap) UCL	59.8	58.4
Sum DDE	µg/kg	Gamma	75.6	31.0	95% KM UPL (t)	128	159	95% KM (BCA) UCL	83.0	80.1
Sum DDT	µg/kg	Gamma	30.5	29.0	95% KM UPL (t)	79.4	106	95% KM (t) UCL	37.3	42.6
Total DDx - LWG case	µg/kg	Gamma	151	63.9	95% KM UPL (t)	258	301	95% KM (Percentile Bootstrap) UCL	165	163
Total DDx - EPA case	µg/kg	Normal	146	56.1	95% KM UPL (t)	240	301	95% KM (t) UCL	159	158
alpha-Hexachlorocyclohexane	µg/kg	N/A	N/A	N/A	N/A	N/A	220	N/A	N/A	45.2
beta-Hexachlorocyclohexane	µg/kg	Gamma	36.0	47.3	95% KM UPL (t)	116	230	95% KM (t) UCL	46.7	70.4
delta-Hexachlorocyclohexane	µg/kg	Normal	10.4	2.16	95% KM UPL (t)	14.1	19.0	95% KM (t) UCL	11.1	9.70
gamma-Hexachlorocyclohexane	µg/kg	--	--	--	--	--	24.6	--	--	10.4
Chlordanes (Total)	µg/kg	Non-parametric	28.8	19.7	95% KM UPL (t)	62.0	82.1	95% KM (t) UCL	33.4	35.0
Aldrin	µg/kg	Normal	14.9	3.60	95% KM UPL (t)	21.0	28.7	95% KM (t) UCL	15.9	15.1
Dieldrin	µg/kg	Normal	9.39	8.13	95% KM UPL (t)	23.2	44.4	95% KM (t) UCL	11.6	13.4
Endrin	µg/kg	--	--	--	--	--	450	--	--	105
Endrin ketone	µg/kg	Normal	6.37	0.558	95% KM UPL (t)	7.33	8.00	95% KM (t) UCL	6.55	4.90
Heptachlor	µg/kg	N/A	N/A	N/A	N/A	N/A	38.8	N/A	N/A	12.6

Table 2.2-5. Upriver Surface Sediment Background Values (OC-Normalized)

			Kaplan-Meier Statistics		Upper Threshold Statistics			Central Tendency Statistics		
		Distribution			95-UPL		95-Percentile	95-UCL		Mean
	Units	(ND = ROS)	KM Mean	KM SD	Type	UPL	Percentile	Type	UCL	(ND = DL)
Heptachlor epoxide	µg/kg	N/A	N/A	N/A	N/A	N/A	220	N/A	N/A	47.7
MCPP	µg/kg	--	--	--	--	--	181000	--	--	146000
Total PAHs	µg/kg	Lognormal	7770	9260	95% KM UPL (t)	23300	28000	95% KM (Chebyshev) UCL	12600	7830
cPAH BaPEq	µg/kg	Lognormal	951	1260	95% KM UPL (t)	3060	3550	95% KM (BCA) UCL	1230	1010
Total LPAHs	µg/kg	Approx. Gamma	973	848	95% KM UPL (t)	2400	3160	95% KM (Percentile Bootstrap) UCL	1190	1080
Benzo(a)anthracene	µg/kg	Non-parametric	627	794	95% KM UPL (t)	1960	2830	95% KM (BCA) UCL	799	706
Benzo(a)pyrene	µg/kg	Non-parametric	527	755	95% KM UPL (t)	1790	1810	95% KM (t) UCL	682	664
Benzo(b)fluoranthene	µg/kg	Lognormal	844	1010	95% KM UPL (t)	2530	3540	95% KM (BCA) UCL	1090	926
Benzo(k)fluoranthene	µg/kg	Non-parametric	527	838	95% KM UPL (t)	1930	2200	95% KM (Chebyshev) UCL	969	575
Chrysene	µg/kg	Non-parametric	890	1340	95% KM UPL (t)	3140	3780	95% KM (BCA) UCL	1200	964
Dibenzo(a,h)anthracene	µg/kg	Non-parametric	230	336	95% KM UPL (t)	795	1140	95% KM (Chebyshev) UCL	411	297
Indeno(1,2,3-cd)pyrene	µg/kg	Non-parametric	555	670	95% KM UPL (t)	1680	1420	95% KM (BCA) UCL	698	597
Bis(2-ethylhexyl) phthalate	µg/kg	Gamma	3900	3690	95% KM UPL (t)	10100	11500	95% KM (BCA) UCL	4750	4690
Diethyl phthalate	µg/kg	Non-parametric	276	129	95% KM UPL (t)	496	778	95% KM (t) UCL	313	396
Benzyl alcohol	µg/kg	Approx. Gamma	609	302	95% KM UPL (t)	1120	1740	95% KM (t) UCL	689	798
Carbazole	µg/kg	Non-parametric	132	106	95% KM UPL (t)	312	631	95% KM (t) UCL	162	209
Hexachlorobenzene	µg/kg	Non-parametric	34.8	52.3	95% KM UPL (t)	125	204	97.5% KM (Chebyshev) UCL	90.8	42.0
Pentachlorophenol	µg/kg	Gamma	425	548	95% KM UPL (t)	1350	2120	95% KM (t) UCL	540	442
4-Methylphenol	µg/kg	Non-parametric	695	1140	95% KM UPL (t)	2610	6490	95% KM (t) UCL	949	1270
Phenol	µg/kg	Normal	363	136	95% KM UPL (t)	609	712	95% KM (t) UCL	434	458
Tributyltin ion	µg/kg	N/A	N/A	N/A	N/A	N/A	153	N/A	N/A	69.2

Notes:

For bedded surface sediment, the upriver reach of the Lower Willamette River, extending from RM 15.3 to 28.4, was selected by EPA as the reference area for determining background concentrations.

Sediment statistics are based on datasets with primary outliers removed. See Appendix A for background value statistical methods and rationale.

-- Indicates not applicable or data not available
BaPEq - benzo(a)pyrene equivalent
cPAH - carcinogenic polycyclic aromatic hydrocarbon
DDx - total of 2,4' and 4,4'- DDD, -DDE, -DDT
DL - detection limit
EPA - U.S. Environmental Protection Agency
KM - Kaplan-Meier
LWG - Lower Willamette Group
N/A - not available
ND - non-detect
OC - organic carbon
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
ROS - regression on order statistics (Helsel 2005)
SD - standard deviation
TEF - toxicity equivalency factor
TEQ - toxic equivalent concentration
UPL - upper prediction limit
UCL - upper confidence limit
WHO - World Health Organization

Table 2.4-1. Vessel Site Use Survey

River Mile	East/West	Max Water Depth Range (ft CRD)	Adjacent Bank/Property	Vessel Activity	Vessel Owner/Type	Vessel Operation Frequency	Maintenance Dredge Activity?	Notes
2	East	Equal to the Navigation Channel (-43 CRD currently)	Evraz OSM	Currently Inactive - Little to No Vessel Activity	Foss - all Foss tugs from Brix facility at RM 5.5	Currently Inactive - Little to No Vessel Activity	Historically dredged	Member has indicated docks are currently inactive but would like to evaluate alternatives that preserve the future use as well as more cost effective alternatives that may limit access to docks.
2	East	Equal to the Navigation Channel (-43 CRD currently)	Ash Grove- RM 2	Currently active	Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.3	Currently active	Routinely dredged	Member has indicated docks are currently active and would like to evaluate alternatives that preserve the future use.
2	East	Equal to the Navigation Channel (-43 CRD currently)	JR Simplot/POP/James River	Currently active	Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.4 Tidewater barges - from Willbridge moorage at RM 7.8 Various international ocean vessels	Currently active	Historically dredged, JR Simplot routinely dredged	Member has indicated docks are currently active and would like to evaluate alternatives that preserve the future use.
3	East	Equal to the Navigation Channel (-43 CRD currently)	Time Oil	Currently Inactive - Little to No Vessel Activity	Currently Inactive - Little to No Vessel Activity	Currently Inactive - Little to No Vessel Activity		Member has indicated docks are currently inactive but would like to evaluate alternatives that preserve the future use as well as more cost effective alternatives that may limit access to docks. Need information on future required depths.
3	East	-30	International Slip/Schnitzer	Scrap barge/salvage with ocean tug assist	Unknown tug operator, maybe Sause Bros. or Foss, but ocean going tugs tow in vessels to be scrapped to the head of the slip	Quarterly	Routinely dredged	
3	East	Equal to the Navigation Channel (-43 CRD currently)	International Slip/Schnitzer Entrance/Schnitzer	Deep draft ocean-going international cargo ships with tug assist handling processed metal/ocean container handling	Various ocean-going international cargo ships Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.3	Monthly	Historically dredged	
3	East	Equal to the Navigation Channel (-43 CRD currently)	PEO	Deep draft ocean-going international cargo ships with tug assist handling processed metal/ocean container handling	Various ocean-going international cargo ships Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.4	Monthly - less affected from these operations than at AOPCs 3 & 4	Historically dredged	Member has indicated docks are currently inactive but would like to evaluate alternatives that preserve the future use as well as more cost effective alternatives that may limit access to docks. Need information on future required depths.
3	West	-30	GP Linnton	Gravel barge with tug assist	Glacier tug and barge	Quarterly	Historically the dock was used for GP and Morse Bros/ACF operations	

Table 2.4-1. Vessel Site Use Survey

River Mile	East/West	Max Water Depth Range (ft CRD)	Adjacent Bank/Property	Vessel Activity	Vessel Owner/Type	Vessel Operation Frequency	Maintenance Dredge Activity?	Notes
4	West	-30	Kinder Morgan	Fuel barge with tug assist	Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.3 Olympic - all tugs from facility at RM 6.2 Tidewater - all tugs from Vancouver W Others - (Crowley/Sause etc.) infrequent privateer fueling operations	Weekly operations - barges will often remain moored for loading/unloading fuel over 1 to 2 days	Routinely dredged	
4	East	Equal to the Navigation Channel (-43 CRD currently)	Terminal 4 Berth 401	Bulk Carriers (sizes range from 20,000 to 60,000 dwt, Length 540 to 700 feet, Breadth 80 to 105 feet). Used for mooring ocean going vessels. Not a cargo berth		401: 10 vessels per year, average stay 3 days	Last maintenance dredge in 1987. Future dredging to 43 feet is planned to occur at a frequency of about every 7 years.	
4	East	-25	Terminal 4 Berth 408	Vessels approach from channel centerline directly to the dock. Used for barges until February 2010.		None currently		If there is no CDF, then continued use of shallow draft capacity (e.g., barges) is likely. Max depth - 25 ft CRD (This does not consider advanced maintenance, overdredge, and other safety factors).
4	East	Equal to the Navigation Channel (-43 CRD currently)	Terminal 4 Berth 410/411	Bulk Carriers (sizes range from 20,000 to 60,000 dwt, Length 540 to 700 feet, Breadth 80 to 105 feet). Stern first berthing by turning sideways in the adjacent channel. Used for soda ash loading to vessels.		100 vessels per year, average stay 2.5 days	Routinely dredged	
4	East	Equal to the Navigation Channel (-43 CRD currently)	Terminal 4 Berth 414	Pure Car Carriers (average size is 15,500 dwt, Length 660 feet, Breadth 105 feet). Berth on the starbord side, turn completely around in the channel.		100 vessels per year, average stay 1.5 days	Routinely dredged	
4	West	-20	Columbia Sand & Gravel	Sand barge with Multnomah Channel % Columbia River Bar dredged material - with tug assist	Glacier tug and barge	Daily operations - usually barge and tug activities daily		

Table 2.4-1. Vessel Site Use Survey

River Mile	East/West	Max Water Depth Range (ft CRD)	Adjacent Bank/Property	Vessel Activity	Vessel Owner/Type	Vessel Operation Frequency	Maintenance Dredge Activity?	Notes
5	West	-35	BP ARCO Terminal 22T	Fuel barge with tug assist	Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.3 Olympic - all tugs from facility at RM 6.2 Tidewater - all tugs from Vancouver W Others - (Crowley/Sause etc.) infrequent privateer fueling operations	Weekly operations - barges will often remain moored for loading/unloading fuel over 1 to 2 days	Routinely dredged	
4								Dock is visible in aerial photographs but no vessel activity information available.
5	West	-25	Foss Maritime/Brix Maritime	Tug operations	Foss - all tugs from this facility	Daily - tugs move in and out of moorage multiple times daily - also facility uses tug prop wash to 'blast out' sediment to keep adequate water depth with the facility docks		
5	West	-30	Marine Finance	Tug & crane barge operations	Advanced American Construction tugs Foss - all tugs from this facility	Monthly - tugs with crane barges move in and out of moorage monthly		
6	West	Equal to the Navigation Channel (-43 CRD currently)	USACE Moorings	Essayons dredge ship moorage - with tug assist	350-ft Ocean-going USACE dredge Essayons Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.4	Quarterly moorage for ship maintenance	Historically dredged	
6	West	-30	NW Natural Gasco/Koppers	Barge & tug activity fuel/coal tar barges	Olympic facility tugs and fuel barges - located at this facility and Osprey Arrow http://www.vesseltracker.com/en/Ships/Osprey-Arrow-8313697.html	Daily - tugs move in and out of moorage multiple times daily, and for Koppers 4 to 6 times per year		
5	East	-25	P.O.P					Port notes that in the past a dock was located here. This is a marine dependent use area that needs to be preserved.
5	East	-10	Cathedral Park	Pleasure craft, fishing boats, LWG consultants etc. using Cathedral Park Boat Ramp	Privately owned small vessels	Daily	No maintenance dredging	
7	West	Equal to the Navigation Channel (-43 CRD currently)	Arkema	Currently Inactive - Little to No Vessel Activity	Currently Inactive - Little to No Vessel Activity	Currently Inactive - Little to No Vessel Activity		Member has indicated docks are currently inactive but would like to evaluate alternatives that preserve the future use as well as more cost effective alternatives that may limit access to docks.
7	West	-32	Conoco Phillips Upstream Dock	Fuel barge and tug assist/ocean-going fuel barge	Multiple big West Coast ocean-going vessels importing/exporting fuel to and from major ports including SF, SD and Seattle Tidewater tugs moving wood chip/paper barges from Conoco Philips end of bay	Daily - tugs move in and out of moorage multiple times daily	Routinely dredged	

Table 2.4-1. Vessel Site Use Survey

River Mile	East/West	Max Water Depth Range (ft CRD)	Adjacent Bank/Property	Vessel Activity	Vessel Owner/Type	Vessel Operation Frequency	Maintenance Dredge Activity?	Notes
7	West	Equal to the Navigation Channel (-43 CRD currently)	Willbridge fuel Terminal (except for Conoco Dock)	Fuel barge and tug assist/ocean-going fuel barge	Multiple big West Coast ocean-going vessels importing/exporting fuel to and from major ports including SF, SD and Seattle Tidewater tugs moving wood chip/paper barges from Conoco Philips end of bay	Daily - tugs move in and out of moorage multiple times daily	Routinely dredged	
7	East	-30	Triangle Park	Barge storage/moorage	Crowley, Sause Bros, occasionally Marks Marine tugs	Monthly - new and old fuel barges usually unlaiden		
8	East	-25	Swan Island Lagoon					In areas outside of specific Berths assume shallow draft capacity (if CDF/CAD not constructed) -25
8	East	Varies see Figure	Vigor Industrial - Berths 301 to 315 (Previously Cascade General)	Large ocean vessel moorage for maintenance - with tug assist USACE dredge tender barges and equipment storage Pleasure craft and Sternwheeler moorage temporary shallow draft vessel moorage. Freightliner: wind tunnel air vent use. Becker: tugs and barges moorage and repair. Dredge Base: shallow draft Port and US dredge plant and equipment. Marine Salvage: shallow draft salvage vessels. USMC/Navy: US vessels. Coast Guard: shallow draft coast guard vessels. Presence of floating dry docks	Various vessel owners from US Navy to Alaskan ferries to USACE to Sternwheeler Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.4	Daily to monthly operations	Routinely dredged	In areas outside of specific Berths assume shallow draft capacity (if CDF/CAD not constructed) -25
9	East	-10	Swan Island Lagoon Boat Launch	Recreation Boat Launch	recreational small motorized and unmotorized boats.	Daily - except that the dock is currently closed for emergency repairs	No maintenance dredging conducted or planned.	
8	West	-25	Front Ave LP	Gravel barge with tug assist delivering Multnomah Channel dredge material	Glacier tug and barge	Daily		

Table 2.4-1. Vessel Site Use Survey

River Mile	East/West	Max Water Depth Range (ft CRD)	Adjacent Bank/Property	Vessel Activity	Vessel Owner/Type	Vessel Operation Frequency	Maintenance Dredge Activity?	Notes
8	West	-25	Shaver Transportation	Tug operations	Shaver tugs - facility and barge moorage adjacent to Lakeside docks	Daily - tugs move in and out of moorage multiple times daily - also facility uses tug prop wash to 'blast out' sediment to keep adequate water depth with the facility docks	Historically dredged	
8	West	-25	Lakeside	Gravel barge with tug assist	Lakeside & Glacier barge, Tidewater tugs from Vancouver WA, and privateer tugs	daily	Coarse gravel overburden from loading operations throughout	
8	West	Equal to the Navigation Channel (-43 CRD currently)	Equilon Texaco Dock	Fuel barge with tug assist	Olympic facility tugs and fuel barges Other unknown tugs and fuel barges	weekly?	Historically dredged	
9	West	-30	Gunderson LLC	New barge launch area - slipway launch with tug assist Chip barge/paper cargo barge with tug assist New fuel barge moorage with tug assist	Gunderson-made fuel barges Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.3 James River barges storage and load/unload docks Sause Bros - all tugs	Monthly to weekly operations - barges will often remain moored for loading over 1 to 2 days		
9	West	-25	Sause Bros	New fuel barge moorage with tug assist	Sause Bros - all tugs	Weekly	Historically dredged	
9	West	-25	Port of Portland - Terminal 2, Berth 203	Barge Traffic				
9	West	-10	PDX Fireboat	Fireboats and Inflatable Rescue Boat	87-foot fireboat, 41-foot fireboat, 20-foot inflatable rescue boat.	Daily	No regular maintenance dredging	
10	East	Equal to the Navigation Channel (-43 CRD currently)	Ash Grove RM 10	Gravel barge with tug assist	Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.3	Weekly operations - barges will often remain moored for loading over 1 to 2 days	Dredged in 2009	
10	West	Equal to the Navigation Channel (-43 CRD currently)	P.O.P/Sulzer	Ocean vessel route to upstream loading/offloading facilities - with tug assist	Various international ocean vessel owners Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.5	Weekly operations - vessels will often remain moored for loading/unloading grain over 1 to 2 days		

Table 2.4-1. Vessel Site Use Survey

River Mile	East/West	Max Water Depth Range (ft CRD)	Adjacent Bank/Property	Vessel Activity	Vessel Owner/Type	Vessel Operation Frequency	Maintenance Dredge Activity?	Notes
11	East	-21	Ross Island/KF Jacobson	Loading/unloading sand & gravel barges - with tug assist	Ross Island Sand & Gravel tug Glacier NW tug	daily	Coarse gravel overburden from loading operations throughout	
11	East	-36 and -21	Glacier NW	Ocean vessel moorage for unloading dry cement with tug assistance	Various international ocean vessel owners Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.5 Glacier NW	Weekly operations-vessesl will oftern remain moored for several days	Routinely dredged	
11	East	Equal to the Navigation Channel (-43 CRD currently)	CDL Pacific Grain (Cargill)	Ocean vessel moorage for grain unloading/loading with tug assistance	Various international ocean vessel owners Foss - all Foss tugs from Brix facility at RM 5.5 Shaver - all Shaver tugs from Shaver facility at RM 8.5 Glacier NW	Weekly operations-vessesl will oftern remain moored for several days	Routinely dredged	

Table 2.4-2. Site Dredging and Capping Activities

	Dredge Location					
Description	**Fiscal Year Dredged**	**River Mile or Channel Station Positioning**	**Terminal**	**Berth**	**Purpose**	**Quantity (cubic yards)**
FY 97 Corps by Great Lakes #53 Clam	1997	8.5 to 10	--	--	Maintenance	346,000
POP Willamette River Dredging	1997	4.5	4	410, 411	Maintenance	5,454
Goldendale Aluminum (former)	2000[a]	10 to 10.1	--	Goldendale Dock	Maintenance	unknown
Chevron Products Company	2001	7.5 to 7.8	Willbridge	Chevron Dock	Maintenance	15,000
Cargill, Incorporated	2002	11.6	Irving Elevator	Irving Elevator	Maintenance	5,556
POP Willamette River Dredging	2002	10	2	204 - 206	Maintenance	8,330
POP Willamette River Dredging	2002	4.5	4	410, 411	Maintenance	2,250
POP Willamette River Dredging	2003	4.5	4	410, 411	Maintenance	500
POP Willamette River Dredging	2004	4.5	4	410, 411	Maintenance	750
Schnitzer Steel Industries	2004	3.8 to 4	International Terminals	1, 2, 3, 4, 5	Maintenance	138,000
Gasco	2005	6.4	--	--	Remediation	15,005
City of Portland Fire Bureau Station 6 Dock	2005	9.7	--	Fire Boat Dock	Maintenance	4,130
POP Willamette River Dredging	2005	4.5	4	410, 411	Maintenance	4,329
Evraz Oregon Steel Mills	pending	1.9 to 2.5	--	--	Remediation	29,000
Vigor Industrial, Inc.	*NA*	*8.2*	*Portland Shipyard*	*Pier C*	*Maintenance*	*1,100*
CLD Pacific Grain, Inc.	2009	11.6	Irving Elevator	Grain O Dock	Maintenance	1,430
CLD Pacific Grain, Inc.	2009	11.8	Irving Elevator	--	Maintenance	unknown
Glacier Northwest	*2004-2006*[b]	*11.3*	*Portland Cement Terminal*	*Main Dock & Barge Dock*	*Maintenance*	*1,430 and 5,000*
Ash Grove Cement	*NA*	*10*	--	--	*Maintenance*	*22,400*
Ash Grove Cement	*2005*	*2.9*	*Rivergate Lime Plant*	--	*Maintenance*	*2,000*
Gunderson, Inc.	*pending*	*8.9*	--	--	*Maintenance*	*10,000*
BP West Coast Products LLC	2008	4.9	22T	--	Remediation	13,293
POP Willamette River Dredging	2008	10	2	205, 206	Maintenance	12,242
POP Willamette River Dredging	2008	4.5	4	Slip 3, 410, 411	Remediation/ Maintenance	6,315/ 6,223
USACE Post Office Bar	*2011*		*2*	--	*Maintenance*	*52,292*
ConocoPhilips	2011	7.5 to 7.8	Willbridge	ConocoPhilips Dock	Maintenance	NA
Chevron Products Company	2011	7.5 to 7.8	Willbridge	Chevron Dock	Maintenance	~20,000
Kinder Morgan	2011	7.5 to 7.8	Willbridge	Kinder Morgan	Maintenance	26,105

Table 2.4-2. Site Dredging and Capping Activities

Description	Fiscal Year Capped	River Mile or Channel Station Positioning	Terminal	Berth	Purpose	Area (Acres)
McCormick & Baxter Sediment Cap	2004-2005	6.7-7.2	--	--	Remediation	23
Gasco Early Action Tar Body Removal	2005	6.3-6.5	--	--	Remediation	1
POP Terminal 4	2008	4.5	4	Adjacent to 411	Remediation	0.24

Notes:

Italicized projects were obtained from USACE Public Notices.

Information for this table provided by Integral et al. 2011 - See Draft RI August 2011 and input from LWG members

a - Permit authorized dredging of up to 1,500 cubic yards of material annually between September 8, 1999 to August 31, 2004.

b - Dredging has been performed but completion date is unknown. Permit authorization in effect between June 14, 2004 and June 14, 2006.

FY - fiscal year

LWR - Lower Willamette River

NA - not available

POP - Port of Portland

USACE - U.S. Army Corps of Engineers

Table 2.4-3. Potential Habitat Restoration Sites in Portland Harbor as Preliminarily Identified by Portland Harbor Natural Resource Damages Trustees

River Mile	Project Name
2.5 (West)	Joslin Property
3 (West)	Alder Point (Alder Creek Lumber Company)
3.2 (MC)	Miller Creek Confluence*
3.2 (MC/West)	PGE (PGE Harborton)
3.25 (East)	Ash Grove Cement
4 (West)	Owens-Corning Floodplain
4.6 (West)	Linnton Neighborhood
5.75 (East)	Cathedral Park
6 (East)	Steel Hammer (Crawford Street Corp)
6.25 (East)	Willamette Cove
7 (West)	Doane Creek/Railroad Corridor
7.5 (East)	Triangle Property (Triangle Park)
7.5 (West)	Saltzman Creek
9 (SIL)	Swan Island Lagoon
9.85 (West)	Balch Creek Confluence
10.75 (East)	Albina Yards
11.4 (West)	Centennial Mills

*This is entirely in Multnomah Channel; however, the Trustees present it as being in the Site.

Table 2.5-1. Summary of Quantitative Estimates of External Contaminant Source Loads

Source Loading	Contaminant Mass Loading to Study Area (kg/yr)		
	Total PCB	BaP	DDE
Watershed/Upstream	5.1	12	2.9
Stormwater	1.9	0.8	0.08
Groundwater[a]	0.03	0.5	0.001
Process Water Discharges (NPDES)	---	0.05	---

a - It should be noted that the groundwater source term shown on Figure 2.5-2 includes contributions from upland groundwater plume sources described here, but also includes an internal groundwater advection source (i.e., loading to the system resulting from movement of groundwater through contaminated sediments). The contaminant contribution from this source is relatively small and does not affect the relative comparison of source loads discussed in this section.

This section describes RAOs and RGs, which are the numeric values used to evaluate achievement of RAOs, for the draft FS. ARARs defined for the project are also briefly described. The RAOs address attainment of acceptable risk levels for contaminants posing potentially unacceptable risks from sediment, biota, water, and groundwater to human health and ecological receptors. The contaminants potentially posing unacceptable risk and COCs for these pathways are defined from the findings of the risk assessments. This list is evaluated to determine a manageable subset of contaminants, which are representative of the larger list of COCs, to be the focus of most of the draft FS evaluations and analyses. The PRGs available for the COCs are reviewed, and from these, a set of RGs are selected for use throughout the remainder of the draft FS evaluations. The primary RGs used in the draft FS are total PCBs, BaPEq, BaP, DDE (as a representative of DDx), PCDF (as a representative of dioxin/furans), chlordane, and benthic toxicity mean quotient (MQ; explained more below). These sediment RGs were selected because they are consistent with EPA directives and past project agreements on these various risk pathways and are generally representative of the wide range of goals potentially available for the Site. Consistent with EPA guidance (2005a), a range of RGs for several contaminants/scenarios/receptors is also presented based on uncertainty/sensitivity analyses detailed in Appendix E. Several of these RG ranges are defined for total PCBs and BaPEq and used in the remainder of the draft FS to generally represent uncertainty/sensitivity around all the RG estimates.

3.0 REFINED REMEDIAL ACTION OBJECTIVES (RAOS) AND REMEDIAL GOALS (RGS)

Per EPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005a), in selecting the most appropriate remedy for a site, it is important to develop clearly defined RAOs. RAOs are used in developing and comparing alternatives for a site and in providing the basis for developing more specific RGs, which in turn are used by project managers to select final sediment cleanup levels based on the other NCP remedy selection criteria. RAOs, RGs, and cleanup levels are three steps along a continuum leading from RI/FS scoping (RAOs) to the selection of a remedial action by EPA in the ROD (cleanup levels). RAOs provide a general description of what the cleanup is expected to accomplish and help focus alternative development and evaluation. The BHHRA and BERA results serve as the basis for defining RAOs in the draft FS for contaminants in sediment, surface water, biota, and groundwater[1] that pose potentially unacceptable risk via significant exposure pathways.

EPA guidance (EPA 2005a) also states that:

> *"When developing RAOs, project managers should evaluate whether the RAO is achievable by remediation of the site or if it requires additional actions outside the control of the project manager. For example, complete biota recovery may depend on the cleanup of sources that are regulated under other authorities. The project manager may discuss these other actions in the ROD and explain how the site*

[1] Upland groundwater remediation is part of source control for Portland Harbor, which is administered by DEQ working with individual parties. However, the LWG investigated TZW in the surface sediments within the Site and conducted evaluations of whether those contaminants were likely upland groundwater sourced. References to risks in groundwater here and in the RAOs refer to the potential in-river risks in TZW caused by currently known upland groundwater sourced contaminants.

remediation is expected to contribute to meeting area-wide goals outside the scope of the site, such as goals related to watershed concerns, but RAOs should reflect objectives that are achievable from the site cleanup."

RGs are numeric expressions of the RAOs that are expected to meet acceptable risk levels targeted under the RAOs. RGs are developed for those risks, contaminants, and pathways representing potentially unacceptable risk at the Site where a numeric goal can be calculated. As discussed below, in some situations a numeric RG cannot be reliably calculated, and in those cases the intent is to at least qualitatively assess, to the extent practicable, whether the RAO can be met by the alternatives. Also, the RAOs can refer to specific ARARs, which are requirements or standards that, under CERCLA, remedial actions must comply with, unless such standards are waived by EPA.

This section identifies the COCs, RAOs and RGs for the draft FS and describes how they are used to develop and evaluate the remedial alternatives. This process starts with defining the COCs and pathways representing potentially unacceptable risk at the Site and then moves into the RAOs and RGs that are defined to remediate the Site in order to reduce those risks.

3.1 CONTAMINANTS POTENTIALLY POSING UNACCEPTABLE RISK AND RISK ASSESSMENTS

The draft final BHHRA and BERA identified contaminants in sediments, surface water, biota, and groundwater (TZW) and the pathways whereby humans, fish, wildlife, and certain other organisms could be exposed to those contaminants at levels resulting in potentially unacceptable risks.

In accordance with guidance from EPA (1989) and DEQ (2010c), the BHHRA incorporated the four steps of the baseline risk assessment process: data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization (which includes an uncertainty assessment). The BHHRA provided quantitative estimates of risk and the related uncertainties. The BHHRA also identified those exposure scenarios and contaminants that were the primary contributors to overall risks, consistent with EPA guidance (1989).

Risk estimates in the BERA were calculated consistent with CERCLA guidance (EPA 1997a, 1998) and EPA's BERA Problem Formulation. In accordance with EPA's *Ecological Risk Assessment Guidance for Superfund* (ERAGS) (EPA 1997a), the risk conclusions in the BERA identified the receptor-contaminant pairs that potentially result in adverse effects on the assessment endpoints selected to represent the valued ecological attributes of the Site.

Consistent with agreements between EPA Region 10 and the LWG (see EPA comments [2010b] and see Appendix O for resolutions to those comments), contaminants found to pose cancer risks greater than 1 x 10^{-6} or HQs greater than 1 were identified as contaminants potentially posing unacceptable risks in the BHHRA. In the BERA, contaminants with HQs greater than or equal to 1 at the end of the risk characterization were identified as contaminants posing potentially unacceptable risks.[2] Contaminants identified as posing potentially unacceptable risks in the BHHRA and BERA have been carried forward into the draft FS and are summarized in Table 3.1-1.

Risk management recommendations for all the contaminants posing potentially unacceptable risks are presented in detail in Kennedy/Jenks and Windward Environmental (2011). A subset of the contaminants posing potentially unacceptable risks is recommended for purposes of developing and evaluating remedial alternatives in the draft FS. The contaminants that are recommended for this purpose are referred to as Contaminants of Concern[3] (COCs) and are also summarized in Table 3.1-1. The *Portland Harbor RI/FS Risk Management Recommendations* document (Kennedy/Jenks and Windward Environmental 2011) recommends the COCs, exposure pathways, receptors, and comprehensive benthic risk areas that should be used in the draft FS to develop and evaluate remedial alternatives that are protective of human health and ecological resources. Additional contaminants identified in the BHHRA and BERA potentially contribute to unacceptable risks. Sections 4 and 5.9 explain why the identified COCs are sufficient for draft FS purposes to address potentially unacceptable risks from exposure to contaminants in general within the Site.

3.1.1 Human Health Risk Management Recommendations and Identification of COCs

Based on the results of the draft final BHHRA, those exposure pathways and contaminants identified as potentially posing unacceptable risks in the BHHRA were considered in the recommendations of COCs for use in the draft FS. Additional considerations in the recommendations of COCs included:

- The relative percentage of each contaminant’s contribution to the total human health risk consistent with assumptions on exposure areas.
- Frequency of cancer risks greater than 1×10^{-6} or HQs greater than 1, both on a localized basis and Site-wide.
- Potential contributions from background concentrations to the cancer risks and noncancer hazards.
- Magnitude of risk exceedance above EPA’s target range for managing cancer risk of 1×10^{-4} to 1×10^{-6} and noncancer HQs of 1.

The recommended COCs based on the above criteria for the exposure pathways evaluated in the BHHRA are presented in Table 3.1-1.

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[2] The BERA term “posing potentially unacceptable risk” and the BHHRA term “potentially posing unacceptable risk” are used synonymously.

[3] The recommended COCs present the primary risk in various areas of the Site consistent with EPA risk assessment guidance. The focus on recommended COCs is not intended to suggest that other contaminants located with the recommended COCs and at the Site generally do not also present potentially unacceptable risk or would not require remedial action if the COCs were not present.

The BHHRA intentionally incorporated conservative assumptions regarding potential frequency and magnitude of exposure, consistent with EPA guidance. It is not known whether the exposure scenarios evaluated in the BHHRA best represent exposures at the Site.

The BHHRA intentionally incorporated conservative assumptions regarding potential frequency and magnitude of exposure, consistent with EPA guidance. It is not known whether the exposure scenarios evaluated in the BHHRA best represent exposures at the Site. Also, given the diversity of physical configurations, access, and resulting site uses, it is not known how exposures may vary across the Site in ways that would affect protectiveness and effectiveness of remedial alternatives. This is primarily due to the lack of Site-specific fish consumption surveys. For those scenarios that may actually be occurring, the true exposures are not known relative to the conservative exposures assumed in the BHHRA using EPA guidance.

For the fish consumption exposure pathway, PCBs, dioxins/furans, and total DDx are the contaminants recommended as COCs. PCBs and dioxins/furans are the primary contributors to cumulative risk estimates. Risks associated with total DDx are localized to RM 7, where it contributes only approximately 3 percent of the total risks.

A number of assumptions used throughout the BHHRA are conservative in nature, and this is particularly true in the case of fish consumption. The EPA-directed fish ingestion rates, type of fish species, fish tissue consumed, and assumed cooking and preparation methods for estimating potential risks from fish consumption are considered in Section 3.6 to understand the potential sensitivities and uncertainties associated with RGs developed based on these assumptions. The implications of these RG sensitivity/uncertainties relative to determinations of remedial alternative effectiveness are presented discussed in Section 8. PCBs, dioxins/furans, and cPAHs are recommended as COCs for the clam consumption exposure pathway as a surrogate for shellfish consumption. Crayfish consumption is not a recommended pathway because evaluation of fish and clam consumption will address contaminants that may pose risk from crayfish consumption. Uncertainties arising from the BHRRA assumptions about the shellfish species consumed, exposure duration, ingestion rates, spatial scale of exposure areas, and use of undepurated tissue in risk estimates are considered later in the draft FS in evaluating RG sensitivity/uncertainties and determinations of remedial alternative effectiveness.

For the in-water sediment exposure pathway, dioxins/furans and cPAHs are recommended as COCs. Dioxins/furans are the primary contributor to risk for this pathway in RM 7 West. cPAHs are the primary contributor to risk for this pathway in RM 6 West. The localized nature of risk exceedances from direct exposure to in-water sediment are considered later in the draft FS in evaluating remedies that would be protective of this human health pathway.

COCs are not recommended for any of the other exposure pathways evaluated in the BHHRA. No chemicals are recommended as COCs for the beach sediment exposure pathway due to the low magnitude of risks and high degree of uncertainty in the exposure parameters for this exposure scenario. Similarly, no contaminants are recommended as COCs for the surface water pathway given the low magnitude of risks and high degree of uncertainty associated with the direct contact exposure assumptions. No chemicals are recommended as COCs for the groundwater seep pathway because the BHHRA did not identify any contaminants potentially posing unacceptable risk for this pathway.

3.1.2 Ecological Risk Management Recommendations and Identification of COCs

The purpose of the ecological risk management recommendations is to identify COCs, receptors, and benthic areas of concern that the LWG considers necessary and sufficient to develop and evaluate remedial alternatives that are protective of ecological resources.

In summary, the following are recommended as receptor-COC pairs of concern for further consideration in the draft FS:

- For non-benthic receptors, PCBs and dioxins/furans are the recommended COCs for assessing risk. Mink is the recommended receptor of concern, given that the highest risks were found for this receptor as compared to other wildlife receptors. Most of the contaminants posing potentially unacceptable risk were not recommended as COCs for the non-benthic receptors based on risk characterization considerations (magnitude, spatial extent, and ecological significance of HQs greater than or equal to 1). This list includes all the metals, butyltin, phthalate, pesticide, and VOCs.
- For aquatic receptors exposed via TZW, 4,4′-DDT, total DDx, chlorobenzene, benzo(a)anthracene, BaP, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and TCE are the recommended COCs.
- For benthic receptors, recommended benthic areas of concern were identified by applying the comprehensive benthic approach based on EPA’s April 21, 2010 comments for assessing benthic risk in the draft FS (EPA 2010c). The locations where benthic risks need to be addressed (termed comprehensive benthic risk areas) in the draft FS are discussed more in Sections 4.4 and 5.3 and Appendix P. This draft FS uses the comprehensive benthic risk areas in concert with predicted toxicity metrics to evaluate potential remedies and also accounts for sediment quality changes (due to MNR processes) that are expected to take place during and after active remedy implementation.

3.1.3 Identification of Additional Contaminants for Consideration in the Draft FS

In addition to considering all contaminants posing potentially unacceptable risks (as defined for this purpose) and COCs in the draft FS, the EPA directed that the LWG carry forward into the draft FS contaminants in surface water and TZW that exceed potential

ARARs. This larger combined list of contaminants (Table 3.1-2) is considered in the draft FS. Individual surface water and TZW sampling results were compared, without any temporal or spatial averaging, to various drinking water and surface water quality criteria, with the resulting chemicals identified as contaminants exceeding water screening values; these contaminants are also evaluated in the draft FS. The process for and results of the surface water and TZW screening are detailed in Appendix C (Section 2.1 and 2.2).

On October 17, 2011, EPA approved new human health water criteria for Oregon based on a fish consumption rate of 175 grams/day. The criteria are specific for the protection of humans from potential adverse health effects associated with long-term exposure to toxic substances associated with consumption of fish, shellfish, and water (OAR 340-041-0033(4)). These criteria are slightly different than other existing Oregon water quality criteria in that EPA also specifically approved a site-specific background pollutant criteria provision to be used in conjunction with the numeric criteria and a revised process for requesting variances from the criteria, which is in addition to existing narrative provisions under Oregon rules that are applicable to all water quality criteria generally. Because of the timing of this revision, this draft FS has not been able to fully evaluate the impact of the changes. However, it is important to note that these new criteria are based on a consumption rate that has already been fully evaluated in the LWG's draft final BHHRA.

The resulting set of contaminants based on the screening in Appendix C is large and the draft FS cannot practically evaluate all the chemicals for every type of evaluation for every remedial alternative. Therefore, a smaller group of ICs was identified for use as representative surrogates for the overall list of contaminants. These ICs are used for the various technology and remedial alternative evaluations related to expected contaminant mobility and expected future contaminant concentrations from the remedial alternatives. The ICs are summarized in Table 3.1-3. The process by which they were identified is detailed in Appendix C (Section 3).

A small group of ICs was identified for use as representative surrogates for the overall list of contaminants. These ICs are used for the various technology and remedial alternative evaluations related to expected contaminant mobility and expected future contaminant concentrations from the remedial alternatives.

3.2 REVIEW OF RAOS AND ADDITIONAL RAO CONSIDERATIONS

RAOs provide a general description of what the cleanup is expected to accomplish and help focus draft FS alternative development and evaluation. EPA has also indicated that RAOs will be used by others as the basis for the evaluation, design, and implementation of upland source control actions being performed under DEQ oversight (EPA 2009b).

EPA directed the LWG (EPA 2009b) to use the following RAOs in the draft FS (with some purely organizational changes shown here):

Human Health

- **RAO 1 – Sediments:** Reduce to acceptable levels human health risks from exposure to contaminated sediments resulting from incidental ingestion of and dermal contact with sediments,[4] and comply with identified ARARs.
- **RAO 2 – Biota Ingestion**: Reduce to acceptable levels human health risks from indirect exposures to COCs through ingestion of fish and shellfish that occur via bioaccumulation pathways from sediment and/or surface water and comply with identified ARARs.
- **RAO 3 – Surface Water:** Reduce risks from COCs in surface water at the Site to acceptable exposure levels that are protective of human health risks from ingestion of, inhalation of, and dermal contact with surface water; protect the drinking water beneficial use of the Willamette River at the Site; and comply with identified ARARs.
- **RAO 4 – Groundwater:** Reduce to acceptable levels human health risks resulting from direct exposure to contaminated groundwater and indirect exposure to contaminated groundwater through fish and shellfish consumption, and comply with identified ARARs.

Ecological

- **RAO 5 – Sediments:** Reduce to acceptable levels the risks to ecological receptors resulting from the ingestion of and direct contact with contaminated sediments and comply with identified ARARs.
- **RAO 6 – Biota (Prey) Ingestion:** Reduce to acceptable levels risks to ecological receptors from indirect exposures through ingestion of prey to COCs in sediments via bioaccumulation pathways from sediment and/or surface water and comply with identified ARARs.
- **RAO 7 – Surface Water:** Reduce risks from COCs in surface water at the Site to acceptable exposure levels that are protective of ecological receptors based on the ingestion of and direct contact with surface water and comply with identified ARARs.
- **RAO 8 – Groundwater:** Reduce to acceptable levels the risks to ecological receptors resulting from the ingestion of and direct contact with contaminated groundwater and indirect exposures through ingestion of prey via

[4] Sediments are defined by (EPA 2009b) as soils, sand, organic matter, or minerals that accumulate on the river bottom. For purposes of describing the RAOs, sediment also includes the interstitial water and TZW that is influenced by groundwater and surface water and thus can also be contaminated by groundwater, surface water, or chemicals dissolving off of the sediments. Sediments extend up to the mean high water mark (13.3 feet NAVD88) along the banks (including beach sediments) within the Portland Harbor Superfund Site. Riparian soils are found along the riverbanks from the mean high water mark to the OHW mark (20 feet NAVD88). High water mark datum is from Proposed Round 3 Scope of Work, Portland Harbor Superfund Site, February 17, 2006.

bioaccumulation pathways from groundwater, and comply with identified ARARs.

The full text of EPA's 2009 RAOs additional considerations (EPA 2009b) is provided in Appendix B.

3.2.1 RAO Considerations

The draft FS focuses evaluations on those contaminants that were found more likely to pose potentially unacceptable risk through evaluations presented in the risk management document (i.e., recommended COCs).

RAOs are developed to address unacceptable risks to human health and the environment; however, the baseline risk assessments identify potentially unacceptable risks. Risk management recommendations for all the contaminants posing potentially unacceptable risks are presented in detail in Kennedy/Jenks and Windward Environmental (2011). As described in Section 3.1, that document recommends the COCs, exposure pathways, receptors, and benthic areas of concern that should be used in the draft FS to develop and evaluate remedial alternatives that are protective of human health and ecological resources.

EPA directed LWG to "carry forward" into the draft FS all contaminants posing potentially unacceptable risk (EPA 2010b). The draft FS focuses evaluations on those contaminants that were found more likely to pose potentially unacceptable risk through evaluations presented in the risk management document (i.e., recommended COCs) (Kennedy/Jenks and Windward Environmental 2011). However, Section 5.9 evaluates the whole class of contaminants posing potentially unacceptable risks and explains why the identified COCs are sufficient for draft FS purposes to effectively evaluate remedies to address potentially unacceptable risks from exposure to contaminants in general at the Site.

The sediment remedies developed and evaluated in this draft FS can assist with, but not solve, surface water quality issues. Similarly, sediment remedies will not have any direct impact on known upland sources, which remain the primary mechanism for reducing risks from groundwater plumes to in-water receptors.

The sediment remedies developed and evaluated in this draft FS can assist with, but not solve, surface water quality issues. Similarly, sediment remedies will not have any direct impact on known upland sources, which remain the primary mechanism for reducing risks from groundwater plumes to in-water receptors. Therefore, groundwater RAOs will only apply to groundwater plumes downgradient of the upland source control measure as identified and measured through in-river TZW evaluations for the RI/FS.

Control of ongoing known sources of contamination to the Site is an implicit requirement for achieving RAOs for the Site and is a basic assumption for the draft FS. Active sediment remediation in the absence of adequate source control could lead to sediment recontamination and continuing impairment of surface water quality. The known or potential ongoing sources to the Site are described in Section 2.5 and include upstream watershed and stormwater inputs (among others). Understanding how each of these potential sources and pathways may impact localized areas of each sediment remediation alternative is a complex undertaking and beyond the scope of this draft FS. Therefore, the draft FS does not attempt to determine acceptable levels of upland sources or source controls or targets for specific source control efforts. However, the draft FS evaluates in later sections the extent to which ongoing sources, at a Site-wide scale, are expected to contribute to sediment recontamination or not.

Additional considerations for each Site RAO are discussed below.

RAO 1 – Human Health Sediments Exposure:
Reduce to acceptable levels human health risks from exposure to contaminated sediments resulting from incidental ingestion of and dermal contact with sediments, and comply with identified ARARs.

This RAO applies to direct human health sediment exposure scenarios found to have an unacceptable risk. The goal for this RAO is to reduce risks to human health from contaminant concentrations in contaminated sediments through sediment remedies at the Site, comply with chemical-specific ARARs identified for the Site, and protect beneficial uses of the Willamette River at the Site. No chemical-specific sediment ARARs have been identified for the Site (see Section 3.4).

Reasonable Maximum Exposure (RME) cancer risks from direct contact with and incidental ingestion of in-water sediment exceed 1×10^{-4} for Tribal fishers. Per the BHHRA, this finding applies to shoreline sediments outside of the navigation channel, which represents the likely exposure area for this scenario. Dioxins/furans and cPAHs are the primary contributors to risk under this exposure scenario and are recommended COCs. Noncancer HQs are greater than 1 for the Tribal fisher due to dioxins/furans and for breastfeeding infants of Tribal fishers, non-Tribal fishers, in-water workers, and wet-suited divers due to PCBs and dioxins/furans. Sediment RGs developed for dioxins/furans (in RM 7 West) and cPAHs (in RM 6 West) are used in the draft FS to develop and evaluate remedial alternatives. RGs based on breastfeeding infants were not developed in accordance with agreements with EPA (verbal agreement in October 15, 2010 EPA-LWG meeting).

RAO 2 – Human Health Fish and Shellfish Consumption:
Reduce to acceptable levels human health risks from indirect exposures to COCs through ingestion of fish and shellfish that occur via bioaccumulation pathways from sediment and/or surface water and comply with identified ARARs.

This RAO applies to fish and shellfish consumption scenarios found to have an unacceptable risk. The goal is to reduce risks to human health through sediment remedies that protect humans from indirect exposures to contaminants through eating fish and shellfish exposed to contaminants via bioaccumulation and bioconcentration, comply

Reduction and elimination of the Portland Harbor fish advisory can only be achieved when conducted in conjunction with other Portland Harbor source controls and PCB reduction efforts conducted under other regulations and programs within the Willamette River watershed.

with chemical-specific ARARs identified for the Site (as discussed more below), and protect the beneficial uses of the Willamette River at the Site. This RAO is expected to contribute to the reduction, and possibly, elimination of Portland Harbor PCB fish consumption advisories. It is recognized that reduction and elimination of the Portland Harbor fish advisory can only be achieved when conducted in conjunction with other Portland Harbor source controls and PCB reduction efforts conducted under other regulations and programs within the Willamette River watershed, as described below for Management Goal 1 (source control). Upstream background concentrations of PCBs in surface water and suspended sediment entering the Site are likely to cause fish consumption risks exceeding 1×10^{-6} according to Site-specific bioaccumulation modeling (Windward 2009).

PCBs contribute the majority of the total potential cancer risk for the fish tissue consumption pathway (both whole body and fillet tissue) on a Site-wide exposure area basis, and are the primary contributor to risk under this exposure scenario. Dioxins and furans are the secondary contributor to risk that occurs on a Site-wide basis. Total DDx had a greater contribution to the cumulative risk on a localized basis only for RM 7. For the fish tissue consumption exposure pathway, PCBs, dioxin/furans, and total DDx are recommended COCs.

For the shellfish consumption exposure pathway, PCBs, dioxin/furans, and cPAHs are recommended COCs. However, the extent to which shellfish consumption occurs or will reasonably occur in the future within the Site is unknown. Significant uncertainties related to risk estimates for shellfish consumption include assumptions about the shellfish species consumed, exposure duration, ingestion rates, spatial scale of exposure areas, and use of undepurated tissue in risk estimates. Overall, there is insufficient evidence of risk from the consumption pathway associated with illegally harvested invasive clams to contribute to determination of SMAs (as discussed more in Section 4.5). Nonetheless, the draft FS does evaluate the extent to which each alternative attains contaminant concentrations in sediments that can be compared to clam consumption related sediment PRGs,[5] which are provided below and in Appendix Da (Section 2.2).

EPA has identified Oregon Water Quality Standards (WQS) for fish consumption and National Recommended Water Quality Criteria (NRWQC) for human health consumption of aquatic organisms as potential chemical-specific ARARs for surface water at the Site.[6] Per the RI, the upstream background surface water 95th percentile UPL concentrations of arsenic, total PCBs, total PAHs, dieldrin, 4’4-DDT, sum DDT, and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) entering the Site exceeded the respective

[5] Section 3.5 further explains the distinction between the terms RG and PRG.
[6] A state WQS will generally be identified as an ARAR unless the comparable NRWQC is more stringent than the WQS and the WQS adopted by the state is not based on waterbody-specific reasons.

fish consumption values for these contaminants.[7] Because of these upstream loads, Portland Harbor sediment remedies by themselves will not result in the achievement of surface water concentrations at the Site below these potential surface water ARARs. Other contaminant reduction efforts conducted under other regulations and programs within the Willamette River watershed would be necessary to achieve these surface water criteria.

RAO 3 – Human Health Surface Water Exposure:
Reduce risks from COCs in surface water at the Site to acceptable exposure levels that are protective of human health risks from ingestion of, inhalation of, and dermal contact with surface water; protect the drinking water beneficial use of the Willamette River at the Site; and comply with identified ARARs.

Remedial alternatives do not need to be evaluated relative to RAO 3, because the RAO is already being achieved.

This RAO applies to direct human health surface water exposure scenarios found to have a potentially unacceptable risk and the protection of the drinking water beneficial use of the Willamette River. The goal is to reduce risks from contaminant concentrations in surface water, to the extent practicable, through sediment remedies that protect humans from the ingestion of and dermal contact with surface water, comply with chemical-specific ARARs identified for the Site, and protect the beneficial uses (domestic/private water supply) of the Willamette River at the Site. Although the BHHRA identified potential localized cancer risks exceeding 1×10^{-4}, based on the weight of evidence, potentially unacceptable risk from existing and likely future surface water exposures at the Site were not identified in the LWG's risk management recommendations. Similarly, as noted below, none of the surface water samples exceed drinking water standards. Therefore, remedial alternatives do not need to be evaluated relative to this RAO, because the RAO is already being achieved. Nonetheless, the LWG has agreed to evaluate remedial alternatives relative to some specific water criteria that EPA has directed as noted below.

For direct exposures to surface water, only cPAHs resulted in a cancer risk estimate exceeding 1×10^{-4}. cPAHs in surface water are not recommended as COCs in the draft FS based on the limited spatial scale of the cancer risk exceedance and the high degree of uncertainty in the exposure assumptions.

EPA has identified maximum contaminant levels (MCLs) as potential chemical-specific ARARs for surface water at the Site.[8] EPA has also specified that depth-integrated water

[7] As explained in Section 3.1.3, the draft FS generally has not been updated to incorporate the Oregon Human Health Water Quality Criteria for Toxic Pollutants that became effective October 17, 2011. The Oregon WQS for fish consumption used in this evaluation were the Oregon Water Quality Criteria for Human Health, Effective June 1, 2010. Comparison of potential ARAR values (including the pre- and post-October 2011 Oregon Human Health Water Quality Criteria for fish consumption) to Site surface water 95th percentile UPL background concentration values is provided in Table 5.5-3.

[8] The LWG disagrees that MCLs are ARARs against which the surface water itself should be measured, because, under OAR 340-041-0340 Table 340A, the beneficial use designation of the Willamette for domestic water supply

column samples should be used when evaluating compliance of surface water with drinking water ARARs (EPA 2010b). None of the contaminant concentrations in depth-integrated water column samples from the Study Area exceed MCLs. Additionally, domestic water supply has not been identified as a current or reasonably likely future use of surface water in the Lower Willamette River within Portland Harbor.

RAO 4 – Human Health Groundwater Exposure:
Reduce to acceptable levels human health risks resulting from direct exposure to contaminated groundwater and indirect exposure to contaminated groundwater through fish and shellfish consumption, and comply with identified ARARs.

This RAO applies to human health risks via exposure to contaminated groundwater plumes. These risks include indirect exposure to contaminants in groundwater plumes discharging to the Willamette River and found to have an unacceptable risk in the risk assessment based on fish and shellfish consumption. Groundwater plumes will be controlled to achieve ARARs and risk-based remediation goals through upland source control actions. The goal for this RAO is to reduce potentially unacceptable risks to human health from contaminant concentrations in contaminated groundwater through sediment remedies at the Site to the extent feasible, comply with chemical-specific ARARs identified for the Site, and protect beneficial uses of groundwater and the Willamette River at the Site. However, it is understood that sediment remedies cannot have any direct impact on upland sources, which remain the primary mechanism for reducing potentially unacceptable risks from groundwater plumes to in-water receptors. Therefore, this RAO only applies to groundwater plumes downgradient of the upland source control measure.

Indirect exposure to contaminants in groundwater plumes discharging to the Willamette River was not explicitly evaluated in the BHHRA. As described above under RAO 2, the recommended COCs for the fish tissue and shellfish consumption human exposure pathways are PCBs, dioxin/furans, cPAHs, and total DDx. However, as discussed in the draft final RI, it is difficult to differentiate between impacts to TZW from groundwater plume discharges and those associated with sediment partitioning processes, so no conclusions have been made regarding indirect exposures to fish and shellfish consumers from contaminants in groundwater plumes.

Risks from direct exposures to groundwater seeps were evaluated in the BHHRA for exposure by a transient; the transient exposure scenario did not result in cumulative cancer risks greater than 1×10^{-6} or HIs greater than 1.

EPA has identified Oregon WQS for fish consumption and NRWQC for human health consumption of aquatic organisms as potential chemical-specific ARARs for TZW at the

assumes adequate pre-treatment will be applied. Therefore, the LWG believes that direct application of MCLs to individual, untreated surface water samples at the Site is inappropriate. This analysis was, nonetheless, carried through as directed by EPA.

Site. EPA has also identified MCLs as potential chemical-specific ARARs for groundwater (including TZW) at the Site. The LWG disagrees that these ARARs are applicable to TZW but was directed to evaluate remedial alternatives relative to these criteria.

RAO 5 – Ecological Sediment Exposure:
Reduce to acceptable levels the risks to ecological receptors resulting from the ingestion of and direct contact with contaminated sediments and comply with identified ARARs.

This RAO applies to all ecological receptors found to have an unacceptable risk via direct sediment exposure. The goal is to reduce potentially unacceptable risks to ecological receptors from contaminant concentrations in contaminated sediments through sediment remedies at the Site, prevent unacceptable effects on the survival, growth, and reproduction of ecological receptors at the Site, and comply with chemical-specific ARARs identified for the Site. No chemical-specific sediment ARARs have been identified for the Site.

No unacceptable risks to fish, wildlife, amphibians, or aquatic plants resulting from the ingestion of and direct contact with contaminated sediments were identified in the BERA. The BERA found potentially unacceptable risks to the benthic community in some areas, which were identified as comprehensive benthic risk areas. Recommended sediment COCs for the benthic community include PAHs, PCBs, and total DDx.

RAO 6 – Ecological Prey Ingestion:
Reduce to acceptable levels risks to ecological receptors from indirect exposures through ingestion of prey to COCs in sediments via bioaccumulation pathways from sediment and/or surface water and comply with identified ARARs.

This RAO applies to all ecological receptors found to have an unacceptable risk in the risk assessment through ingestion of prey. The goal is to reduce risks from contaminants through sediment remedies that protect ecological receptors from exposures to contaminants through consumption of fish and shellfish, benthic organisms, and other prey items exposed to contaminants via bioaccumulation and bioconcentration, comply with chemical-specific ARARs identified for the Site, and protect the beneficial uses of the Willamette River at the Site. This RAO is expected to contribute to reduction of prey ingestion related ecological risks through reduction in sediment chemical contributions to fish tissue. It is recognized that reduction of and elimination of these risks can only be achieved when conducted in conjunction with other Portland Harbor source control efforts conducted under other regulations and programs within the Willamette River watershed, as described below for Management Goal 1 (source control).

The risk management recommendations in the BERA identified PCBs and total TEQ as COCs likely posing unacceptable risk to birds and mammals via indirect exposure through ingestion of prey.

EPA has identified Oregon freshwater chronic aquatic life WQS and NRWQC freshwater chronic aquatic life values as potential chemical-specific ARARs for surface water at the Site. The 95th percentile UPL upstream background surface water concentrations of mercury entering the Site as measured by the LWG exceed the Oregon chronic criterion for this contaminant, but not the EPA NRWQC.[9] Thus, Portland Harbor sediment remedies by themselves will not be able to result in the achievement of surface water concentrations at the Site below this potential Oregon surface water ARARs. Other contaminant reduction efforts conducted under other regulations and programs within the Willamette River watershed would be necessary to achieve these surface water criteria. Remedial alternatives are, however, evaluated against these criteria.

RAO 7 – Ecological Surface Water Exposure:
Reduce risks from COCs in surface water at the site to acceptable exposure levels that are protective of ecological receptors based on the ingestion of and direct contact with surface water and comply with identified ARARs.

This RAO applies to all ecological receptors found to have an unacceptable risk through exposure to surface water. The goal is to reduce potentially unacceptable risk from contaminant concentrations in surface water to the extent practicable as discussed above, through sediment remedies that prevent unacceptable effects on survival, growth, and reproduction of ecological receptors; comply with identified chemical-specific ARARs; and protect the beneficial uses of the Willamette River.

Remedial alternatives do not need to be evaluated relative to RAO 7, because the RAO is already being achieved.

No unacceptable risks to fish, wildlife, amphibians, or aquatic plants resulting from the ingestion of and direct contact with surface water were identified in the BERA. Surface water was used as a supporting LOE in the comprehensive benthic evaluation; however, no surface water COCs for the benthic invertebrates were identified in the BERA risk management recommendations. Therefore, remedial alternatives do not need to be evaluated relative to this RAO, because the RAO is already being achieved. Nonetheless, as noted below, the LWG has agreed to evaluate remedial alternatives relative to some specific water criteria that EPA has directed.

EPA has identified Oregon freshwater chronic aquatic life WQS and NRWQC freshwater chronic aquatic life values as potential chemical-specific ARARs for surface water at the Site. Upstream background surface water concentrations of mercury measured in the

[9] Upstream background surface water as measured by the LWG also exceeded an EPA non-priority criteria for aluminum that is based on toxicity testing in waters with ph <6.6 and hardness <10 milligrams per liter (mg/L). When Oregon adopted this criterion in its Table 33B aquatic life criteria, it adopted the criterion only under those specific circumstances—where pH is < 6.6 and hardness <10 mg/L, conditions which do not apply to the Site. See OAR 340-041-033 Table 33C note w. Also, with respect to mercury, chronic criteria are the average concentrations for 96 hours (4 days) that should not be exceeded more than once every 3 years. See OAR 340-041-0033. The LWG sampling and the analysis that has been provided are not specific to this temporal aspect of the criteria.

LWG samples entering the Site exceed the respective Oregon chronic criteria for this contaminant, but not the EPA NRWQC.[10] Thus, Portland Harbor sediment remedies by themselves will not be able to result in the achievement of surface water concentrations at the Site below this potential Oregon surface water ARAR. Other contaminant reduction efforts conducted under other regulations and programs within the Willamette River watershed would be necessary to achieve this surface water criteria. Remedial alternatives are, however, evaluated against these criteria as directed by EPA.

RAO 8 – Ecological Groundwater Exposure:
Reduce to acceptable levels the risks to ecological receptors resulting from the ingestion of and direct contact with contaminated groundwater and indirect exposures through ingestion of prey via bioaccumulation pathways from groundwater, and comply with identified ARARs.

This RAO applies to all ecological receptors found to have an unacceptable risk via exposure to contaminated groundwater plumes discharging to the Willamette River and through ingestion of prey with the understanding that groundwater plumes will be controlled to achieve ARARs and risk-based remediation goals through upland source control actions. The goal is to reduce potentially unacceptable risks to ecological receptors from contaminant concentrations in contaminated groundwater through sediment remedies at the Site to the extent feasible; prevent unacceptable effects on the survival, growth, and reproduction of ecological receptors at the Site; and comply with chemical-specific ARARs identified for the Site. However, it is understood that sediment remedies cannot have any direct impact on upland known sources, which remain the primary mechanism for reducing risks from groundwater plumes to in-water receptors. Therefore, this RAO would only apply to groundwater plumes downgradient of the upland source control measure.

For aquatic receptors exposed via TZW, 4,4′-DDT, total DDx, chlorobenzene, benzo(a)anthracene, BaP, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and TCE are the recommended TZW COCs at particular AOPCs within the Site. There is considerable uncertainty as to whether some of the contaminants in TZW are truly associated with upland groundwater plumes; in particular, 4,4′-DDT, total DDx and some of the PAHs in some areas, are likely to be associated with sediment particulates rather than migrating groundwater plumes.

EPA has identified Oregon freshwater chronic aquatic life WQS and NRWQC freshwater chronic aquatic life values as potential chemical-specific ARARs for TZW at the Site. The LWG disagrees that these ARARs are applicable to TZW. However, remedial alternatives are evaluated against these criteria as EPA directed.

[10] See note 9 above.

3.2.2 Attainment of RAOs

In many cases unacceptable risks are also posed solely due to upstream concentrations entering the Site or by levels below likely background levels. Consequently, it is highly uncertain whether many of the numeric levels that could be derived relevant to the RAOs would be achievable.

As noted above, expected attainment of RAOs by remedial alternatives is typically gauged through comparison of expected future concentrations for each alternative to numeric values such as sediment RGs. Each numeric value used is assumed to represent attainment of "acceptable" risk levels as described in the RAOs above. However, for this draft FS, as recognized through the additional considerations discussion, in many cases unacceptable risks are also posed solely due to upstream concentrations entering the Site or by levels below likely background levels. Consequently, it is highly uncertain whether many of the numeric levels that could be derived relevant to the RAOs would be achievable. As noted previously, EPA (2005a) guidance indicates:

> *"The project manager may discuss these other actions in the ROD and explain how the site remediation is expected to contribute to meeting area-wide goals outside the scope of the site, such as goals related to watershed concerns, but RAOs should reflect objectives that are achievable from the site cleanup."*

EPA guidance on background levels (EPA 2002a) also indicates:

> *"Generally, under CERCLA, cleanup levels are not set at concentrations below natural background levels. Similarly, for anthropogenic contaminant concentrations, the CERCLA program normally does not set cleanup levels below anthropogenic background concentrations."*

Further, in most cases there is a considerable sensitivity associated with risk assumptions supporting RG development and/or uncertainty associated with RG development as discussed more in Section 3.6. With regards to this issue EPA (2005a) guidance indicates:

> *"RGs should be represented as a range of values within acceptable risk levels so that the project manager may consider the other NCP criteria when selecting the final cleanup levels…The development of the human health-based RGs should provide a range of risk levels (e.g., 10^{-6}, 10^{-5}, and 10^{-4} and a noncancer Hazard Index of 1 or less depending on the health end points of the specific contaminants of concern). The development of the ecologically based RGs should also provide a range of risk levels based on the receptors of concern identified in the ecological risk assessment (see Section 2.3)"*

In general consistency with this concept, this draft FS identifies a range of numeric sediment values that may eventually be judged by EPA to meet the RAOs within the acceptable risk ranges noted in the guidance as well as other factors that contribute to a range of potentially calculable values for any point within that acceptable risk range.

Consequently, attainment of acceptable risk levels for each RAO cannot be simply defined as a single numeric value for each contaminant, and acceptable risk levels may be below upstream or background conditions. Instead the remedial alternative evaluations in Section 8 compare predicted future contaminant levels for each alternative against a range of potentially acceptable values and background levels that EPA will later select from in the Proposed Plan and ROD. This means that some evaluations of the alternatives, such as the time to achieve RAOs, must be discussed in terms of a range of potential outcomes, at least for draft FS purposes.

For evaluations of predicted future surface water concentrations, these are compared against potential chemical numeric surface water ARARs. However, the same issue of potential exceedance of those ARARs in upstream surface waters or at background levels exists. For that reason, comparisons are made to the chemical-specific numeric potential ARAR in question for each contaminant in three respects: 1) assessing whether the potential surface water ARAR is expected to be achieved in the water column at the Site post-remedy; 2) for those contaminants where the potential surface water ARAR is not expected to be achieved, assessing whether that exceedance is impacted by current Site conditions or attributable to upstream background; and 3) as compared across alternatives, assessing whether any alternative is projected to contribute more than another to reduction in surface water concentrations post-remedy. Thus, the relative ability of each alternative to approach these upstream or background levels is factored into that alternative's evaluation, given that, because of upstream surface water concentrations above certain of the potential ARAR, no sediment alternative is anticipated to result in the water column at the Site achieving those chemical-specific potential ARAR surface water quality criteria values.

Also, because potentially unacceptable risks from consumption of biota tissue will remain due to background levels in surface water, numeric levels in biota tissue are not proposed for directly assessing attainment of RAOs and performance of any remedial alternatives (see Appendix T, Section 3 for discussion of long-term performance monitoring using sediment-based criteria). Tissue levels that are derived from sediment RGs are used in Sections 8 and 9 as a general measure of alternative effectiveness. However, because of the uncertainties in correlating fish home range to specific areas of elevated sediment concentrations and given that fish exposure is complete through other pathways (e.g., incoming upstream surface water), these tissue levels are not proposed as the final determinants of RAO attainment. Rather, the sediment RGs that these tissue levels are related to should instead be used more directly for evaluation of long-term attainment of RAOs relating to bioaccumulation in biota.

3.3 REVIEW OF ADDITIONAL MANAGEMENT GOALS AND ADDITIONAL CONSIDERATIONS

Site-wide management goals are goals that are evaluated in the draft FS to ensure a successful remedy and will require integration with other regulatory mechanisms to implement. These regulatory mechanisms include, but are not limited to, State of Oregon Water Quality and Environmental Cleanup programs. Per EPA direction (EPA 2009b), specific numeric RGs are not developed for these management goals in the draft FS. Management goals are not RAOs and the effectiveness of remedial alternatives will not be directly determined by comparison to management goals. EPA directed the LWG (EPA 2009b) to discuss the following Portland Harbor Site-wide management goals in the draft FS:

Management Goal 1:
Ensure sediment cleanup activities consider, complement, and are compatible with, upland and upstream source control efforts designed to prevent recontamination by COCs in groundwater, stormwater, soil erosion, upstream sources, and overwater activities at the Site and are consistent with the RAOs for the Site; and allow in-water remedies at the Site to proceed in a timely manner.

This management goal recognizes that a successful Site remedy includes the implementation of effective in-water remedies and upland source control measures. The goal is to have a sediment cleanup that is compatible with upland and upstream source controls that prevent sediment recontamination after cleanup. The goal must also consider sequencing and other approaches in conducting sediment remedies that will minimize downstream migration of contaminants and prevent recontamination of downstream response actions. Recontamination potential from sediment remedies/sequencing is assessed via an assumed example sequence of construction for each alternative and including a construction period in each alternative.

Further, sediment remediation activities should not hinder upland source control actions and water quality programs being implemented by DEQ. Upland and upstream source identification and control is being regulated and directed by DEQ working with individual parties within and outside Portland Harbor. The goal of these source controls is to reduce potentially unacceptable risk and prevent the unacceptable recontamination of remediated sediments. Upland source control activities need to be implemented in a timeframe and manner that reduces potentially unacceptable risk and minimizes the potential for recontamination by contaminants through groundwater, stormwater, soil erosion, and overwater activities at and upstream from the Site and are that consistent with and facilitate the achievement of Site cleanup goals and compliance with ARARs. The draft FS includes an evaluation of the potential for in-river risks and recontamination from ongoing upland and upstream sources as allowed by existing data and information. Recontamination potential from ongoing sources is assessed via the fate and transport model for each alternative, where quantifiable (i.e., based on available watershed/upstream, groundwater, stormwater, and process water discharges [NPDES] data) and at the spatial scale quantifiable for a large-scale draft FS.

The draft FS also estimates, as existing information allows, the source reduction levels on a Site-wide basis that would be expected to meet ranges of sediment and water RGs including the uncertainty of such estimates, as noted above. As directed by EPA, the draft FS does not attempt to estimate the source reduction actually provided by various individual potential, planned, or implemented source controls at properties along the river or the watershed as a whole. Estimates of Site-wide source reduction levels needed to minimize recontamination are assessed through evaluation of sensitivities of source assumptions for the detailed alternatives.

With regards to riparian soils, there may be cost savings by integrating sediment remedies along the shoreline with upland source control efforts. Upland source control efforts will address riparian soils that are likely to have a direct effect through the erosion of bank material upon sediments and surface water below the mean high water mark. Factors that are considered in Section 2.5 to estimate whether riparian soils are likely to have a direct effect on sediments include the characteristics of the riverbank, the presence of contamination, and the status of upland source control efforts. The potential impacts from riparian soils on sediments is assessed in Section 2.5 qualitatively using general information on the status of ongoing riverbank investigations and source controls due to the limited availability of riverbank data.

Management Goal 2:
To the maximum extent practicable, minimize the long-term transport of COCs in the Willamette River from the Site to the Columbia River and the Multnomah Channel.

The goal is to prevent the migration of sediment contaminants at levels that would potentially pose unacceptable risks to human health and ecological receptors downstream of the Site. Sediment cleanup alternatives are evaluated in the draft FS under the long-term effectiveness criterion to estimate, as existing information allows, whether downstream transport would be minimized (or not) by each alternative. Minimization of downstream contaminant transport is a sub-criterion presented in the draft FS under the more general long-term effectiveness criterion. Long-term transport of contaminants downstream from the Site is evaluated in Section 8 for each alternative using the fate and transport model.

Management Goal 3:
Clean up contaminated sediments in a manner that promotes habitat that will support a healthy aquatic ecosystem and the conservation and recovery of threatened and endangered species.

The goal is to ensure that sediment cleanup alternatives selected for the Site consider the benefits of re-establishing ecological habitats in those areas remediated to support a diverse ecosystem. Sediment remedial actions must comply with ARARs, including the CWA compensatory mitigation and Section 404(b)(1) analysis and the ESA. The draft

FS includes a draft 404(b)(1) analysis to address CWA issues. ESA issues are addressed in the Preliminary Draft BA (Anchor QEA 2012) submitted under separate cover.

Other potential ARARs may include the Marine Mammal Protection Act and/or Migratory Bird Treaty Act. The need for habitat mitigation in conjunction with the remedial action alternatives is evaluated in the draft FS for each detailed sediment cleanup alternative under the long-term effectiveness, ARARs, and cost criteria. This is accomplished by estimating the current habitat value of each remediation area and the impacts on those habitat values by each remedial technology applied in each alternative using both Relative Habitat Values (RHVs) provided by National Marine Fisheries Service (NMFS) and Functional Habitat Values developed by LWG. For each detailed alternative, the draft FS evaluates reasonably anticipated future land use with respect to habitat, including potential restoration activities under the Natural Resource Damage Assessment (NRDA) process as identified in Section 2. The draft FS also describes the degree to which habitat mitigation needs to be included to meet substantive requirements of potential ARARs. For each detailed alternative, Section 7 describes whether habitat mitigation needs to be included to meet the substantive requirements of potential ARARs and the estimated costs of that mitigation. This aspect of the draft FS does not include evaluation of any potential habitat restoration activities under the NRDA provisions of CERCLA, the CWA, and the Oil Pollution Act (OPA).

3.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

This section discusses potential ARARs for the Site. The ARARs discussed in this section may require attainment or consideration during implementation of the various remedial alternatives developed in this draft FS. Final ARARs determinations will be made by EPA during the preparation of the ROD.

Section 121(d) of CERCLA requires remedial actions to generally comply with all applicable or relevant and appropriate federal environmental or promulgated state environmental or facility siting laws, unless such standards are waived. "For the purposes of identification and notification of promulgated state standards, the term promulgated means that the standards are of general applicability and are legally enforceable" (NCP, 40 Code of Federal Regulations [CFR] 300.400[g][4]). If it is found that the most suitable remedial alternative does not meet an ARAR, the NCP provides for waivers of ARARs under certain circumstances. Pursuant to 40 CFR 300.430(f)(1)(ii)(C), EPA may determine that ARAR waivers are needed for the selected Site remedy.

"Applicable requirements" as defined in 40 CFR 300.5 are,

> *"those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a*

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

"Relevant and appropriate requirements," also defined in 40 CFR 300.5 are,

"those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws, that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate."

In addition to ARARs, advisories, criteria, or guidance may be identified as To Be Considered (TBC) for a particular release. As defined in 40 CFR 300AOO(g)(3), the TBC category "consists of advisories, criteria, or guidance developed by the U.S. Environmental Protection Agency, other federal agencies, or states that may be useful in developing CERCLA remedies." TBCs are non-promulgated advisories or guidance that are not legally binding and do not have the status of potential ARARs.

Under CERCLA 121 (e), federal, state, or local permits need not be obtained for remedial actions which are conducted entirely on-site. "On-site" is defined as the "areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (40 CFR 300.5). Although a permit would not have to be obtained, the substantive (non-administrative) requirements of the permit must be met. Remedial activities performed off-site would require applicable permits.

3.4.1 Portland Harbor ARARs

Table 3.4-1 summarizes the ARARs identified by EPA for use in the draft FS for the Portland Harbor Site (EPA 2010a).

In general, there are three categories of ARARs:

- Chemical-specific requirements
- Location-specific requirements
- Performance, design, or other action-specific requirements

These categories are discussed below, and specific ARARs that will be important to later draft FS evaluations are discussed.

Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. If a contaminant has more than one such requirement that is an ARAR, alternatives should generally comply with the most stringent.

The RAOs identify sediment, surface water, and groundwater as media of concern at the Site. Although there are no promulgated federal or Oregon ARARs providing numerical standards for contaminants in sediment, both federal and Oregon standards and criteria are available for surface water and groundwater.

In addition to Oregon WQS (OAR 340-041-0340), EPA has identified federal NRWQC developed to protect ecological receptors and human consumers of fish and shellfish as potential relevant and appropriate requirements. With respect to application of NRWQC, EPA directed the LWG to compare the NRWQC to the Oregon WQS. If there is no Oregon WQS and there is a NRWQC, comparisons should be made to the NRWQC. If the Oregon WQS have not been updated to reflect the most recent NRWQC, then comparisons should be made to the NRWQC. However, if the Oregon WQS is adopted after the most recent NRWQC, but is less stringent due to waterbody-specific reasons, EPA may determine that the NRWQC is not relevant and appropriate as long as the remedy will be protective using the Oregon promulgated standard (EPA 2010f). Specific Oregon WQS and federal NRWQC and other chemical-specific ARAR numeric values are provided in Appendix C.

Oregon Hazardous Substance Remedial Action Rules [OAR 340-122-0040(2)(a) and (c), 0115 (3),(32) and (51)] set standards for the degree of cleanup required and establish acceptable risk levels for humans and protection of ecological receptors at the individual level for threatened or endangered species and the population level for all others. OAR 340-122-0040 requires that hazardous substance remedial actions achieve one of three standards: 1) acceptable residual risk levels as defined in OAR 340-122-0115 and as demonstrated by a residual risk assessment, 2) generic soil numeric cleanup levels, or 3) background levels in areas where hazardous substances occur naturally. Oregon Hazardous Substance Remedial Action Rules (OAR 340-122-0115) define the following acceptable risk levels:[11]

- 1 in 1,000,000 (1×10^{-6}) lifetime excess cancer risk for individual carcinogens (e.g., BaP)
- 1 in 100,000 (1×10^{-5}) cumulative lifetime excess cancer risk for multiple carcinogens (e.g., total PCBs)
- A HI[12] of 1.0 for noncarcinogens
- For populations of ecological receptors, a 10 percent or less chance that more than 20 percent of the total local population will be exposed to an exposure point value

[11] OAR 340-122-0115 also provides separate "acceptable risk levels" for probabilistic risk assessments for human health and for individual ecological receptors listed as threatened or endangered, which are not addressed in these bullets.
[12] A Hazard Index (HI) represents the sum of individual contaminant HQs.

greater than the ecological benchmark value for each COC and no other observed significant adverse effects on the health or viability of the local population

- For individuals of species listed as threatened or endangered, a toxicity index less than or equal to 1.

EPA's target range for managing cancer risk is 1 x 10^{-4} to 1 x 10^{-6}, and the level for noncancer risk is an HQ of 1. While the target risk levels in the Oregon Rules for noncarcinogens and for the protection of ecological receptors are similar to those of the NCP, the Oregon Rules for individual and multiple carcinogens are somewhat different than those under the NCP, which are nevertheless protective.

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations. Some examples of specific locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats.

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Because there are usually several alternative actions for any site remediation, very different requirements could come into play. These action-specific requirements do not in themselves determine the remedial alternative; they instead indicate how a selected alternative must be achieved. Several select action-specific ARARs important to later draft FS discussions are briefly described below.

Under the State of Oregon's Environmental Cleanup Law, Oregon hot spots are defined as hazardous substances that are present in high concentrations, are highly mobile or cannot be reliably contained, and that would present a risk to human health or the environment exceeding the acceptable risk level if exposure to these materials were to occur (ORS 465.315(2)(b)) See also, OAR 340-122-115(32), also see draft FS Section 5.5.1.

Section 7 of the ESA requires that federal agencies consult with NMFS and the USFWS to ensure that action, "authorized, funded or carried out by such agency . . . is not likely to jeopardize the continued existence of any threatened or endangered species" or result in adverse modification of species' critical habitat (16 U.S.C. § 1536(a)(2)). Five species of listed salmonids are known to use the Lower Willamette River as a rearing and migration corridor. Moreover, eight listed salmonid species, three additional listed fish species, and one listed mammal species are known to occur in the Lower Columbia River near the confluence with the Willamette River. Due to the presence of these listed species at and near the Site, the Preliminary Draft BA was developed and submitted to the agencies (Anchor QEA 2012). The Preliminary Draft BA includes consideration of impact avoidance and minimization measures and voluntary conservation measures.

Section 404 of the CWA regulates the discharge of dredged or fill material into navigable waters, with the exception of incidental fallback associated with dredged materials (EPA

2009f). This ARAR is applicable to cleanup actions in navigable waters of the Site. Appendix M provides a summary of the Section 404(b)(1) analysis of each of the alternatives. The alternative development process included considerations of the CWA hierarchy to avoid, minimize, and mitigate potentially adverse effects of all of the alternatives, with the final determination of mitigation to be made during remedial design. Appendix M also summarizes the methodology used to determine an acceptable level of CWA compensatory mitigation to be included in the defined alternatives for FS purposes. This level of mitigation was then considered to be part of each alternative as it was then evaluated for ESA compliance in the Preliminary Draft BA described above.

The Federal Emergency Management Act (FEMA) floodplain ARAR requires that any action that encroaches on the floodways of United States waters (such as sediment cleanup) cannot cause an increase in the water surface elevation of the river during a 100-year flood event.

3.4.2 ARAR Waivers

If it is found that the most suitable remedial alternative does not meet an ARAR, the NCP provides for waivers of ARARs under certain circumstances. According to 40 CFR 300.430(f)(1)(ii)(C):

> *"An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances:*
>
> 1. *The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;*
> 2. *Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;*
> 3. *Compliance with the requirement is technically impracticable from an engineering perspective;*
> 4. *The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach;*
> 5. *With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state; or*
> 6. *For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund money to respond to other sites may present a threat to human health and the environment."*

The EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9234.2-25 guidance entitled *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA 1993), although specific to groundwater, is the primary guidance for technical impracticability (TI) waivers (TI guidance). Although the TI guidance indicates that the TI evaluation may be included in the RI/FS, a TI evaluation is not included in this draft FS.

3.5 PRGS AND PROPOSED RGS

This section describes the sediment PRGs and RGs developed for the draft FS. Appendix Da provides additional detail on the calculation of sediment RGs and a full list of all goals calculated and evaluated for use in the draft FS. There is a distinction for the draft FS between the use of the term PRG (including the word “preliminary”) as compared to RG. The term PRG is applied to describe three general situations:

- Development of goals that occurred prior to initiation of the draft FS writing in early 2011, representing a preliminary stage in the iterative process of RG development.
- Goals that are not sufficiently refined to be defined as RGs. This may be due to a lack of information or substantial uncertainty in the calculation of the goal that goes beyond most RGs’ uncertainties.
- Goals for non-COCs (i.e., contaminants posing potentially unacceptable risk)

RGs represent numeric goals for COCs that have been recently and sufficiently refined for use in the draft FS. Even in these cases, there are considerable sensitivities and/or uncertainties in the determination of the RG, and thus, RGs are primarily discussed in the draft FS in terms of RG ranges (see Section 3.6). The iterative nature of RG development reflected by the above definitions and the use of RG ranges is consistent with EPA (2005a) guidance on iterative development of RGs and their eventual adaptation into cleanup levels by EPA in the Proposed Plan and ROD.

The draft FS addresses all contaminants posing potentially unacceptable risk as identified in the baseline risk assessments as well as contaminants yielded from the EPA-required additional water screening steps described in Section 3.1. Section 3.1 addresses and presents all of the contaminants yielded from the water screening. Section 3.1 also presents all of the contaminants associated with potentially unacceptable risk determined via the risk assessments. This group of contaminants is further evaluated in Section 3.5 in an iterative process to develop RGs for use in the remainder of the draft FS. This overall process is summarized in the flowchart in Figure 3.5-1. Consistent with this flowchart, sediment PRGs (and eventual RGs) are developed with the following general considerations:

- Sediment PRGs support draft FS determinations relevant to sediment contact and fish/prey consumption based RAOs (i.e., RAOs 1, 2, 5, and 6).

- All sediment PRGs are based on Site-specific risk analyses; there are no sediment ARARs in the State of Oregon from which to derive sediment PRGs.
- Sediment PRGs do not directly support surface water and groundwater RAO determinations (i.e., RAOs 3, 4, 7 and 8). PRGs associated with these RAOs are evaluated through applicable water quality standards/criteria (ARARs) or guidelines as discussed above and in Appendix C.
- Sediment PRGs are not established below estimated background levels for any human health scenario, ecological receptor, or contaminant (see Section 3.5.4 for details).
- Sediment PRGs that represent target risk levels higher than the risks actually found in the Site risk assessments (i.e., that are inconsistent with the risk assessment findings) are not used in draft FS evaluations (see Section 3.5.4 for details).
- Each sediment PRG is representative of a specific contaminant, human health scenario, ecological receptor, human health cancer risk level, exposure assumption, or other specific risk assessment factors as detailed in tables supporting this section (i.e., Tables 3.5-2, 3.5-3, 3.5-4 and Appendix Da Tables 1 to 4).

The contaminants from the Section 3.1 water screening effort have been refined down to a smaller list of ICs that also includes consideration of sediment-related contaminants posing potentially unacceptable risk. This list of ICs is used in draft FS contaminant mobility evaluations (as described in Section 3.1; Figure 3.5-1).

With regards to contaminants that pose potentially unacceptable risk, in addition to contributing to the determination of the IC list, these contaminants are refined into a list of sediment RG contaminants that are used to represent the RAOs, help define alternatives, and help evaluate the effectiveness of each remedial alternative in Sections 8 and 9 (Figure 3.5-1). The process of evaluating this large list of contaminants and refining it into a manageable list that is appropriate for broad application in the draft FS is discussed in the following subsections.

3.5.1 PRGs

Sediment PRGs were provided by EPA (EPA 2008b; Windward et.al. 2009). All of the PRGs developed for the draft FS, consistent with the most recent revisions of the risk assessment as well as a description of methods to calculate the PRGs, are presented in Appendix Da.

For many contaminants posing potentially unacceptable risks, sediment PRGs could not be developed due to several factors including:

- Lack of tissue/sediment relationship – This is when contaminants are found in the sampled biota tissue as well as in the sediments, but there is no clear pattern or correlation between the two sets of concentrations. If a relationship cannot be defined, it is difficult or impossible to calculate a sediment PRG that would be needed to meet any given acceptable target tissue level.

- Contamination only poses potentially unacceptable risk in surface water or TZW – The risk assessments determine potentially unacceptable risks in various Site matrices, including water. Contamination in water may be present from various sources such as upstream water, stormwater inputs, and/or flux from sediments, and in the case of TZW, flux from upland groundwater sources (among others). Thus, the relationship between concentrations in water and sediments are complex and cannot be resolved to sediment PRGs with any accuracy. Potentially unacceptable risks in water exist, but it is unclear whether and to what extent sediment remedies would reduce those risks. Consequently, as noted above, achievement of water-related RAOs is determined via comparison to chemical-specific ARARs and guidelines, rather than to sediment PRGs.

- The calculated PRG would be less than zero – This occurs due to the fact that upstream surface water concentrations alone can cause fish tissue concentration threshold exceedances. Thus, the sediment PRG could be zero, and the tissue threshold would still be exceeded due to exposure from upstream surface water contaminant concentrations alone.

- Other technical factors – There are some other specific situations that may limit the ability to calculate a sediment PRG such as low detection frequency or that the PRGs calculated are well outside of the range of the data.

These issues, and where they occur, are described more in Appendix Da.

The sediment PRGs have gone through several revisions to maintain consistency with updates to the risk assessments. The current list of contaminants posing potentially unacceptable risk in sediments, as well as those contaminants for which PRGs can be calculated is shown in Table 3.5-1. Appendix Da contains tables of all PRGs updated consistent with the most recent risk assessments.

In addition, the sediment PRG list was refined to account for two additional issues:

- PRGs that are below likely background levels
- PRGs that represent target risk levels higher than risks observed at the Site.

Background concentrations were calculated in the draft final RI (Integral et al. 2011), following EPA-directed procedures and are summarized in Appendix A. Consistent with EPA guidance (2002a) on use of background in remediation, PRGs that are below anthropogenic background are generally not used in EPA cleanup decisions. Consequently, those PRGs that are below the EPA-established background levels are not used in the draft FS. PRGs are identified as above and below background levels in Appendix Da, Tables 1 through 3.

Also some PRGs are calculable at target risk levels that are higher than risks that may exist at the Site. For example, a PRG may be calculable using theoretical target tissue levels at 10^{-4} cancer risk level for a particular human health fish exposure scenario, but the fish tissue level may not have actually been observed at the Site and risks at that level do not exist. Consequently, in these cases, the Site existing conditions already meet the theoretical PRG, indicating that these PRGs are above risk levels observed at the Site and do not need to be further evaluated.

Although sediment PRGs below background levels and/or above the risk levels observed at the Site are not discussed further in the draft FS, all calculated PRGs including identification of those PRGs relevant to these issues, are presented in Appendix Da for reference. Also, Table 3.5-1 summarizes which contaminants have PRGs that are above background and are above risk levels observed at the Site.

Additional human health scenarios were included in the revised BHHRA. These additional scenarios include the combined adult/child scenario for fish consumption and the infant consumption of human milk for bioaccumulative compounds (i.e., PCBs, dioxins/furans, DDx, and PBDEs). Per an agreement with EPA, development of RGs is not required for the combined adult/child scenario. The RGs for PCBs for smallmouth bass consumption are assumed to be protective of infant consumption of human milk and would likely be below background.

3.5.2 Focused PRGs

The broad list of sediment PRGs discussed above were refined into a smaller list of “Focused” PRGs by EPA (EPA 2010c) for primary use in the draft FS as part of an EPA risk management decision.

EPA has indicated that all PRGs, including those with lower values than Focused PRGs, need to be “addressed” in the draft FS (EPA 2011f). Although the exact method for addressing this wider range of PRGs has not been described by EPA, the draft FS examines how various sizes of active remedy footprints relate to and address this larger number and range of potential PRGs (see Section 5.9).

The Focused PRGs encompass a list of contaminants with a variety of exposure pathways, ingestion rates, and risk levels. Although the LWG has requested it, EPA has not provided either oral or written rationale for their selection of these sediment Focused PRGs. As a consequence, the LWG does not endorse the Focused PRGs as necessarily representing the most appropriate set of PRGs for use in the draft FS. For example, the mixing of human health cancer risk levels for the same exposure scenario may be inappropriate because it does not effectively result in a reduction of risk. That is, if a 10^{-5} cancer risk level is used for one contaminant (e.g., for sum-DDE) and a 10^{-4} cancer risk level is used for another contaminant (e.g., PCBs and PCDF) for fish consumption, the risk from fish consumption is still 10^{-4}. Thus, cleanup of sediments for some scenarios or contaminants below the 10^{-4} level would result in no actual reduction in that person’s excess risk of cancer due to their overall exposure to Site media. The contaminants for which Focused PRGs were developed by EPA are shown in Table 3.5-1, and the further explanation of these PRGs is provided in Table 3.5-2.

Because the risk assessments have been revised since the Focused PRGs were first provided by EPA, as shown in Table 3.5-1, Focused PRGs exist for some contaminants that are not recommended COCs. However, all of the Focused PRGs represent contaminants posing potentially unacceptable risk per the revised risk assessments.

3.5.2.1 Refinements to Focused PRGs

Focused PRGs for sediment were refined to be consistent with subsequent revisions to the risk assessments. These Focused PRG refinements include:

- **TBT (Fish Dietary Assessment PRGs for Sculpin and Smallmouth Bass) –** Since the Focused PRG list was first developed, new literature references for fish TRVs related to TBT were provided by LWG to EPA (LWG 2010c). Results of the draft final BERA indicated potentially unacceptable fish dietary risks related to TBT in the Site (Windward 2011). However, because of the updated TRV, TBT was not identified as a recommended COC in the draft final BERA. Therefore, these Focused PRGs for TBT were not used in the development and screening of alternatives.
- **Aldrin (Human Health Fish Consumption, Large Home Range Single Species High Ingestion Rate, Low Bioaccumulation, 10^{-6} risk) –** Using the current draft FS database, this PRG is already met based on existing data on a Site-wide SWAC basis. No other aldrin fish consumption PRGs are between background and baseline conditions at the Site (see Appendix Da). Therefore, this Focused PRG for aldrin was not used in the development and screening of alternatives and is not evaluated further in the draft FS.
- **Sum DDE (Human Health Fish Consumption, Smallmouth Bass, Low Ingestion Rate, 10^{-5} risk) –** The BHHRA does not identify actual risk exceeding 10^{-5} for this pathway and contaminant. However, other sum DDE fish consumption PRGs are between background and baseline conditions at the Site. The PRG for sum DDE human health adult fish consumption, large home range fish, low bioaccumulation, low ingestion rate at a 10^{-6} risk level was substituted for the original sum DDE EPA Focused PRG. (Note that there are no other smallmouth bass DDE PRGs for adult consumption that are both above background and are representative of risk levels found in the BHHRA.) The large home range fish sum DDE PRG results in a similar mapped area applied on a Site-wide basis and is used for development and screening of alternatives in the draft FS. (Mapping procedures are discussed more in Section 5.)
- **Arsenic (Background 95th Percentile Upper Prediction Limit (UPL) calculated on a dry weight basis) –** Using the current draft FS database, this PRG is already met on a Site-wide SWAC basis. Therefore, this Focused PRG

for arsenic was not used in the development and screening of alternatives and is not evaluated further in the draft FS.

- **BaP (Human Health Clam Consumption, High Consumption Rate of 18 grams/day, 10^{-5} risk) –** As discussed in the draft final BHHRA, the exposure area for this PRG was modified to areas above OLW (5.1 feet NAVD88) because clams cannot be reasonably harvested deep underwater. Although this PRG is retained for use in the draft FS, there are a number of substantial uncertainties associated with this PRG beyond those typically associated with the other PRGs. These include the following:
  - At the current clam population densities, it is very difficult to harvest quantities of clams equivalent to the BHHRA exposure assumptions.
  - It is highly uncertain that, after sediment remediation, future clam populations will be sufficient to support harvest quantities equivalent to the exposure assumptions.
  - The clams in question are an exotic species and are illegal to harvest.
  - The rate, extent, and areas over which people in and around the harbor actually harvest and consume clams is unknown, although anecdotal information exists that harvest may occasionally occur.
  - Risk was calculated using undepurated clam tissue, and it is unclear to what extent clam tissue may be eaten in this manner.
  - The relationship between BaP in sediment and clam tissue is weak (Windward 2009).

  Consequently, although retained, in the remainder of the draft FS where this PRG for BaP is used to evaluate alternatives, it may be given lesser weight in remedial evaluations as compared to other Focused PRGs.

3.5.2.2 Comprehensive Benthic Risk Approach for Benthic Focused PRGs

Several of the Focused PRGs for sediment in Table 3.5-2 are associated with the benthic risk pathway. These PRGs are evaluated using the "comprehensive benthic approach" per the draft final BERA (Windward 2011) and EPA (2010c) input. Appendix P contains additional details of the comprehensive benthic approach as it is used to define comprehensive benthic risk areas for the draft FS consistent with project agreements (LWG 2011a and EPA 2011b).

Sediment toxicity bioassays form the primary line of evidence (LOE) for the comprehensive benthic approach used to delineate the recommended comprehensive benthic risk areas. Predicted toxicity (based on multiple sets of sediment quality values [SQVs]) and tissue residues (both empirical and predicted) provide secondary LOEs to identify benthic risk areas. TZW and surface water were used as supporting LOEs.

Bioassays cannot form the primary LOE for the draft FS analysis of alternatives because the analysis is of potential future conditions and future bioassay results after remediation cannot be easily predicted, if at all. Therefore, the sediment chemistry LOE, as applied in the comprehensive benthic approach, is used in the draft FS to judge protectiveness of potential remedies for the benthic invertebrate community. The comprehensive benthic approach uses concordance between a MQ based on the Site-specific SQVs developed using the Floating Point Model (FPM; described more in Appendix P) and the maximum probability of toxicity (pMax) predicted using the Logistic Regression Model (LRM) to identify benthic risk areas. EPA selected the MQ threshold of 0.7 and the pMax threshold of 0.59 that the LWG used in defining benthic areas of concern.

For the pMax threshold, each of the individual LRM models is based on one of four normalizations: dry weight (DW), organic carbon (OC) normalized concentrations, fines-adjusted DW concentrations, and fines-adjusted OC normalized concentrations. These normalizations make the use of pMax values in the draft FS for evaluation of alternatives difficult, because predicted pMax thresholds are defined using a combination of contaminant concentrations and OC and fines content in the sediments. These latter sediment characteristics may cause benthic toxicity, but are not directly related to the presence of materials that are the focus of CERCLA.

So while the pMax value is used as an LOE to delineate the comprehensive benthic risk areas (as discussed more in Section 5), the MQ values are used as the benthic Focused PRGs for other draft FS evaluations such as identifying depth of contaminated sediment impact for volume estimates as discussed later in the draft FS. The Site-specific SQVs from the FPM that form the benthic Focused PRGs are included in Table 3.5-3.

3.5.3 Remediation Goals (RGs) for the Draft FS

Consistent with the above discussions, the sediment RGs, refined Focused PRGs, and PRGs proposed for use in the draft FS are provided in Table 3.5-4. In summary, these sediment RGs, refined Focused PRGs, and PRGs are:

- BaPEq (i.e., cPAHs) – 423 ppb based on human Tribal fisher direct contact with sediments at the 10^{-6} cancer risk level (RG)
- BaPEq (i.e., cPAHs) – 162 ppb based on health Tribal fisher direct contact with sediments at shoreline beaches at the 10^{-6} cancer risk level (RG)
- Total PCBs – 29.5 ppb based on human health adult consumption of 17.5 grams per day (approximately two 8-ounce meals per month) of whole body smallmouth bass at the 10^{-4} cancer risk level (RG)
- Total PCBs – 17 ppb based on EPA's estimated background concentration (Focused PRG)
- Polychlorinated dibenzofuran (2,3,4,7,8-PCDF) – 0.0541 ppb based on ecological bird dietary (worm) assessment (Focused PRG)

- 2,3,4,7,8-PCDF – 0.0205 ppb based on human health adult fish consumption of 17.5 grams per day (approximately two 8-ounce meals per month) of whole body smallmouth bass at the 10^{-4} cancer risk level (RG)
- 2,3,4,7,8-PCDF – 0.056 ppb based on ecological mink multi-species diet (RG)
- Total chlordane – 1.87 ppb based on human health adult fish consumption of 142 grams per day (approximately nineteen 8-ounce meals per month) of whole body black crappie (large home range species) and low bioaccumulation at the 10^{-6} cancer risk level (Focused PRG)
- Sum DDE – 3.02 ppb based on human health adult fish consumption of 17.5 grams per day (approximately two 8-ounce meals per month) of whole body black crappie (large home range species) and low bioaccumulation at the 10^{-6} cancer risk level (RG)
- MQ – 0.7, which is a measure of toxicity to the benthic community (RG)
- BaP – 5.9 mg/kg-OC based on human health clam consumption of 18 grams per day (approximately two 8-ounce meals per month) of undepurated clams at the 10^{-5} cancer risk level (PRG).

These sediment PRGs, Focused PRGs, and RGs pertain to attainment of sediment contact and fish/prey consumption RAOs (i.e., RAOs 1, 2, 5, and 6). Attainment of surface water and groundwater RAOs is assessed through water quality criteria/standards (ARARs) and guidelines as discussed above and in Appendix C.

As shown in Table 3.5-4, some of these goals are defined as sediment RGs and some continue to be defined as only Focused PRGs or PRGs, consistent with the definitions and rationale provided at the start of Section 3.5. The draft FS does not refer to the clam BaP PRG as a "Focused PRG" to distinguish the greater uncertainties with the use of this goal as discussed above.

The benthic risk pathway RGs are represented by the MQ SQV list in Table 3.5-3 for contaminants identified in the draft final BERA to be statistically correlated (although not necessarily causally correlated) with benthic risk.

All evaluations in the draft FS make comparisons to the range of possible RGs represented by each contaminant and risk scenario/ receptor shown in Table 3.5-4.

These sediment RGs were selected because they are consistent with EPA directives and past project agreements on these various risk pathways, and are generally representative of the wide range of remedial goals that are potentially available for the Site as detailed in the RG sensitivity analysis in Appendix E. However, consistent with EPA guidance (2005a), a range of RGs should be presented in the draft FS for use by EPA. The next subsection discusses the sensitivities and uncertainties associated with select RGs, and discusses how RG ranges, rather than just the point estimates in Table 3.5-4, are used in draft FS evaluations. In summary, all evaluations in the draft FS make comparisons to the range of possible RGs represented by each contaminant and risk scenario/receptor shown in Table 3.5-4 where such ranges are available, including, but not limited to, the point estimates in that table.

Also, Sections 4 and 5 discuss more how sediment RGs are used in the draft FS alternatives development both in terms of RALs and in AOPC and SMA development, respectively.

3.6 RG SENSITIVITIES AND UNCERTAINTIES

An analysis was conducted as part of the draft FS to understand how various assumptions, interpretations, and calculations described in the BERA, BHHRA, and site characterization sections of the RI report influence RGs and SMAs. This work was performed consistent with EPA sediment remediation guidance (EPA 2005a), which advocates the importance of understanding the "sensitivity" of RG values proposed for COCs to alternate assumptions about site conditions and potentially unacceptable risks to ecological and human receptors.

The Focused PRGs and the RGs were selected from deterministic exposure and risk calculations in the BHHRA, based on conservative estimates for most input parameters that result in exposure and risk estimates that are expected to be at the upper bound of estimates for the Site. However, these "point estimates" do not provide the risk managers and developers of the FS with context that is important for making risk management decisions. EPA (2005b) and the State of Oregon (DEQ 2010c and 1998c) recognize the importance of this context in risk assessment guidance:

> *"The intent of this approach is to convey an estimate of risk in the upper range of the distribution, but to avoid estimates that are beyond the true distribution. Overly conservative assumptions, when combined, can lead to unrealistic estimates of risk. This means that when constructing estimates from a series of factors (e.g., emissions, exposure, and unit risk estimates) not all factors should be set to values that maximize exposure, dose, or effect, since this will almost always lead to an estimate that is above the 99th-percentile confidence level and may be of limited use to decisionmakers."* (EPA 2005b)

and

> *"It is also important to inform risk managers of the final distribution of risk estimates (U.S. EPA, 2000b; 1995). Otherwise, risk management decisions may be made on varying levels of conservatism, leading to misplaced risk priorities and potentially higher overall risks. (Nichols and Zeckhauser, 1986; Zeckhauser and Viscusi, 1990)."* (EPA 2005b)

Further, the importance of risk managers being informed on the implications of compounding uncertainties is also highlighted in EPA risk assessment guidance (EPA 2005b).

This guidance should be considered when evaluating the protectiveness of remedial alternatives.

This section summarizes the results of the sensitivity analysis for RGs selected from the bounding COCs described in Sections 2.2 and 2.6. The sensitivity analysis focused on sensitivities of PCBs and BaPEq RGs (as well as comprehensive benthic risk areas), which, of the bounding COCs, were selected as having the greatest potential impact on SMA identification. The full sensitivity/uncertainty analysis for these RGs is provided in Appendix E, and is summarized here in the context of overall RG discussions above.

As described in the Risk Management Recommendations report prepared as part of the RI (Kennedy/Jenks and Windward 2011), the results of the risk assessments, together with information on background physical/chemical conditions in the river, were intended to serve as the basis for setting RGs and SMAs for COCs in the draft FS. The BHHRA and BERA identified the contaminants and the pathways whereby humans, fish, wildlife, and certain other ecological receptors could be exposed at levels resulting in potentially unacceptable risks. The degree to which COCs and exposure pathways posed greater or lower concerns to ecological and human receptors was dependent on certain calculation assumptions and parameter values that describe how those receptors could be exposed to COCs. Using valid alternate assumptions that were different from those required by EPA in the risk assessments could result in different RGs. Therefore, an analysis of how COC-specific RGs could vary for each COC-risk assessment pathway scenario and still result in risks that are protective of human health and the environment is an important consideration when making final cleanup decisions (EPA 2005a).

The results of the sensitivity analysis in Appendix E demonstrate that the range of potential RGs for the Site for the two select bounding COCs (total PCBs and BaPEq) extends from background levels to baseline conditions in Portland Harbor. Thus, there is scientifically defensible evidence that baseline conditions might already meet the CERCLA threshold criterion for overall protection of human health and the environment for the scenarios evaluated in the analysis. The sensitivity analysis demonstrates that RGs considerably higher than EPA's point estimates of RGs (i.e., April 2010 Focused PRGs; Table 3.5-4) are likely to satisfy the NCP protectiveness criterion. Alternative RGs have significant cost and implementability implications that are relevant to remedial alternative selection.

RG ranges help inform EPA decisions about the potential use of specific RG values concerning alternate assumptions about Site conditions and potentially unacceptable risks to ecological and human receptors, per guidance.

The sensitivity of RGs to uncertainties and assumptions about baseline risks and background conditions makes the NCP balancing criteria critically important in setting RGs and analyzing draft FS alternatives. As RGs and RALs decrease, implementability declines and cost increases without a proportional increase in protectiveness, as will be explained in the alternatives evaluations found in Sections 8 and 9. Therefore, as discussed in Section 3.5, the resulting range of RGs reflecting these sensitivities is used in the evaluation of alternatives in this draft FS, rather than single values (i.e., point estimates) for each RG predicated on the exposure assumptions and deterministic calculations in the risk assessments. These ranges help inform EPA decisions about the potential use of specific RG values concerning alternate assumptions about Site conditions and potentially unacceptable risks to ecological and human receptors, per guidance (EPA 1998c, 2005b).

As discussed above, RGs were based on those bounding COCs that included the most widespread areas of potentially unacceptable risk as discussed in the RI and Sections 2.2, 2.6 and 5.9 of this draft FS, although there is uncertainty in whether these exact exposures indeed occur, which impacts SMA sizes, volumes, and cost. The RGs evaluated in the sensitivity analysis were:

As discussed above, RGs were based on those bounding COCs that included the most widespread areas of potentially unacceptable risk as discussed in the RI and Sections 2.2, 2.6 and 5.9 of this draft FS.

- Total PCBs, particularly due to widespread potentially unacceptable risks to human health from fish consumption (represented by smallmouth bass PRGs) and/or risks to ecological receptors, primarily from ingestion of fish and invertebrates (represented by mink dietary PRG).
- BaPEq, particularly due to relatively widespread potentially unacceptable risks to human health from in-water direct contact with sediments, and to a lesser extent, potential shellfish consumption.
- Benthic toxicity (defined as areas where potentially unacceptable benthic risks are estimated to occur rather than via a COC concentration, as described in Section 3.5).

DDx (including component DDD, DDE, and DDT forms) and dioxin/furans (represented in the RGs by a surrogate PCDF compound) were also identified as COCs for human health via fish consumptions (either smallmouth bass or large home range fish). However, in general, examination of surface sediment concentration distributions indicated that localized areas around RM 7 to 8 have the highest concentrations of these compounds that are identified by mapping areas exceeding various RGs using a RAL-type approach (Section 5). The RG sensitivity analysis did not include these more locally distributed contaminants, although similar uncertainties as discussed below exist for these contaminants' RGs as well.

The key uncertainties and sensitivities, as well as the resulting ranges of RG estimates, are summarized below for ecological, human health, and background RGs. The RG ranges are compared to various RALs in Section 4.

3.6.1 Ecological RGs

The sensitivity analysis examined a broad range of total PCB RGs through analyzing the sensitivity of the PCB RG to BERA assumptions about exposure, toxicity, and potentially unacceptable population-level risk.[13] It calculated the probability of protectiveness of alternative PCB RGs for mink and assessed whether mink RGs would be protective of other ecological receptors, based on analyses of river otter and bald eagle exposure assumptions.

The risk management recommendations report (Kennedy/Jenks and Windward 2011) identified the need to analyze draft FS alternatives for protectiveness against potentially unacceptable PCB risks to mink, and to use river otter and bald eagle to analyze whether alternatives that are protective against potentially unacceptable PCB risks to mink are also protective of other ecological receptors (but not the benthic community, which is the focus of a separate assessment in the draft FS).

The sensitivity analysis also focused on assumptions used in the PCB bioaccumulation model (Windward 2009) to support both the BERA and BHHRA because the results of the bioaccumulation model have a significant influence on RGs and SMAs, comparable in magnitude to the influence of other assumptions that were considered in this sensitivity analysis.

The results of the sensitivity analysis are summarized in Figure 3.6-1 and indicate that:

The 31 ppb RG identified by EPA as protective of mink is lower than necessary to protect the three ecological receptors of most concern—mink, river otter, and bald eagle. The results of the sensitivity analysis indicate PCB goals as high as 200 ppb based on a 1-river mile SWAC could be protective of mink, river otter, and bald eagle.

- The range of PCB RG values that are protective of mink exposed to PCBs in sediment and meet EPA requirements for protection of human health and the environment is from 79 to 640 ppb based on a 1-river mile SWAC basis.
- The mean estimate of the PCB RG for mink from the sensitivity analysis is 256 ppb, significantly higher than the EPA's preferred point estimate of the mink RG of 31ppb. Bounding assumptions for reduced kit productivity and bioaccumulation extend the RG range by about a factor of two in either direction, indicating that the RG could possibly go as low as 36 or as high as 1,192 ppb. The point estimate RG (31 ppb) actually falls below the lower end of this range.

The EPA's preferred estimate of the RG of 31 ppb identified by EPA as protective of mink is lower than necessary to protect the three ecological receptors of most concern—mink, river otter, and bald eagle. The results of the sensitivity analysis indicate PCB

[13] Note that mink PRGs were never designated by EPA formally as Focused PRGs or RGs. However, EPA identified that their point estimate of the human health smallmouth bass Focused PRG could be considered as a surrogate for the EPA point estimate for the mink RG. Thus, the mink PRG can be considered as indirectly adopted into the Focused PRG list, and thus is termed as an RG in the draft FS.

goals as high as 200 ppb based on a 1-river mile SWAC could be protective of mink, river otter, and bald eagle.

3.6.2 Human Health RGs

The Risk Management Recommendations report (Kennedy/Jenks and Windward 2011) identified the need to account for variability in several assumptions that are important in estimating human exposure and potentially unacceptable risk associated with PCBs and cPAHs. (The RGs for cPAHs were developed on the basis of BaPEq.) Consequently, the sensitivity analysis examined exposure assumptions pertaining to human exposure to PCBs from consumption of smallmouth bass and cPAHs from direct contact with in-water sediments. The general assumption for the purposes of the draft FS is that PCB RGs for human consumption of smallmouth bass should be achieved on an approximate 1-river mile basis, which is the exposure area assumed for this pathway in the BHHRA. The general assumption for the purposes of the draft FS, consistent with the assumptions in the BHRRA, is that human health sediment direct contact RGs should be met on an approximately half-river mile basis for areas shoreward (outside) of the navigation channel, where these exposures occur.

For total PCBs, RGs were developed for cancer and noncancer endpoints. While total PCBs RGs were initially developed for diets consisting only of whole body fish, the extent to which smallmouth bass is consumed as whole body tissue versus fillet tissue or skinned fillet is not known. Therefore RGs were also developed using assumptions of diets consisting of fish fillet with skin and fish fillet without skin. The resulting RGs represent the highest sediment concentrations that would result in risks that do not exceed the target risk levels for the given probability percentile based on the human health sensitivity analyses. The uncertainty associated with the exposure parameters associated with fish ingestion and with the bioaccumulation model discussed in Section 3.6.1 was used to provide ranges of confidence on the RGs resulting from the human health sensitivity analyses.

The results of the sensitivity analysis for total PCBs are summarized in Figure 3.6-2 and 3.6-3 and indicate that:

- The RG values for PCBs that are protective of human health from fish consumption as represented by smallmouth bass range from below the Focused PRG background value of 17 ppb to 6,346 ppb for 1×10^{-4} cancer risks (Figure 3.6-2 focuses on the lower end of the RG range as a comparison with EPA's point estimate of the smallmouth bass RG).
- The range of RG values for PCBs that are protective of human health from fish consumption as represented by smallmouth bass based on noncancer endpoints is from below the Focused PRG background value of 17 ppb to 373 ppb.

The results of the sensitivity analysis of total PCB RGs for human consumption of smallmouth bass demonstrate that a range of RGs would be protective of human health for purposes of fish consumption for both cancer and noncancer health effects, and that many of these RGs are higher than EPA's point estimate RG for this scenario of 29.5 ppb (per Table 3.5-4). The analyses also show that the EPA point estimate RG is actually near the 99th percentile of the RG distribution for the whole-body scenario and a 1 x 10^{-4} cancer risk level. For comparison, the 95th percentile for this scenario corresponded to an RG of 95 ppb.

The sensitivity analysis demonstrates that a range of RGs would be protective of human health for purposes of fish consumption for both cancer and noncancer health effects, and that many of these RGs are higher than EPA's point estimate RG of 29.5 ppb (human consumption of smallmouth bass) For comparison, the 95th percentile for this scenario corresponded to an RG of 95 ppb.

In addition, it is important to consider the benefits of fish consumption relative to potentially unacceptable health risks from fish consumption, as the probability of benefits is likely higher than the potential risks of cancer (Stone and Hope 2010).

The sensitivity analysis also considered exposure assumptions for direct contact of Tribal fishers with cPAHs (BaPEq) in in-water sediment. The general assumption for the purposes of the draft FS, consistent with the exposure area for this pathway in the BHHRA, is that BaPEq RGs for direct contact with in-water sediment by humans should be achieved on an approximate half-river mile basis for areas shoreward (outside) of the navigation channel, where these exposures could occur. A range of RGs for BaPEq that would be protective of direct contact with in-water sediment by a Tribal fisher was also developed for various target cancer risk levels (1 x 10^{-6}, 1 x 10^{-5}, and 1 x 10^{-4}). Similar to total PCBs, the resulting BaPEq RGs represent the highest sediment concentrations that would result in risks that do not exceed the target risk levels for the given probability percentile based on the human health sensitivity analyses. Because this exposure scenario is based on direct contact, a bioaccumulation model was not needed to calculate RGs, and the range of RGs resulting from the analysis only reflects uncertainties associated with the risk model.

The results of the sensitivity analysis for BaPEq indicate that that the range of RGs are protective of human health from direct contact with in-water sediment is from 1,437 ppb to 3,702 ppb (1 x 10^{-6} cancer risk). These RGs are all higher than EPA's point estimate of the BaPEq RG (per Table 3.5-4) of 423 ppb for direct sediment contact by a Tribal fisher at this risk level. The EPA point estimate RG of 423 ppb represents a greater than 99th percentile estimate of the risk distribution output from the sensitivity analysis.

The sensitivity analysis also generally examined the assumptions used in the BHHRA for exposure to BaP from clam consumption. As noted in Section 3.5, the EPA point estimate for this scenario and contaminant (per Table 3.5-4) was termed a PRG (not an RG) consistent with the definitions of those terms as defined in that section, and indicating a lower level of certainty in the risk estimates for this scenario in general. The uncertainties with the assumptions of human exposure to BaP from clam consumption are detailed in Section 3.5.2. For these reasons, and the fact that RGs for direct contact with in-water sediment are considered protective of potential human exposures to BaP, ranges of PRGs were not developed for clam consumption.

3.6.3 Background RGs

In addition to risk assessment considerations, the procedures used to calculate background conditions for the Site were examined for total PCBs. These procedures were used by EPA to set a background-based total PCB Focused PRG, based on one point estimate of these background levels (see Table 3.5-4). EPA also uses similar point estimates for PCBs and other contaminants to determine whether other RG estimates are above or below background conditions. EPA also uses similar point estimates for PCBs and other contaminants to determine whether other RG estimates are above or below background conditions. Because there are alternate scientifically defensible methods and assumptions for the determination of 'background' contaminant conditions at the Site, the sensitivity analysis explored how background estimates could vary using the upstream bedded sediment data to determine: 1) a range of values for the EPA point-estimate background Focused PRG; and 2) whether other total PCB RGs might reasonably be considered to be at or below background levels. The factors examined in the sensitivity analysis included consideration of alternate upper-limit background statistics (e.g., UPL and Upper Tolerance Limit [UTL]), the use of DW or OC-normalized data, treatment of outliers, reliance on a point estimate approach rather than a population comparison approach, and the handling of data below the detection limit for calculating total or summed values for different contaminants. In addition, the sensitivity analysis examined estimates of central tendency in the datasets describing different contaminant concentrations in sediment, including upper confidence limits on the mean and surface weighted averaging.

With regard to the estimation of background values in sediment, the sensitivity analysis concluded:

> *Alternate estimates of background concentrations of PCBs result in substantially higher background levels (up to 37 ppb) than calculated using the single Focused PRG background statistic selected by EPA (17 ppb).*

- Background conditions for PCBs range between 5 ppb[14] and 37 ppb depending on the statistical method applied to the upstream bedded sediment dataset. Alternate estimates of background concentrations of PCBs result in substantially higher background levels than calculated using the single Focused PRG background statistic selected by EPA (17 ppb).

[14] The low estimate total PCB background of 5 ppb is based on a 95 UCL and not a UPL as is used for the EPA Focused PRG background estimate.

3.6.4 Application to the Draft FS

The findings of this sensitivity analysis inform the evaluation of draft FS alternatives by providing a range of RG values that satisfy the NCP protectiveness criterion for two of the bounding COCs (i.e., PCBs and BaPEq) and receptors (i.e., adult, child, and Tribal fishers for human receptors and mink and benthic community for ecological receptors). The range of RGs for the different COC-risk assessment pathway scenarios aid risk management decision making in selecting RALs that achieve various points in the RG ranges, which directly influences the spatial extent of SMAs (see Section 4 for a discussion of RAL development). The range of RGs also informs decision making in regard to determining how effective draft FS alternatives are likely to be at achieving protectiveness at various points in time after the remediation work is complete.

Based on the results of the sensitivity analysis, Table 3.6-1 summarizes RG ranges from Appendix E for COCs, human health exposure scenarios, and ecological receptors that fall within the approximate range represented by background estimates to approximately the existing Site-wide SWACs for these COCs.

For specific evaluations conducted in later sections of the draft FS, a subset of RGs were selected to be consistent with the cancer risk levels associated with the RGs noted in Table 3.5-4 and a range of upper percentile exposure assumptions (90^{th} to 99^{th} percentile) that EPA might normally consider in protectiveness determinations. As shown in Table 3.6-1, these ranges are generally also inclusive or partially inclusive of similar ranges of values that might be devised for different types of consumption scenarios (e.g., fillet without skin or fillet with skin consumption) or endpoints (e.g., noncancer) and were therefore chosen to be representative of the overall range generally inclusive of these other scenarios and endpoints presented in Table 3.6-1. It is important to note that the other types of values and estimates presented in Table 3.6-1 could be used to provide equally valid ranges or RG points within those ranges that also represent reasonable potential protectiveness decisions by EPA (e.g., RG ranges based on ecological risks). Also, for some draft FS evaluations, some of these additional RGs or RG ranges provide useful points of comparison in specific cases. The background range provided (Table 3.6-1) encompasses the entire range of background estimates discussed in Appendix E, but comparisons to any particular background estimate should only be made with full consideration of the caveats and conditions discussed for each estimate in Appendix E. For example, as detailed in Appendix E, any application of Upper Confidence Limits (UCLs) on the mean in comparison to a Site central tendency estimate (i.e., a SWAC) is not considered a statistically robust approach and should be performed with caution.

The above RG ranges are used in later draft FS evaluations. In addition, the uncertainties and sensitivities represented by these RG ranges should be understood and used in the context of other draft FS uncertainties evaluated in Appendix E and summarized in draft FS sections as follows:

- RAL development uncertainties (Section 4.4)

- SMA uncertainties (Section 5.11)
- Volume calculation uncertainties (Section 5.11)
- Modeling and alternative evaluation uncertainties (Appendices Ha, Hb, U, and Section 9)

The relative importance of all these uncertainties is also compared and summarized and discussed in Section 10.3. Further, Appendix E (Section 6.1) places each of these uncertainties into overall relative categories including “large,” “medium,” and relatively “small” uncertainties, based on their ability to impact the overall decisions with the draft FS. Based on these categories, the RG uncertainties are placed in the “large” category, and generally pose the greatest potential impact on remedial decisions.

3.6.5 Measurement Uncertainty

The assessment of uncertainty in RGs and background estimates focuses on uncertainties from exposure assumptions and statistical methods. There is the additional uncertainty related to measuring low levels of COCs that is important in evaluating achievement of RGs, particularly RGs near or within the range of background estimates. The sources of measurement uncertainties include known acceptable levels established prior to a sampling event (i.e., analytical precision or accuracy identified in a Quality Assurance Project Plan [QAPP]) and relatively unknown sources (e.g., ability in the field to accurately sample an intended area of sediment consistently). Outside of any uncertainties in the calculation of an RG, measurement uncertainties may limit the ability to refine SMAs in remedial design that are intended to achieve very low RGs and accurately determine whether an RG has been achieved after a remedy is completed.

The additional uncertainty related to measuring low levels of COCs is important in evaluating achievement of RGs, particularly for RGs near or within the range of background estimates.

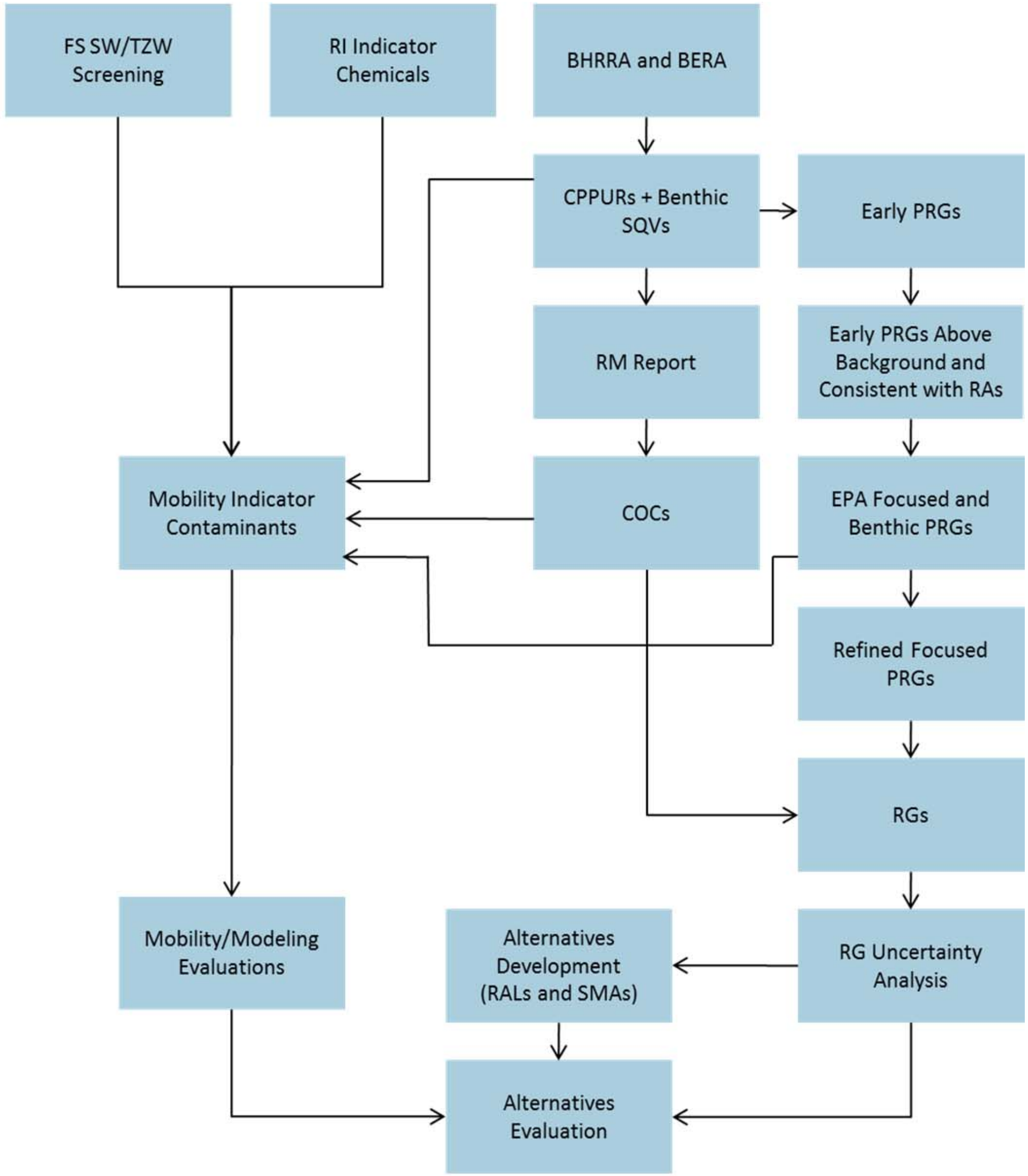
For example, a Relative Percent Difference (RPD) of 50 percent is established for the LWG QAPP as a conservative target control limit for variations in concentrations between field duplicates and/or split samples for results detected at greater than 5 times the reporting limit (which is approximately 5 parts per trillion (ppt or ng/kg when referring to sediments and ng/L when referring to water) for individual PCB congeners). Given that the RG ranges discussed here are well above 5 times the reporting limit, this RPD of 50 percent generally applies. Therefore, for sampling attempting to test compliance with the smallmouth bass whole body EPA point estimate PRG of 29.5 ppb, the concentrations in field duplicates could acceptably vary from 14.75 to 44.25 ppb. This acceptable measurement range extends from well below the PCB background Focused PRG of 17 ppb to above the LWG high estimate background value of 37 ppb and nearly equal to the smallmouth bass fillet with skin consumption noncancer RG of 45 ppb. Thus, differences in only the most disparate of the RG estimates shown in Table 3.6-1 could be routinely identified in any future monitoring program using best available sampling and measurement techniques. This issue is even further compounded when evaluating the

PCB congener method, as the summed non-detects (or half detection limits [DLs]) themselves may be in this range of acceptable measurement uncertainty.

3.7 CONCLUSION

This section described the RAOs, ARARs, contaminants potentially posing unacceptable risk, COCs, PRGs, RGs, and RG ranges that are used in the remainder of the draft FS. The RGs and RG ranges selected provide numeric values that are used in later sections to evaluate achievement of RAOs as defined here. The RAOs and RGs, acting as surrogates of the larger list of COCs, along with comprehensive benthic risk areas, are representative of all of the potentially unacceptable risks identified in the human health and ecological risk assessments. Therefore, they are used to develop RALs and SMAs, screen technologies, and assemble and evaluate alternatives in the remainder of this draft FS. Consistent with EPA guidance (2005a), a range of RGs for several contaminants/scenarios/receptors is also presented based on uncertainty/sensitivity analyses and used in the remainder of the draft FS to generally represent uncertainty/sensitivity around all the RG estimates.

This flow chart illustrates the relationship between contaminant lists from the RI, BHRRA, and BERA and the COCs, RGs, and mobility contaminant lists developed for and used in the draft FS for mobility/modeling evaluations, alternatives development, and alternatives evaluation.



Legend:

BHHRA – Baseline Human Health Risk Assessment
BERA – Baseline Ecological Risk Assessment
COCs – Contaminants of Concern
CPPUR – Contaminants Potentially Posing Unacceptable Risks
FS – Feasibility Study
(P)RGs – (Preliminary) Remediation Goals
RA – Risk Assessment
RALs – Remedial Action Levels
RI – Remedial Investigation
RM – Risk Management
SW – Surface Water
SMAs – Sediment Management Areas
SQVs – Sediment Quality Values
TZW – Transition Zone Water

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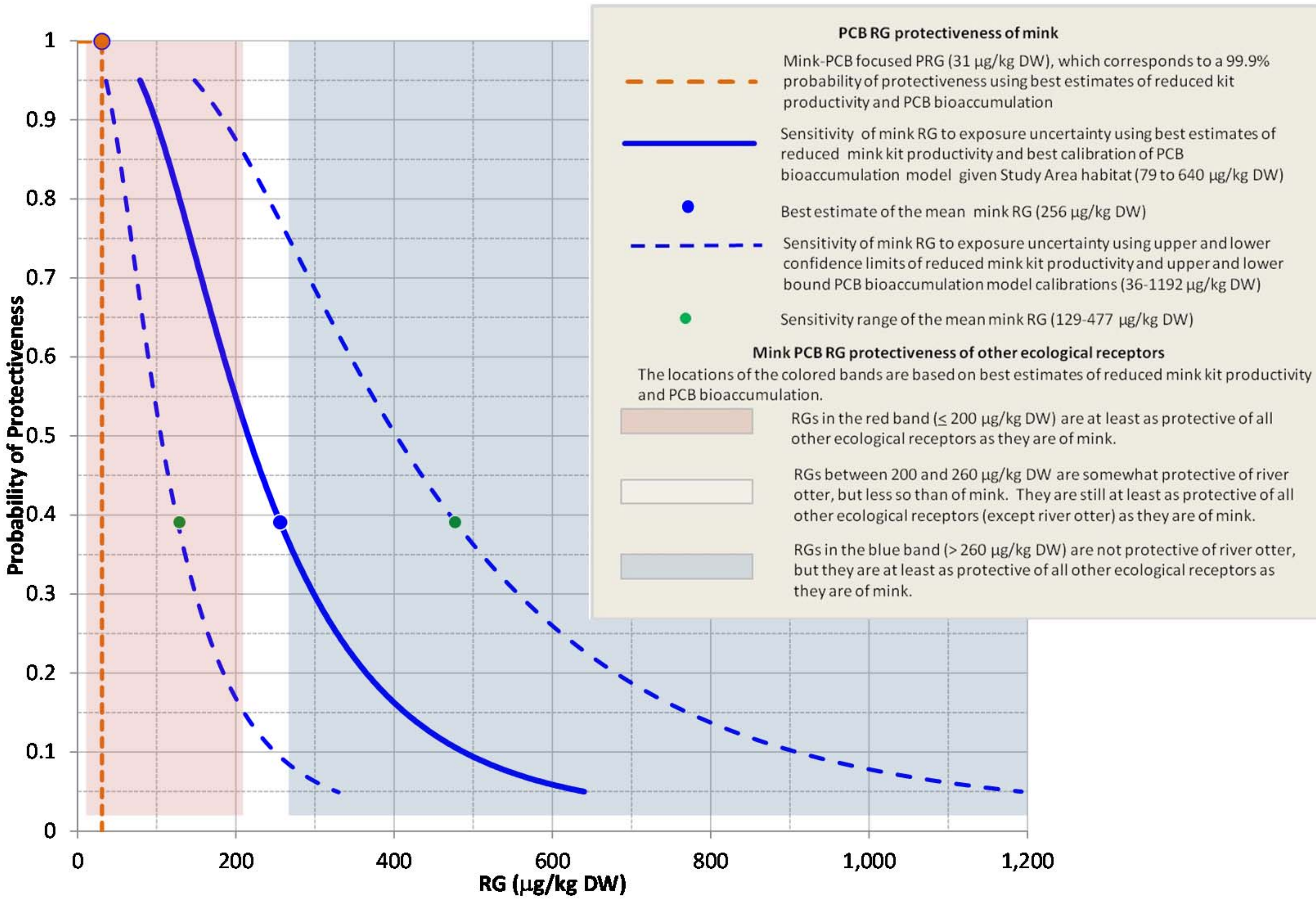
Figure 3.5-1
Portland Harbor RI/FS
Draft Feasibility Study
Flow Chart of Contaminants, PRGs, and RG Development

Figure 3.6-1. Sensitivity Analysis Results for the Mink PCB RG, Including Protectiveness of Other Ecological Receptors



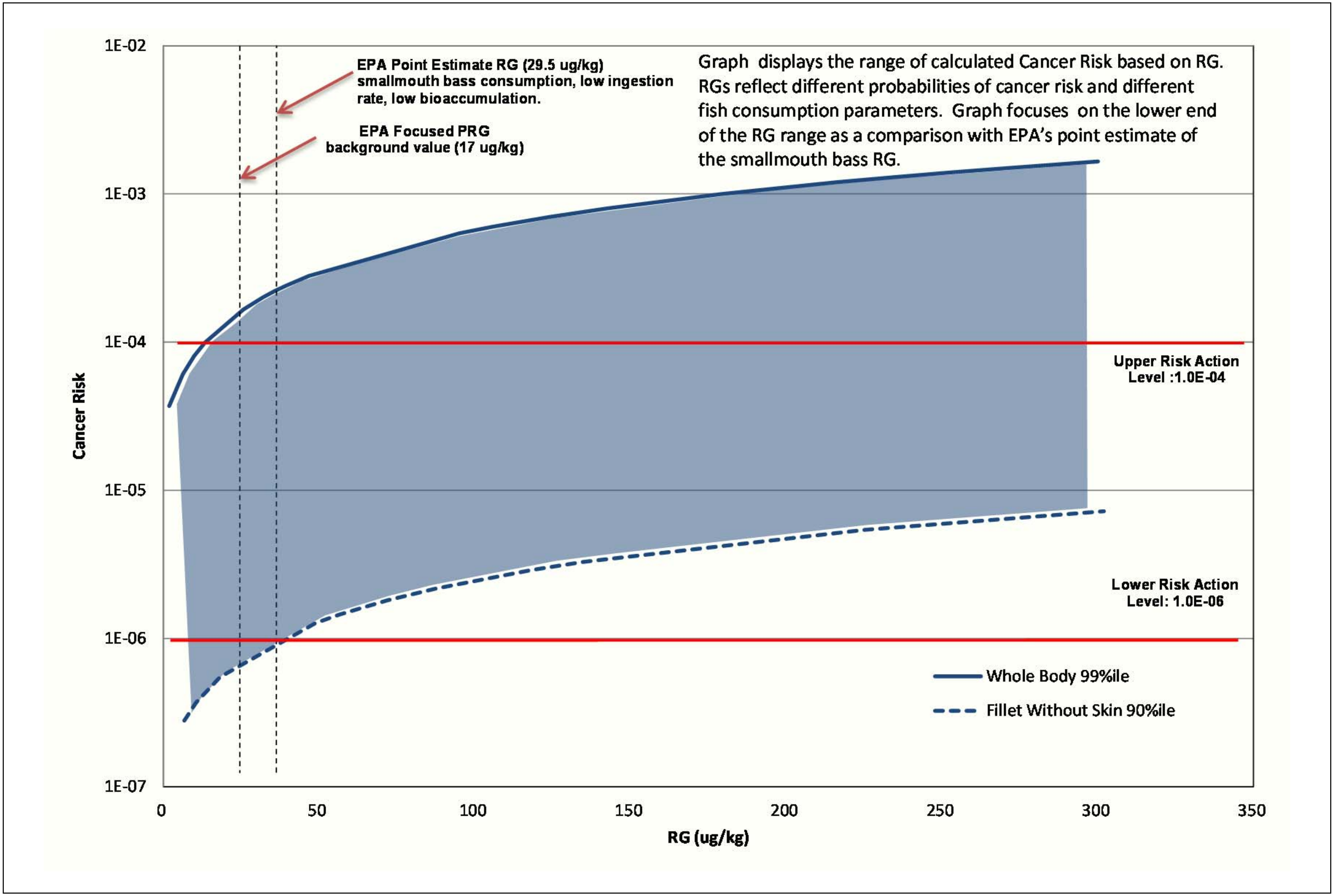
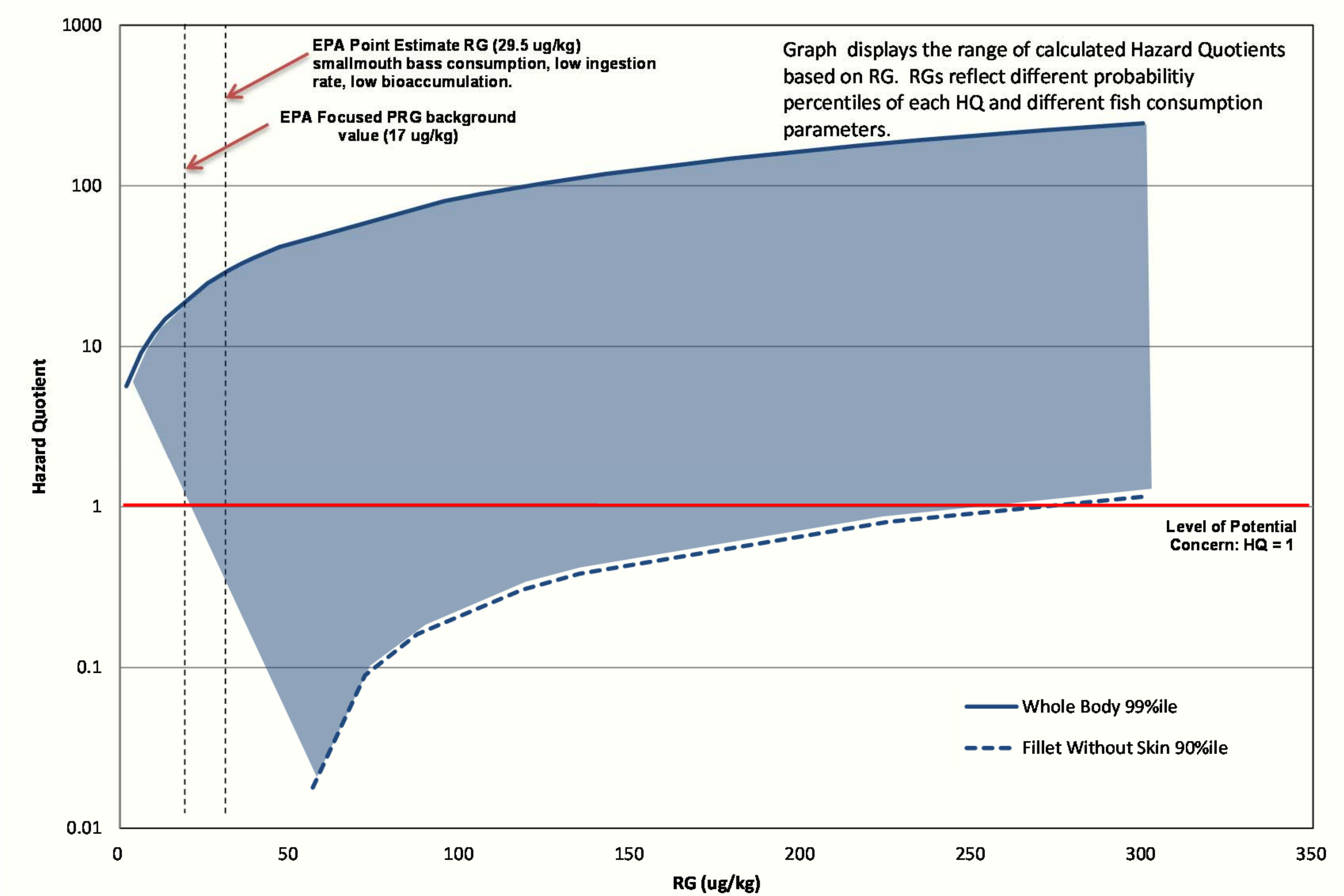


Figure 3.6-2
Portland Harbor RI/FS
Draft Feasibility Study
Sensitivity of PCB Human Health Remediation Goals – Cancer Endpoint



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This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part

Figure 3.6-3
Portland Harbor RI/FS
Draft Feasibility Study
Sensitivity of PCB Human Health Remediation Goals – Noncancer Endpoint

Table 3.1-1. Identification of Contaminants Posing Potentially Unacceptable Risk and Contaminants of Concern

Human Health Fish Consumption	Human Health Shellfish Consumption	Human Health Direct Sediment Contact	Benthic Invertebrate Community	Other Ecological Receptors
Contaminants Posing Potentially Unacceptable Risk				
Human Health: Contaminants with excess cancer risk estimates greater than 1 × 10^{-6} or an HQ greater than 1 for any RME scenario. *Ecological: Contaminants with HQs greater than or equal to 1.0.*				
26 contaminants[1], including metals, PAHs, PCBs, dioxins/furans, pesticides, PBDEs, and other SVOCs (see draft final BHHRA Table 7-1)	17 contaminants[1], including metals, PAHs, PCBs, dioxins/furans, pesticides, and other SVOCs (see draft final BHHRA Table 7-1)	11 contaminants, including metals, PAHs, PCBs, and dioxins/furans (see draft final BHHRA Table 7-1)	47 sediment contaminants, including metals, PAHs, PCBs, dioxins/furans, pesticides, and other SVOCs (see draft final BERA Tables 6-10 and 6 11) 54 TZW contaminants including metals, PAHs, pesticides, VOCs, and other SVOCs (see draft final BERA Table 6-43)	**Fish**- 59 contaminants[2] (see draft final BERA Table 7-44) **Birds**- 12 contaminants (see draft final BERA Table 8-37) **Mammals**- 6 contaminants (see draft final BERA Table 8-37) **Amphibians**- 33 contaminants[3] (see draft final BERA Table 9-5) **Aquatic Plants**- 33 contaminants3 (see draft final BERA Table 10-2)
Contaminants of Concern				
Human Health: Contaminants with excess cancer risk estimates greater than 1 × 10^{-4} or an HQ greater than 1 were selected as COCs based on magnitude and scale of risk, the frequency of detection, and uncertainties associated with the risk posed by the COC. *Ecological: Selection based on risk estimates, magnitude of HQs, spatial distribution and frequency of HQ ≥ 1, and the uncertainty of exposure and effects assumptions.*				
PCBs, dioxins/furans, total DDx	PCBs, dioxins/furans, cPAHs	Dioxins/furans, cPAHs	**Sediment**- PAHs, PCBs, total DDx **TZW**- 4,4'-DDT, total DDx, chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and TCE	**Fish**- TZW: 4,4'-DDT, total DDx, chlorobenzene, benzo(a)anthracene, benzo(a)pyrene, naphthalene, carbon disulfide, cyanide, cis-1,2-dichloroethene, and TCE (lamprey and sculpin) **Birds**- PCBs, dioxins/furans (individual bald eagles) **Mammals**- PCBs (mink and otter), dioxins/furans (mink) **Amphibians**- None **Aquatic Plants**- None

Table 3.1-1. Identification of Contaminants Posing Potentially Unacceptable Risk and Contaminants of Concern

Note:

1 - Some of the contaminants posing potentially unacceptable risk represent groups of contaminants that are inclusive of other individual contaminants (e.g., total cPAHs are inclusive of individual carcinogenic PAHs such as benzo(a)pyrene).

2 - 44 contaminants posing potentially unacceptable risk had HQs ≥ 1 only for the TZW Line of Evidence (LOE).

3 - 27 contaminants posing potentially unacceptable risk had HQs ≥ 1 only for the TZW LOE.

Table 3.1-2. Contaminants Posing Potentially Unacceptable Risk or Exceeding Water Screening Levels

Analyte	Contaminant Posing Potentially Unacceptable Risk			Contaminant Exceeds Water Screening Levels	
	Human Health	Ecological	Benthic Toxicity Model Chemicals	Surface Water	TZW
Conventionals					
Ammonia			X		
Sulfide			X		
Cyanide		X			X
Perchlorate		X		X	X
Metals		X			
Aluminum[d]				X	X
Antimony	X	X			X
Arsenic[f]	X	X		X	X
Barium		X			X
Beryllium		X			
Cadmium		X	X		X
Chromium			X		X
Cobalt		X			X
Copper		X	X		X
Hexavalent Chromium				X	
Iron		X			X
Lead	X	X	X		X
Magnesium		X			
Manganese		X			X
Mercury	X	X	X	X	X
Nickel		X			X
Potassium		X			
Selenium	X				
Silver			X		X
Sodium		X			
Thallium					X
Vanadium		X			X
Zinc	X	X		X	X
Butyltins					
Monobutyltin		X			
Tributyltin ion		X	X		
PCBs					
Total PCBs (congeners or Aroclors)	X	X	X	X	
Total PCB TEQ	X	X		X	
PCDD/Fs					
2,3,7,8-TCDD				X	
Total Dioxins/Furans [a]					
Total Dioxin/Furan TEQ	X	X		X	X

Table 3.1-2. Contaminants Posing Potentially Unacceptable Risk or Exceeding Water Screening Levels

	Contaminant Posing Potentially Unacceptable Risk			Contaminant Exceeds Water Screening Levels	
Analyte	**Human Health**	**Ecological**	**Benthic Toxicity Model Chemicals**	**Surface Water**	**TZW**
Total TEQ	X	X		X	
Herbicides					
Silvex TM [a]					
Organochlorine Pesticides					
2,4'-DDD			X		
4,4'-DDD		X	X	X[c]	X
4,4'-DDE			X	X[c]	X
4,4'-DDT		X	X	X	X
Total of 2,4' and 4,4'-DDD (Sum DDD)	X		X	X	X
Total of 2,4' and 4,4'-DDE (Sum DDE)	X	X	X	X	X
Total of 2,4' and 4,4'-DDT (Sum DDT)	X		X	X	X
Total of 2,4' and 4,4'-DDD, -DDE, -DDT		X		X	X
Aldrin	X	X		x[c]	
cis-Chlordane			X		
Total Chlordanes	X			x[c]	
Dieldrin	X		X	X	
Total Endosulfan			X		
Endrin			X		
Endrin ketone			X		
Heptachlor				X	
Heptachlor Epoxide	X			x[c]	
beta-Hexachlorocyclohexane			X		
delta-Hexachlorocyclohexane			X		
gamma-Hexachlorocyclohexane [b]					
MCPP	X				
Polycyclic Aromatic Hydrocarbons					
2-Methylnaphthalene		X	X		
Acenapthene		X	X		x[c]
Acenapthylene			X		
Anthracene		X	X		
Benzo(a)anthracene	X	X	X	x[c]	X
Benzo(a)pyrene	X	X		X	X
Benzo(b)fluoranthene	X	X	X	X	X
Benzo(b+k)fluoranthene			X		
Benzo(g,h,i)perylene		X	X		
Benzo(k)fluoranthene	X	X	X	X	X
Chrysene		X	X	x[c]	X
Dibenzo(a,h)anthracene	X	X	X	X	X
Fluoranthene		X	X		X

Table 3.1-2. Contaminants Posing Potentially Unacceptable Risk or Exceeding Water Screening Levels

	Contaminant Posing Potentially Unacceptable Risk			Contaminant Exceeds Water Screening Levels	
Analyte	**Human Health**	**Ecological**	**Benthic Toxicity Model Chemicals**	**Surface Water**	**TZW**
Fluorene		X	X		
Ideno(1,2,3-cd) pyrene	X	X	X	x[c]	X
Naphthalene		X		X	X
Phenanthrene		X	X		
Pyrene		X	X		
Total HPAHs			X		
Total LPAHs			X		
Total PAHs[e]			X	X	X
Total Carcinogenic PAHs	X				
Phthalates					
Bis(2-ethylhexyl) phthalate	X	X		x[c]	
Butylbenzyl phthalate [a]					
Dibutyl phthalate		X	X		
Diethyl phthalate [b]					
Semivolatile Organic Compounds					
Benzyl Alcohol			X		
Carbazole			X		
Dibenzofuran		X	X		
1,2-Dichlorobenzene		X			X
1,4-Dichlorobenzene		X			X
Hexachlorobenzene	X			x[c]	
Phenols					
4-Methylphenol			X		
Phenol			X		
Pentachlorophenol	X				
Polybrominated Diphenyl Ethers					
Polybrominated Diphenyl Ethers (PBDE)	X				
Volatile Organic Compounds					
1,1-Dichloroethene		X			X
1,2-Dichloroethane					X
1,2-Dichloropropane					X
1,1,2-Trichloroethane					X
1,2,4-Trimethylbenzene		X			X
1,3,5-Trimethylbenzene		X			
Acrolein					X
Benzene		X		X	X
Bromochloromethane					X
Bromodichloromethane					X
Carbon disulfide		X			

Table 3.1-2. Contaminants Posing Potentially Unacceptable Risk or Exceeding Water Screening Levels

	Contaminant Posing Potentially Unacceptable Risk			Contaminant Exceeds Water Screening Levels	
Analyte	**Human Health**	**Ecological**	**Benthic Toxicity Model Chemicals**	**Surface Water**	**TZW**
Chlorobenzene		X			X
Chloroethane		X			
Chloroform		X			X
cis-1,2-Dichloroethene		X			X
Ethylbenzene		X		X	X
Isopropylbenzene		X			
Methylene chloride					X
MTBE					X
Tetrachloroethene					X
Toluene		X			
trans-1,2-Dichloroethene					X
Trichloroethene		X		X	X
Vinyl chloride				X	X
m,p-Xylene		X			
o-Xylene		X			
Total xylenes		X			X
Petroleum (TPH)					
Diesel-Range Hydrocarbons		X	X		
Gasoline-Range Hydrocarbons		X			
Residual-Range Hydrocarbons[a]					
Total Petroleum Hydrocarbons[a]					

Notes:

[a] Indicator Chemical in Remedial Investigation

[b] EPA Focused PRG (Preliminary Remedial Goal)

[c] Analyte only exceeds October 2011 Oregon human health water criteria based on a fish consumption rate of 175 grams/day.

[d] Samples exceeded only the EPA non-priority pollutant NRWQC criteria for aluminum that is based on toxicity testing in waters with ph <6.6 and hardness <10 milligrams per liter (mg/L). When Oregon adopted this criterion in its Table 33B aquatic life criteria, it adopted the criterion only under those specific circumstances—where pH is < 6.6 and hardness <10 mg/L, conditions which do not apply to the Site. See OAR 340-041-033 Table 33C note w.

[e] Although until 2011, Oregon had a human health fish consumption standard for Total PAHs, the new October 17, 2011 human health standards no longer include a standard for Total PAHs, nor is there a federal NWRQC for Total PAHs.

[f] Oregon adopted a state-specific arsenic standard October 17, 2011 and Site surface waters no longer exceed the Oregon standard.

HPAH - high molecular weight polycyclic aromatic hydrocarbon
LPAH - low molecular weight polycyclic aromatic hydrocarbon
PAH - polycylic aromatic hydrocarbon
TEQ - toxic equivalent quotient
TPH - total petroleum hydrocarbon
PCB - polychlorinated biphenyl
TZW - transition zone water

Table 3.1-3. Indicator Chemicals Selected for Contaminant Mobility Evaluation in FS

Contaminant mobility and long-term fate and transport modeling
Arsenic
Copper
Mercury
Benzo(a)pyrene
Naphthalene
Total PCBs
4,4'-DDD
4,4'-DDE
4,4'-DDT
BEHP
Contaminant mobility evaluations only
Benzene
Chlorobenzene
Vinyl chloride

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Federal ARARs			
Clean Water Act, Section 404 and Section 404(b)(1) Guidelines	33 USC 1344, 40 CFR Part 230	Regulates discharge of dredged and fill material into navigable waters of the United States.	Action-specific. Applicable to dredging, covering, capping, and designation and construction of in-water disposal sites and in-water filling activities in the Willamette River.
Clean Water Act	33 USC 1313, 1314 Most recent 304(a) list, as updated up to issuance of the ROD	Under Section 304(a), minimum criteria are developed for water quality programs established by states. Two kinds of water quality criteria are developed: one for protection of human health, and one for protection of aquatic life.	Chemical-specific and Action-specific. Relevant and appropriate for cleanup standards for surface water and contaminated groundwater discharging to surface water if more stringent than promulgated state criteria. Relevant and Appropriate to short-term impacts to surface water from implementation of the remedial action that result in a discharge to navigable water, such as dredging and capping if more stringent than promulgated state criteria.
Clean Water Act, Section 401	33 USC 1341, 40 CFR Section, 121.2(a)(3), (4) and (5)	Any federally authorized activity which may result in any discharge into navigable waters requires reasonable assurance that the action will comply with applicable provisions of sections 1311, 1312, 1313, 1316, and 1317 of the Clean Water Act.	Action-specific. Relevant and Appropriate to implementation of the remedial action that results in a discharge to the river if more stringent than state implementation regulations.
Clean Water Act, Section 402	33 USC 1342	Regulates discharges of pollutants from point sources to waters of the U.S., and requires compliance with the standards, limitations and regulations promulgated per Sections 301, 304, 306, 307, 308 of the CWA.	Relevant and Appropriate to remedial activities that result in a discharge of pollutants from point sources to the river if more stringent than state promulgated point source requirements.
Safe Drinking Water Act	42 USC 300f, 40 CFR Part 141, Subpart O, App. A. 40 CFR Part 143	Establishes national drinking water standards to protect human health from contaminants in drinking water	Chemical-specific Relevant and Appropriate as a performance standard for groundwater and surface water which are potential drinking water sources.

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Resource Conservation and Recovery Act	40 CFR 260, 261	Establishes identification standards and definitions for material is exempt from the definition of a hazardous waste.	Action-specific. Applicable to characterizing wastes generated from the action and designated for off-site or upland disposal; potentially relevant and appropriate for use in identifying acceptance criteria for confined in-water disposal.
RCRA – Solid Waste	40 CFR 257 Subpart A		RCRA Solid Waste requirements may be relevant and appropriate to remedial actions that result in upland or in-water disposal of dredged material. Requirements for the management of solid waste landfills may be relevant and appropriate to upland disposal.
Hazardous Materials Transportation Act	49 USC §5101 et seq. 40 CFR Parts 171-177		Hazardous Materials Transportation Act requirements are applicable to remedial actions that involve the transport of hazardous materials (i.e., dredged material)
Fish and Wildlife Coordination Act Requirements	16 USC 662, 663 50 CFR 6.302(g)	Requires federal agencies to consider effects on fish and wildlife from projects that may alter a body of water and mitigate or compensate for project-related losses, which includes discharges of pollutants to water bodies.	Action-specific. Potentially applicable to determining impacts and appropriate mitigation, if necessary, for effects on fish and wildlife from filling activities or discharges from point sources.
Magnuson-Stevens Fishery Conservation and Management Act	50 CFR Part.600.920	Evaluation of impacts to Essential Fish Habitat (EFH) is necessary for activities that may adversely affect EFH.	Location-specific. Potentially applicable if the removal action may adversely affect EFH.
Federal Emergency Management Act	44 CFR 60.3(d)(2) and (3)		FEMA flood rise requirements are considered relevant and appropriate requirements for remedial actions.
River and Harbors Act	33 USC 401 et seq. 33 CFR parts 320 to 323	Section 10 prohibits the unauthorized obstruction or alteration of any navigable water. Structures or work in, above, or under navigable waters are regulated under Section 10.	Action-specific. Applicable requirements for how remedial actions are taken or constructed in the navigation channel.
Clean Air Act	42 USC §7401 et seq.		Action-specific. Applicable to remedial activities that generate air emissions.

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Toxic Substances Control Act	15 USC §2601 et seq.		Chemical-specific. TSCA requirements are applicable to contaminated material or surface water with PCB contamination
Marine Mammal Protection Act	16 USC §1361 et seq. 50 CFR 216		Action-specific. Applicable to remedial actions that have the potential to affect marine mammals.
Migratory Bird Treaty Act	16 USC §703 50 CFR §10.12	Makes it unlawful to take any migratory bird. "Take" is defined as pursuing, hunting, wounding, killing, capturing, trapping and collecting.	Action-specific. Applicable to remedial actions that have the potential to effect a taking of migratory birds.
National Historic Preservation Act	16 USC 470 et seq. 36 CFR Part 800	Requires the identification of historic properties potentially affected by the agency undertaking, and assessment of the effects on the historic property and seek ways to avoid, minimize or mitigate such effects. Historic property is any district, site, building, structure, or object included in or eligible for the National Register of Historic Places, including artifacts, records, and material remains related to such a property.	Action-specific. Potentially applicable if historic properties are potentially affected by remedial activities.
Archeological and Historic Preservation Act	16 USC 469a-1	Provides for the preservation of historical and archeological data that may be irreparably lost as a result of a federally-approved project and mandates only preservation of the data	Action-specific. Potentially applicable if historical and archeological data may be irreparably lost by implementation of the remedial activities.

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Requires Federal agencies and museums which have possession of or control over Native American cultural items (including human remains, associated and unassociated funerary items, sacred objects and objects of cultural patrimony) to compile an inventory of such items. Prescribes when such Federal agencies and museums must return Native American cultural items. “Museums” are defined as any institution or State or local government agency that receives Federal funds and has possession of, or control over, Native American cultural items.	Location-specific; action-specific. If Native American cultural items are present on property belonging to the Oregon Division of State Lands (DSL) that is a part of the removal action area, this requirement is potentially applicable. If Native American cultural items are collected by an entity which is either a federal agency or museum, then the requirements of the law are potentially applicable.
Endangered Species Act	16 USC 1531 et seq. 50 CFR 17	Actions authorized, funded, or carried out by federal agencies may not jeopardize the continued existence of endangered or threatened species or adversely to avoid jeopardy or take appropriate mitigation modify or destroy their critical habitats. Agencies are to avoid jeopardy or take appropriate mitigation measures to avoid jeopardy.	Action-specific. Applicable to remedial actions, that may adversely impact endangered or threatened species or critical habitat that are present at the site.
Executive Order for Wetlands Protection	Executive Order 11990 (1977) 40 CFR 6.302 (a) 40 CFR Part 6, App. A	Requires measures to avoid adversely impacting wetlands whenever possible, minimize wetland destruction, and preserve the value of wetlands.	Location-specific. Relevant and appropriate in assessing impacts to wetlands, if any, from the response action and for developing appropriate compensatory mitigation for the project.
Executive Order for Floodplain Management	Exec. Order 11988 (1977) 40 CFR Part 6, App. A 40 CFR 6.302 (b)	Requirements for Flood Plain Management Regulations Areas Requires measures to reduce the risk of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains.	Location-specific. Relevant and appropriate for assessing impacts, if any, to the floodplain and flood storage from the response action and developing compensatory mitigation that is beneficial to floodplain values.
National Flood Insurance Act and Flood Disaster Protection Act	42 USC 4001 et seq. 44 CFR National Flood Insurance Program Subpart A	Requirements for Flood Plain Management Regulations Areas Requires measures to reduce the risk of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains.	Location-specific. Relevant and appropriate for assessing impacts, if any, to the floodplain and flood storage from the response action and developing compensatory mitigation that is beneficial to floodplain values.

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
State ARARs			
Oregon Environmental Cleanup Law ORS 465.315.	Oregon Hazardous Substance Remedial Action Rules OAR 340-122-0040(2)(a) and (c), 0115(3),(32) and (51).	Sets standards for degree of cleanup required, including for oil and other petroleum products/wastes. Establishes acceptable risk levels for human health at 1x10-6 for individual carcinogens, 1x10-5 for multiple carcinogens, and Hazard Index of 1 for noncarcinogens; and protection of ecological receptors at the individual level for threatened or endangered species and the population level for all others. OAR 340-122-0040 and 0115(3).	Chemical-specific: a risk-based numerical value that, when applied to site-specific conditions, will establish concentrations of hazardous substances that may remain or be managed on-site in a manner avoiding unacceptable risk.
	OAR 340-122-and (b), 340-122-0040(4) 0115(32)	For hot spots of contamination in water, requires treatment, if feasible, when treatment would be reasonably likely to restore or protect beneficial uses within a reasonable time. For hot spots contamination of sediments, requires treatment or excavation and off-site disposal of hazardous substances if treatment is reasonably likely to restore or protect such beneficial uses within a reasonable time.	Chemical-specific and action-specific: when contaminant concentrations fall within the definition of “hot spot” set forth in subpart 0115(32), treatment (including excavation and offsite disposal) of contaminated media to levels below such risk levels or beneficial-use impacts needs to be evaluated in the feasibility study.
Hazardous Waste and Hazardous Materials II	ORS 466.005(7) OAR 340-102-0011 - Hazardous Waste Determination	Defines "Hazardous Waste" and the rule contains the criteria by which anyone generating residue must determine if that residue is a hazardous waste.	Chemical- and Action-specific: specifies substantive requirements if remedial action will involve on-site treatment, disposal, or storage of RCRA-listed or characteristic hazardous waste. (Note: off-site treatment, storage, or disposal subject to all administrative and substantive state requirements.)
	Identification and Listing of Hazardous Waste OAR 340-101-0033	Identifies additional residuals that are subject to regulation as hazardous waste under state law.	Action-specific: specifies requirements if remedial action will involve on-site treatment, disposal, or storage of additional listed wastes.

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Solid Waste: General Provisions	Specific regulatory references to be provided by DEQ when alternatives are identified for FS analysis	Substantive Requirements for the location, design, construction, operation, and closure of solid waste management facilities.	Action-specific: applicable if upland disposal facility contemplated on-site for solid, nonhazardous, waste disposal, handling, treatment, or transfer. (Note: off-site transfer, treatment, handling, or disposal subject to all administrative and substantive state requirements.)
	Solid Waste: Land Disposal Sites Other than Municipal Solid Waste Landfills, specific regulatory references to be supplied by DEQ	Requirements for the management of solid wastes at land disposal sites other than municipal solid waste landfills.	Action-specific: applicable to the on-site management and disposal of contaminated sediment, soil, and/or groundwater.
Water Pollution Control Act ORS 468B.048	Water Quality Standards OAR 340-041-0340, Table 20 and Table 33A	DEQ is authorized to administer and enforce CWA program in Oregon. DEQ rules designate beneficial uses for water bodies and narrative and numeric water quality criteria necessary to protect those uses. OAR 340-041-0340 designates and defines the beneficial uses that shall be protected in the Willamette Basin. For the purposes of state law, Table 20 are the applicable criteria, unless there is a corresponding criterion under Table 33A, in which case Table 33A is applicable. (Note: if Oregon promulgates new criteria prior to ROD, such new criteria will be ARAR).	Chemical- and action-specific: applicable to any discharges to surface water from point sources, groundwater, overland flow of stormwater, and activities that may result in discharges to waters of the state, such as, dredge and fill, de-watering sediments, and other remedial activities. Relevant and appropriate as performance standards for sites and where contaminants are left in place.
Water Pollution Control Act ORS 468B.048	Regulations Pertaining to NPDES Discharges Specific regulatory references to be supplied by DEQ	Effluent limitations and management practices for point-source discharges into waters of the state (otherwise subject to NPDES permit but for on-site permit exemption).	Chemical- and Action-specific: applies state water quality standards and effluent limitations to point-source discharges to the Willamette River.

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
	Certification of Compliance with Water Quality Requirements and Standards ORS 468b.035	Provides that federally-approved activities that may result in a discharge to waters of the State requires evaluation whether an activity may proceed and meet water quality standards with conditions, which if met, will ensure that water quality standards are met.	Action-specific: Applicable to implementation of the remedial action (e.g., dredging, capping, and construction of confined disposal facility) that may result in a discharge to waters of the State.
	Rules Governing the Issuance and Enforcement of Removal-Fill Authorizations within Waters of Oregon Including Wetlands OAR 141-085 0680, 141-085-0695, 141-085-0710, 141-085-0765	Substantive requirements for dredge and fill activities in waters of the state, including in designated Essential Indigenous Anadromous Salmonid Habitat.	Action-specific: Applicable to remedial action dredge and fill activities, capping, and riverbank remediation.
ODFW Fish Management Plans for the Willamette River	OAR 635, div 500	Provides basis for in-water work windows in the Willamette River.	Action-specific. Potentially applicable to timing of implementation of the remedial action due to presence of protected species at the site.
Oregon Air Pollution Control ORS 468A et. seq.	General Emissions Standards OAR 340-226	DEQ is authorized to administer and enforce Clean Air program in Oregon. Rules provide general emission standards for fugitive emissions of air contaminants and require highest and best practicable treatment or control of such emissions.	Action-specific: applicable to remedial actions taking place in on-site uplands. Could apply to earth-moving equipment, dust from vehicle traffic, and mobile-source exhaust, among other things.
Oregon Air Pollution Control ORS 468A et. seq.	Fugitive Emission Requirements OAR 340-208	Prohibits any handling, transporting, or storage of materials, or use of a road, or any equipment to be operated, without taking reasonable precautions to prevent particulate matter from becoming airborne. These rules for "special control areas" or other areas where fugitive emissions may cause nuisance and control measures are practicable.	Action-specific: applicable to remedial actions taking place in on-site uplands. Could apply to earth-moving equipment, dust from vehicle traffic, and mobile-source exhaust, among other things

Table 3.4-1. ARARs for Remedial Action at the Portland Harbor Superfund Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Indian Graves and Protected Objects ORS 97.740-760		Prohibits willful removal of cairn, burial, human remains, funerary object, sacred object or object of cultural patrimony. Provides for reinterment of human remains or funerary objects under the supervision of the appropriate Indian tribe. Proposed excavation by a professional archeologist of a native Indian cairn or burial requires written notification to the State Historic Preservation Officer and prior written consent of the appropriate Indian tribe. Prohibits persons from excavating, injuring, destroying or damaging archeological sites or objects on public or private lands unless authorized.	
Archeological Objects and Sites ORS 358.905-955 ORS 390.235		Imposes conditions for excavation or removal of archeological or historical materials.	Location-specific; action-specific. Potentially relevant and appropriate if archeological material encountered.
	Survival Guidelines OAR 635-100-0135	Survival Guidelines are rules for state agency actions affecting species listed under Oregon's Threatened or Endangered Wildlife Species law.	Action-and location specific: Substantive requirements of Survival Guidelines relevant and appropriate to remedial activities affecting state-listed species.
Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment DEQ, 2007		Describes a process to evaluate chemicals found in sediment for their potential contribution to risk as a result of bioaccumulation. Provides alternative methods for developing sediment screening levels and bioaccumulation bioassay data.	To be Considered: in level of cleanup or standard of control that is protective.

Table 3.5-1. Sediment Contaminants with PRGs, Focused PRGs, SQVs, COC Designations, RGs, and RALs

Contaminant	Draft Final BERA and BHHRA Non-Water Contaminants Posing Potentially Unacceptable Risk	PRGs	PRG Above Background and Consistent with the Risk Assessments	Comprehensive Benthic Approach FPM and LRM SQVs	Sediment COCs[e]	EPA Focused PRGs	RALs
Metals							
Aluminum	X						
Antimony	X						
Arsenic [a]	X	X	X			X	
Cadmium	X			X			
Chromium				X			
Copper	X			X			
Lead	X	X		X			
Mercury	X			X			
Nickel							
Selenium	X						
Silver				X			
Zinc	X						
Tributyltin ion	X	X[b]		X			
Butyltins				X			
PAHs							
Benzo(a)anthracene	X	X	X	X			
Benzo(a)pyrene	X	*X*	*X*			X	
Benzo(b)fluoranthene	X	X	X	X			
Benzo(k)fluoranthene	X	X	X	X			
Dibenzo(a,h)anthracene	X	X	X	X			
Indeno(1,2,3-cd)pyrene	X	X	X	X			
Total cPAH (BaPEq)	X	X	X		X	X	X
Total LPAHs				X			
Total PAHs				X			
Total HPAHs				X			
2-Methylnaphthalene				X			
Acenaphthene				X			
Acenaphthylene				X			
Anthracene				X			
Benzo(g,h,i)perylene				X			
Chrysene				X			
Fluoranthene				X			
Fluorene				X			
Phenanthrene				X			
Pyrene				X			
Naphthalene							
Phthalates and SVOCs							
Bis(2-ethylhexyl)phthalate	X						
Dibutyl phthalate	X			X			
Diethyl phthalate							
Hexachlorobenzene	X	X	X				

Table 3.5-1. Sediment Contaminants with PRGs, Focused PRGs, SQVs, COC Designations, RGs, and RALs

Contaminant	Draft Final BERA and BHHRA Non-Water Contaminants Posing Potentially Unacceptable Risk	PRGs	PRG Above Background and Consistent with the Risk Assessments	Comprehensive Benthic Approach FPM and LRM SQVs	Sediment COCs[e]	EPA Focused PRGs	RALs
Pentachlorophenol	X						
4-methylphenol				X			
Benzyl Alcohol				X			
Carbazole				X			
Phenol				X			
Dibenzofuran				X			
PCBs							
PCB-77 (Surrogate for PCB TEQ)							
PCB-126 (Surrogate for PCB TEQ)		X	X				
Total PCBs	X	X	X	X	X	X	X
Total PCB TEQ	X	X	X				
Dioxins/Furans							
Dioxins/Furans					X		
2,3,4,7,8 PCDF (Surrogate for Dioxin/Furan TEQ)		X	X			X	X[c]
Total Dioxin/Furan TEQ	X	X	X				
Pesticides							
Aldrin	X	X	X			X	
Dieldrin	X	X	X	X			
Endrin				X			
Endrin Ketone				X			
Heptachlor Epoxide	X	X	X				
Total Chlordane	X	X	X			X	
Sum DDD	X	X	X	X			X[d]
Sum DDE	X	X	X	X		X	X[d]
Sum DDT	X	X	X	X			X[d]
Total DDx	X	X			X		
4,4'-DDD	X			X			
delta-HCH				X			
gamma-HCH							
beta-HCH				X			
Total endosulfan				X			
2,4'-DDD				X			
4,4'-DDE				X			
4,4'-DDT				X			
cis-Chlordane				X			
Petroleum Hydrocarbons							
Diesel-range hydrocarbons				X			

Notes:
a - Analytes in *italics* are fate and transport model chemicals
b - PRGs for TBT have changed due to updated TRVs (see BERA).
c - 2,3,4,7,8 PCDF RALs selected to represent dioxins/furans as directed by EPA for select alternatives (See Section 4).
d - Sum DDE, Sum DDD, and Sum DDT RALs represent total DDx. Sum DDE focused PRG selected by EPA to represent total DDx. Sum DDD and Sum DDT RALs are for select alternatives as directed by EPA (See Section 4).
e - COCs are defined in Risk Management Recommendations (Kennedy Jenks/Windward 2011)

Table 3.5-2. Focused PRGs and Path Forward for the Draft FS

Chemical	Line of Evidence	Value	Units	Notes	Exposure Area	Additional 10 and 17 March LWG Notes	Path Forward for FS
Metals							
Arsenic	Eco Benthic - PEL SQG	17	mg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Arsenic	Background DW UPL	3.97	mg/kg		Site-wide		Site already meets PRG on a Site-wide basis.
Cadmium	FPM High SQG	3.51	mg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Chromium	Eco Benthic - PEL SQG	90	mg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Copper	Eco Benthic - PEC SQG	149	mg/kg	This is lower than the FPM low SQG of 493 mg/kg	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Copper	Eco Benthic - FPM High SQG	562	mg/kg	Including both FPM and PEC is inconsistent with other decisions for most chemicals	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Lead	Eco Benthic - PEL SQG	91.3	mg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Mercury	Eco Benthic - FPM High SQG	0.41	mg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Nickel	Eco Benthic - PEL SQG	36	mg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Silver	Eco Benthic - FPM High SQG	1.72	mg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
TBT	Eco - Fish Dietary Assessment - Small Mouth Bass	5.93	mg/kg-OC	Covers all other TBT PRGs except sculpin below.	1 RM		LWG provided EPA with new literature references for fish TRV's related to TBT on July 8, 2010. Current LWG assessment: No TBT fish dietary risks at the site; will be presented in final BERA.
TBT	Eco - Fish Dietary Assessment - Sculpin	3.78	mg/kg-OC	Weak Line of Evidence	AOPC development - point by point, BERA - 1/10th rivermile	EPA would like to retain this PRG but acknowledges that there are uncertainties regarding sculpin exposure in deeper non-nearshore areas that can be discussed in the FS. EPA was unclear how the large additional area included outside the current localized AOPC boundaries should be handled in the FS (i.e., expansion of localized AOPCs or part of Site-wide AOPC). EPA also agreed that the LWG can evaluate data density and quality issues in the FS.	LWG provided EPA with new literature references for fish TRV's related to TBT on July 8, 2010. Current LWG assessment: No TBT fish dietary risks at the site; will be presented in final BERA.
Zinc	Eco Benthic - PEL SQG	315	mg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach

Table 3.5-2. Focused PRGs and Path Forward for the Draft FS

Chemical	Line of Evidence	Value	Units	Notes	Exposure Area	Additional 10 and 17 March LWG Notes	Path Forward for FS
PAHs							
BaP	HH Clam Consumption, High Consumption Rate 18 g/day, 10^{-5}	5.9	mg/kg-OC	Weak Line of Evidence	1 RM, excluding navigation channel, (E and W separate)	EPA considered making alternative water depth or consumption exposure assumptions but prefers using assumptions consistent with the risk assessment.	Exposure area was modified to areas above Ordinary Low Water (5.1 NAVD 88) because clams cannot be reasonably harvested under water. Only applied to areas identified in the risk assessment as having risk for this pathway, risk level, and chemical.
BaPEq	HH Tribal Fisher In-water Direct Contact 10^{-6} (cPAH)	423	µg/kg	Cut off at AOPC lines per EPAs June 2009 AOPC development rules	1/2 RM, excluding navigation channel, (E and W separate)	EPA indicated that cutting areas at the AOPC boundary lines is not a rigid rule and the LWG should understand that the future boundary lines might vary somewhat based on the distribution of the chemical concentrations. The exact methods for the LWG to determine these variations is unclear.	Applied on a 1/2 river mile basis outside of the navigation channel. No adjustments for consistency with the risk assessment were needed. Areas outside of existing AOPCs were not included, per EPA agreement, and are evaluated as part of the Site-wide AOPC.
BaPEq	HH HF Fisher Beach Sediment Direct Contact 10^{-6} (cPAH)	162	µg/kg		Beach Type	EPA considered whether this PRG would be part of the Site-wide AOPC or not. They decided that because BaP clam consumption PRG above highlights this same area, that there is no additional area created and this BaP beach PRG should be included as part of the localized AOPCs.	Applied to tribal fisher beaches. Only two beaches in the Study Area were identified as consistent with this pathway and risk level. One is located in AOPC 5 and included in the SMAs. The other beach is outside of the EPA AOPCs and is located downstream of Multnomah channel. This area will be evaluated as part of the Site-wide AOPC.
Total LPAHs	Eco Benthic - FPM High SQG	9300	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Total PAHs	Eco Benthic - PEC SQG	22800	µg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
SVOCs							
4-methylphenol	Eco Benthic - FPM High SQG	96	µg/kg	Issues of High Non-Detect and/or High Non-Detect Frequencies	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Benzyl Alcoh	Eco Benthic - FPM High SQG	36	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Carbazole	Eco Benthic - FPM High SQG	1100	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Phenol	Eco Benthic - FPM High SQG	120	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Phthalates							
Diethyl Phtha	Eco Benthic - FPM Low SQG	120	µg/kg	EPA said use FPM high, but one does not exist, so FPM Low is shown	Point by Point	EPA would prefer is some more relevant chemical or phthalate were provided by the FPM model. EPA indicated that the chemical list available from the FPM model should be further considered in the FS comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach

Table 3.5-2. Focused PRGs and Path Forward for the Draft FS

Chemical	Line of Evidence	Value	Units	Notes	Exposure Area	Additional 10 and 17 March LWG Notes	Path Forward for FS
PCBs							
Total PCBs	HH Adult Fish Consumption - Small Mouth Bass - Low IR - 10^-4	29.5	µg/kg	Cut off at AOPC lines per EPAs June 2009 AOPC development rules	1 RM	EPA indicated that cutting areas at the AOPC boundary lines is not a rigid rule and the LWG should understand that the future boundary lines might vary somewhat based on the distribution of the chemical concentrations. The exact methods for the LWG to determine these variations is unclear.	Applied on a river mile basis. Applied throughout the Site, because fish move throughout the river. The extent of AOPC 25 was modified to include the extent of the SMA created by this PRG since new data was collected in these area since the AOPC lines were drawn. Limited areas outside of existing AOPCs were not included, per agreement with EPA and are evaluated as part of the Site-wide AOPC.
Total PCBs	Background DW UPL	17	µg/kg	Cut off at AOPC lines per EPAs June 2009 AOPC development rules	Site wide	EPA indicated that cutting areas at the AOPC boundary lines is not a rigid rule and the LWG should understand that the future boundary lines might vary somewhat based on the distribution of the chemical concentrations. The exact methods for the LWG to determine these variations is unclear.	Will be evaluated using Fate and Transport Model to determine whether background levels are met on a Site-wide basis.
Total PCBs	Eco Benthic - FPM High SQG	500	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Dioxin Furans							
2,3,4,7,8 PCDF	Eco Bird Dietary Assessment - Sandpiper Worms	0.0541	µg/kg		Beach Type	Sandpiper PRGs should be mapped to sand piper beaches. (Not wide shoreline sediments in general).	Applied to sand piper beaches consistent with BERA.
2,3,4,7,8 PCDF	HH Adult Fish Consumption, Small Mouth Bass Low IR, 10^-4	0.0205	µg/kg		1 RM	EPA agreed to move the 10^-5 PRG to the Site-wide AOPC, but would like to continue to look at the 10^-4 PRG within the localized AOPCs.	Applied on a river mile basis. Applied throughout the Site because fish move throughout the Site.
2,3,4,7,8 PCDF	Eco - Mink Multi-Species Diet	0.056	µg/kg		1 RM		Applied on a river mile basis.
Pesticides							
Total Chlordane	HH Fish Consumption - Large Home Range Single Species High IR, Low BA 10^-6	1.87	µg/kg		Study Area		Mapped on a Site wide basis and carried into the FS with no refinements.
delta-HCH	Eco Benthic - FPM High SQG	2.35	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach

Table 3.5-2. Focused PRGs and Path Forward for the Draft FS

Chemical	Line of Evidence	Value	Units	Notes	Exposure Area	Additional 10 and 17 March LWG Notes	Path Forward for FS
Aldrin	HH Fish Consumption - Large Home Range Single Species High IR, Low BA 10^$^{-6}$	0.84	µg/kg		Study Area	Given that a very small area maps out for PRG that is totally covered by other PRGs, the LWG may want to consider accepting this PRG.	PRG is already met on a Site-wide SWAC-basis. No other PRG was substituted because this was the only aldrin fish consumption PRG above background and consistent with the BHHRA
Dieldrin	Eco Benthic - FPM High SQG	21.5	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Endrin	Eco Benthic - FPM High SQG	20.8	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Endrin Ketone	Eco Benthic - FPM High SQG	8.5	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Gamma HCH	Eco Benthic - PEL SQG	1.38	µg/kg	Issues of high Non-Detect (923 of 1106 samples in BERA dataset were non-detect). No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Sum DDD	Eco Benthic - PEC SQG	28	µg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Sum DDE	Eco Benthic - PEC SQG	31.3	µg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Sum DDE	HH Adult Fish Consumption, Small Mouth Bass Low IR, 10^$^{-5}$	8.8	µg/kg		1 RM		EPA Focused PRG of Sum DDE HH adult fish consumption, small mouth bass (SMB) low IR, 10^{-5} is inconsistent with the BHHRA (risk does not exceed 10^{-5}). Sum DDE HH adult fish consumption, 10^{-6} large home range fish, low BA, low IR = 3.02 µg/kg was substituted. Results in a similar mapped area applied on a Site-wide basis.
Sum DDT	Eco Benthic - PEC SQG	62.9	µg/kg	No FPM SQG exists	Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach
Total DDX	Eco Benthic - FPM High SQG	218	µg/kg		Point by Point	Benthic SQG that will be further evaluated in comprehensive benthic approach.	Evaluated using Comprehensive Benthic Approach

Note:
PRGs where there is disagreement between LWG and EPA that has significant impact on the current AOPC boundaries.
PRGs referenced in EPA's AOPC Development Rules, June 2009

Table 3.5-3. Level Three SQVs from Floating Point Model

Analyte	Units	Chironomus Growth Level 3	Chironomus Survival Level 3	Hyalella Growth Level 3	Hyalella Survival Level 3
Cadmium	mg/kg	3.51	3.51	3.51	3.51
Chromium	mg/kg	na	na	**45.9**	na
Copper	mg/kg	562	na	562	562
Lead	mg/kg	na	na	na	na
Mercury	mg/kg	0.624	0.722	**0.235**	0.722
Nickel	mg/kg	na	na	na	na
Silver	mg/kg	1.72	1.72	1.72	1.72
Zinc	mg/kg	na	na	na	na
Total HPAHs (calc'd)	µg/kg	610,000	610,000	1,300,000	1,300,000
Total LPAHs (calc'd)	µg/kg	650,000	**2,000**	650,000	**2,000**
Benzyl alcohol	µg/kg	36	36	36	36
Carbazole	µg/kg	1,100	2,500	**8,500**	30,000
Dibenzofuran	µg/kg	**340**	7,200	**170**	7,200
4-Methylphenol	µg/kg	**80**	**260**	**260**	**260**
Pentachlorophenol	µg/kg	na	na	na	na
Phenol	µg/kg	120	120	120	120
Total PCBs (calc'd)	µg/kg	**500**	3,500	3,500	3,500
Aldrin	µg/kg	na	na	na	na
beta-Hexachlorocyclohexane	µg/kg	10.8	10.8	10.8	10.8
delta-Hexachlorocyclohexane	µg/kg	2.35	2.35	**1.29**	2.35
Dieldrin	µg/kg	21.5	21.5	21.5	21.5
Endrin	µg/kg	20.8	20.7	na	na
Endrin ketone	µg/kg	8.5	8.5	8.5	8.5
Sum DDD (calc'd)	µg/kg	**114**	**331**	2,460	2,460
Sum DDE (calc'd)	µg/kg	906	906	**906**	**906**
Sum DDT (calc'd)	µg/kg	8,110	8,110	8,110	**8,110**
Total Chlordane (calc'd)	µg/kg	na	na	na	na
Total Endosulfan (calc'd)	µg/kg	**2.42**	na	na	na
Ammonia	mg/kg	276	334	**168**	334
Sulfide	mg/kg	**38.5**	**38.5**	**336**	**336**

Notes:
na: SQV > Maximum concentration in Bioassay Dataset
bold SQGs < AET

Table 3.5-4. Proposed List of RGs and Refined Focused PRGs for the Draft FS

Chemical	RG or Focused PRG - and Rationale	Line of Evidence	Value	Units	Exposure Area
BaP	PRG - due to substantial uncertainty associated with this scenario, the LWG does not recommend use of the term "Focused" in refernce to this PRG.	HH Clam Consumption, High Consumption Rate 18 g/day, 10^{-5}	5.9	mg/kg-OC	1 RM, excluding navigation channel, (E and W separate)
BaPEq	RG - Site COC per RM Report	HH Tribal Fisher In-water Direct Contact 10^{-6} (cPAH)	423	µg/kg	1/2 RM, excluding navigation channel, (E and W separate)
BaPEq	RG - Site COC per RM Report	HH HF Fisher Beach Sediment Direct Contact 10^{-6} (cPAH)	162	µg/kg	Beach Type
Total PCBs	RG - Site COC per RM Report	HH Adult Fish Consumption - Small Mouth Bass - Low IR - 10^{-4}	29.5	µg/kg	1 RM
Total PCBs	Focused PRG - Substantial uncertainty exists with the determination of appropriate background levels	Background DW UPL	17	µg/kg	Site-wide Hilltop
2,3,4,7,8 PCDF	Focused PRG - Not a COC in the RM Report.	Eco Bird Dietary Assessment - Sandpiper Worms	0.0541	µg/kg	Beach Type
2,3,4,7,8 PCDF	RG - Site COC per RM Report	HH Adult Fish	0.0205	µg/kg	1 RM
2,3,4,7,8 PCDF	RG - Site COC per RM Report	Eco - Mink Multi-Species Diet	0.056	µg/kg	1 RM
Total Chlordane	Focused PRG - Not a COC in the RM Report.	HH Fish Consumption - Large Home Range Single Species High IR, Low BA 10^{-6}	1.87	µg/kg	Site

Table 3.5-4. Proposed List of RGs and Refined Focused PRGs for the Draft FS

Chemical	RG or Focused PRG - and Rationale	Line of Evidence	Value	Units	Exposure Area
Sum DDE	RG - Site COC	HH adult fish consumption, 10^{-6} large home range fish, low BA, low IR	3.02	µg/kg	Site
MQ	RG - Site COCs per RM Report	Comprehensive Benthic Risk Approach	0.7	NA	Point by Point

Note:

Focused PRGs identified for the Benthic Line of Evidence are evaluated using the Comprehensive Benthic Risk Approach.

Table 3.6-1. Summary of RG Estimates within the Overall Range of RG Ranges Used for Evaluation of Alternatives (see Appendix E for details)

COC	Exposure Assumption	RG	Risk Type (Cancer/ Noncancer)	Description
Total PCBs (µg/kg)	Smallmouth Bass Whole Body Consumption	5	10^{-5} cancer	95th percentile RG
		13	Noncancer	90th Percentile
		23	**10^{-4} cancer**	**99th percentile RG**
		29.5	**10^{-4} cancer**	**EPA's point estimate**
		95	**10^{-4} cancer**	**95th percentile RG**
	Smallmouth Bass Fillet with Skin Consumption	14	10^{-5} cancer	99th percentile RG
		45	Noncancer	95th percentile RG
		71	10^{-5} cancer	95th percentile RG
	Smallmouth Bass Fillet without Skin Consumption	18	10^{-6} cancer	95th percentile RG
		26	Noncancer	99th percentile RG
		58	10^{-6} cancer	90th percentile RG
Total PCBs (µg/kg)	Ecological - Mink	31		EPA point estimate
		36		5th percentile lower bound RG
		79		5th percentile RG
Total Background PCBs (µg/kg)		**5**		**Kaplan-Meier 95% UCL**
		17		EPA Focused PRG Background
		37		**Kaplan-Meier 95% UPL with a Certain Non-Detect Substitution Scenario**
BaPEq (µg/kg)	Tribal Fisher Sediment Direct Contact	**423**	**10^{-6} cancer**	**EPA point estimate (>99th percentile)**
		1,437	**10^{-6} cancer**	**99th percentile RG**
		2,750	**10^{-6} cancer**	**95th percentile RG**
		3,702	**10^{-6} cancer**	**90th percentile RG**
		14,367	10^{-5} cancer	99th percentile RG
		27,496	10^{-5} cancer	95th percentile RG
		37,020	10^{-5} cancer	90th percentile RG

Notes:

UCL – Upper Confidence Limit

UPL – Upper Probability Limit

RGs in **bold** are those used in later draft FS evaluations as generally representative of the overall relevant RG ranges shown in this table.

Section 3 described the COCs and RGs that are used in the draft FS to develop and evaluate remedial alternatives. Section 4 describes, for select RG COCs, the RALs that were developed to define areas of sediment that are actively remediated (SMAs) under each alternative that will be described and evaluated later in this draft FS. RALs were developed for the bounding COCs of PCBs, BaP, DDD, DDE, DDT, and PCDF, and areas posing potentially unacceptable benthic risk via multiple contaminants were defined through additional methods described below. These RALs are developed with the understanding that remediation focusing on the bounding COCs (and potentially unacceptable risks to benthos) will also address the remaining contaminants potentially posing unacceptable risk based upon the contaminant distributions described in the RI and Sections 2.2 and 5.5 of the draft FS. RALs are an efficient way of identifying areas that may require active remediation without conducting an analysis of every contaminant posing potentially unacceptable risk. RALs for each of the bounding COCs are combined into groups of RALs across a scale of progressively lower and more conservative RALs, which are then used in Section 5 to define active remediation areas (i.e., SMAs). The uncertainties associated with RAL development and their impact on RAL selections are also discussed at the end of Section 4.

4.0 REMEDIAL ACTION LEVELS (RALS) DEVELOPMENT

This section describes the process of developing RALs for use in the draft FS. By definition, RALs are point concentrations that exceed RGs and require active remediation. Whereas RGs are set to achieve protection over long time spans and over large spatial areas for some receptors, RALs are set to achieve point-by-point concentrations immediately after active remedy construction is completed. The overall concept is that RGs can be met over longer periods of time and over larger relevant exposure areas through a combination of immediate or near-term active remedies in limited areas above the RALs and MNR processes throughout the entire Site. Thus, the active remedy defined by the RAL helps achieve the RG over larger areas and longer time spans. The effectiveness of MNR to assist active remedies in attaining RALs was extensively evaluated using empirical information collected for the RI/FS and detailed modeling based on this information. This evaluation is described more in Section 6.2.

This section extensively discusses RGs, RALs, future sediment concentrations predicted from modeling, and background levels in sediments. As discussed in Section 1, generally for the draft FS, there are uncertainties associated with the calculation of values for each of these parameters that must be considered to select RALs in an informed manner. Appendix E discusses the uncertainties associated with each of these parameters, and these uncertainties are summarized in main sections of this draft FS (e.g., Section 3.6 summarizes RG uncertainties).

4.1 RALS AND FS APPROACH

RALs are developed with the understanding that remediation focusing on the bounding COCs (and potentially unacceptable risks to benthos) will also address the remaining contaminants potentially posing unacceptable risk. RALs are an efficient way of identifying areas that may require active remediation without conducting an analysis of every contaminant posing potentially unacceptable risk.

Where areas exceeding the RAL are actively remediated, the RG is expected to be met in time (i.e., following natural recovery) over its applicable exposure area, which is set to be consistent with risk assessment methods used for the Site. For example, an RG developed based on consideration of potentially unacceptable risks to human health associated with consumption of fish with a large home range (including specific assumptions about consumption rates, cancer risk levels, and other exposure parameters) would usually be assessed over the entire Site consistent with the risk assessment methods. Thus, RALs selected to achieve such an RG would result in a Site-wide average concentration that is below the RG either immediately after active remedy implementation or with time through additional recovery across the Site. Similarly, an RG developed based on consumption of smaller home range fish (e.g., the smallmouth bass range is conservatively assumed for the BHHRA to be approximately 1 river mile) would usually be assessed over that smaller spatial scale. The design of the RALs also needs to account for the uncertainties in the RGs and the predictions of the long-term average concentration estimated to be achieved by any RAL. These uncertainties are discussed more in Section 4.5. Because of these uncertainties, some SMA-specific refinements of RALs may be appropriate during remedial designs.

For the purposes of the draft FS, a range of possible RALs is developed for bounding COCs considering the magnitude of risk reduction achieved (as measured by changes in average surface sediment contaminant concentrations) and the rate of anticipated natural recovery. This range of RALs will be used to develop a range of remedial alternatives considered later in the draft FS. At many sediments sites, a combination of active remediation measures (triggered by the RALs), natural recovery processes, and institutional controls often best meets overall CERCLA requirements (EPA 2005a). As discussed above, RALs are not the same as RGs. RALs provide specific values, and the remedial design documents (construction drawings and specifications) can be developed based upon these values. As indicated by later analyses in this section and Sections 8 and 9, it is reasonable to expect that RGs can be achieved at the Site by several different RALs.

For the purposes of the draft FS, a range of possible RALs is developed for bounding COCs considering the magnitude of risk reduction achieved (as measured by changes in average surface sediment contaminant concentrations) and the rate of anticipated natural recovery.

The development and use of RALs for this draft FS is based on two premises. First, immediately after active remediation is complete in areas exceeding RALs, SWACs[1] for bounding COCs will be lower than pre-remediation conditions. Second, following completion of active remediation, areas inside and outside the actively remediated area will continue to undergo natural recovery processes. The potentially unacceptable risk,

[1] For purposes of estimating Site-wide, Segment and river mile SWACs for the draft FS, the Study Area boundaries were considered to be the Site. Also, the area of the McCormick and Baxter remediation cap near RM 7 was not included in the calculation. This may result in conservative estimate (higher value) SWACs in some cases, particularly in river miles near RM 7.

or residual risk, in sediments after active remediation decreases over time and is estimated in terms of surface sediment SWACs as a function of time after the active remediation is complete.

RALs are developed using a simple approach of identifying an area using NN contouring (a geo-statistical method of interpolating sediment data that is described more in Section 5) above the potential RAL in question and then examining the SWAC achieved via assumed active remediation of that area. A simple example of this approach is shown in Figure 4.3-1 using PCBs. The figure shows that as the value of the RAL decreases (top axis), the area actively remediated increases (bottom axis), and the SWAC achieved by this active remediation decreases (y-axis). The SWAC reduction achieved is time-dependent, given that natural recovery processes will occur over time and the SWAC immediately after construction will be different than the SWAC, for example, 30 years after construction. Thus, the same RAL applied to the same area will achieve different SWACs over time (as indicated by the different color curves in Figure 4.3-1, as an example). The SWACs achieved at time zero, immediately after construction, can be estimated based on expected outcomes of typical dredging and capping remedial efforts and measured concentrations outside of the area of active remediation. The QEAFATE contaminant fate model (Appendix Ha) is used in the draft FS to predict future post-remediation conditions that vary over time (i.e., after time zero). Fate modeling approaches to defining the long-term outcomes associated with possible remedial alternatives are a commonplace tool at sediment sites. Various models of this type have been used in the Duwamish (AECOM 2010), Fox (EPA 2003b), Hudson (EPA 2000a), and Housatonic (EPA 2006b; Arcadis et al. 2010) Rivers, to name a few, to help determine long-term remediation goals. The fate modeling approach allows an assessment of RALs that can achieve various RGs at specified time periods following remediation (incorporating all of the fate and transport processes represented in the model), and simultaneously assesses long-term chemical changes over other areas of the Site that are not dredged or capped.

For this draft FS, ranges of RALs were developed for bounding COCs that have been shown in the risk management recommendations (Kennedy Jenks and Windward 2011) to be primary contributors to potentially unacceptable risks at the Site overall, as reviewed in Section 3.1. These bounding COCs encompass potentially unacceptable risks associated with other contaminants. Section 5.9 contains additional analysis of the contaminant overlapping found at the Site. Consistent with risk management recommendations, the bounding COCs selected for RAL development by LWG were:

For this draft FS, ranges of RALs were developed for bounding COCs that have been shown in the risk management recommendations to be primary contributors to potentially unacceptable risks at the Site overall. These bounding COCs encompass the areas of potentially unacceptable risks associated with other contaminants. Section 5.9 contains additional analysis of the overlapping distributions of contaminants found at the Site.

- Total PCBs, particularly due to widespread potentially unacceptable risks to human health from smallmouth bass consumption and/or ecological mink dietary risks.
- BaPEq, particularly due to relatively widespread potentially unacceptable risks to human health from in-water direct contact with sediments, and to a lesser extent, potential shellfish consumption.
- Sum-DDE, particularly due to relatively localized potentially unacceptable risks near RM 7 to human health via fish consumptions (either smallmouth bass or large home range fish).
- Benthic toxicity (defined as comprehensive benthic risk areas where potentially unacceptable benthic risks are estimated to occur rather than via a COC concentration, as described in Section 3.5).

EPA provided comments requiring that the draft FS contain RALs for some additional contaminants (EPA 2011f); therefore, the LWG added these RALs for some alternatives for the following additional COCs (LWG 2011b and see Appendix O):

- Sum-DDD due to relatively localized potentially unacceptable risks near RM 7
- Sum-DDT due to relatively localized potentially unacceptable risks near RM 7
- 2,3,4,7,8-PCDF as a surrogate for overall dioxin/furan potentially unacceptable risks.

As a reminder, RALs are developed with the understanding that remediation focusing on these bounding COCs (and potentially unacceptable risks in the case of benthos) will also address the remaining contaminants posing potentially unacceptable risk. An analysis of how the bounding COCs/risks address other COCs and their associated RGs, as well as the larger list of contaminants posing potentially unacceptable risk and their associated PRGs, is presented in Section 5.9.

COCs with defined RALs are not the only contaminants that require remediation. Rather, focusing on the COCs with RALs provides a means to design a remedy to address all contaminants posing potentially unacceptable risk.

Overall, RALs for bounding COCs are an efficient way of identifying areas that may require active remediation without conducting an analysis of every contaminant posing potentially unacceptable risk. Even though a RAL may not have been developed for a specific contaminant potentially posing unacceptable risk at the Site, remediation may still be necessary for that contaminant in some or many portions of the Site. Thus, COCs with defined RALs are not the only contaminants that require remediation. Rather, focusing on the COCs with RALs provides a means to design a remedy to address all contaminants posing potentially unacceptable risk.

4.2 RAL DEVELOPMENT METHODS

As noted above, a range of RALs was developed for each COC that produced different areas/volumes of sediment to be actively remediated, levels of risk reduction immediately after completion of remedy construction, and timeframes for achieving RGs. This range of RALs allows a broad array of remedial alternatives to be defined for the draft FS.

Also as noted above, a combination of technically feasible active remediation, natural recovery, and institutional controls is commonly used to achieve RGs. This combined approach for achieving RGs is particularly useful for RGs based on human health fish consumption and where RG ranges are close to or overlap with the uncertainty ranges of background estimates. Methods to evaluate how these approaches attain RGs are described below. RALs for DDD, DDT, and 2,3,4,7,8-PCDF were also added for some alternatives as a requirement by EPA (EPA 2011f). EPA's rationale for some of these RALs may differ from the methods described below, and is generally described in EPA (2011f). The LWG methods of determining RALs are based on the following concepts:

- Maximum Incremental Reduction. Maximum incremental reduction in the SWAC is a practicability assessment. It evaluates the incremental reduction, which is the rate of SWAC reduction as a function of the RAL, and identifies the point at which the incremental reduction starts to decline. The maximum incremental reduction was explored for total PCBs, BaPEq, and DDE. (EPA conducted other evaluations related to DDD, DDT, and 2,3,4,7,8-PCDF RALs [EPA 2011f].) The incremental reduction is expressed as curves plotting the relationship between SWACs and acres remediated (see Figure 4.3-1 as an example). The maximum incremental reduction occurs before the "knee of the curve" (e.g., Figure 4.3-1). As discussed more below, RALs within the zone of these curves were selected for alternative development for each RAL COC addressed.
- Point of Minimal Change in Concentration. Predicted concentrations will reach a point where minimal change in SWAC is expected to occur as more acres are remediated. This point is known as the "asymptote," which occurs after the "knee of the curve." The estimated rate of change (SWAC reduction per acre remediated) is expected to be sufficiently small after this point is reached that the Site is approximately in equilibrium. As discussed more below, one RAL within the zone of minimal change was selected for alternative development for each RAL COC addressed.
- Sensitivity/Uncertainty of SWACs Achieved by RALs. As discussed more in Section 4.5, the uncertainties associated with the calculation of the SWAC achieved by RALs over various time periods, either through mapping exercises (for time zero SWACs) or through modeling (for future SWACs years after construction), are characterized as "medium" uncertainties as compared to RG uncertainties. (These categories of uncertainty are defined in the conclusion of Appendix E and summarized in Section 3.6.)

> *Consistent with EPA guidance (2005a), a range of RGs is typically presented in the draft FS for EPA's assessment. The ranges of RGs were determined through the PRG/SMA uncertainty/ sensitivity analysis and compared to estimated SWACs achieved by RALs.*

- RG Sensitivity/Uncertainty. The SWACs achieved by each RAL are compared to a range of potentially relevant RGs discussed in Section 3 for each COC. Just as there is uncertainty in the SWAC achieved, as noted above, there is uncertainty associated with threshold (RG) that the SWAC is compared against. Consistent with EPA guidance (2005a), a range of RGs is typically presented in the draft FS for EPA's assessment. Consequently, the RALs were not selected to achieve SWACs that meet one select RG with certainty at some particular time interval. Rather, the range of RGs was determined through the PRG/SMA uncertainty/sensitivity analysis (see Appendix E [Section 5]; also summarized for RGs in Section 3.6), and these ranges of RGs were compared to estimated SWACs achieved by RALs.
- Time period of remedy. As noted previously, SWACs achieved by various RALs were estimated for time zero (immediately after active remedy construction) as well as in the future using model estimates of future SWACs. For RAL development purposes, SWACs were also estimated for 10 and 30 years after active remedy construction, accounting for natural recovery processes occurring throughout the Site. These time periods were selected based on timeframes that are often evaluated in sediment remediation projects, with the longer time periods often being assessed to address the potential for long-term attainment of relatively low human health fish consumption assumed acceptable risk levels (e.g., Fox River). As discussed more below, because the RI and Site CSM (Section 2.6) indicate that natural recovery is taking place, RAL selection focused on the year 10 and 30 SWAC estimates. Although the degree of natural recovery varies spatially across the Site and by contaminant and there is some uncertainty with the evaluations (see Section 4.5), the evidence clearly supports that some natural recovery of the system is taking place (see Section 6.2.2 and Appendix Ha)).
- Spatial Scale of Assessment. SWAC estimates are compared to RG ranges on spatial scales relevant to the risk assessment exposure assumptions underlying the RGs. These spatial scales range from the entire Site (referred to as "Site-wide") to shoreline half river miles. RAL curves are therefore developed across these spatial scales. As with other elements of this analysis, there are uncertainties associated with these spatial scales. For example, it is not known for certain whether human health smallmouth bass consumption occurs primarily over approximate 1-river mile exposure areas, although this is the assumption used in the BHHRA. Consequently, RALs were not selected such that a specific RG (given the uncertainty ranges for those values) must be attained at a specific spatial scale. Rather, RALs that achieve a range of RGs over a range of spatial scales (e.g., from Site-wide down to half shoreline river miles for some COCs) were selected.

- Vertical Point of Compliance. SWAC estimates discussed below are determined using the vertical sediment bed weighted-average up to 30 cm below the mudline. This vertical point of compliance is consistent with the RI and risk assessments, which assumed that exposures were generally within this top 30 cm interval.

Using the above concepts, RALs are selected over a range of areas, RGs, time periods, and spatial scales (i.e., dimensions of the analysis) for use in alternative development. In general, RALs should be selected that span the area of maximum incremental reduction of the SWAC, because this is the region in which the greatest changes in remedy effectiveness will occur. In addition, the low end of the RAL range should include a RAL that is clearly on the asymptote of minimal change for comparative purposes in the draft FS, and for similar comparisons, the other end of the RAL range should include a value relatively high in the region of maximum incremental reduction. Although the overall range of RALs should include the asymptote portion of the curve, having multiple alternatives built upon RALs in this zone of minimal change will likely not provide much additional information for the alternatives analysis. This is because very little change in effectiveness is seen in this region of the curves, and thus, the effectiveness of all RALs in this asymptote region are very similar and provide no differentiation in the detailed evaluation of alternatives. Further, as discussed below and later in the draft FS, when MNR over longer periods of time (e.g., 30 to 45 years) is considered, there are relatively small differences in the SWACs achieved by most of the RALs.

As noted above, RALs are evaluated over a range of spatial scales from the entire Site to a half river mile shoreline. As described in Section 2.9, the four Site segments (approximately 3 river miles each in size) developed for alternatives analysis are useful in that they represent an intermediate scale within this range that can be used to compare to a wide range of RGs. Although RAL curves are not developed on this segment scale, performance of alternatives relative to the SWACs achieved within each segment is evaluated in Section 8 and 9. These segments provide a good intermediate scale with which to evaluate the consistency of SWAC attainment when the same RALs are used across the Site, and it helps to identify areas where the RALs attain substantially higher or lower SWACs over time that may be significant in terms of alternatives evaluation. In cases where substantially different SWACs are attained in one segment as compared to the other three, this may indicate the need for further modifications or refinements to the alternative in question either in the draft or final FS, or as part of remedy refinements in the Proposed Plan by EPA. Further, where substantial uncertainties about the applicability of RALs in a particular area may exist, additional refinement of RALs is expected for specific remedial designs, as needed.

The uncertainties discussed above associated with the dimensions of the RAL analysis should not be taken to indicate that RAL selection is so uncertain as to be meaningless. Rather, these overall uncertainties indicate that it is more important to capture an adequate range of RALs to understand the relationships between RALs and the various FS evaluation criteria (e.g., short- and long-term effectiveness, ARAR attainment, feasibility, and costs) than it is to select one specific RAL versus another for any given alternative.

4.3 RAL RANGE SELECTION AND DETAILED METHODS BY COC

This section reviews the process of RAL range selection using the above methods for each COC discussed above.

4.3.1 Total PCB RALs

Figure 4.3-1 shows how the Site-wide total PCB SWAC would change across a range of assumed active remediation acreages and their associated RALs. The three curves on the plot indicate the resulting SWACs after active remediation at time zero immediately after active remedy construction, 10 years after construction, and 30 years after construction.

To develop these curves, application of select potential RALs were modeled as shown on the top x-axis. “No Action” on this axis refers to a model run that assumes zero area of active remediation. The acreage assumed to be actively remediated at each RAL value is shown on the bottom x-axis.

Some details underlying the development of Figure 4.3-1 are worth noting. First, for all three curves shown in the figure, an estimated SWAC achieved immediately after construction must be estimated. The issues related to achieving low contaminant concentrations using various sediment remedial technologies is discussed more in Section 6.2 and include dredge residuals and other factors. The RAL curve development here assumes a post-construction sediment concentration at time zero that is consistent with dredge evaluations discussed more in Section 6.2 and Appendix Ib. These estimates account for the effect of dredge residuals during remediation as well as placement of post-dredge suitable sand cover to help address residuals as part of the active remediation.

Second, to develop the 10- and 30-year curves, the calibrated QEAFATE contaminant fate model (Appendix Ha) was used and assumes that all active remediation is completed at time zero, without significant natural recovery to the system during the active remediation period. This is a simplifying and conservative assumption used for RAL development purposes only; detailed modeling and evaluations of alternatives in Section 8 include assessment of Site recovery processes both during and after construction. The no-construction-period assumption for RAL development is not expected to greatly impact RAL ranges, as evidenced by the relatively small difference between the 10-year and 30-year plots. This illustrates that adding additional time to the modeling period does not substantially impact the Site-wide SWACs achieved over longer timeframes for total PCBs, particularly for mid- to lower-range RALs.

Third, Figure 4.3-1 shows RAL curves on a Site-wide SWAC basis. As noted above, SWAC estimates are compared to RG ranges on several spatial scales relevant to the risk assessment exposure assumptions underlying the RGs. For total PCBs, there is a Focused PRG range based on Site-wide achievement of background ranges as presented in Section 3.6. The Site-wide RAL curve is most appropriately compared to this total PCB background Focused PRG range. RAL curves based on the 1-river mile spatial scale are also developed and presented in Appendix Db to help further assess where RALs attain RG ranges on this scale. The PCB SWACs estimated to be achieved in various river miles under various time periods and RALs are listed in Table 4.3-1, and Table 4.3-2 notes the number of river miles expected to achieve the smallmouth bass whole body point estimate RG of 29.5 ppb. As noted in Section 3.6, care should be taken in comparing to point estimates of any RGs, and the uncertainty/sensitivity ranges for those RGs should always be considered. For example, Table 4.3-1 compares estimated SWACs on a river mile basis to one representative RG range based on smallmouth bass whole body consumption, which includes the 99th percentile estimate for this RG (23 ppb) as well as the 95th percentile estimate (95 ppb). Also, in many cases, SWACs achieved as shown in these tables are well within estimated background ranges and/or are not measurably different from the standpoint of sampling/analysis method practical limitations.

In some of the river mile RAL curves shown in Appendix Db, the time zero RAL curve crosses the year 10 and/or 30 curves (e.g., PCB RAL curve for RM 7 to 6). This indicates that use of the RALs at these points in the curves would create a lower sediment concentration than the equilibrium condition that the model predicts this section of river will maintain. Thus, the time zero concentration may be estimated to be very low, but over time, the system returns to the equilibrium bedded sediment contaminant concentration that represents the balance of all contaminant loads affecting this portion of the river. Also, in a few cases, the cross in curves is due to localized erosional events that temporarily reveal recently buried, somewhat higher levels of contaminants at or near the 10- or 30-year points in time. As discussed more in Appendix Ha, these situations generally appear to be temporary and focused around specific erosional events.

The river mile curves in Appendix Db also show that in some cases, for example downstream of RM 6, that SWACs substantially below the point estimate RG are attained by the vast majority, or even all, of the RALs evaluated. This indicates that, although a particular RAL may be needed to attain an RG of interest in some river miles, the same RAL may essentially "over remediate" other river miles substantially below that RG. The 10- and 30-year estimated RAL curves most clearly show this effect and, in many cases, indicate that no action by itself may achieve the RG of interest. Thus, there will be a need in post-FS SMA-specific remedial designs to closely examine the course of natural recovery between the time of the draft FS dataset and remedial design to 1) determine whether these portions of the Site have already attained cleanup levels determined by EPA and/or 2) whether design performance goals to attain cleanup levels can be modified for specific river mile conditions as better understood in remedial design.

There will be a need in post-FS SMA-specific remedial designs to closely examine the course of natural recovery between the time of the draft FS dataset and remedial design to 1) determine whether these portions of the Site have already attained cleanup levels determined by EPA and/or 2) whether design performance goals to attain cleanup levels can be modified for specific river mile conditions as better understood in remedial design.

> *Time zero estimates represent the least likely outcome, which assumes that the Site remains essentially static in perpetuity (i.e., during and after construction).*

Figure 4.3-1 shows that there is a decreasing ability to change the Site-wide SWAC as the RALs are decreased (and the acreage actively remediated is increased). This effect is more pronounced when periods of recovery after construction are considered (i.e., 10- and 30-year estimates). Given that RAL curve development does not include a construction period, and as discussed in the RI and this draft FS in the CSM text in Section 2.6 and Section 6.2, natural recovery is an ongoing process occurring at the Site, and the time zero curve on Figure 4.3-1 should be used with caution. Time zero estimates represent the least likely outcome, which assumes that the Site remains essentially static during and after construction in perpetuity.

Focusing instead on longer time periods in Figure 4.3-1, a RAL of 500 ppb for total PCBs corresponds to a value that is approximately at or below the “knee of the curve” of maximum incremental reduction in SWAC. As discussed above, inclusion of several alternatives based on RALs above this knee of the curve will likely be highly informative to the overall draft FS evaluation. There is virtually no change in the Site-wide SWAC for RALs below 150 ppb, and the change in the SWAC is only a few ppb between the 150 and 200 ppb RALs. Thus, 200 ppb is near the approximate “asymptote” corresponding to the point of minimal change in the SWAC. (Note that changes of a few ppb are essentially meaningless within the overall uncertainties of the analysis, given that, for example, areas for active remediation cannot even be identified and mapped at this level of precision [see Appendix E]). As discussed above, one alternative based on a RAL in this asymptote range will be useful for comparison to RALs in the range of maximum incremental reduction.

Further, for RALs less than approximately 500 ppb, the EPA-selected point estimate for PCB background at 17 ppb is estimated to be achieved at 30 years on a Site-wide SWAC basis, again taking into account the uncertainties of the analysis and estimation of the background value, which is estimated to range between 37 and 5 ppb. Further, as discussed in Section 3.6, there is limited ability to measure the differences between these values given current sampling and analysis methods.

Finally, although these RALs are selected through close examination of the time zero through year 30 curves, the longer duration estimates shown here and discussed later in the alternatives evaluation using 45-year simulations (see Sections 8 and 9) indicate that there is very little long-term difference in the SWACs achieved by any of these RALs.

4.3.2 BaPEq RALs

For BaPEq, the primary exposure from the risk assessments, as noted above, is a human health sediment direct contact scenario. There is also a clam consumption PRG for BaP, but given the uncertainties associated with that PRG (see Section 3), it is not generally used for comparative purposes in this RAL assessment. Consistent with the BHHRA, the sediment direct contact exposures have been generally assessed on a half river mile basis, confined to the segments of shoreline shoreward of the navigation channel, where people are potentially exposed. Appendix Db shows RAL curve plots for BaP on a half river mile basis within these shoreline segments on either side of the river. The contaminant fate model is set up to evaluate the single contaminant BaP, and the plots provided in Appendix Db show changes in BaP SWACs based on a range of potential BaP RALs. BaP concentrations are closely correlated to BaPEq concentrations at the Site, which is the form of PAH contamination related to potentially unacceptable risks from sediment direct contact in the BHHRA. Given that there is generally not a large difference between BaP and BaPEq concentrations at the Site, it is expected that the relationships shown in Appendix Db on a BaP basis would be similar to a relationship expressed on BaPEq basis, if this could be modeled. Appendix E (Section 5.5) describes the uncertainty created with mapping SMAs using RALs on a BaP versus BaPEq basis; those differences were found to be relatively small (placed in the "medium" uncertainty category as discussed in Section 3.6), particularly as compared to some other aspects of uncertainty present in the overall analysis of RGs, RALs, and SMAs. Consequently, it appears reasonable to use a RAL developed on a BaP basis to map SMAs on a BaPEq basis.

As is clear from the RI, elevated BaP concentrations (or, more broadly, PAHs) generally do not occur at the Site above approximately RM 7, with some isolated exceptions. Consequently, the plots in Appendix Db above RM 7 show little if any decrease in BaP SWACs for any of the RALs modeled. This is because this region of the river is generally already below the sediment direct contact point estimate RG of 423 ppb.

Below RM 7, in some half-mile shoreline segments, a relationship can be observed between potential BaP RALs, the related active remediation acreage within that half-mile shoreline segment, and corresponding changes in SWACs, that is similar to that discussed above for PCBs. Examples of this relationship for two half river miles with elevated BaP concentrations are shown in Figure 4.3-2.

Examining all the shoreline half river miles, there are 20 half-mile segments below RM 7. The SWACs in nine of these segments are currently below the EPA point estimate RG of 423 ppb (RMs 7 to 6.5 East, 5.5 to 5 East, 4 to 3.5 East, 4 to 3.5 West, 3.5 to 3 East, 3 to 2.5 East, 3 to 2.5 West, 2.5 to 2 East, and 2.5 to 2 West) and thus do not need further evaluation in the draft FS. The remaining 11 segments are predicted to achieve SWACs below the point estimate RG of 423 ppb by the time periods and RALs summarized in Table 4.3-3. Again, the sensitivities/uncertainties about this point estimate RG should be considered when evaluating such predictions, and in this case, the 99th, 95th, and 90th percentiles for this RG are estimated to be 1,440, 2,750, and 3,700 ppb, respectively. Table 4.3-4 presents estimated SWACs for each half river mile by various time periods and RALs as compared to the percentile ranges for this RG.

Because of the wide range of conditions found across half river mile exposure areas relevant to BaPEq, it is more difficult to identify overall points of maximum incremental decrease or minimal change. However, Figure 4.3-2 shows that for the two half river miles with the highest BaPEq SWACs, RALs in the range of 20,000 to 2,000 ppb result in decreases in the SWACs in these areas, although there are notable differences in these two half river miles. For example, in RM 5 to 4.5 East, most of the SWAC reduction actually occurs between RALs of 10,000 and 2,000 ppb, given it has generally lower concentrations than RM 6.5 to 6 West. In both half river miles, at RALs less than 2,000 ppb, there is minimal change in the SWACs, particularly for the 10- and 30-year estimates. Similarly, Table 4.3-3 shows that SWACs below the RG point estimate of 423 ppb are achieved at time zero in all but six of the half-river miles (and this RG is achieved at year 10 in those same areas) using a RAL of 2,000 ppb including the two half river miles with high existing SWACs shown in Figure 4.3-2. Consequently, several RALs above the 2,000 ppb level to capture the zone of maximum incremental decrease as well as one RAL below 2,000 ppb to capture the zone of minimal change appears appropriate.

4.3.3 Sum-DDE RALs

For sum-DDE, the primary potential exposure from the risk assessments is from human health fish consumption. As discussed in Section 3, the most relevant RG ranges for sum-DDE are for human consumption of large home range fish at a 10^{-6} cancer risk level, which is applied on a Site-wide basis consistent with the BHHRA. However, EPA initially selected a 10^{-5} cancer risk level PRG based on smallmouth bass that was later found to be inconsistent with the findings of the BHHRA (see Section 3). Consistent with the LWG recommended RG for sum-DDE, for the purposes of RAL development, sum-DDE RALs are evaluated on a Site-wide (large home range fish exposure assumption) basis and compared to the large home range fish RG of 3.02 ppb. Note that, similar to above discussions for BaPEq, sum-DDE is modeled as 4,4-DDE but is evaluated as the sum of the 2,4- and 4,4-DDE species. (The same is also true for sum-DDD and sum-DDT in Section 4.3.4.) As with BaPEq, the uncertainties caused by this extrapolation are estimated to be minor for the draft FS.

Figure 4.3-3 shows the DDE RAL curves generated on a Site-wide basis.

As with PCBs, the DDE figure shows that there is a decreasing ability to change the Site-wide SWAC as the RALs are decreased and the acreage actively remediated is increased. (As noted previously, as the RAL becomes smaller, the area of sediment identified for active remediation becomes larger.) Focusing on the 10- and 30-year time periods, the zone of maximum incremental reduction is above a RAL of 100 ppb, and there is minimal change in the SWAC below this RAL. Further, the DDE point estimate RG of 3.02 ppb is met on a Site-wide basis at time zero using a RAL of 200 ppb. Note that although a sensitivity/uncertainty analysis was not conducted for DDE, the same ranges of sensitivities/uncertainties certainly exist for this point estimate RG similar to those for PCB and BaPEq RGs. Given the conservatism of point estimates for contaminants within their overall RG ranges, the DDE point estimate RG of 3.02 ppb is likely a relatively low value within its overall sensitivity/uncertainty range. Consequently, RALs that achieve this DDE point estimate RG are conservative and achieve SWACs within the likely ranges for this RG.

Appendix Db shows plots of RAL curves for DDE on a river mile basis and Table 4.3-5 shows the estimated SWACs achieved by river mile, respectively. As is clear from the RI and Section 2 of the draft FS, elevated DDE concentrations (or, more broadly, DDx) generally occur in RMs 7 to 8. Consequently, the plots in Appendix Db outside these river miles show little if any decrease in DDE SWACs for any of the RALs modeled. This is a consequence of the low SWACs already present. Within the RM 7 to 8 region of the Site, a covariance relationship exists between potential DDE RALs, the related active remediation acreage within those river miles, and corresponding changes in SWACs that are similar to those discussed above for PCBs and BaPEq. In the absence of a river mile-based DDE RG, it is worth noting that a RAL of 1,000 ppb will attain SWACs in each river mile that is below the Site-wide DDE RG of 3.02 ppb at year 30 for every river mile except RM 7 to 6, which will have a SWAC very close to this Site-wide RG at 3.5 ppb. However, such comparisons of the Site-wide point estimate RG of 3.02 ppb to river mile SWACs should be used with caution. Given the uncertainty in any given RG point estimate and the approximation associated with Site-wide RGs at this smaller spatial scale, indications that a RAL meets a Site-wide RG on a river mile basis should be viewed only as a highly conservative confirmation that river mile-based potentially unacceptable risks would not exist. Thus, given these uncertainties, much higher RALs might also be reasonably judged to achieve protective levels on a river mile basis.

4.3.4 Sum-DDD and Sum-DDT RALs

EPA provided sum-DDD and sum-DDT RALs to the LWG for development of two SMA footprints for two alternatives (EPA 2011f and LWG 2011b). SMA and alternative development is discussed more in Sections 5 and 7, respectively. EPA's rationale for selection of these RALs is provided as attachments to their direction on RALs (EPA 2011f).

Time zero RAL curves on Site-wide and river mile scales for DDD and DDT are provided in Appendix Db figures. Because the LWG did not propose RALs for these contaminants and the relatively recent timing of the EPA's direction on such RALs, the LWG did not model year 10 and 30 RAL curves for these contaminants. The figures in Appendix Db also include comparison to DDD and DDT smallmouth bass (river mile exposures) and large home range fish (Site-wide exposures) human health PRGs that represent the same exposure scenarios as the DDE smallmouth bass 10^{-4} cancer level Focused PRG that EPA directed during PRG negotiations and the DDE large home range fish DDE 10^{-6} cancer risk RG that LWG recommends in its place. Although these goals have not been defined as Focused PRGs by EPA or as RGs recommended by LWG, they provide a useful frame of reference consistent with other EPA directives on the use of DDx related goals.

As shown in Appendix Db figures, DDD and DDT RALs of approximately 100 ppb meet the relevant river mile and Site-wide PRGs at time zero. As noted above, comparisons to point estimate goals such as these PRGs is a conservative approach given the overall understanding of the conservatism inherent in the BHHRA PRGs and RGs as detailed in the sensitivity analysis of PCBs and BaPEq in Appendix E (Section 5). The above RAL evaluations are further conservative in that they only assess the time zero timeframe and do not account for any recovery of the system over time after active remediation.

4.3.5 2,3,4,7,8-PCDF RALs

EPA directed 2,3,4,7,8-PCDF RALs to the LWG for development of two SMA footprints for two alternatives (EPA 2011f and LWG 2011b). The SMAs and alternatives developed are discussed more in Sections 5 and 7. EPA's rationale for selection of these RALs is provided as attachments to their direction (EPA 2011f).

Time zero RAL curves on Site-wide and river mile scales for 2,3,4,7,8-PCDF are provided in Appendix Db figures. Because the LWG did not develop a model for PCDF and did not propose RALs for these contaminants, the LWG did not model year 10 and 30 RAL curves for these contaminants. EPA provided direction to include PCDF RALs too late in the process for a PCDF model to be developed in time for the draft FS. The figures in Appendix Db also include comparisons to 2,3,4,7,8-PCDF RGs from Table 3.5-4.

As shown in Appendix Db figures, a 2,3,4,7,8-PCDF RAL of approximately 1 ppb (or slightly more) is estimated to meet the relevant river mile 10^{-4} cancer risk RGs at time zero. As noted above, comparisons to point estimate goals such as these RGs is a conservative approach given the overall understanding of the conservatism inherent in the BHHRA PRGs and RGs based on the sensitivity analysis of PCBs and BaPEq in Appendix E (Section 5). The above evaluations are further conservative in that they only assess the time zero timeframe and do not account for any recovery of the system over time after active remediation.

4.3.6 Potentially Unacceptable Benthic Risks

The BERA concluded that the benthic community of the Site is typical of a large river system that is strongly influenced by physical processes, with limited areas of potential chemical toxicity. Although contaminant RALs cannot specifically be calculated for potentially unacceptable benthic risks, the comprehensive benthic risk areas are overlaid on maps with areas determined using the above ranges of RALs. These areas are presented and discussed more in Section 5.3.1 and Appendix P (Section 1.1). Because the comprehensive benthic risk areas are determined through multiple LOEs including bioassays and sediment chemistry (among others), it is more difficult to evaluate changes in these potentially unacceptable risks over time similar to the time-based RAL approach (e.g., future bioassay toxicity results cannot be determined through contaminant fate modeling). As discussed in more detail in Appendix E (Section 5.4), the natural recovery (or attenuation) of contaminant concentrations over time are expected to be important to future potentially unacceptable benthic risks and should be considered for benthic risk areas, but methods to accomplish this are not readily available. This is because potentially unacceptable benthic risks, as measured by MQ, are based on many different contaminants potentially causing toxicity in combination. Therefore, it is difficult to estimate which contaminants contribute most to the observed toxicity or to model the recovery of the many different contaminants. To estimate the uncertainty that may be involved in assessing natural recovery of benthic areas over time, the contaminant concentration data within the comprehensive benthic risk areas were examined.

This evaluation focused on one LOE used to develop the benthic risk areas as described in Section 3.5, which is the MQ. (The pMax values were also briefly evaluated for assessing future changes in potentially unacceptable benthic risk, but it was found that these values were highly variable both inside and outside the comprehensive benthic risk areas and were not further investigated. Furthermore, pMax is problematic because of the various normalizations that were used in the LRM.) In coordination with EPA, the LWG determined that MQ values above 0.7 generally indicated a reasonable correlation with toxicity observed in bioassays (LWG 2011a and EPA 2011e). Further examination of MQs in the comprehensive benthic risk areas indicated that 64 percent of the stations have MQ values below 0.7 and 44 percent have MQ values below 0.3. Given the uncertainties in the derivation of the MQ values (or any statistical model of this type) and the somewhat limited correlation between this measure and bioassay toxicity results, the large number of low MQs within benthic risk areas is not surprising. To the extent that MQs appear to be the best measure of the relationship between chemistry and bioassay results, it also appears reasonable to use MQs as at least an approximate measure of areas that might recover in the future. On this basis, areas within the benthic risk areas that are currently below an MQ of 0.7 should be considered as having a greater potential for recovery over longer time periods (i.e., 5 to 10 years). An MQ of 0.7 was selected as a conservative assessment of potential future recovery of benthic SMAs given that, in the absence of bioassay data, an area with an MQ of 0.7 would currently be assumed to likely have acceptable levels of benthic risk. However, if areas characterized by PCB and DDx levels that may represent potentially unacceptable bioaccumulation risks (see Appendix P) were co-located in areas where the MQ was below 0.7, such areas were not presumed to naturally recover from potential benthic toxicity. Based on this approach, Section 5.3.1 presents areas above the MQ of 0.7 that are used to define SMAs that are less likely to recover for potentially unacceptable benthic risks within a reasonable period.

These areas can only be considered a very approximate estimate. In that context, this evaluation suggests that there are considerable portions of the current benthic risk areas that might be considered suitable candidates for:

1. Additional bioassay testing to confirm or refute toxicity as a part of remedial design, and/or
2. A focused monitoring program for a natural recovery of benthic toxicity, as part of an overall long-term monitoring program, with appropriate contingency

measures should these areas not show actual recovery over a reasonable time period (e.g., 5 to 10 years). (See Appendix T [Section 3] for more information on likely long-term monitoring programs.)

4.4 SUMMARY OF SELECTED RALS FOR THE DRAFT FS

As noted above, RALs are selected for alternative development over a range of areas, RGs, time periods, and spatial scales (i.e., dimensions of the analysis). RALs should be selected that span the area of maximum incremental reduction of the SWAC, because this is the region in which the greatest changes in remedy effectiveness will occur. In addition, the low end of the RAL range should include a point that is clearly on the asymptote of minimal change for comparative purposes, and for similar comparisons, the other end of the RAL range should include a point relatively high in the region of maximum incremental reduction. Also as previously noted, it is more important to capture an adequate range of RALs to understand the relationships between RALs and the various FS evaluation criteria (e.g., short- and long-term effectiveness, ARAR attainment, feasibility, and costs) than it is to select one specific RAL versus another for any given alternative.

The above approach addresses selection of RALs for each contaminant. There is the additional decision of how to select RALs across contaminants so that they play a similar role when grouped for each alternative. In general, a more consistent analysis is obtained by matching the scales of the RALs for each contaminant, as best can be achieved, so that RALs are grouped on the following basis:

- RALs very high in each contaminant's zone of maximum incremental reduction
- RALs below the highest RALs but within the zone of maximum incremental reduction and before the "knee of the curve" (as defined in Section 4.2)
- A representative set of lower RALs that are clearly within the zone of minimal change and after the "knee of the curve"

As noted above, the second group of RALs lies within the region where the greatest changes in remedy effectiveness will likely occur. Consequently, two to three RALs should be selected and grouped for alternatives spanning this region of the RAL curves.

On this basis, Table 4.4-1 shows the LWG-recommended groups of RALs for total PCBs, BaPEq, and sum-DDE to use in alternative development. This table also includes EPA's direction for sum-DDD, sum-DDT, and 2,3,4,7,8-PCDF RALs grouped into these same categories (EPA 2011f and LWG 2011b).

As noted above, RALs should also consider the timeframes over which SWACs are achieved. Tables 4.3-1 through 4.3-5, Figures 4.3-1 through 4.3-3, Appendix Db figures, and Appendix E (Figures 5.6-1 to 5.6-4) present information comparing SWACs achieved for total PCB, BaPEq, and sum-DDE RALs for time zero, year 10, and year 30 timeframes. Thus, some of the RALs in Table 4.4-1 may reside outside the zones of maximum incremental reduction or have minimal change noted on the table depending on the timeframe in question. Because it appears unlikely that the Site will remain static over time (see Section 2 and Section 6.2.2), in general, the RALs proposed by LWG in Table 4.4-1 were selected based on the year 10 and 30 RAL curves, with consideration of the time zero curves. EPA has generally indicated that they made their RAL selections based exclusively on the time zero curves (EPA 2011f).

The highest RALs were selected by LWG primarily based on the high end of the range of RAL increments initially evaluated. The lowest RALs were selected by either LWG or directed by EPA. The LWG judged the lower RALs to reside clearly within the zone of minimal change for the year 10 and 30 estimates and within a range that would generally be expected to achieve levels toward the lower end of the RG ranges presented in Section 3 across the Site for each contaminant. For some of the lower RALs provided by EPA, EPA generally appeared to judge these RALs to attain specific RG or PRG point estimates at time zero (EPA 2011f).

Overall, many, if not all, of the lowest RALs are unnecessarily conservative for two reasons: 1) the RG point estimates are generally very low in the overall potential reasonable range of RGs for each contaminant and should not be used exclusively for RAL development; and 2) focusing exclusively on time zero SWAC estimates is the least likely and most conservative decision making process for the Site given the Site CSM discussed in Section 2 and the overall discussion of system recovery in Section 6.2.2. Supporting this overall conclusion is a contaminant-specific discussion below, which is based on the evaluations of the RAL figures and tables discussed above.

For sum-DDE, the point estimate RG of 3.02 ppb is met on a Site-wide basis at time zero using a RAL of 200 ppb (Section 4.3.3). Thus, selection of more than one sum-DDE RAL below this level to represent the asymptote of the RAL curve is unnecessary. EPA has selected two such RALs (50 and 20 ppb) (Table 4.4-1). It appears this was based on the application of the point estimate RG of 3.02 ppb on a river mile basis, which is very conservative. Given that all river miles are expected to be below or very near this point estimate Site-wide RG at year 30 using a RAL of 200 ppb, selection of the 20 ppb RAL appears particularly conservative. These lower RALs are attempting to protect for greater than 10^{-5} smallmouth bass potentially unacceptable risks that do not actually exist at the Site (per the BHHRA findings).

For sum-DDD, a RAL of approximately 100 ppb meets the relevant and likely conservative river mile and Site-wide point estimate PRGs at time zero (Section 4.3.4). EPA selected one sum-DDD RAL at 100 ppb and another at 50 ppb (Table 4.4-1). Thus, selection of these sum-DDD RALs is highly conservative, from both the standpoint of use of specific point estimate PRGs as well as the time zero comparison.

For sum-DDT, a RAL of approximately 100 ppb meets the relevant and likely conservative river mile and Site-wide point estimate PRGs at time zero (Section 4.3.4). EPA selected one sum-DDT RAL at 150 ppb and another at 60 ppb (Table 4.4-1). Thus, selection of the 60 ppb RAL in particular is highly conservative, from both the standpoint of use of specific point estimate PRGs as well as the time zero comparison. Also, although the DDT 150 ppb RAL is not estimated to meet the point estimate PRGs at time zero, based on the DDE year 10 and 30 estimates, it is more than likely this DDT RAL is also conservative relative to year 10 or 30 estimates, if they were available for DDT.

For 2,3,4,7,8-PCDF, a RAL of approximately 1 ppb meets the relevant and likely conservative river mile point estimate RGs at time zero (Section 4.3.5). EPA selected two 2,4,4,7,8-PCDF RALs that are two orders of magnitude below this level at 0.02 and 0.01 ppb. EPA appears to have selected these values to assess whether a 10^{-5} cancer risk level for smallmouth bass consumption by river mile could be achieved. The PRG associated with this level is 0.0011 ppb. However, the RAL curves in Appendix Db show that even a RAL of 0.005 ppb would not achieve this PRG in every river mile, and at the same time would nearly double the acreage remediated as compared to a 0.01 ppb RAL.

Also, EPA directed some lower RALs than those shown for Table 4.4-1 (EPA 2011f and LWG 2011b) for all of the RAL contaminants discussed in this section. These include RALs of 50 ppb for PCBs, 600 ppb for BaPEq, 10 ppb for sum-DDE, 15 ppb for sum-DDD, 20 ppb for sum-DDT, and 0.005 ppb for 2,3,4,7,8-PCDF. Based on the above evaluations, these values are well out into the asymptote region of the individual RAL curves, and from an alternative development standpoint are likely redundant with the lowest RALs presented in Table 4.4-1. Section 7 discusses a potential alternative constructed based upon these additional lowest RALs and conducts a screening evaluation of this potential alternative as it compares to alternatives constructed consistent with the RAL increments in Table 4.4-1.

As noted above, the selected RALs address other contaminants posing potentially unacceptable risk that were identified through the BERA and BHHRA in coordination with EPA (see Section 3). The relationships between contaminants posing potentially unacceptable risks and contaminants that are also COCs and/or have sediment PRGs or RGs are discussed in Section 3.5. The method for addressing these broad lists of contaminants varies depending on whether they are also COCs and/or have sediment PRGs or RGs. For many contaminants posing potentially unacceptable risk, there are no sediment PRGs at all for a variety of factors discussed in Section 3.5; therefore, quantitative methods of determining how RALs address these contaminants do not exist. Contaminants with PRGs or RGs can be quantitatively assessed, and the primary methods to understand how select RALs address those contaminants involve mapping and/or SWAC estimation techniques that are introduced in Section 5. Consequently, the question of how RALs address these other contaminants is discussed more in Section 5.9.

4.5 RAL DEVELOPMENT UNCERTAINTIES FOR PCBS AND BAPEQ

Section 3.6 describes the sensitivity/uncertainty analyses for RGs that were undertaken for the draft FS. These analyses were conducted for total PCBs and BaPEq based on technical analysis early in the project that these contaminants were likely to be important to the RAL, SMA, and alternative development in the draft FS. In addition to the sensitivity/uncertainty associated with the RGs discussed in Section 3.6, similar issues were examined for RAL development methods for the same contaminants and are discussed here.

RAL development involves determining the relationship between an independent variable—the RAL—and a dependent variable—the SWAC achieved for any given RAL. The relationship between these two variables is a function of the surface sediment concentration distribution at the Site (i.e., a surface area map of Site sediment contaminant concentrations of some type). Thus, the RAL can be readily converted back and forth to an area (e.g., acreage) remediated using such a map, as shown in the RAL curve graphs in the subsections above. A third variable or dimension of the analysis is time, over which the distribution of the surface sediment contaminant concentrations is expected to change (i.e., natural recovery). Thus, the sensitivities/uncertainties associated with RAL development can be understood by examining the methods related to each variable:

1. Area Remediated – There are various methods for defining the area above a certain RAL concentration using scattered point measurements of surface sediment concentrations.
2. SWAC – There are various methods to determine and assign future post-construction sediment concentrations in remediated areas and determine a new sediment concentration distribution, which is expressed in terms of a SWAC.
3. Time – There are various methods to determine how sediment concentrations (in areas either actively remediated or not) will change over time.

The first type of sensitivity/uncertainty is discussed briefly below and quantified and discussed more in Section 5.11 which addresses the uncertainties associated with mapping areas above a selected concentration in the context of SMA development. The second two types of sensitivity/uncertainty are quantified and discussed below more specifically in terms of the development of RAL curves used above in this section.

For area remediated sensitivities/uncertainties, this is the same basic set of mapping issues as defining AOPCs or SMAs based on a given sediment concentration threshold. For example, an area above a certain concentration can be obtained by placing a grid over sediment stations with known concentrations and assigning grid areas concentrations based on the points that fall within or near each grid cell. Similarly, such areas can be obtained by geostatistical techniques such as Thiessen polygons or various contouring methods. Given that there are multiple geostatistical methods, each one can provide a different area for the same RAL. The sensitivities/uncertainties associated with assigning areas above selected concentrations (e.g., SMAs) are described in Section 5.11. In general, estimation of the area remediated for any given RAL (i.e., SMA development) is categorized as a “medium” uncertainty using the categories defined in Section 3.6 and Appendix E (Section 6.1).

For SWAC calculation uncertainties, there are various estimates or assumptions that can be made about the surface sediment concentration achieved in active remediation areas immediately or very soon after construction. These can range from relatively complex exercises of estimating the performance of various remedial technologies (e.g., estimating the concentrations below the target dredging horizon, dredging residuals calculations, and/or cap/cover material concentration estimates) to simple assumptions based on the target concentration for the active remedies (e.g., using the RAL or half of the RAL). Some of the simpler assumptions can be complicated by the fact that an area may be remediated for one contaminant but may already be below the RAL for another contaminant. Thus, in these cases, a simple assignment of half the RAL, for example, may be a reasonable estimate for one contaminant but a poor estimate for another contaminant. In general, estimation of non-time-based SWACs fall into the "medium" category of uncertainties per the categories in Section 3.6.

For time-based SWAC estimates, future conditions both within and outside the actively remediated areas must be estimated, and are also dependent on the immediate post-construction SWAC calculations discussed above. For this draft FS, future SWACs are estimated using the QEAFATE model, which is calibrated to existing/historical information on contaminant concentration trends at the Site. Such modeling exercises have uncertainties that are discussed and quantified in detail in Appendix Ha (Section 4.2).

Figures 4.5-1 and 4.5-2 show estimates of the uncertainties associated with these last two variables, for total PCBs and BaPEq, respectively.

The uncertainties associated with SWAC estimates are represented by the blue time zero line estimates in these figures. The uncertainties associated with modeling of future SWACs are represented by the bands around the red and green year 10 and year 30 estimates, respectively.

The SWAC estimate uncertainties for the time zero estimate were calculated using a reasonable range of SWAC development assumptions that are intended to illustrate the general potential uncertainties involved. In this case, the following range of assumptions was used:

1. The solid blue line is plotted using the QEAFATE model grid cell sediment concentration assignments. Any grid cells that are above RAL concentration are assumed to be remediated and are assigned a new concentration assuming that dredging with a post-dredge suitable sand cover is the remedial technology. This was approximately estimated by assigning a new surface sediment concentration based on dredging residuals calculations consistent with those described in EPA's *Technical Guidelines for Environmental Dredging of Contaminated Sediments* (Palermo et al. 2008) and described in Appendix Ib; these calculations resulted in an approximate 95 percent reduction in existing sediment concentrations (on average) in active remediation areas. The calculations were conducted consistent

with the evaluation in Appendix Ib that includes one dredge residual (or cleanup) pass after the neatline is removed, plus placement of 1 foot of suitable sand post-dredge cover.

2. The dotted blue line is plotted using the NN contouring used for SMA development (see Section 5). Any contour areas above the RAL concentration are assumed to be remediated and are assigned a new concentration that is equal to half the RAL (a much simpler but potentially less accurate assumption than using dredge residual estimates).

3. The dashed blue line is also plotted using the NN contouring used for SMA development (see Section 5). Any contour areas above the RAL concentration are assumed to be remediated and are assigned a new concentration that is equal to the 95th percentile upper prediction limit (95 UPL) background. (Again, this is a simpler but likely less accurate assumption than using dredge residual estimates.)

The uncertainties for the year 10 and 30 estimates are calculated using the upper and lower bound calibration estimates from the QEAFATE modeling (Appendix Ha, Section 3.3.2). These bounds represent the upper and lower limits of primary calibration parameter adjustments that still provide a reasonable overall calibration to the empirical dataset. The calibration to the empirical dataset and the bounds of reasonable calibration are discussed more in Section 3.3 of Appendix Ha. It should be noted that sensitivities related to assumed stormwater load inputs presented in Appendix Ha are not specifically factored into RAL development uncertainties discussed here. The calibration bounds evaluated include the assumption that existing observed stormwater loads continue into the future. However, the sensitivity analysis conducted in Appendix Ha indicates that, although stormwater does have some localized impacts on surface sediment concentrations, it is not the primary determinant in large-scale surface sediment concentrations over time at the Site (see Section 8). Also, note that these estimates also include the starting assumption of immediate post-construction SWACs in remediated areas that are consistent with the modeling approach for the time zero estimate provided above. Overall, the uncertainties associated with time-based SWAC estimates are likely larger than SMA development and non-time-based SWAC estimates, but are still much smaller than the RG uncertainties. Thus, the time-based SWAC estimate uncertainties are categorized as "medium" using the categories described in Section 3.6 and Appendix E (Section 6.1).

At some point in the decreasing RAL curve, the ability to discern between likely background levels and likely long-term Site levels becomes impossible. This can be seen in the large overlap between the RAL and background estimates in Figure 4.5-1.

All of these uncertainties indicate that it is probably most useful to use the RAL versus SWAC relationship to evaluate the relative effect of RALs in comparison to each other, rather than expecting a certain RAL to achieve a specific SWAC over time with certainty. Although there is "medium" category uncertainty with the exact SWAC achieved by any given RAL, the shapes of the RALs curves are generally consistent within the bounds of quantified uncertainties. Because the RAL curve relationship is relatively consistent, this indicates that the RALs selected: 1) are reasonable points within an overall range that is relevant to determining the overall relationship between various sized alternatives and draft FS evaluation criteria; and 2) still fall within or mostly within the expected zones of either maximum incremental reduction or minimal change that they are intended to represent, as described in Section 4.4.

In addition, as discussed for the RGs in Section 3 of Appendix E, the uncertainty becomes relatively greater as the concentrations involved decrease, particularly when they approach background estimates or levels of measurement accuracy (e.g., near detection limits). This is also true of RALs. At some point in the decreasing RAL curve, the ability to discern between likely background levels and likely long-term Site levels becomes impossible. This can be seen in the large overlap between the RAL and background estimates in Figure 4.5-1.

4.6 RALS CONCLUSIONS

Overall, RALs for bounding COCs and comprehensive benthic risk areas are an efficient way of identifying areas that may require active remediation without conducting an analysis of every contaminant posing potentially unacceptable risk. COCs with defined RALs are not the only contaminants that require remediation. Rather, focusing on the COCs with RALs provides a means to design a remedy to address all contaminants posing potentially unacceptable risk.

Using the method concepts of maximum incremental reduction, point of minimal change in concentration, and others described in Section 4.2, RALs were selected over a range of areas, RGs, time periods, and spatial scales for use in alternative development later in the draft FS. In general, RALs were selected that span the area of maximum incremental reduction of the SWAC, because this is the region in which the greatest changes in remedy effectiveness will occur. Some RAL values were also selected from the asymptote of minimal change for comparative purposes in the draft FS.

Using these methods, the RALs were selected and grouped as shown in Table 4.4-1 for total PCBs, BaPEq, sum-DDE, sum-DDD, sum-DDT, and 2,3,4,7,8-PCDF. The uncertainties in the development of these RALs were explored. Although there is a "medium" category of uncertainty (as defined in Section 3.6) with the exact SWAC value achieved by any given RAL, the RALs selected: 1) are reasonable points within an overall range that is relevant to determining the overall relationship between various sized alternatives and draft FS evaluation criteria; and 2) still fall within or mostly within the expected zones of either maximum incremental reduction or minimal change that they are intended to represent, as described in Section 4.4.

The groups of RALs shown in Table 4.4-1 are used in Section 5 to define active remediation areas (SMAs) and impacted sediment volumes, which in turn are used in Section 7 to develop the remedial alternatives evaluated in this draft FS.

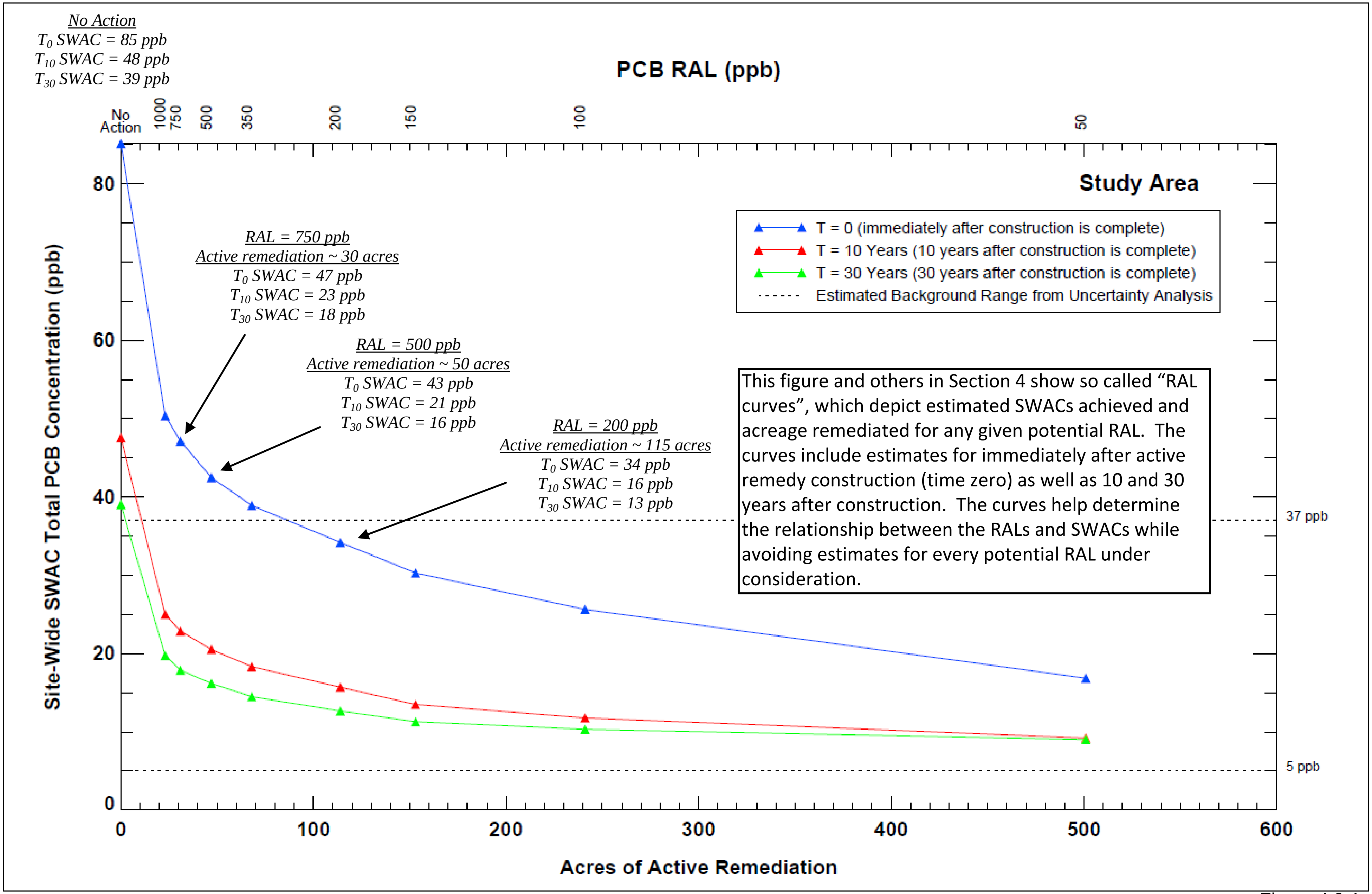

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Figure 4.3-1
Portland Harbor RI/FS
Draft Feasibility Study Report
Comparison of Total PCBs Site-wide SWAC to Potential RALs/Acres Remediated at Three Points in Time Following Construction Completion

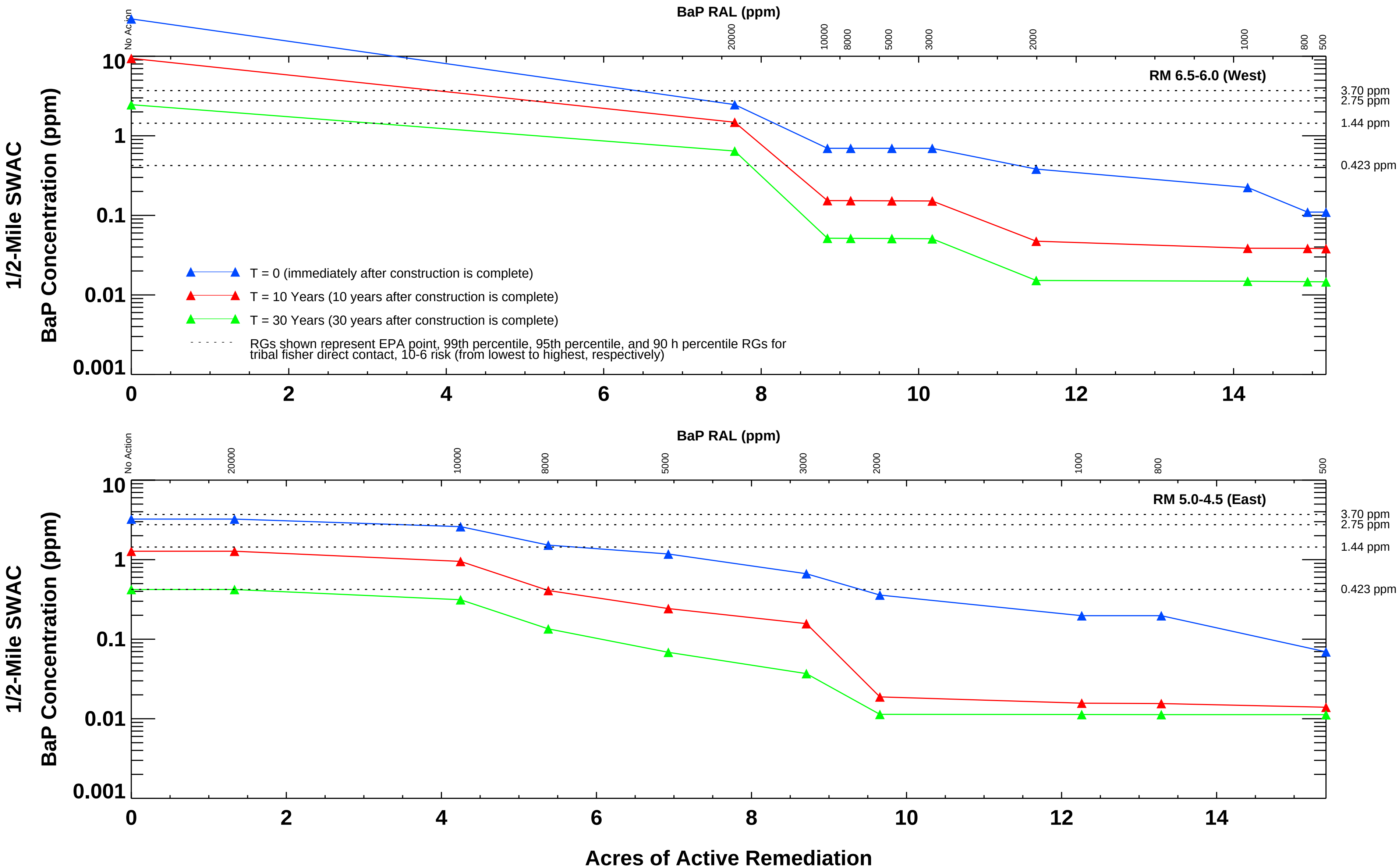

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Figure 4.3-2

Portland Harbor RI/FS

Draft Feasibility Study

Comparison of BaP 1/2-Mile SWAC to Potential RALs/Acres Remediated at Three Points in Time Following Construction Completion.

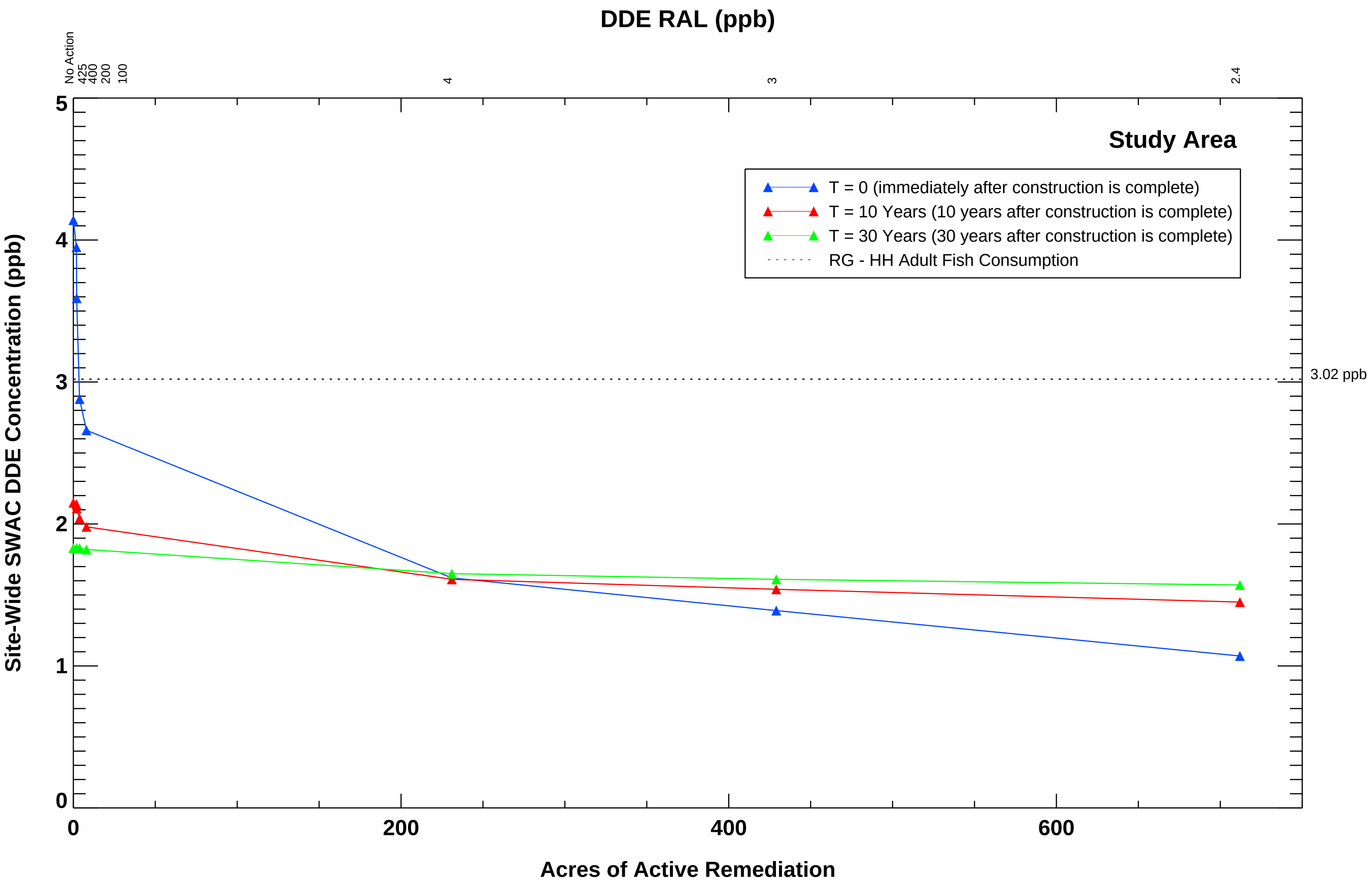

Figure 4.3-3

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Portland Harbor RI/FS
Draft Feasibility Study
Comparison of DDE Site-wide SWAC to Potential RALs/Acres Remediated at Three Points in Time Following Construction Completion.

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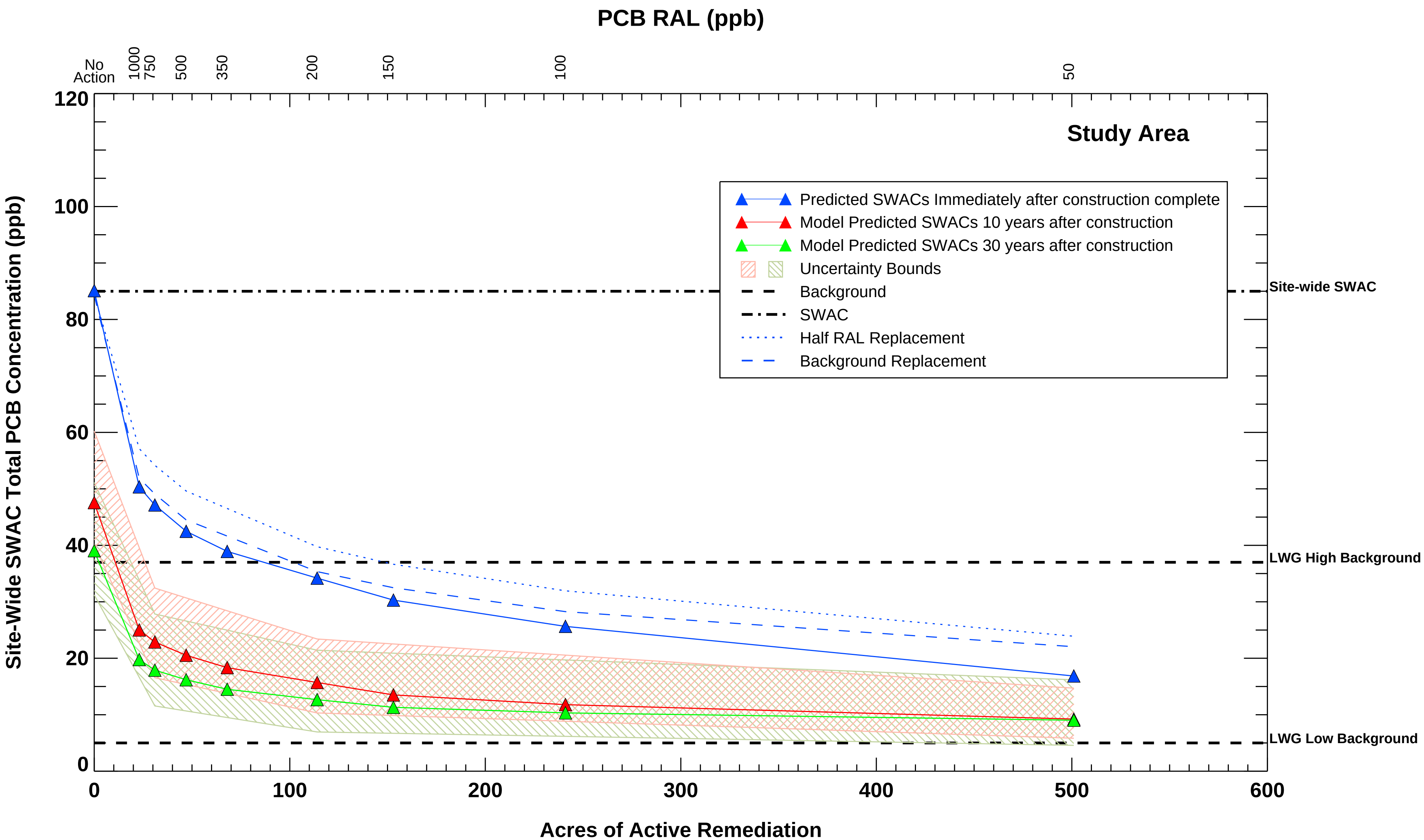

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Figure 4.5-1
Portland Harbor RI/FS
Draft Feasibility Study
Total PCBs Site-wide RAL Curves with Uncertainty Bounds

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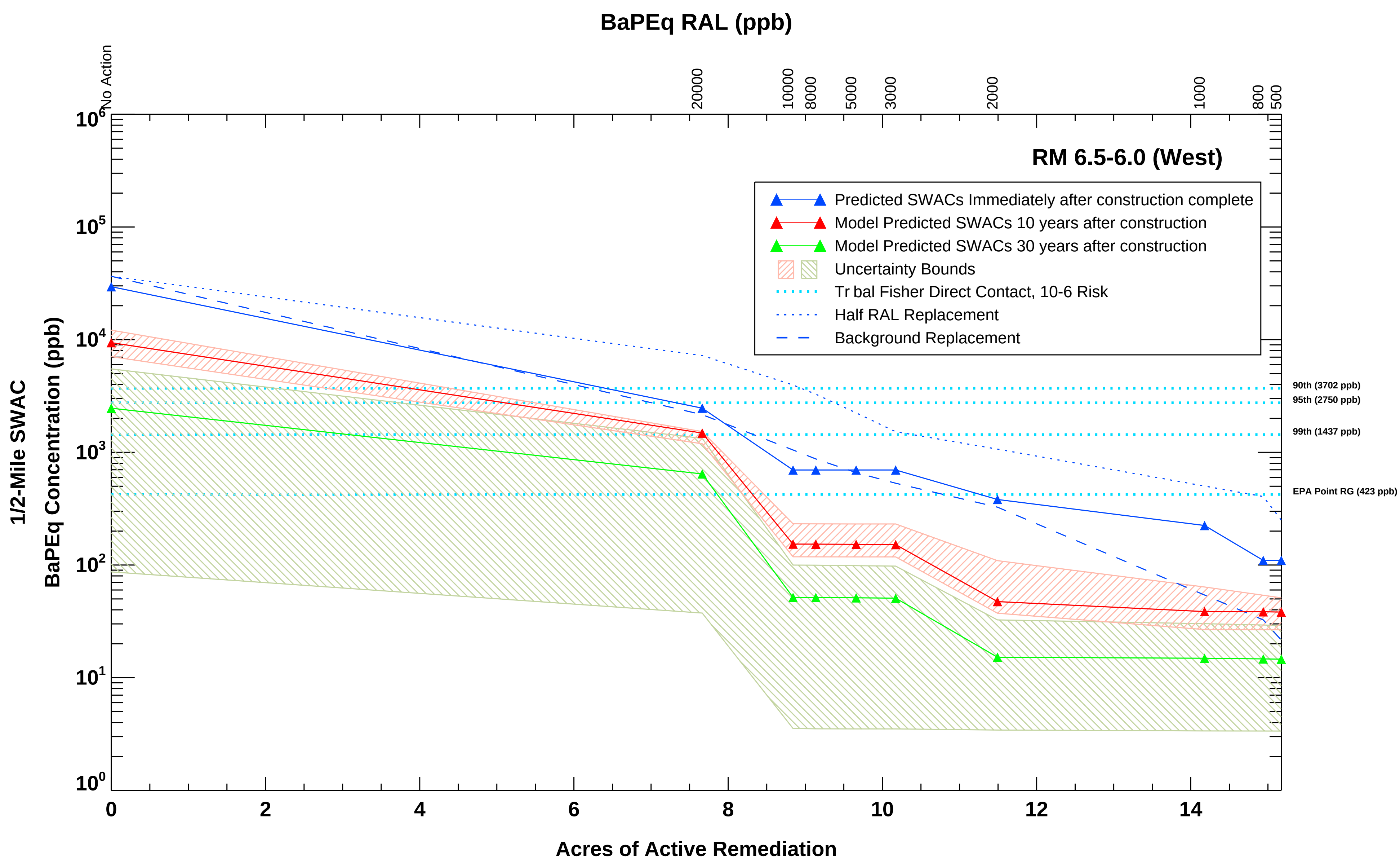

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Figure 4.5-2
Portland Harbor RI/FS
Draft Feasibility Study
BaPEq Shoreline Half River Mile RAL Curves for Two Select Areas with Uncertainty Bounds

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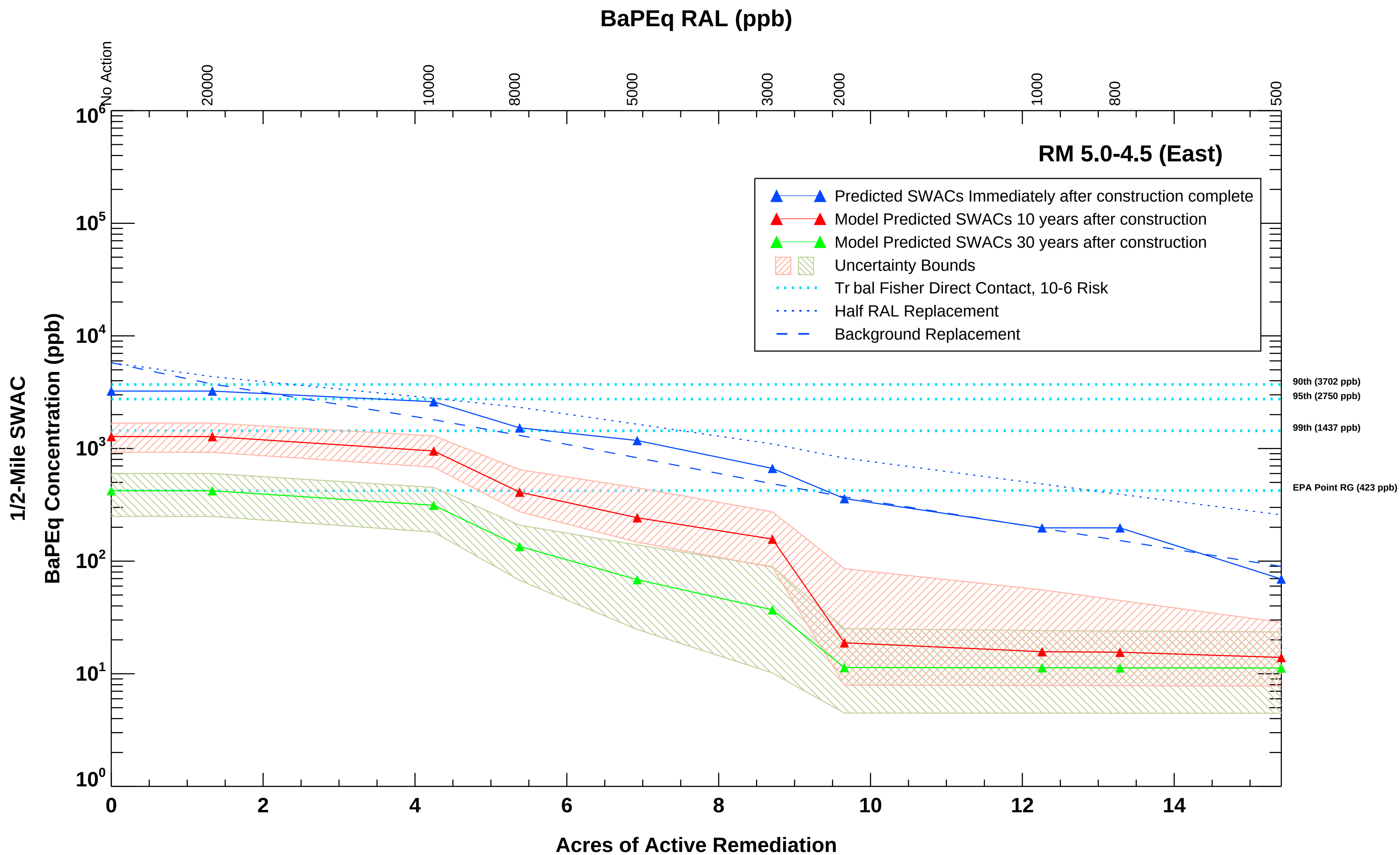

Figure 4.5-2

Portland Harbor RI/FS

Draft Feasibility Study

BaPEq Shoreline Half River Mile RAL Curves for Two Select Areas with Uncertainty Bounds

Table 4.3-1. PCB SWACs Estimated to Be Achieved by River Mile by Various RALs

River Miles	T=0 Years									T=10 Years									T=30 Years								
	No Action	1000 ppb	750 ppb	500 ppb	350 ppb	200 ppb	150 ppb	100 ppb	50 ppb	No Action	1000 ppb	750 ppb	500 ppb	350 ppb	200 ppb	150 ppb	100 ppb	50 ppb	No Action	1000 ppb	750 ppb	500 ppb	350 ppb	200 ppb	150 ppb	100 ppb	50 ppb
RM 11.8-11.0	91	53	43	28	28	26	24	22	19	14	14	14	13	13	13	13	13	12	11	11	11	11	11	11	11	11	11
RM 11.5-10.5	86	56	48	37	37	35	34	30	22	12	12	12	11	11	11	11	11	10	10	10	10	10	10	10	10	10	10
RM 11.0-10.0	50	50	50	50	50	50	46	35	20	8	8	8	8	8	8	7	7	5	5	5	5	5	5	5	5	5	4
RM 10.5-9.5	59	59	59	59	56	44	40	29	16	13	13	13	13	11	8	8	7	6	11	11	11	11	9	7	7	7	7
RM 10.0-9.0	62	62	56	51	49	35	33	29	17	17	17	16	15	14	10	9	8	7	11	11	11	11	10	8	8	8	8
RM 9.5-8.5	123	56	50	46	42	37	35	28	19	13	11	11	10	10	9	8	7	6	5	5	5	5	5	5	5	5	5
RM 9.0-8.0	99	42	42	42	39	36	35	30	20	10	8	8	8	8	8	8	8	6	6	6	6	6	6	6	6	6	6
RM 8.5-7.5	39	39	39	39	39	38	37	36	21	11	10	10	10	10	10	10	10	7	7	6	6	6	6	6	6	6	6
Swan Island	670	231	192	146	108	59	30	13	4	615	205	169	128	94	53	27	13	6	530	172	141	107	79	47	26	15	9
RM 8.0-7.0	42	42	42	42	36	35	33	32	19	13	13	12	12	11	11	10	10	7	7	7	7	6	6	6	6	6	6
RM 7.5-6.5	76	57	57	57	49	46	36	27	14	47	31	31	31	30	28	22	16	10	29	19	19	19	18	18	15	12	8
RM 7.0-6.0	77	55	55	55	55	51	40	29	14	65	48	48	48	47	46	40	33	21	47	35	35	35	35	34	31	28	20
RM 6.5-5.5	33	33	33	33	33	32	29	24	16	34	34	34	34	34	34	33	31	24	29	29	29	29	29	29	29	28	23
RM 6.0-5.0	24	24	24	24	24	24	23	20	18	14	14	14	14	14	14	13	12	11	13	12	12	12	12	12	12	12	11
RM 5.5-4.5	27	27	27	27	27	27	27	26	19	8	8	8	8	8	8	8	8	7	8	8	8	8	8	7	7	7	7
RM 5.0-4.0	43	43	43	31	29	28	28	26	18	16	16	16	13	11	10	9	8	6	12	12	12	10	9	8	8	7	5
RM 4.5-3.5	68	49	46	35	32	30	26	23	17	50	32	28	25	22	20	18	16	13	45	28	24	22	20	19	18	17	16
RM 4.0-3.0	48	31	28	28	26	26	22	20	16	42	25	22	22	21	20	18	17	16	40	24	20	20	19	19	18	18	17
RM 3.5-2.5	20	20	20	20	20	19	18	17	15	10	10	9	9	9	9	9	9	9	8	8	8	8	8	8	8	8	8
RM 3.0-2.0	51	31	31	29	27	25	25	22	15	6	6	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4
RM 2.5-1.9	69	35	35	31	28	27	27	24	15	7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Note:
RAL - Remedial Action Level
ppb - parts per billion
Exceeds the 99th percentile of the smallmouth bass RG at a 10^{-4} cancer risk level of 23 ppb.
Exceeds the EPA's point estimate smallmouth bass RG at a 10^{-4} cancer risk level of 29.5 ppb.
Exceeds the 95th percentile of the smallmouth bass RG at 10^{-4} cancer risk level of 95 ppb.

Table 4.3-2. Number of River Miles* Exceeding the PCB RG of 29.5 ppb at Various Potential RAL Levels

RAL	T=0 Yr.	T=10 Yr.	T=30 Yr.
No Action	10	3	3
1000 ppb	10	2	2
750 ppb	9	2	2
500 ppb	7	2	2
350 ppb	6	2	2
200 ppb	6	2	2
150 ppb	6	1	1
100 ppb	3	1	0
50 ppb	0	0	0

Note:
RG - Remediation Goal
RAL - Remedial Action Level
ppb - parts per billion
* Calculated as sequential river miles starting at RM 11.8 to 11.0 and ending at RM 3.0 to 1.9.

Table 4.3-3. Number of Shoreline Half River Miles* Exceeding the BaPEq RG (423 ppb) at Various Potential RAL Levels

RAL (ppb)	T=0 Year	T=10 Year	T=30 Year
No Action	11	5	1
20,000	11	5	1
15,000	11	4	0
10,000	11	3	0
8,000	11	2	0
5,000	11	2	0
2,000	6	0	0
1,000	2	0	0
800	0	0	0
500	0	0	0

Note:

RG - Remediation Goal

RAL - Remedial Action Level

ppb - parts per billion

* Calculated as sequential half river mile starting at RM 11.8 and ending at RM 1.9, confined to shoreline areas (outside navigation channel) on both sides of the river.

Table 4.3-4. BaP SWACs (ppb) Estimated to Be Achieved by River Shoreline Half River Mile by Various RALs

Shoreline Half River Miles	Near-shore Area	T=0 Years										T=10 Years										T=30 Years									
		No Action	20,000	15,000	10,000	8,000	5,000	2,000	1,000	800	500	No Action	20,000	15,000	10,000	8,000	5,000	2,000	1,000	800	500	No Action	20,000	15,000	10,000	8,000	5,000	2,000	1,000	800	500
RM 11.8-11.5	east	14	14	14	14	14	14	14	14	14	14	43	43	43	43	43	43	43	43	43	43	14	14	14	14	14	14	14	14	14	14
RM 11.5-11.0	east	46	46	46	46	46	46	46	46	46	46	6	6	6	6	6	6	5	4	4	4	3	3	3	3	3	3	3	3	3	3
RM 11.0-10.5	east	39	39	39	39	39	39	39	39	39	39	6	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4
RM 10.5-10.0	east	358	358	358	358	358	358	358	358	130	130	11	11	11	11	11	11	9	9	7	7	5	5	5	5	5	5	5	5	5	5
RM 10.0-9.5	east	20	20	20	20	20	20	20	20	20	20	8	8	8	8	8	8	5	5	5	5	4	4	4	4	4	4	4	4	4	4
RM 9.5-9.0	east	18	18	18	18	18	18	18	18	18	18	8	8	8	8	8	8	7	7	7	7	3	3	3	3	3	3	3	3	3	3
RM 9.0-8.5	east	22	22	22	22	22	22	22	22	22	22	7	7	7	7	7	7	5	5	5	5	4	4	4	4	4	4	4	4	4	4
RM 8.5-8.0	east	56	56	56	56	56	56	56	56	56	56	11	11	11	11	11	11	8	8	8	7	5	5	5	5	5	5	5	5	4	4
RM 8.0-7.5	east	22	22	22	22	22	22	22	22	22	22	10	10	10	10	10	10	7	7	7	7	4	4	4	4	4	4	4	4	4	4
RM 7.5-7.0	east	33	33	33	33	33	33	33	33	33	33	13	13	13	13	13	13	11	11	11	11	5	5	5	5	5	5	5	5	5	5
RM 7.0-6.5	east	58	58	58	58	58	58	58	58	58	58	27	27	27	27	27	27	26	26	26	26	12	12	12	12	12	12	12	12	12	12
RM 6.5-6.0	east	441	441	441	441	441	441	268	268	227	198	234	234	234	234	234	234	155	155	143	130	86	86	86	86	86	86	63	63	62	57
RM 6.0-5.5	east	599	599	599	599	599	599	599	599	298	190	207	207	207	207	207	207	205	205	80	54	55	55	55	55	55	55	55	55	19	14
RM 5.5-5.0	east	413	413	413	413	413	413	413	413	266	162	43	43	43	43	43	43	40	40	29	5	9	9	9	9	9	9	9	9	9	4
RM 5.0-4.5	east	3238	3238	2919	2601	1525	1178	359	198	198	69	1277	1276	1114	952	410	243	19	16	16	14	422	422	368	314	135	68	11	11	11	11
RM 4.5-4.0	east	990	990	990	990	990	990	403	181	139	82	477	476	476	476	476	475	177	65	44	18	150	150	150	150	150	150	65	25	19	10
RM 4.0-3.5	east	145	145	145	145	145	145	145	119	119	101	65	64	64	64	63	63	62	48	48	38	25	25	24	24	24	24	24	19	19	16
RM 3.5-3.0	east	74	74	74	74	74	74	74	74	74	74	39	38	38	38	37	37	35	35	35	35	14	13	13	13	13	13	13	13	13	13
RM 3.0-2.5	east	351	351	351	351	351	351	97	57	57	57	37	35	34	34	34	33	8	7	6	6	5	5	5	5	5	5	4	4	4	4
RM 2.5-2.0	east	46	46	46	46	46	46	46	46	46	46	13	10	10	9	9	9	6	6	6	5	5	5	5	5	5	5	4	4	4	4
RM 11.8-11.5	west	18	18	18	18	18	18	18	18	18	18	32	32	32	32	32	32	31	31	31	31	11	11	11	11	11	11	11	11	11	11
RM 11.5-11.0	west	79	79	79	79	79	79	79	79	79	79	7	7	7	7	7	7	4	4	4	4	4	4	4	4	4	4	3	3	3	3
RM 11.0-10.5	west	22	22	22	22	22	22	22	22	22	22	7	7	7	7	7	7	6	6	6	6	5	5	5	5	5	5	5	5	5	4
RM 10.5-10.0	west	111	111	111	111	111	111	111	111	111	111	10	10	10	10	10	10	8	8	8	8	3	3	3	3	3	3	3	3	3	3
RM 10.0-9.5	west	161	161	161	161	161	161	161	161	161	161	35	35	35	35	35	35	32	32	32	32	20	20	20	20	20	20	20	20	20	20
RM 9.5-9.0	west	36	36	36	36	36	36	36	36	36	36	11	11	11	11	11	11	9	9	9	9	7	7	7	7	7	7	6	6	6	6
RM 9.0-8.5	west	85	85	85	85	85	85	85	85	85	85	9	9	9	9	9	9	6	6	6	6	5	5	5	5	5	5	5	5	5	5
RM 8.5-8.0	west	101	101	101	101	101	101	101	101	101	101	15	15	15	15	15	15	12	12	12	12	6	6	6	6	6	6	6	6	6	6
RM 8.0-7.5	west	55	55	55	55	55	55	55	55	55	55	12	12	12	12	12	12	9	9	9	9	5	5	5	5	5	5	5	5	5	5
RM 7.5-7.0	west	365	365	365	365	365	365	365	127	127	127	53	53	53	53	53	53	51	33	33	33	7	7	7	7	7	7	7	6	6	6
RM 7.0-6.5	west	799	799	799	799	799	799	683	233	182	77	389	388	388	388	388	388	341	100	70	30	198	198	198	198	198	198	192	73	22	11
RM 6.5-6.0	west	29502	2467	1582	697	697	697	382	224	110	110	9409	1483	818	153	153	152	47	39	38	38	2464	644	348	52	51	51	15	15	15	15
RM 6.0-5.5	west	1233	1233	1233	1233	1233	1233	748	380	307	139	535	525	525	524	524	523	330	189	140	28	173	171	171	171	170	170	139	93	67	14
RM 5.5-5.0	west	2693	2693	2125	1558	1558	1131	417	168	93	93	726	705	471	236	235	131	103	29	12	11	72	69	46	22	22	21	19	8	5	5
RM 5.0-4.5	west	542	542	542	542	542	542	542	257	257	159	71	43	42	40	38	37	31	19	19	10	8	7	6	6	6	6	5	5	4	4
RM 4.5-4.0	west	564	564	564	564	564	564	564	442	355	103	104	83	82	81	79	78	74	60	51	11	11	9	8	8	8	8	7	7	6	4
RM 4.0-3.5	west	394	394	394	394	394	394	394	183	183	162	136	124	123	123	122	121	119	62	62	58	23	20	20	19	19	19	18	12	12	11
RM 3.5-3.0	west	488	488	488	488	488	488	488	315	267	142	222	214	213	213	212	212	211	168	148	105	102	100	100	100	99	99	98	80	72	61
RM 3.0-2.5	west	258	258	258	258	258	258	258	258	211	166	37	16	15	14	13	12	9	9	9	6	5	4	4	4	4	4	3	3	3	3
RM 2.5-2.0	west	68	68	68	68	68	68	68	68	68	68	42	15	13	12	11	10	7	7	6	6	6	5	5	4	4	4	4	3	3	3
Swan Island - North		216	216	216	216	216	216	216	216	182	141	106	106	106	106	106	106	105	105	88	70	37	37	37	37	37	37	37	37	31	27
Swan Island - South		225	225	225	225	225	225	225	225	225	181	114	114	114	114	114	114	114	114	114	92	39	39	39	39	39	39	39	39	39	32

Note:

RG - Remdiation Goal
RAL - Remedial Action Level
ppb - parts per billion
SWAC - surface weighted average concentration

(grey) Exceeds the >99th percentile sediment direct contact EPA Point RG at a 10^{-6} cancer risk level of 423 ppb.
(green) Exceeds the 99th percentile sediment direct contact RG at a 10^{-6} cancer risk level of 1,440 ppb.
(blue) Exceeds the 95th percentile sediment direct contact RG at a 10^{-6} cancer risk level of 2,750 ppb.
(orange) Exceeds the 90th percentile sediment direct contact RG at 10^{-6} cancer risk level of 3,700 ppb.
1234 Numbers in red are those that were extrapolated because we do not have model results for a 15,000 ppb RAL simulation

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Table 4.3-5. DDE SWACs Estimated to Be Achieved by River Mile by Various RALs

River Miles	T=0 Years							T=10 Years							T=30 Years						
	No Action	1,000 ppb	200 ppb	100 ppb	4 ppb	3 ppb	2.4 ppb	No Action	1,000 ppb	200 ppb	100 ppb	4 ppb	3 ppb	2.4 ppb	No Action	1,000 ppb	200 ppb	100 ppb	4 ppb	3 ppb	2.4 ppb
RM 11.8-11.0	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
RM 11.0-10.0	1.57	1.57	1.57	1.57	1.57	1.47	1.36	1.26	1.26	1.26	1.26	1.25	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24
RM 10.0-9.0	1.45	1.45	1.45	1.45	1.3	1.3	1.21	1.44	1.44	1.44	1.44	1.42	1.42	1.42	1.54	1.54	1.54	1.54	1.54	1.54	1.54
RM 9.0-8.0	7.26	7.26	3.56	3.56	1.56	1.46	1.12	1.84	1.84	1.75	1.75	1.69	1.68	1.65	1.68	1.68	1.68	1.68	1.68	1.68	1.68
Swan Island	2.66	2.66	2.66	2.66	1.89	1.5	0.81	2.52	2.52	2.52	2.52	1.84	1.48	0.94	2.3	2.3	2.3	2.3	1.78	1.45	1.02
RM 8.0-7.0	12.26	10.75	5.66	4.91	1.89	1.46	1.08	3.82	3.71	3.04	2.88	1.86	1.8	1.73	2.06	2.06	2.05	2.04	1.88	1.88	1.87
RM 7.0-6.0	6.53	6.53	6.53	5.03	1.19	0.86	0.68	4.46	4.46	4.45	4.01	1.82	1.67	1.5	3.53	3.53	3.53	3.38	1.99	1.91	1.8
RM 6.0-5.0	1.62	1.62	1.62	1.62	1.53	1.33	1.01	1.44	1.44	1.44	1.43	1.4	1.31	1.17	1.44	1.44	1.44	1.43	1.42	1.39	1.33
RM 5.0-4.0	2.24	2.24	2.24	2.24	1.89	1.56	1.08	1.77	1.77	1.77	1.77	1.67	1.62	1.56	1.76	1.76	1.76	1.76	1.71	1.69	1.66
RM 4.0-3.0	1.71	1.71	1.71	1.71	1.68	1.34	1.11	1.8	1.8	1.79	1.79	1.75	1.6	1.48	1.89	1.89	1.89	1.89	1.85	1.78	1.73
RM 3.0-2.0	2	2	2	2	1.94	1.71	1	1.69	1.69	1.69	1.69	1.68	1.67	1.62	1.63	1.63	1.63	1.63	1.62	1.62	1.62

Note:
RAL - Remedial Action Level
ppb - parts per billion
SWAC - surface weighted average concentration
1,000 ppb estimated with a model run that identifies remediation of one model cell with an average concentration of 425 ppb and point concentrations within that cell in excess of 1,000 ppb.

Table 4.4-1. Summary of Selected RALs for the Draft FS (ppb)

	LWG Recommended RALs*			EPA Directed RALs		
Type of RAL	**PCB RAL**	**BaPEq RAL**	**Sum DDE RAL**	**Sum DDD RAL**	**Sum DDT RAL**	**2,3,4,7,8 PCDF RAL**
RALs very high in the zone of maximum incremental reduction	1,000	20,000	1,000	NA	NA	NA
RALs within the zone of maximum incremental reduction (first increment)	750	15,000	1,000	NA	NA	NA
RALs within the zone of maximum incremental reduction (second increment)	500	8,000	200	NA	NA	NA
RALs within the zone of maximum incremental reduction (third increment)	200	4,000[a]	50[b]	100	150	0.02
RALs within the zone of minimal change	75	1,500	20[c]	50	60	0.01

Note:
RAL - Remedial Action Level
ppb - parts per billion
*This portion of the table shows LWG recommended RALs except where noted due to specific EPA directives.
a - The LWG recommended a BaPEq value of 8,000 ppb and EPA directed 4,000 ppb.
b - The LWG recommended a sum DDE value of 200 ppb and EPA directed 50 ppb.
c - The LWG recommended a sum DDE value of 100 ppb and EPA directed 20 ppb.

This section discusses the areal extent and volume of sediments within the Site that will be the focus of each respective sediment remedial alternative evaluated in this draft FS. There are three main topics discussed in this section:

1. *Localized Areas of Potential Concern (AOPCs) – Localized AOPCs were defined early in the pre-FS planning process and represent a general indicator of the localized areas of interest for the draft FS.*

2. *Sediment Management Areas (SMAs) – SMAs were developed using RALs and comprehensive benthic risk areas as a refinement to AOPCs for use in alternatives development and include consideration of other engineering factors (described more below) relevant to the draft FS evaluation including sediment volume determination. Some areas were added to SMAs to account for buried contamination as discussed in Section 5.6. Once SMAs are defined, localized AOPCs are no longer relevant to draft FS development for any purpose.*

3. *The Site-wide AOPC – The Site-Wide AOPC is inclusive of the entire Site outside of SMAs and represents lower levels of contaminant concentrations that will not be the focus of active remedies.*

The uncertainties associated with SMA development and volume calculations are also discussed at the end of this section.

5.0 AREA OF POTENTIAL CONCERN AND SEDIMENT MANAGEMENT AREA DEVELOPMENT

This section discusses the areal extent and volume of potentially unacceptable contaminant levels in sediments within the Site that will be the focus of sediment remedies evaluated in this draft FS. The overall concept is for the draft FS to evaluate remedial alternatives in sufficient and appropriately located areas and sediment depths that will result in achievement of the RAOs, as measured by attainment of a range of numeric RGs over appropriate exposure areas and time periods (Section 3), and implemented via RALs (Section 4). The remainder of this section defines these areas and volumes in terms relevant to the draft FS alternative development and evaluation.

The broadest identification of the areal extent of potentially unacceptable contaminant levels in sediments is termed AOPC. AOPCs were defined early in the FS planning process and represent a general indicator of the areas of interest for the draft FS. The AOPC boundaries are not defined based on precise methods or rules. SMAs are refinements of AOPCs that account for additional factors related to risk, the appropriate mapping of risk, definition of contaminated sediment volumes, as well as engineering considerations related to designing and conducting sediment remediation. The refinement from AOPCs to SMAs reflects the RI/FS iterative process as outlined in guidance (EPA 2005a).

5.1 HISTORY OF AREAS OF POTENTIAL CONCERN

Sediment AOPCs for the Site were first defined by EPA in June 2009 (EPA 2009a) as approximate estimates of areas that might need to be addressed in the draft FS (Figure

5.1-1). As part of this effort, EPA identified several select PRGs (for PCB human health smallmouth bass consumption, PCB background levels, BaPEq human health sediment direct contact, and benthic risk areas), which later became part of the RG ranges described in Section 3.5. EPA indicated that in most instances these PRGs would be mapped only within the AOPC boundaries, subject to later EPA confirmation (i.e., review of this draft FS). This mapping method was followed for the draft FS because mapping routines have difficulty accurately mapping areas where data density is low, which is generally the case at the edges of AOPC boundaries.

EPA also defined a "Site-wide AOPC" outside the "localized" AOPCs shown in Figure 5.1-1, which includes areas of lower levels of potentially unacceptable risks as determined using a broad range of PRGs (see Sections 3 and 4). The overall concept of Site-wide versus localized AOPCs is an important one for the draft FS that is described more in Section 5.9. This concept recognizes there are:

1. More discrete localized areas representing higher levels of potentially unacceptable risk that will be the focus of active remedies
2. A larger area inclusive of the entire Site that represents lower levels of potentially unacceptable risk that will not be the focus of active remedies.

> *Currently, upstream background concentrations in surface water and suspended sediment entering the Site are high enough to cause greater than a 10^{-5} cancer risk. Consequently, the complete elimination of potentially unacceptable risks in the Site-wide AOPC through MNR or as assisted by active remediation in SMAs, is not an expectation of the draft FS evaluation.*

As discussed in the RAOs section (Section 3.2), sediment remedies by themselves are not expected to completely eliminate potentially unacceptable risk (i.e., because they cannot attain levels below background) either inside the localized AOPCs or in the Site-wide AOPC, particularly for human health fish consumption using exposure assumptions from the BHHRA, even with long-term MNR as part of the overall remedy. Source controls and other PCB reduction efforts conducted under other regulations and programs within the Willamette River watershed would be necessary to achieve these very low risk levels, if attainment of these levels is even possible. Currently, upstream background concentrations in surface water and suspended sediment entering the Site are high enough to cause greater than a 10^{-5} cancer risk level in people (e.g., using BHHRA assumptions for human health fish consumption of PCBs for adult, non-Tribal, smallmouth bass, whole body low consumption rate per the BHHRA). Consequently, the complete elimination of potentially unacceptable risks in the Site-wide AOPC through MNR or as assisted by active remediation in SMAs, is not an expectation of the draft FS evaluation.

The above concept of localized versus Site-wide AOPCs has been refined by LWG using SMAs in the following subsections to further differentiate where active remedies will and will not be considered in alternatives development. In addition, the AOPC outlines originally proposed by EPA have been refined to be more consistent with the most recent data and RG ranges available for the project.

5.2 OVERALL DEVELOPMENT OF SEDIMENT MANAGEMENT AREAS

Whereas AOPCs provide the broadest and most approximate delineation of sediment areas with higher potentially unacceptable risk, SMAs refine that delineation for use in alternatives development and include consideration of other engineering factors (described more below) relevant to the draft FS evaluation including sediment volume determination. The variation in SMA sizes is determined by the range of RALs described in Section 4, with higher RALs identifying smaller SMAs and lower RALs identifying larger SMAs. The total SMA size is the aggregate of the areas identified by a combination of RALs, overlain with the benthic comprehensive risk areas (described more in Section 5.3). As noted in Section 4, the benthic comprehensive risk areas also include some size variation based on a range of expectations about where within some of these areas the benthic community will naturally recover. Sections 5.3 through 5.8 contain additional details and information related to SMA development.

SMAs are explicitly defined as areas proposed for active remediation (e.g., where capping, dredging, and similar active remedial construction will be included in remedial alternatives). “Non-active” remediation refers to MNR, which is described more in Section 6. The effectiveness of MNR outside the SMAs is considered in SMA development. MNR effectiveness in these wider areas was extensively evaluated using empirical information collected for the RI/FS as well detailed modeling based on this information. This evaluation is described more in Section 6.2.2. Given that SMAs represent a refinement of localized AOPCs, once SMAs are defined, localized AOPCs play no further role in determining where active remedies versus MNR take place in alternatives. Therefore, from this point forward in the draft FS, SMA boundaries are the means used to define active remedy versus MNR areas.

Once SMAs are defined, a map is created that shows the extent of these areas across the entire Site for each of the groups of RALs noted above. These areas, as mapped across the entire Site, define the acreages for the range of Site-wide remedial alternatives described more in Section 7 (i.e., Alternatives B through F). For Section 5 purposes and later, these overall Site-wide acreages defined by each set of RALs are referred as the “alternatives” or “alternative areas” even though alternatives are not fully defined until Section 7. This helps to differentiate these Site-wide acreages from the term “SMA,” which is used to refer to the process of developing active remedy areas, specific areas within the Site (e.g., SMA 17S), or issues related to specific areas within the overall alternative area defined by a set of RALs.

5.3 SMA MAPPING METHODS

This section describes in more detail the methods of mapping SMAs for the draft FS using the basic approach described in Section 5.2. The surface sediment distribution for each RAL contaminant is mapped in a Geographic Information System (GIS) using a geostatistical contouring algorithm known as NN. The LWG recommended and EPA generally accepted the use of this contouring approach because of its relative simplicity as compared to some other contouring approaches that require more explicit assumptions and determination of input variables, which are often subject to negotiation. Selection of this contouring method should not be taken as an endorsement of the method over other potential methods, all of which have their own advantages and disadvantages and which may be more appropriate for decision making at the remedial design stage. Some of the sensitivities/uncertainties related to contouring assumptions are described more in Section 5.11 and Appendix E (Section 5).

Once the surface sediment contaminant concentration contours are defined, the RALs for each alternative can be mapped by highlighting areas above the contour line equivalent to the RAL in question for each contaminant. The groups of RALs to be mapped in this way, along with benthic risk areas, are described in Section 4, Table 4.4-1. These RALs, and the benthic risk areas, have been further organized into SMA groups and expressed in terms of alternative designations in Table 5.3-1. The alternatives are designated B through F, with Alternative A being the no action alternative, as described more in Section 7.[1] For Alternative B, the comprehensive benthic risk areas were adjusted based on areas qualitatively estimated to naturally recover within 5 to 10 years, as described in Section 4.3. For all other alternatives, the entire comprehensive benthic risk area is included in the SMAs. Maps of SMAs for Alternatives B through F are shown in Figures 5.3-1a through e.[2]

In addition, the mapping of RALs to define SMAs was adjusted for consistency with where the risk assessments found the types and levels of potentially unacceptable risks associated with the comparative RGs used to develop the RALs. Specifically, risks do not exceed 10^{-6} cancer risk level for BaPEq for Tribal fisher sediment direct contact scenario consistent with the primary BaPEq RG upstream of RM 8.5 where lower RALs could highlight some areas. In these cases, SMAs exceeding RALs were not developed in these areas. For example, although localized areas exist above the BaPEq RAL for Alternative F in AOPC 17S Swan Island, the average concentrations in these areas do not pose potentially unacceptable risks (exceeding 10^{-6}) for this scenario, per the BHHRA. BaPEq risks exceeding 10^{-6} for this scenario were mapped via RALs in the following shoreline half river miles outside of the navigation channel:

- RM 1.5-2E[3]
- RM 2.5-3W
- RM 5-5.5E
- RM 5.5-6W

[1] As described in Section 4, EPA also directed some lower RALs than those shown for Table 4.4-1 (EPA 2011f and LWG 2011b) for all of the RAL contaminants. These include RALs of 50 ppb for PCBs, 600 ppb for BaPEq, 10 ppb for sum-DDE, 15 ppb for sum-DDD, 20 ppb for sum-DDT, and 0.005 ppb for 2,3,4,7,8-PCDF. As agreed with EPA, Section 7 discusses a potential alternative constructed based upon these additional lowest RALs and conducts a screening evaluation of this potential alternative as it compares to alternatives constructed consistent with the RAL increments in Table 4.4-1.

[2] These maps also show refined AOPC boundaries. These refinements are described more Section 5.3.2.

[3] Note that the draft FS Site starts at RM 1.8, but the BHHRA included evaluation downstream to RM 1.5.

- RM 2.5-3E
- RM 3-3.5W
- RM 3.5-4W
- RM 3.5-4E
- RM 4-4.5W
- RM 4-4.5E
- RM 4.5-5W
- RM 4.5-5E
- RM 5-5.5W
- RM 5.5-6E
- RM 6-6.5W
- RM 6-6.5E
- RM 6.5-7W
- RM 7-7.5W
- RM 7-7.5E
- RM 8-8.5W
- RM 8-8.5E

5.3.1 Comprehensive Benthic Risk Area Mapping

The approach for identifying recommended comprehensive benthic risk areas is described further in Appendix P and summarized below.

The following LOEs were developed to identify comprehensive benthic risk areas:

1. Sediment AOPCs for the Site were first defined by EPA in June 2009 (EPA 2009a) in coordination with LWG. This predated the draft final BERA.
2. Locations with empirical bioassay results indicating significant toxicity were identified.
   – One toxicity endpoint (*Chironomus* biomass or growth, *Hyalella* biomass or growth) exceeding a Level 3 (L3) threshold or two endpoints exceeding a Level 2 (L2) endpoint were considered significant toxicity.
3. Locations where significant sediment toxicity is predicted based on sediment chemistry exceeding a MQ[4] of 0.7 or a pMax[5] of 0.59 were identified.
   – Sampling locations where both the MQ and the pMax thresholds were exceeded were considered toxic.
   – Sampling locations where neither the MQ or pMax threshold was exceeded were considered non-toxic.
   – Sampling locations where the models disagreed (i.e., either the MQ or the pMax threshold was exceeded, but not both) were considered uncertain.
4. Locations where empirical tissue residues or, in the absence of empirical tissue residue data, predicted tissue residues exceeded their toxicity reference values (TRVs) were identified.

[4] The MQ is the average exceedance factor across the entire set of Site-specific FPM SQVs.
[5] The pMax is the maximum probability of toxicity predicted by the Site-specific LRM, across all chemicals with some potential contribution to the observed toxicity seen in the empirical bioassays.

   - The evidence of risk provided by measured or predicted exceedance of metals TRVs was considered weak because of species-specific differences in metals sequestration or other bioregulation.
   - The evidence of risk provided by predicted exceedance of the TBT TRV was considered weak because of high uncertainty in the TBT bioaccumulation model.

5. Areas where concentrations in shallow TZW exceeded ambient water quality criteria for the protection of aquatic life by a factor greater than 100 were delineated.
6. All of the above LOEs were then overlaid on a map and assessed as follows:
   - Comprehensive benthic risk areas were identified where two or more adjacent sampling locations indicated potential risk to the benthic community based on either empirical or predicted toxicity, empirical or predicted bioaccumulation, empirical TZW chemistry, or a combination of bioassay and chemistry LOEs.
   - Because empirical toxicity is the primary LOE, toxicity predicted by chemistry exceedances (i.e., MQs or pMax) were overridden by no-hit bioassays where these lines co-occurred.
   - TZW exceedance areas were identified as comprehensive benthic risk areas.
   - Boundaries of the comprehensive benthic risk areas split the distance between sampling locations exceeding criteria and surrounding clean sampling locations except where:
     - Other physical features were present (e.g., pier, channel edge, property boundary), in which case the boundary was drawn at the physical features.
     - The nearest sampling location was at a distance greater than 200 feet, in which case the boundary was drawn at a subjective distance less than halfway to nearest sampling location.

The resulting benthic risk areas are shown on Figure 5.3-1b through e. The reduced benthic risk areas to qualitatively account for potential natural recovery are shown in Figure 5.3-1a. Benthic risk areas are generally inside of alternatives otherwise defined by RALs and add between 1 to 5 percent to the total area of alternatives.

5.3.2 Refinement of AOPC Boundaries

EPA's original AOPC outline boundaries as shown in Figure 5.1-1 were slightly modified to be consistent with the SMAs as described above. These refinements are shown in Figure 5.3-2 and include:

1. After EPA's development of the first AOPCs, new data in the area of RM 11E was added to the draft FS dataset. Prior to this data being added to the FS dataset, it was recognized that limited data existed in this area in the river, and that once these data were available, AOPC 25 would be refined to include these data. This refinement resulted in a relatively small expansion of this AOPC boundary line.
2. EPA's AOPC 1B was removed and the line for AOPC 1 was adjusted to be inclusive of SMAs for Alternatives B through F.
3. EPA's AOPCs provided an overlap of AOPC 9 and AOPC 14. Having the same areas designated by two AOPC numbers was found to be confusing, and therefore, these AOPCs were redefined to cover the same total area with no overlap in the designations.
4. EPA AOPCs 9 and 17 covered large areas and, for logistical purposes, these AOPCs were each split in two to make them a more manageable size for the draft FS. This resulted in:
   a. AOPCs 9U (upstream) and AOPC 9D (downstream), with AOPC 9U being consistent with the 2009 Gasco/Siltronic AOC (see Section 2.7).
   b. AOPCs 17D (downstream) and AOPC 17S (for Swan Island Lagoon) such that 17S is consistent with the physical extents of Swan Island Lagoon and the shipyard area and 17D represents a large downstream area with relatively low PCB and other contaminant concentrations. An area with several results at or near the EPA average dry weight background estimate of 17 ppb total PCBs was used to split these two AOPCs.

Finally, it should be noted that no SMAs were defined using the above methods in AOPCs 2 or 26. These AOPCs are still shown on Figure 5.3-2 for inventory purposes only, and as a practical matter are not handled any differently than the Site-wide AOPC for the draft FS.

5.3.3 Low Data Density and Natural Neighbor Refinements

The mapping of individual RALs to define SMAs was refined in two ways to account for issues of low data density in some areas and artifacts of the NN contouring method. Examples of both of these refinements are shown in Figure 5.3-3.

The individual RALs were reviewed for low data density. First, for PCBs, DDT, DDE, and DDD,[6] it was recognized that in some areas of the navigation channel large areas were associated in the contouring program with one or two samples with few nearby neighboring samples. This resulted in these few samples over-representing likely contaminant extents in the overall contour maps and resulting SMA maps. To adjust for this, a "buffer distance" was applied to samples in the navigation channel based on the average distance between samples in the navigation channel throughout the Study Area.

[6] BaPEq RALs were mapped in shoreline areas outside the navigation channel, which generally have much higher data density. Therefore, these refinements were not carried out for BaPEq mapping.

This buffer distance essentially sets a circle around the station with the radius equal to the buffer distance, such that SMA areas were not mapped beyond this distance. The buffer distance was calculated separately for each contaminant, so that a buffer for one contaminant may be different than another.

It was also recognized that 2,3,4,7,8-PCDF data density created similar issues in shoreline areas outside of the navigation channel. To adjust for this, a similar "buffer distance" was applied to 2,3,4,7,8-PCDF samples outside of the navigation channel based on the average distance between samples outside of the navigation channel throughout the Study Area. A further analysis of data density of 2,3,4,7,8-PCDF is included in Section 5.11.1.

Buffer distances are shown in Table 5.3-2.

Additionally, areas with BaPEq and total PCBs concentrations greater than RGs were not mapped outside of AOPC boundaries consistent with EPA AOPC development methods, as described in Section 5.1. These areas were minor. If BaPEq and total PCBs areas were mapped outside of AOPC boundaries, this would increase the total area of Alternative F by 1 percent and would not affect the size of Alternatives B through E. RALs for all other contaminants were mapped to their full extents regardless of AOPC boundaries, with the exception of one area downstream of AOPC 4 in Alternative E and F. This area was based on one sum-DDT sample collected in Round 1. All other samples collected in the same general area in Round 2 were well below the Alternative E and F sum-DDT RALs; therefore, this area was not included in Alternatives E and F.

It is important to note that although these data density refinements were applied, the dataset is considered adequate for draft FS purposes and FS-level descriptions of SMAs, alternatives, volumes, and cost estimates. It is common for draft FS datasets to have some areas of lower density samples, which are sampled in remedial design where needed to refine SMAs for design-level analyses.

The NN contouring algorithm has some limitations in terms of recognizing physical features that are real boundaries, and individual RALs were analyzed to remove NN artifacts. Areas without a sample were considered an artifact and removed. For example, the NN algorithm does not recognize shorelines as boundaries to the contouring program. This is particularly pronounced where the shoreline is more convoluted, such as around the Swan Island peninsula and the small peninsula in the downstream end of AOPC 19 as shown in Figure 5.3-3. Consequently, in these cases, the additional areas identified by the NN algorithm where there is no sample point within them are not included in the SMAs, as shown, for example, in Figure 5.3-3.

Finally, the combined RAL areas for each alternative were reviewed for similar data density and NN contouring issues. Isolated areas of less than 500 square feet with no samples inside them were not included in SMAs. Similarly, isolated gaps within the SMAs of less than 500 square feet were included in the SMA if there were no samples defining the gap.

5.4 DEVELOPMENT OF SUBSMAS BASED ON SITE USE/PHYSICAL FEATURES

SubSMAs are developed in order to identify areas within the overall SMAs where Site use or physical factors may influence the implementability or application of various remedial technologies (Section 6) that will be used in alternative development (Section 7). EPA Region 10 has indicated that "Sediment Management Unit" (SMU) is the terminology that is more familiar within the region for this concept. Given that the terms SMU and SMA have been used almost interchangeably on many sediment remediation projects, both nationally and within Region 10, to avoid potential confusion, for the remainder of this document the term subSMA is used for this concept.

Site use data and physical features were used to determine subSMA types and are based on available information at the draft FS stage (see Section 2). SubSMAs are developed in order to simplify volume and cost estimates for the draft FS. These areas will be refined as part of remedial design.

SubSMA types as presented in Table 5.4-1were developed based on the range of factors expected to most likely affect the implementability of various remedial technologies. These same factors are then used for the identification and screening of technologies in Section 6. Each subSMA is given a two character code that describes the most relevant physical features and Site uses that are present in any given area. Other considerations as detailed in Section 5.4.3 were used to assign an additional code suffix to subSMA types as needed for particular areas within the Site. Figure 5.4-1 shows the subSMAs types that were spatially defined and assigned to the categories in Table 5.4-1 for Alternative F, the largest alternative.

5.4.1 Site Use SubSMA Types

Site uses affect the way that remedial technologies may be applied because they may limit where certain technologies are effective or implementable. Site use information was gathered from the Site Use Survey and from publicly available materials as described in Section 2.4.

- Navigation Channel (NC)
  - The NC designation was applied to the area identified as the federally authorized navigation channel, as detailed in Section 2.4. Maintenance dredging to maintain the channel and vessel traffic can impact the implementability of some remedial alternatives (e.g., capping).
- Potential Future Maintenance Dredge (FMD)
  - Potential FMD areas were identified as areas where current or likely future Site uses may result in dredging to accommodate vessel access to docks and similar shoreline areas. These areas are identified in Section 2.4 (Table 2.4-1 and Figure 2.4-3) including assumptions of current or likely future required depths. Note that some areas in AOPC 1 and 2 are identified as FMD areas

even though they are currently inactive with no access requirements because they may be used in the future. FMD areas present similar implementability issues for remedial technologies as discussed above for NC areas.

5.4.2 Physical Feature SubSMA Types

Physical features were determined from a variety of sources including field observations, bathymetric data, and aerial images.

- Structure Considerations – The following subSMA types describe physical features related to structures at the Site. The presence of structures can impact the implementability of remedial technologies in many ways, creating access issues, additional time or expense, and the need for more specialized equipment from that used in open areas. Areas around structures were assigned to one of the subSMA types listed below (SS, SN, SU, or SL) based on engineering review of the sources of information noted above:
  - Under Robust Structures (SS) (i.e., heavy structures on tables and figures)
    - This sub-SMA applies to areas under or close to structures where dredging could undermine structural stability. This subSMA designation was applied to any area under a structure or in the adjacent structural offset area (5 feet around the structure as an FS-level assumption). This subSMA type addresses the potential limiting effects of structures on construction operations. This includes the potential impact on implementability and costs of potential removal of these structures, which is evaluated more in Section 6.
  - Limited Access Structures (SL)
    - Areas identified as limited access areas due to structures, obstructions, and/or water depth are usually behind a pier where construction access with typical equipment is difficult. These areas are usually accessible from water, but typically the working space is small and is confined by a combination of shallow water (shoreline) and in-water structures. This subSMA type reflects difficulties larger equipment will have working in such a small space and indicates the need for smaller equipment and slower construction rates.
  - Upland Dredging (SU)
    - Areas identified as upland dredging are confined by in-water structures such that water-based operations are infeasible without structure removal. However, these areas have characteristics that allow for land-based dredging to occur. Favorable characteristics for upland dredging include sufficient open space for equipment to operate safely, gentle slopes that allow access to areas, or robust piers from which construction operations could potentially occur.
  - Behind Structures with No Access (SN)

    - When areas are not covered by a structure, but structures or other obstructions and/or water depth impede the feasibility of dredging from water and nearshore features prevent land-based removal, the area is considered SN. These areas typically have characteristics that will make water-based or land-based dredging operations difficult. In water, these areas were typically surrounded on all sides by robust structures. In order to be considered SN, the areas must also be inaccessible from land. Typical obstacles to land-based operations include steep slopes and upland structures that limit working space.

- Open Water (OW)
  - Open water areas are areas not impacted by structures (SS, SL, SU, SN) or within NC or potential FMD areas. By definition, they are free of structures, Site usage, and maintenance dredging requirements. This includes areas of light structures (e.g., floating docks) noted on Figure 5.4-1 that can be relatively easily moved to allow open water access and then returned to their former location after remediation.
- Previously Remediated Area (CAP)
  - Engineered caps have been installed as part of remediation activities in two areas of the Site (AOPC 6 and the McCormick and Baxter remediation area in RM 6). No active remediation will occur in these areas since it is assumed that these areas have already been actively remediated.

5.4.3 Other Considerations for SubSMAs

In addition to the subSMAs identified above, the considerations listed below also potentially affect the effectiveness and implementability of technologies. Because these considerations could occur in combination with the conditions discussed in Section 5.4.1 and 5.4.2, a suffix was added to the above codes in areas where both conditions occur.

- Disposal Sites (Z)
  - These are locations of confined aquatic disposal (CAD) and CDFs within the Site. Disposal facility locations evaluated for the draft FS are described more in Section 6.2.9. They are only added to some alternatives developed in Section 7. In cases where the location of a particular CAD or CDF overlaps with a particular subSMA, these areas are identified by adding a “z” suffix to the end of the subSMA designation. In these cases, the disposal facility can provide a means to remediate contamination in the subSMA, if properly designed, by isolating contamination in place.
- Wave Zone (WZ)
  - The WZ area is defined by the wind wave/vessel wake analysis (Section 4.1 of Appendix Hc) as any area above an elevation of 0 feet NAVD88 extending to

the top elevation boundary of the Study Area (13 feet NAVD88). Any area in this zone is given a "wz" suffix. Waves cause physical disturbance of the sediment bed that may cause implementability issues for some remedial technologies.

The steepness of sediment bed slopes was also considered in this evaluation and slopes steeper than 2 horizontal to 1 vertical ratio (2H:1V) can have some impact on technologies that require placement of materials on the sediment bed (e.g., capping). However, it was found that in general there are not large areas of steep slopes in excess of 2H:1V within the Study Area that would require special management at an FS-level of detail. Slopes between 2H:1V and 3H:1V would likely need additional measures based on evaluations during remedial design.

The level of debris (e.g., sunken logs and piles) on the sediment bed was also considered based on the information in Section 2.1. The amounts and areal coverage of debris fields were not sufficient across the Study Area to cause development of a separate subSMA type for this issue. However, the presence of substantial debris fields was factored into the cost estimates for dredging in some areas.

5.5 EVALUATION OF POTENTIAL OREGON HOT SPOTS, PRINCIPAL THREAT MATERIAL (PTM) AND HAZARDOUS WASTE

This section presents the identification of potential Oregon hot spots, PTM areas, and hazardous waste, as required under Oregon Environmental Cleanup Law (a potential ARAR), CERCLA policy, and Resource Conservation and Recovery Act (RCRA) policy, respectively.

5.5.1 Potential Oregon Hot Spots

Oregon's hot spot law represents an additional step in cleanup alternatives analysis when there are hazardous substances that are present in high concentrations, are highly mobile or cannot be reliably contained, and that would present a risk to human health or the environment exceeding the acceptable risk level if exposure occurs (ORS 465.315(2)(b)(A); see also OAR 340-122-0115(32)(b)). For such potential Oregon hot spots, the draft FS applies a preference for treatment or excavation and off-site disposal by applying a higher threshold for evaluating the reasonableness of the cost of treating or excavating the hot spot (ORS 465.315(1)(d)(E) and (e)).

For the following reasons, LWG has concluded that there are no identifiable potential Oregon hot spots within the Site to be addressed by this draft FS:

- As discussed in Section 5.5.1.2 and 5.5.1.3, the LWG has concluded that there are not identifiable areas within the Site that are likely to migrate or that are not reliably contained.[7] If, as with the federal "principal threat" approach, an Oregon

[7] NAPL exists in some of the sediments in SMA 9U. The presence of this material and potential treatment or removal of it is being evaluated under the SOW for the 2009 Gasco/Siltronic AOC. The SOW includes a

hot spot is defined by the occurrence of all three conditions, there are no potential Oregon hot spots at the Site.[8]

- The application of the "high concentration" criterion by itself is problematic because the Site risk assessment proceeded based on EPA guidance and direction rather than under Oregon State regulation and guidance. As detailed in Section 5.5.1.1, the LWG evaluated several approaches for identifying areas of "high concentration," and each has limitations and inconsistencies with application of Oregon rules. The approach that is most consistent with both the Oregon hot spot rule and guidance focuses on individual contaminants and the exposure pathways primarily responsible for unacceptable risk. The result of that approach is that no "high concentration" Oregon hot spots are identified.
- As discussed in detail below, there are significant obstacles in attempting to apply the Oregon hot spot rule to the results of the Portland Harbor Superfund Site risk assessments. The conservative assumptions used in the risk assessments result in estimates of potentially unacceptable risk at concentrations well below background levels. Consequently, these risk assessment assumptions could be used (under some approaches discussed more below) to determine potentially very large areas that exceed potential Oregon hot spot levels, which is contrary to the intent of these programs.

5.5.1.1 High Concentration Potential Oregon Hot Spots

OAR 340-122-0115(32)(b) provides the following definition for a high concentration Oregon hot spot.

"If hazardous substances present a risk to human health or the environment exceeding the acceptable risk level, the extent to which the hazardous substances:

> *(A) Are present in concentrations exceeding risk-based concentrations corresponding to:*
>
> > *(i) 100 times the acceptable risk level for human exposure to each individual carcinogen;*
> >
> > *(ii) 10 times the acceptable risk level for human exposure to each individual noncarcinogen; or*

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definition of "substantial product" that may be found at SMA 9U and describes a preference for removal of such material that is generally consistent with the Oregon hot spot procedures.

[8] The language of the statute is somewhat ambiguous. Although the statute could be interpreted to mean that hazardous substances in high concentrations are only Oregon hot spots if they are also either highly mobile or cannot be reliably contained, the regulatory definition appears to suggest that any of these conditions alone can be sufficient to define a hot spot. Regardless of this ambiguity, the draft FS evaluates hot spots on the basis of each element alone.

> *(iii) 10 times the acceptable risk level for exposure of individual ecological receptors or populations of ecological receptors to each individual hazardous substance."*

Consistent with this regulation, the Focused PRGs were reviewed to determine whether contaminant receptor pairs potentially pose risk at the Site at 100 times (for human health cancer risk) and 10 times (for human health noncancer and ecological risk) acceptable risk levels. Three contaminant receptor pairs with Focused PRGs were found to exceed these levels. BaP clam consumption was not designated as a Focused PRG or an RG for reasons stated in Section 3.5 and was not evaluated further for potential Oregon hot spots. The only other contaminant receptor pairs found to exceed the levels were total PCBs and dioxin/furans for smallmouth bass fish consumption.

Risk levels much lower than the 10^{-4} cancer risk level represented by the smallmouth bass fish consumption total PCB RG are not attainable with active remedies given that the upstream background risk levels are nearly at this level. The background levels for total PCBs is about 5×10^{-5}, only about two-fold less than the nominal Oregon hot spot levels. Therefore, the RGs selected by EPA for PCBs and the remedial action alternatives in the FS are already focused on reducing risk to potential Oregon hot spot levels using technologies that include removal and/or treatment.

The following subsections describe three of the approaches the LWG undertook in an effort to identify "high concentration" hot spots, each of which ultimately proved inconsistent with Oregon rules.

Based on the evaluation, LWG concludes that each approach involves potentially contradictory or inconsistent elements with respect to the Oregon hot spots rule, but that Approach #3 is most consistent with the rule and guidance. Regardless of the methodology or outcome of these evaluations, the LWG believes the intent of the rule is satisfied in the draft FS, because each active remedy alternative (i.e., Alternatives B through G) identifies the highest concentration areas and volumes and evaluates the cost-effectiveness of dredging or treating those materials.

5.5.1.1.1 Hot Spot Approach #1

Approach #1 identifies areas of the Site where potentially unacceptable risks for individual PCB and PCDF congener surrogates (i.e., surrogates of overall potential PCB and PCDF risks) exceed theoretical Oregon hot spot values for 10^{-4} cancer risk or noncancer HQ of 10, based on whole body smallmouth bass fish consumption per each one river mile SWAC. The one river mile exposure area for the bass consumption scenario is consistent with the draft final BHHRA. The overall methods for this approach were discussed in the February 17, 2010 meeting with Eric Blischke and Chip Humphrey including the use of individual congeners and the SWAC-based mapping.

This approach necessarily steps away from the BHHRA and BERA methodology and the resulting Focused PRGs identified by EPA, which are based on potential risk from total PCBs, because the Oregon hot spot rule applies only to individual contaminants, not classes of contaminants [OAR 340-122-0115(32)(b)]. This approach therefore uses specific congener surrogates for potential total PCB and dioxin/furan risks (i.e., PCB 126 and 118 as well as 2,3,4,7,8-PCDF; (*see* DEQ October 2007, Record of Decision, Owens Brockway Glass Container site including Johnson Lake [which similarly uses PCB 126 as a surrogate for the Oregon hot spot analysis]). There are multiple decisions and judgments that must be made in order to identify the surrogates to represent potential total PCB and total dioxin/furan risks as identified in the BHHRA and BERA. Thus, no set of surrogates will be perfectly representative of risks potentially posed by the summed compounds.

Using this approach, theoretical Oregon hot spot values as shown in Table 5.5-1 were developed.

This approach is an overly conservative interpretation of potential Oregon hot spots because it is based on whole body fish consumption. DEQ's 1998 *Guidance for Identification of Hot Spots* (DEQ 1998a), states that the Oregon hot spot analysis should be performed for "the exposure pathways primarily responsible for any unacceptable risk." In the case of the fish consumption exposure scenarios, a fillet consumption exposure is more typical than a whole body consumption exposure (see Approach #3 below).

Based on the methodology and the stated concerns associated with Approach #1, the LWG does not support pursuing this approach to address Oregon hot spots in the draft FS.

5.5.1.1.2 Approach #2

Approach #2 involves evaluating PCB and 2,3,4,7,8-PCDF congener surrogates based on a value of 100 times the presumed acceptable risk level for the Site. Oregon rules, OAR 340-122-115(31)(b), state that hot spots for media other than groundwater or surface water (e.g., sediments), are defined by concentrations exceeding 100 times the acceptable risk level for human exposure to each individual carcinogen. Although the final acceptable risk level will not be selected by EPA for this Site until the ROD is issued, by selecting the Focused PRG for PCBs based on smallmouth bass consumption at a 10^{-4} cancer risk level, EPA has provided a preliminary indication of the potentially acceptable risk level for highly bioaccumulative compounds that may eventually be selected. Therefore, Approach #2 evaluates data on a point-by-point basis that exceed 100 times the relevant smallmouth bass consumption PCB 126 and 2,3,4,7,8-PCDF theoretical Oregon hot spot values, which are consistent with the total PCB and PCDF Focused PRG scenario.

Using this approach, theoretical Oregon hot spot values as shown in Table 5.5-1 were developed.

This approach is also likely overly conservative in that it evaluates exceedances of the fish consumption risk on a point-by-point basis, as opposed to a river mile SWAC basis. This is contrary to the Oregon hot spot rule that focuses on the areas where, “hazardous substances present a risk to human health or the environment exceeding the acceptable risk level,” which indicates that the risk needs to be evaluated over the exposure area applicable to the particular risk (*see* DEQ, October 2007, Record of Decision, Owens Brockway Glass Container Site including Johnson Lake which considered the exposure area to be the entire lake). This approach also has the same issues and shortcomings as discussed for Approach #1 regarding the use of whole body bass consumption assumptions and surrogate congeners to represent potential total PCB and dioxin/furan risks presented in the BHHRA and BERA.

Based on the methodology and the stated concerns associated with Approach #2, the LWG does not support pursuing this approach to address Oregon hot spots in the draft FS.

5.5.1.1.3 Approach #3

Approach #3 attempts to identify areas of the Site where potentially unacceptable risks for the PCB 126 and 2,3,4,7,8 PCDF congener surrogates exceed theoretical Oregon hot spot values for 10^{-4} cancer risk or noncancer HQ of 10, based on fillet (with skin) bass consumption calculated on a river mile SWAC basis (similar values for PCB 118 were not identified because of the low data density). This is the same methodology as used in Approach #1, except that the theoretical Oregon hot spot values are based on a fillet with skin consumption scenario instead of whole body consumption.

Using this approach, theoretical Oregon hot spot values as shown in Table 5.5-1 were developed. These values result in the identification of no “high concentration” Oregon hot spots. The result is that no Oregon hot spots are identified.

> *Approach #3 appears to be the application that is most consistent with the hot spot rule…The result of this approach is that no hot spots are identified.*

Approach #3 appears to be the application that is most consistent with both the Oregon hot spot rule, which directs an analysis of individual contaminants, and the guidance referenced above, which indicates that the hot spot analysis should be performed using “the exposure pathways primarily responsible for any unacceptable risk.” As stated above, the result of this approach is that no Oregon hot spots are identified. Section 9.2.2.1 furthers presents information on the Oregon hot spots for all the active remedy alternatives.

5.5.1.2 Not Reliably Containable Potential Oregon Hot Spots

Criteria to determine what is a “not reliably containable” potential Oregon hot spot in sediment are provided in the regulation (OAR 340-122-0115(32)(b)(B)) and expanded upon in the DEQ 1998a hot spot guidance. The guidance states that,

> *"Although 'not reliably containable' hot spots can be present in sediments, containment often has been proven to be a protective and feasible remedy for contaminated sediments…As required by the Environmental Cleanup Rules, the extent to which contaminated sediments can be reliably contained must be determined as part of the feasibility study."*

Where the Oregon guidance refers to "containment" as a proven sediment remedy, the most likely sediment remedial technology being referred to is capping. The effectiveness of capping as a sediment remediation technology at this Site is evaluated in detail in Section 6.2 and Appendix Hc, Sections 3 and 4. This information includes evaluations of all the isolation mechanisms that caps are designed to provide including minimization of dissolved phase contaminant flux as well as erosion and/or other disturbances that could cause physical transport of contaminated sediments. The capping effectiveness and stability modeling evaluation in Appendix Hc (Sections 3 and 4), and summarized in Section 6.2, indicates that all sediments at the Site are reliably containable through one or more types of capping technologies that are commonly applied to sediment sites. Consequently, no "not reliably containable" potential Oregon hot spots are identified for this Site in the draft FS.

5.5.1.3 Highly Mobile Hot Spots

Highly mobile hot spots are described under DEQ 1998a Oregon hot spot guidance as follows:

> *"Highly mobile hot spots can be present in sediments if contaminants are likely to leach out of the sediments and move into the surface water at concentrations that would cause a significant adverse impact on the use of the surface water."*

The regulations explain that a hot spot exists under this circumstance only if "treatment is reasonably likely to restore or protect such beneficial uses within a reasonable time, as determined in the feasibility study" (OAR 340-122-0115(32)(a) and (b)(B)). Therefore, existing surface water chemical concentrations are evaluated to determine whether there is any evidence of a significant adverse impact on the beneficial uses of the surface water that could be restored within a reasonable time through treatment.

This evaluation includes two primary steps. The first step uses the results of a comparison of existing surface water sample results to potential ARARs identified by EPA. Under this approach all depth-integrated surface water sample results meeting draft FS data quality objectives (Category 1 QA2) were used for comparison to potential human health ARARs, including Safe Drinking Water Act (SDWA) MCLs, Oregon Effective Water Quality Criteria for Human Health (Effective June 1, 2010; for fish consumption criteria[9]), and NRWQC for consumption of organisms. For comparison to

[9] As explained in Section 3.1.3, the draft FS generally has not been updated to incorporate the Oregon Human Health Water Quality Criteria for Toxic Pollutants that became effective October 17, 2011. However, both the pre- and post-October 2011 Oregon Human Health Water Quality Criteria for fish consumption are provided in Table 5.5-5.

potential ecological ARARs, all surface water sample results meeting draft FS data quality objectives were used. These water sample results were screened against Oregon Table 33A Freshwater Chronic Water Quality Criteria for Protection of Aquatic Life, Oregon Table 20 Freshwater Chronic Water Quality Criteria for Protection of Aquatic Life (chemicals with no Table 33A value), and freshwater chronic NRWQC. The results of this comparison are summarized in Table 5.5-2. For the following chemicals, one or more samples potentially exceeded one or more of these potential ARARs[10]:

- 2,3,7,8-TCDD
- 4,4'-DDT
- Dieldrin
- Total DDT
- Total DDx
- Total PCBs
- Total PAHs
- Aluminum
- Arsenic
- Mercury
- Zinc

Note than an exceedance of the above surface water criteria in the water column is not by itself an indicator of an issue with sediments, especially if the chemical is not "mobile" and/or the criteria are low and background concentrations in suspended or upstream bedload sediment would cause an exceedance of the surface water criteria.

The second step was to compare the concentrations of these 11 contaminants to the 95th percentile UPL background surface water concentrations defined in the draft final RI. In addition, the background concentrations were also compared to the potential ARARs identified above. These screening results are summarized in Table 5.5-3 and indicate that, for all of the contaminants listed above except total DDx and zinc, Site surface water background levels exceed one or more potential ARARs. This demonstrates that surface water entering the Site is already "significantly adversely affected." Therefore, any action in the Site is not reasonably likely to restore or protect such beneficial use, and the Site therefore does not fit within the definition of a highly mobile hot spot in ORS 340-122-0115(32).

5.5.2 Principal Threat Material (PTM) Areas

The NCP states that EPA expects to use "treatment to address the principal threats posed by a site, wherever practicable." This section evaluates "source material" within the Site consistent with EPA guidance on PTM (EPA 1991). Source material[11] is defined as

[10] For example, with respect to mercury and zinc, only the Oregon chronic aquatic protection criteria were exceeded, and less than 5 percent of the samples exceeded those criteria. Also, with respect to those substances flagged for exceeding the chronic aquatic life criteria (mercury, aluminum, zinc, and total DDX) those chronic criteria are meant to be compared to the average concentrations for 96 hours (4 days) and indicate concentrations that should not be exceeded more than once every 3 years (see OAR 340-041-0033). The LWG sampling and the analysis that has been provided are not specific to this temporal aspect of the criteria.

[11] As noted above, NAPL exists in some of the sediments in SMA 9U and is being evaluated consistent with the 2009 Gasco/Siltronic AOC.

"material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to groundwater, to surface water, to air, or acts as a source for direct exposure…" The guidance states:

> *"Principal threat wastes are those source materials considered highly toxic or highly mobile that generally cannot be reliably contained or would present significant risk to human health or the environment should exposure occur. They include liquids and other highly mobile materials (e.g. solvents) or materials having high concentrations of toxic compounds. No "threshold level" of toxicity/risk have been established to equate to a "principal threat." However, where toxicity and mobility combine to pose a potential risk of 10^{-3} or greater, generally treatment alternatives should be evaluated."*

Because all sediments at the Site can be reliably contained, no PTM areas were identified for this draft FS.

The guidance identifies PTM as materials that are "…highly toxic or highly mobile that cannot be reliably contained…," the presence of highly toxic or mobile material does not itself constitute PTM. As detailed in Section 6.2 and Section 3 of Appendix Hc (and as discussed in subsection 5.5.1.2 above) capping is a viable technology across the entire Site in terms of effective contaminant isolation. Because all sediments at the Site can be reliably contained, no PTM areas were identified for this draft FS.

In regards to the highly toxic criteria, the LWG has used RGs to identify and map "highly toxic" materials within the meaning of the PTM guidance. Use of RGs only is consistent with EPA's selection of these RGs (historically in the form of "Focused PRGs") to determine where active remedies will be focused in the draft FS. Thus, the risk assessments were reviewed for any risks exceeding a 10^{-3} cancer risk level for contaminants and human health scenarios on the RG list in Section 3.5. Table 5.5-4 shows the result of this review. The total PCBs human health smallmouth bass consumption RG was the only contaminant/scenario with risks equal to 10^{-3} risk (in 1 river mile only). Given that the guidance identifies PTM as "…highly toxic or highly mobile that cannot be reliably contained…," the determination of highly toxic (via the exceedance of the 10^{-3} cancer risk level RG) by itself, does not constitute PTM.

5.5.3 Hazardous Waste

Sediment moved from the Site is subject to RCRA hazardous waste regulations (40 CFR Parts 260 to 268) if the sediment exhibits a hazardous waste characteristic as shown by the TCLP or contains a listed waste (EPA 2005a). Sediment cores were collected (total of 11 cores in eight SMAs) for TCLP analysis during the RI as outlined in the *Sediment Chemical Mobility Testing Field Sampling Plan* (Anchor Environmental 2008a). The sediment core locations were identified using a sampling rationale that targeted previous RI sediment sampling locations where maximum chemical concentrations for TCLP analytes were measured. The maximum concentrations were screened using an EPA-promulgated screening calculation to assess the locations for TCLP testing and then further screened to maximize the chances of finding any potentially hazardous waste level materials such that the sediments would have substantial potential to leach contaminants at concentrations greater than the TCLP regulatory limits in an actual TCLP test.

TCLP data shown in Table 5.5-5 indicate that concentrations of contaminants in TCLP leachates are generally non-detect or well below RCRA regulatory levels, indicating that the sediments throughout the entire Site do not display hazardous waste characteristics and are non-hazardous waste materials suitable for Subtitle D disposal. Benzene exceeded the regulatory limit in one sample of the 11 cores collected and analyzed for TCLP leachates. The one TCLP exceedance for benzene occurred in one of three cores collected in SMA 9U at the Gasco former MGP sediments site. MGP wastes are, by definition not hazardous wastes per 40 CFR 261.24(a), which states:

> *"A solid waste (except manufactured gas plant waste) exhibits the characteristic of toxicity, if using the Toxicity Characteristic Leaching Procedures...contains any of the contaminants listed in Table 1 at the concentration equal to or greater than the respective valued given in that table."*

Oregon has adopted this rule, including the exception for MGP waste (OAR 340-100-002(1)). Also, NW Natural has already entered into a remedial design effort on this SMA with EPA. Consistent with the above determination, the 2009 Gasco/Siltronic AOC does not define MGP wastes as hazardous waste and also contains detailed procedures to determine appropriate disposal of MGP-related wastes, which will be followed during remediation of this SMA.

Existing information was reviewed to assess whether there is historical knowledge of releases of listed hazardous waste to Site sediment. Sediments that contain listed hazardous waste would need to be managed as hazardous waste if moved from the river unless they could be shown to no longer contain the listed waste. LWG members provided input based on their records of waste management, and waste management by non-LWG members was assessed by reviewing site summaries prepared for the CSM (Integral 2004). Two areas of sediment were identified as potentially containing listed RCRA waste. Certain sediment in the vicinity of the Siltronic NPDES outfall may contain F002 waste resulting from an accidental discharge of spent TCE,[12] and sediments near groundwater discharge zones at RM 6.9W (see Figures 5.7-1d and e for the location of this zone) may contain F027 listed wastes. No additional locations of listed hazardous wastes were identified through review of the site summaries. The potential for Subtitle C disposal of sediments in these immediate areas of potential listed waste (for alternatives that remove and dispose of sediments from these areas) was considered by assuming disposal costs in the alternatives consistent with placement in a Subtitle C landfill.

[12] The 2009 Gasco/Siltronic AOC defines the circumstances under which sediments contain F002 waste and must therefore be managed as hazardous wastes.

5.6 EVALUATION OF BURIED CONTAMINATION

The purpose of this evaluation is to determine whether alternatives should be modified due to the potential for buried contamination to be uncovered from anthropogenic factors such as propeller wash from vessels (propwash), wind/wake generated wave erosion, and maintenance dredging as well as erosion caused by natural river currents, particularly under high flow/velocity conditions.[13] Where reasonable potential exists for future exposure of buried contamination, active remediation of these areas may be warranted

This section addresses erosion or physical processes that might reveal areas of buried contamination and cause potential future risks, and identifies areas that were added to some alternatives based on this evaluation. With regards to other subsurface contaminant transport mechanisms, the only other possible mechanism would be dissolved phase transport of contaminants from deeper sediments to shallower sediments. This process is evaluated in detail through the use of the QEAFATE model, which includes a subsurface sediment package informed by contaminant core data throughout the Site and all physical/chemical processes relevant to dissolved phase transport including diffusion, groundwater advection, degradation (applicable to some contaminants only), surface sediment to surface water flux, and surface sediment mixing (i.e., bioturbation). Consequently, this modeling evaluation of each alternative, including no action, allows the identification of other areas of buried contamination that pose a reasonable potential future risk via dissolved phase transport and is discussed more in Section 6.2. Through this analysis, no specific areas were identified that would require addition to the alternative footprints.

5.6.1 Erosion Due to River Currents

Erosion due to river currents was modeled using the HST model (Appendix La) that is coupled to the QEAFATE model (Appendix Ha), which used subsurface sediment contaminant data from the Site to define subsurface (i.e., below the top 30 cm) sediment initial conditions in that model. This combined model is used to predict the potential for erosion of bedded sediments under large flow events (i.e., the 100-year flow event) and the potential of that erosion to reveal subsurface contamination such that contaminant exposures might occur. The baseline modeling for the draft FS is an evaluation of the "no action" or MNR scenario over 45 years, where no active remediation is assumed to occur. This no action modeling includes the 100-year flow event at Year 17 of the simulation and evaluates the subsequent changes in surface sediment concentrations immediately after this event and for the remainder of the 45-year period.

This modeling shows that, although the 100-year flow event creates some short-term perturbations in the Site surface sediment concentrations, these changes are relatively transient. These modeling results, including the duration and magnitude of surface

[13] Anchor drags and high energy groundings are other possible anthropogenic factors, but none of these forces are expected to create new and consistent erosion to new horizons that would different substantially from the propwash analysis, and they are not evaluated separately.

sediment concentration changes around the modeled flood event are discussed in more detail in Section 3 of Appendix Ha and Section 6.2 regarding MNR effectiveness. Further, similar future conditions associated with a flood event are also evaluated for each of the comprehensive remedial alternatives, where various amounts of active remediation are assumed. These results are discussed more in Section 8, but in general, the comprehensive remedial alternatives often show similar or less potential for changes in surface sediment concentrations, primarily due to the fact that some subsurface contamination is either removed or isolated beneath armored caps in the alternatives that include active remedies before the assumed flood event. An example of the surface sediment changes caused by the flood event at assumed Year 17 and shortly thereafter is shown in Figure 5.6-1 under conditions of no future remedial action. Similar graphs for several segments of the river and on a river mile basis are shown in Section 3 of Appendix Ha.

Expected changes in surface sediment concentrations due to river current erosion are relatively small and short in duration and, under the no action alternative, do not substantially alter the course of natural recovery as generally observed at the Site. There does not appear to be a need to identify any new areas of currently buried contamination that would have substantial impact on surface sediment concentrations. The extent to which any such erosion is expected to occur is fully integrated into and accounted for in the long-term surface sediment modeling results presented in Sections 6 and 8. Therefore, the importance, or lack thereof, of this process in terms of remedy success can be fully assessed via evaluation of the model results.

It should also be noted that this evaluation of erosion due to river currents is not completely reliant on the modeling. Certain portions of the Site show more of a balance of erosion and deposition over time and are not expected to recover as quickly. These areas are identified in the Section 6.2 analysis. Thus, although there is understood and quantified uncertainty (see the uncertainty bands in Figure 5.6-1 and Section 3 of Appendix Ha) associated with the modeling results, the overall LOEs of natural recovery support the above CSM and do not indicate a need to delineate extensive new areas of buried contamination due to river current erosion for addition to the surface derived SMAs presented above. Further, the modeling represents a clear quantitative methodology for evaluation of the potential for current generated erosion and exposure of buried contamination. Thus, the modeling uncertainties associated with the above evaluation are far smaller than those generated by qualitative or semi-quantitative estimates of this process that could otherwise be made.

5.6.2 Erosion Due to Propwash

Propwash modeling results are included in Appendix Fb, including estimates of potential surface sediment disturbance due to propwash forces based on the vessels and operating parameters determined through the Site Use Survey (draft FS Section 2). Disturbance related to “mixing” and “scour” are related concepts, and the extent to which a particular force on the sediment will cause mixing of existing sediments or scour and movement of those sediments to another location has primarily to do with other aspects of the long-term hydrodynamic and sedimentation regime present in any particular area (as quantified in Appendix Ha).

The results of the analysis in Appendix Fb indicates that, in the large majority of cases, propwash disturbance of surface sediments is expected to be to a depth of 30 cm or less, and that this represents the widespread and predominant condition at the Site. The results indicate that the heavier propwash areas are located in relatively shallower water areas of the navigation channel and near active docks (i.e., in future maintenance dredge areas where vessels routinely transit and moor at docks). Figure 5.6-2 shows the areas of estimated heavier propwash forces based on the analysis in Appendix Fb.[14] Even in heavier propwash areas, the extent of propwash-induced erosion is estimated to be mostly limited to the top 30 cm of sediment. This finding is based on a detailed evaluation of the likely sediment disturbance depths from propwash forces accounting for the full range of vessel types and operating water depths across the Site. Thus, although this process can significantly rework sediment, it generally does not have the potential to expose buried sediment well below the current surface sediment layer, although small localized exceptions in particular areas near some docks may exist that are difficult to measure and identify in a Site-wide study (see Appendix Fb).

Empirical surface sediment data in the draft FS dataset include sampling in these heavier propwash areas, in many cases with samples taken over multiple years within any particular area. Over the period of these sampling efforts, Site operations, such as vessel traffic and mooring, and the attendant propwash disturbances to the sediment bed have been ongoing. Thus, any areas of permanent erosion to deeper sediment layers has likely taken place some time ago and the surface sediment samples in these areas would be representative of these layers.

Regardless, a more accurate CSM for this process is that propwash-caused sediment disturbance is a periodic ongoing mixing and short-term resuspension process that exists in balance with natural forces of current driven deposition and/or erosion such that an overall variable equilibrium is set up over time. Rather than propwash creating a sudden new and constant sediment horizon, these areas are at steady state, having contaminant concentrations that represent a balance of increased contribution from deeper layers due to increased localized mixing/resuspension and some contribution of incoming depositing sediment (see Appendix Ha for more information on sediment contaminant concentrations associated with upstream suspended sediment entering and depositing within the Site). Thus, any areas that would have elevated contaminant concentrations due to this overall process are very likely already identified by the use of the draft FS surface sediment dataset at an FS-appropriate level of spatial detail.

5.6.3 Wind/Wake Generated Wave Erosion

A wind-wave and vessel-wake analysis was conducted using information on waterway traffic obtained from the USACE, Port of Portland, and correspondence with other

[14] Note Figure 5.6-2 is based on information provided in Section 2 and is focused on areas inside of AOPCs only.

property owners (see Section 4.1 of Appendix Hc for more details). This analysis considers both wind/wake generated wave forces as well as the variable river stage elevations that occur. The analysis shows that wave erosion is likely limited to areas of the Site along the shoreline above 0 feet NAVD88. Within this zone, there is an area of likely heavier wave/wake action from 6 to 13 feet NAVD88 and area of likely less forceful wave/wake action from 0 to 6 feet NAVD88. Wave erosion effects above 13 feet NAVD88 were not evaluated in the draft FS because they are above the Site boundary.

Like propwash, wave/wake action on the shoreline was ongoing throughout surface sediment sampling events contained in the draft FS database, and in the case of wave/wakes, is an even more constant and continuous process. The effect of this continuous wave action can be seen along most portions of the shoreline, where a nearshore bench exists and persists despite any past historical bank or nearshore maintenance dredging operations in these areas. This indicates that wave/wake action has set up a zone of variable equilibrium that is subject to these continuous forces. Thus, wave/wake action is unlikely to create sudden new and constant sediment horizon. Consequently, as with propwash, any areas that would have elevated contaminant concentrations due to this overall process are very likely already identified by the use of the draft FS surface sediment dataset at an FS-appropriate level of spatial detail.

5.6.4 Potential Future Maintenance Dredge Areas Outside of Navigation Channel

As discussed in Section 2.4, potential FMD areas were identified through Site Use Survey information collected from LWG members and additional potential FMD areas were assumed to exist in front of known active docks. While some of these potential FMD areas may never be dredged in the future, they are a reasonable estimate of the potential for maintenance dredging to reveal potential buried contamination, the subject of this section. The potential FMD areas are shown in Figure 2.4-3 and summarized in Table 2.4-1.

To evaluate the potential for buried contamination to be revealed due to maintenance dredging within potential FMD areas, the interval of elevation in the 2 feet directly below the expected maintained navigation depth was evaluated. This is a reasonable estimate of concentrations that could be uncovered during a maintenance dredging event, given typical overdredge allowances for contracting purposes and safety factors. For potential FMD areas with navigation depths equal to the current proposed navigation channel depth of -43 feet CRD, a larger interval of 10 feet below the required FMD navigation depth was evaluated to account for potential future FMD deepening that might occur after the proposed deepening of the navigation channel occurs.

In some potential FMD areas, no data existed below the proposed required navigation depth, and these FMD areas cannot be further evaluated as part of the FS. The above sediment horizons (i.e., 3 to 8 feet below the expected current navigation depth) were evaluated to determine whether they would represent contaminant levels of concern should they be uncovered by maintenance dredging. Levels of concern were defined in relationship to the RALs associated with each set of SMAs as follows:

- The average contaminant concentrations in each potential FMD area outside the SMA boundaries (in the sediment horizons noted above) were compared to RALs. Any potential FMD areas with an exceedance of more than two times the RAL in those horizons was added to its nearest surface SMA. The value of two times the RAL was selected because there is uncertainty in the following factors:
  - Particularly in the larger FMD areas (e.g., SMA 17S), it is more likely that only a portion of the area, for example an area in front of one dock, would be dredged at any one time.
  - The horizons assumed might not be the exact assumed depth when any particular dredging project is designed, or only achieve that exact depth over a portion of the project.
  - The likelihood of future maintenance dredging at many potential FMD areas is limited because there are no current or specific identified future uses. In these cases, shoreline property owners would likely consider the potential liabilities associated with maintenance dredging in these areas and either not pursue highly uncertain potential future Site uses, or alter their future maintenance dredging plans to maintain surface sediments below the RALs and/or allow natural recovery to continue.
  - The relatively small amount of data available in any given potential FMD area (usually a few cores). Given that RI/FS sampling tends to be biased towards known or suspected contaminated areas, these small datasets will be highly susceptible to outliers and would be more likely to overestimate potential FMD area sediment concentrations than underestimate them.
- The maximum point concentration in any core within potential FMD areas outside SMAs with samples within the target horizons was compared to the RAL. Any point sample in these areas with an exceedance of more than five times the RAL in those horizons was added to its nearest surface SMA.
  - This factor was selected for similar reasons to the average concentration comparison above, and to also recognize that a point exceedance of a RAL is unlikely to greatly impact SWACs on an area basis consistent with relevant exposure areas (e.g., river mile or shoreline half river mile), unless the point exceedance is relatively high. Consequently, although maintenance dredging might reveal select points somewhat above the RALs in the future, by using the above approach, this would not be expected to greatly impact exposure area SWACs that are achieved by any given alternative.
  - This factor also appears to be reasonably protective as a conservative point comparison to PCB and BaP benthic thresholds used in the MQ approach, which are relevant on smaller spatial scales. The PCB benthic thresholds

range from 500 to 3,500 ppb across bioassay endpoints (Table 3.5-3). Thus, five times the PCB RAL is comparable and ranges from 375 to 5,000 ppb across SMAs. Similarly, the HPAH benthic thresholds (the chemical class that includes BaP) range from 610,000 to 1,300,000 ppb across endpoints and five times the BaP RAL ranges from 3,000 to 100,000 ppb across SMAs.

In this evaluation only the potential FMD areas that are outside the SMA boundaries were examined because, by definition, everything inside an SMA boundary is actively remediated and included in the contaminated volumes designated for remediation (as discussed more in Section 5.10). The evaluation was conducted for total PCBs, BaPEq, and MQ because these RALs were found to be inclusive of, and co-vary with, the vast majority of contamination in surface sediments as described earlier in Section 5. Further, a depth of impact (DOI) analysis was conducted, which identified the contaminants bounding the DOI estimates across the Site. The DOI is determined by comparing subsurface chemistry to RALs and MQs for each SMA, as described further in Section 5.10.1. This analysis found that the DOI estimates for all cores in overall SMAs B and C were completely determined by PCBs, BaPEq, and/or MQ. Including additional RAL contaminants (i.e., DDD, DDE, DDT, and 2,3,4,7, 8-PCDF) affects a small percentage of cores in SMAs D through F, but these changes only add between 0 to 6 percent to the overall calculated volumes. Consequently, evaluation of PCBs, BaPEq, and MQ addresses the vast majority of RAL contaminants in the vertical dimension. There may be specific SMAs where buried contamination for other contaminants may be locally important. This issue should be further refined in remedial design on an SMA-specific basis and is not expected to greatly impact the overall FS-level evaluation.

The results of the above evaluation are summarized in tables in Appendix Fa. As shown in Appendix Fa and Figure 5.6-3, two FMD areas had concentrations in locations that could be exposed by future maintenance dredging exceeding either the average or maximum criteria:

- AOPC 6 – Terminal 4, Berth 410/411: Areas were added to overall SMAs B through F due to BaPEq. In this case, an exceedance only occurred using the Alternative D RAL for BaPEq. However, given that much of this slip area could be maintenance dredged as a unit and covers an area that constitutes an entire shoreline river mile by itself, the potential impact of maintenance dredging on this shoreline half river mile is relatively high. Consequently, this area was added to all of the SMAs footprints, not just SMA D. It is important to note the current elevation for the slip is much less than the draft FS designation in Section 2.4, which defines the entire slip as being maintained to a much greater depth than current conditions. During remedial design, the current and future maintenance dredge elevations for this area will need to be further evaluated to determine if these additional areas would likely be revealed through maintenance dredging.
  AOPC 17S – "-57" Area: Area was added to SMAs B through E due to one sample with high PCB and MQ results. No area was added to Alternative F because this core was already a part of this alternative.

Additionally, the average concentration of sediments removed by maintenance dredge activities within potential FMD areas was estimated in order to understand how contaminant levels might impact future maintenance dredging operations or material disposal decisions. If the levels in maintenance dredge material were sufficiently high, it might be more appropriate to include such areas in SMAs rather than to leave contamination to be handled during maintenance dredging operations. The average concentration of potential maintenance dredged sediments was calculated by averaging the subsurface concentrations of sediments in each potential FMD area outside of SMAs located in the interval between the surface and 3 feet below the required navigation depth. These concentrations were compared to the RALs for each SMA. The concentrations and exceedances of the RALs are summarized in Appendix Fa. As with the above analysis, a RAL exceedance factor (analytical result divided by the associated RAL) of two times the RAL for these average concentrations was used to identify areas that may need to be added to SMAs for the same uncertainty reasons discussed above. A maximum point comparison was not made because it is unlikely to reflect the actual concentrations in dredge material after it is dredged, handled, transported, and disposed. For example, the Regional Sediment Evaluation Team (RSET) and other dredge characterization guidance (e.g., Washington State) calls for compositing samples over set intervals and dredge volumes so that they better represent likely dredge material concentrations (USACE et al. 2009).

Appendix Fa tables indicate that estimated contaminant levels in maintenance dredge material in potential FMD areas outside the current SMAs would be below two times the RALs with six exceptions: four FMD areas in AOPC 17S (Swan Island Lagoon) and one each in AOPC 9D and AOPC 16.

- AOPC 17S – Swan Island Lagoon: There are four FMD areas with potential issues. The first FMD area is -57 AOPC 17S, which is the area that was already identified to be added to SMAs B through E as part of the exposed concentration analysis so this does not add any additional area. The other three FMD areas are located within the lagoon slip. The entire Swan Island Lagoon has a variety of potential commercial future uses ranging from simply maintaining the area at its current depth to expanding commercial uses and substantially deepening it. Other site use options include using a portion of the lagoon as a potential CDF or CAD site as discussed more in Sections 6 and 7, and/or as a habitat restoration or mitigation area. In the alternatives development section (Section 7), this range of potential future site uses for this large and unique portion of the Site is discussed and considered in a range of optimized alternatives for the entire lagoon area. Consequently, this later evaluation adequately addresses the overall Swan Island potential FMD areas and integrates them into overall remedies that would either remove this buried contamination or remediate it in place, depending on the alternative.
- AOPC 9D – Advanced American Construction: An area was added to SMA F for BaPEq because this was the only RAL with exceedances.

- AOPC 16 – Conoco Phillips Upstream Dock: An area was added to SMA F for PCBs because this was the only RAL with exceedances.

5.6.5 Maintenance Dredging in the Navigation Channel

A similar analysis to the one performed for potential FMD areas as discussed in Section 5.7.4 was also performed for buried contamination in the navigation channel. For each river mile, the interval of elevation in the 5 feet directly below the required navigation depth, plus an additional 5 feet to account for potential future deepening, was analyzed. These sediment horizons were evaluated to determine whether they would represent contaminant levels of concern should they be uncovered by maintenance dredging. Levels of concern were defined in relationship to the RALs associated with each set of SMAs exactly analogous to the steps described above for potential FMD areas. The navigation channel analysis was not conducted for BaPEq because RGs underlying these RALs are based primarily on human health sediment direct contact exposures, which per the BHHRA are assumed to not occur in the navigation channel. However, PAHs are included in the benthic toxicity values used in calculation of the MQ. For the average value comparison, the average concentration over a navigation channel river mile was assessed because this scale considers regional differences in buried contamination that may exist and is consistent with primary PCB exposure areas (e.g., smallmouth bass consumption). This scale of analysis is also appropriate because most past USACE maintenance dredging efforts have removed material from select areas, as opposed to the entire breadth and length of the channel in the Site. The maximum point analysis was also conducted for any point within each river mile.

Appendix Fa summarizes the results of this analysis and shows that no navigation channel river miles with the exception of RMs 6 and 10 would exceed the average or point concentration levels. For RM 10, the exceedances are for PCBs using RALs for SMAs E and F. Consequently, as shown in Figure 5.6-3, areas were added to SMAs E and F in RM 10 to incorporate areas with elevated PCB concentrations. In many cases, the locations of the samples associated with these exceedances were along the margins of the navigation channel and relatively close to shore. Given that maintenance dredging might create a new sloping surface at the edge of the navigation channel that exceeded the relevant levels, the SMA additions made in this location were extended toward the shoreline. The exact nature and extent of these areas will need to be refined during pre-remedial design studies if EPA selects an alternative consistent with the RALs used to define either SMAs E or F. For RM 6, large exceedances of the MQ are indicated by a few samples in this area. Closer examination of the dataset reveals that these few samples are all older USACE data that is included in the draft FS database. None of these USACE data were of sufficient quality to be included in the risk assessment datasets. Further, work conducted under the 2009 Gasco/Siltronic AOC resampled some of these locations and found no evidence of highly elevated contaminant levels and no exceedances of the MQs at the specific locations sampled. Consequently, the USACE data used to calculate the MQ exceedances shown in Appendix Fa appear highly questionable, and therefore do not warrant additions to SMAs solely on this basis. Again, the nature and extent of buried contamination in RM 6 can be further investigated during remedial designs in this river mile as needed.

Additionally, like the FMD analysis, the average concentration of sediments removed by maintenance dredge activities within navigation channel river miles was estimated in order to understand how contaminant levels might impact future maintenance dredging operations or material disposal decisions. The average concentration of removed sediments was calculated by averaging the subsurface concentrations of sediments in each navigation channel river mile located in the interval between the surface and 8 feet below the required navigation depth.

Appendix Fa summarizes the results of this analysis and shows that only RM 10 for SMA F, which has the lowest PCB RAL, would potentially exceed two times that RAL in the maintenance dredge material. This is the same area identified above as part of the exposed concentration analysis, so no additional areas were added to account for this.

5.6.6 Evaluation of Subsurface Concentrations Left in Place Outside of Alternative Footprints

This mapping demonstrates that there is very little subsurface contamination left in place that will not be actively remediated by any alternative selected. Thus, the potential for buried contamination to be exposed in the future is very limited.

The sum total of the alternative footprints identified by the RALs plus the additional areas added per the results of Sections 5.6.4 and 5.6.5 were used to evaluate what, if any, buried contamination would not be fully addressed by active remedies included in each alternative. Maps were developed using the RALs for each alternative to identify any areas of subsurface contamination above the RALs and outside the areal extent of the alternatives (see Section 3 of Appendix Fa). The maps in Section 3 of Appendix Fa show very few subsurface RAL exceedances outside of footprints of Alternatives B, C, and D. There are relatively more subsurface RAL exceedances outside of footprints of Alternatives E and F, which would be expected given the relatively low RALs associated with these two alternatives. This mapping demonstrates that there is very little subsurface contamination left in place that would not be actively remediated by any alternative selected. Thus, the potential for buried contamination to be exposed by any process discussed above in the future is very limited.

5.7 ANALYSIS OF TZW IMPACTS IN AND NEAR SMAS

The SMAs presented above are defined based on contaminant concentrations in surface and subsurface sediments as compared to the sediment RALs. Matrices other than sediments were also evaluated in the risk assessments including tissue, surface water, and TZW. Tissue and surface water risk results cannot be easily related to any particular area of sediments that may be potentially posing risk, and therefore cannot directly assist in the delineation of SMAs. In contrast, TZW risk evaluation results can be related to specific locations where TZW was measured in sediments. Consequently, the purpose of this evaluation is to determine whether SMAs should be expanded to address areas where contaminant concentrations in TZW exceed potential ARARs, which is used as a measure of potential impacts that are relevant to draft FS determinations.

The initial step in this evaluation was to compare TZW sample concentrations directly to potential water quality ARARs; these results are summarized in Table 5.7-1. As described in Section 3.2, EPA has identified Oregon freshwater chronic aquatic life WQS, NRWQC freshwater chronic aquatic life values, Oregon WQS for fish consumption, and NRWQC for human health consumption of aquatic organisms as potential chemical-specific ARARs for TZW at the Site. EPA has also identified MCLs as potential chemical-specific ARARs for groundwater (including TZW) at the Site. The LWG disagrees that any of these (i.e., Oregon WQS, NRWQC, or MCLs) are ARARs applicable to TZW but has agreed to evaluate remedial alternatives relative to these criteria as discussed more below.

5.7.1 Aquatic Life Potential ARARs

Development of the comprehensive benthic risk areas (Section 5.3.4), which were incorporated into the SMAs, included evaluation of TZW concentrations relative to Oregon freshwater chronic aquatic life WQS and NRWQC freshwater chronic aquatic life values. Therefore, the SMAs were developed to be protective of TZW exposures to aquatic receptors. As indicated in Table 5.7-1 and Figures 5.7-1a-g, TZW samples have contaminant concentrations exceeding these aquatic life potential ARARs. However, as noted in Section 6.6.3.3 of the BERA, actual TZW exposure point concentrations are probably much lower than TZW sample concentrations due to feeding habits, burrowing behavior, avoidance of low oxygen levels at TZW sample depths, and low food content in sediments at the depth that TZW was collected. The BERA recommended that only those TZW COPCs with an HQ greater than or equal to 100 be considered as COCs to develop and evaluate remedial alternatives that are protective of ecological resources. This recommendation is based on two factors. First, by definition any contaminant with HQ greater than or equal to 1 poses potentially unacceptable risk, but the evidence presented in Section 6.6.3.3 of the BERA strongly supports the position that the potential for unacceptable risk at HQs less than 10 is very small. Therefore, a factor of 10 was applied to account for the evidence that benthic receptors are not directly exposed to undiluted TZW. Second, EPA guidance (EPA 2005a) states that remedies should be evaluated under the assumption that sources of COPCs to groundwater plumes have been controlled. The effect of source control should be to reduce the potential flux of groundwater COPCs into the shallow transition zone prior to sediment remediation. An additional factor of 10 was applied to account for the control of COPC sources. TZW HQs (relative to Oregon and NRWQC freshwater chronic aquatic life values) are greater than 100 only for aluminum, iron, and total DDx in areas outside SMAs (Table 5.7-1 and Figures 5.7-1a-g).

Aluminum and iron are among the most common crustal elements and comprise a major component of terrestrial sediments. Although these common metals are also associated with the highest TZW HQs (relative to Oregon and NRWQC freshwater chronic aquatic life values), there is substantial uncertainty that their source is anthropogenic. Furthermore, by agreement with EPA, aluminum was not identified as a COPC in the BERA because its ambient water quality criteria (AWQC) was developed using toxicity data from acidic waters and is not applicable to the nearly pH-neutral waters of the Site. For these reasons, the alternative footprints were not expanded to incorporate TZW sample areas exceeding WQS and NRWQC freshwater chronic aquatic life values for iron or aluminum.

There is uncertainty associated with the total DDx exceedances because the HQs greater than 100 are based on unfiltered TZW samples except for one N-qualified filtered TZW sample result for Station RP03CTR in SMA 14. Regarding the one N-qualified filtered TZW result, this sample is located approximately 20 feet outside the boundaries of Alternatives B through E but is within Alternative F. As discussed in the draft final RI, the "N-qualifier denotes that the identity of the analyte is presumptive and not definitive, generally as a result of the presence in the sample of an analytical interference, such as hydrocarbons or, in the case of pesticides, PCBs. Data that are N-qualified meet the primary identification criteria of the method; however, the confirmation criteria are not met and the identification is potentially a false positive." Regarding exceedances in unfiltered TZW samples, these results suggests that the potentially unacceptable risk from DDx compounds in TZW may be lower than indicated by the maximum concentrations in unfiltered samples due to lower bioavailability of the particulate bound fraction of the contaminant. For these two reasons, and the fact that this location is included in Alternative F, Alternatives B through E were not expanded to incorporate TZW sample areas exceeding WQS and NRWQC freshwater chronic aquatic life values total DDx.

5.7.2 Fish/Shellfish Consumption Potential ARARs

TZW samples also have contaminant concentrations exceeding Oregon WQS for fish consumption and NRWQC for human health consumption of aquatic organisms (Table 5.7-1). Several metals, pesticides, PAHs, and VOCs exceed these WQS in TZW samples from areas outside the alternative footprints. For the purposes of this evaluation, it was assumed that these WQS only apply to clam consumption, as fish and crayfish are mobile and unlikely to be exposed to localized areas of contaminated TZW over extended periods. Therefore, only potential clam harvesting areas (i.e., shallow water above +5.1 feet NAVD88) were evaluated. Also, similar to the approach taken for the protection of aquatic receptors in Section 5.7.1 above, a factor of 10 was applied to account for the evidence that benthic receptors such as clams are not directly exposed to undiluted TZW. Following this approach, arsenic, manganese, BaP, chrysene, indeno(1,2,3-c,d)pyrene, and total PAHs have HQs greater than 10 in TZW samples at scattered locations outside the boundary of Alternative F at several SMAs (Figures 5.7-2a-f). However, given the scattered distribution of these TZW exceedances and the substantial uncertainties in the clam consumption scenario (see Section 3), it was determined that the SMA boundaries should not be expanded based on TZW samples exceeding of fish/shellfish consumption WQS.

5.7.3 Drinking Water Potential ARARs

Shallow and deep TZW samples in areas of currently known or suspected contaminated groundwater plume discharge have concentrations exceeding MCLs (Table 5.7-1 and Figures 5.7-3a-g). Several chlorinated VOCs, chlorobenzene, BaP, arsenic, barium, and lead exceed MCLs in TZW samples from areas outside SMAs. EPA has determined that groundwater plumes will be controlled to achieve ARARs and risk-based remediation goals through upland source control actions including subsequent natural attenuation of groundwater plumes under the riverbed. EPA has further indicated in December 2009 FS Comments (EPA 2009c and see Appendix O) that MCLs must be met throughout the entire extent of contaminated groundwater plumes. Sediment remedies cannot have any direct impact on plumes deep under the river or upland sources, control of which remains the primary mechanism for reducing potentially unacceptable risks from groundwater plumes to in-water receptors. Therefore, alternatives were not expanded to incorporate TZW sample areas exceeding MCLs.

5.8 SUMMARY OF SMAS AND SUBSMAS

Figures 5.3-1 a-e show the SMAs for the five alternatives, B through F, used in the draft FS. This includes areas mapped on the basis of select RALs and the comprehensive benthic risk areas in surface sediments. These SMAs were further refined and detailed in the following steps discussed above:

- Mapping refinements (data density and NN contouring) were conducted as discussed in Section 5.3.
- The SMAs were further categorized into subSMAs based on the physical features and implementability issues discussed in Section 5.4.
- The potential for buried contamination that could be exposed through natural and anthropogenic erosion processes and potential future maintenance dredging activities was evaluated in Section 5.6. This resulted in four areas being added to the alternatives delineated via surface sediments in Section 5.3 due to the potential for this issue to arise in the future (Figure 5.6-3).
- Areas of potential additional TZW ARAR exceedances were evaluated, and it was found that all appropriate TZW impacted areas are included in the alternatives defined via surface sediment contamination.

The resulting overall SMAs and subSMAs for Alternatives B through F are shown in Figure 5.8-1a-k.

SMAs for each alternative define active remediation areas. SMAs are defined based on RALs applied to both surface sediments and buried contamination per above. The RALs factor in estimated rates of overall system recovery, as discussed in Section 4, and therefore, are consistent with the expectation that areas outside SMAs will naturally recover over time. However, despite the SMA definition factoring in natural recovery estimates, there could be localized instances outside SMAs where MNR is reasonably unlikely to occur due to uncertainty in recovery estimates, empirical data, or processes that are not quantified in the QEAFATE modeling efforts (e.g., maintenance dredging). This issue is evaluated further in Section 6.2, and although there are localized areas outside SMAs that are more or less likely to naturally recover, the overall weight of evidence did not identify any new areas that should be added to SMAs. See Section 6.2 for details supporting this conclusion.

5.9 CONTAMINANTS ADDRESSED BY SMAS AND SITE-WIDE AOPC CHARACTERIZATION

As briefly described in Section 5.1, the Site-wide AOPC concept recognizes there are: 1) more discrete localized areas representing higher levels of contaminant concentrations that will be the focus of active remedies for the draft FS; and 2) a larger area, the Site-wide AOPC, inclusive of the entire Site that represents lower levels of contaminant concentrations that will not be the focus of active remedies. This section and Section 1 of Appendix Fa describe the Site-wide AOPC concept more fully and characterize how the SMAs defined by RAL contaminants address other contaminants potentially posing unacceptable risk.

5.9.1 Relationship Between SMAs and Site-wide AOPC

Active remediation SMAs identified through the selected RALs is a sound approach that will substantially reduce the number and magnitude of PRG exceedances as well as the number of contaminants exceeding PRGs.

SMAs defined by RALs for bounding COCs were mapped throughout the Site to define areas of active remediation within the Site-wide AOPC. PRGs for other contaminants potentially posing risk (as presented in Tables 1 through 3 in Appendix Da) were also mapped across the Site-wide AOPC to examine the spatial relationship and overlap between the RAL COCs and the other PRGs. Figure 5.9-1 shows where these PRGs are exceeded, with brighter colors showing where PRG exceedances overlap. (Consistent with EPA direction, only PRGs that are above background and below current baseline Site SWACs are used in this mapping evaluation.)

The figure shows that the areas with more overlapping PRGs are highly correlated with the locations that the RALs identify, as indicated by the comparison to Alternative F in the figure. This means that the RALs selected for the draft FS are correlated with both magnitude of concentrations exceeding potentially unacceptable risk thresholds and the number of contaminants exceeding potentially unacceptable risk thresholds in any given area. This confirms that active remediation SMAs identified through the selected RALs is a sound approach that will substantially reduce the number and magnitude of PRG exceedances as well as the number of contaminants exceeding PRGs.

5.9.2 Contaminants Addressed by SMAs

Site-wide time zero SWACs created by each SMA footprint for contaminants without RALs were calculated to understand how these select RALs address and reduce concentrations of other contaminants across the Site (see Section 1 of Appendix Fa). These estimated time zero SWACs are conservative in that they do not account for any natural recovery processes over time. As described in Appendix Ha, every contaminant examined for the draft FS shows some degree of natural recovery. Although the degree of natural recovery varies spatially across the Site and by contaminant and there is some uncertainty with the evaluations, the various lines of evidence clearly support that some natural recovery of the system is taking place (see Sections 2.2, 2.6, and 6.2.2 as well as Appendix Ha). Consequently, it is expected that the estimated time zero Site-wide SWACs presented here and in Section 1 of Appendix Fa will decrease over time, and the number of PRG exceedances and areas of those exceedances will further decrease over time.

It is expected that the estimated time zero Site-wide SWACs presented here and in Appendix Fa will decrease over time, and the number of PRG exceedances and areas of those exceedances will further decrease over time.

Section 1 of Appendix Fa contains tables showing results of time zero SWAC estimates on exposure scales applicable to the PRGs. These tables include all contaminants with PRGs evaluated in the draft FS. Section 1 of Appendix Fa also contains graphs of the time zero SWACs estimated for each alternative as compared to PRGs.

Overall, the tables and SWAC graphs in Section 1 of Appendix Fa indicate that active remediation using the RALs associated with overall SMAs for Alternatives B through F will substantially reduce SWACs for a wide range of contaminants across the Site. In many cases, these reduced SWACs achieve levels below all PRG levels for these contaminants. For many contaminants, the SWACs achieved are progressively lower and the number of PRG exceedances decreases across the range of SMA sizes from Alternatives B through F, although not always. However, consistent with the development of the Site-wide AOPC concept in general, as discussed above, even SMA F does not result in achievement of all PRGs for all contaminants at time zero.

Overall, these findings indicate that active remediation using the RALs associated with SMAs for Alternatives B through F will substantially reduce SWACs for a wide range of contaminants across the Site.

5.10 DETERMINATION OF SMA VOLUMES

For the purposes of alternative development, volumes of contaminated sediments associated with SMAs are estimated by identifying a DOI in subsurface sediment. The DOI is determined by comparing subsurface chemistry to RALs and MQs for each SMA. The volume is determined by calculating a volume across the SMA and down to the “neatline” depth represented by the DOI. An additional volume allowance is calculated for engineering factors related to how that volume might be removed in an actual construction project. The following subsections describe these steps in more detail.

5.10.1 Depth of Impact (DOI)

Future flexibility for partial dredging of the DOI and subsequent capping is discussed in Section 6.2.5.2.

The draft FS database was queried to select subsurface sediment core locations with at least one result for the RAL contaminants defined in Section 4 or MQ. The core locations were used to create a map of Thiessen polygons covering the Site. The navigational channel was used as a boundary condition to Thiessen polygons as follows. If a core is located within the navigational channel, the Thiessen polygon associated with the core only includes area within the navigation channel. Likewise, Thiessen polygons associated with cores located outside of the navigation channel only include areas outside of the navigation channel. SMA delineations were not used as a boundary condition. Thus, a single Thiessen polygon may include areas within more than one SMA and/or areas outside of the SMAs. In addition, if two cores were co-located, a single Thiessen polygon was developed for the co-located cores. These polygons were used to provide information to the SMAs where they overlapped.

A DOI was then identified for each of these polygons by comparing subsurface sediment data in the core representing each polygon to the RALs for each SMA (defined in Section 4) or MQ. These specific contaminants for Alternatives B, C, and D are PCBs, BaPEq, DDE, and MQ, and for Alternatives E and F the additional contaminants of sum-DDT, sum-DDD, and PCDF are used. The RALs were applied according to the primary underlying RG exposure area assumptions. Thus the BaPEq RALs were only applied to data from cores collected in shoreline areas outside of the navigation channel. The deepest interval in each core with a result above at least one RAL was identified, and the depth of this interval was selected as the DOI for its associated Thiessen polygon. In certain cores, several intervals had different start depths, but the same end depth. In this case, the maximum detected concentration in the intervals with the same end depth was used in the analysis. Co-located cores were treated as a single core with the most conservative result used. This analysis was conducted on a core-by-core basis for each overall SMA (B through F). Thiessen polygons where all core data are below the associated RALs were given a preliminary DOI of 30 cm (meaning no subsurface contamination), consistent with the above determinations that areas within SMAs are above the RALs in the surface sediment data representing the top 30 cm. This DOI was assigned to the portion of the SMA associated with that core polygon. Table 5.10-1 shows the DOI determined for each polygon by SMA footprint (SMAs B through F). Table 5.10-2 presents the average DOI across cores within each SMA. Table 5.10-3 shows the RAL exceedance factors for contaminants in impacted cores at the deepest interval corresponding to the DOI. Section 1 and Figure 1 of Appendix G provide additional information on this analysis including a map showing the DOI of each core polygon.

In addition, an analysis was conducted to examine the concentrations of additional contaminants (i.e., those not on the RG list in Section 3.5) detected below the DOI determined using the RALs. The analysis only considered additional contaminants with

PRGs above background and below appropriately averaged baseline sediment contaminant concentrations. This analysis was conducted consistent with EPA's direction to address every PRG in SMA evaluations (Appendix O). Table 5.10-4 provides summary statistics for these additional contaminants and compares those statistics to background concentrations (defined using EPA's UPL estimate of background as provided in Appendix A) for contaminants with PRGs that are below background or the lowest PRG for each contaminant. This is a conservative assessment because contaminant concentrations are being compared to thresholds at or near background, and these low thresholds should generally not be applied on a point-by-point basis. Regardless, the table shows that in most cases, the limited number of samples remaining in place below the DOI determined using RALs are at or near these Site background levels. This assessment is analogous to the comparisons made in Section 5.9, where surface sediment contaminant distributions in the Site-wide AOPC were compared to this large array of mostly very low PRGs. Similar to the Site-wide AOPC concept, given that there will be likely ongoing sources of these contaminants, it is not a reasonable expectation that the DOI in each core should be defined based on achieving background levels and/or the lowest PRGs. Just as such an approach in surface sediments will identify nearly the entire Site as an SMA, such an approach to determine DOI would likely result in the total depth of every core being identified as part of the SMA volumes. Thus, using the RALs for both surface and subsurface determination of active remediation areas and volumes is the most appropriate and consistent approach.

5.10.2 Methods of Calculating SMA Volumes

The core Thiessen polygon surface was intersected with subSMAs and divided into sub-Thiessens. In this way, a subsurface core could contribute DOI information to multiple subSMAs. A map showing an example of this intersection is provided in Figure 5.10-1. Maps showing sub-Thiessen IDs for each alternative are included in Figure 2a-e of Appendix G.

Volumes were calculated on a sub-Thiessen basis and then summed to provide overall volumes by SMA. SMA volumes were calculated using two separate methods, which are referred to as the LWG method and the EPA method. The LWG proposed the LWG method and EPA directed (EPA 2011e and see Appendix O) a different method. The EPA method is the basis of cost estimates. The following text describes the overall volume calculation methods and identifies where the EPA versus LWG methods differ.

The total volume for each sub-Thiessen is the sum of the neatline volume (NV; as defined by the DOI), plus the additional volume for overdredge allowances and adjustments for engineering factors as described below. Variation in the methods occurs in the calculation of the additional volume for overdredge allowances, adjustments for engineering factors, and residuals. The calculations of volumes for each sub-Thiessen are shown in Section 1 of Appendix G. The total volume for a particular sub-Thiessen is described as follows for both the EPA method and the LWG method, and is shown in Figure 5.10-2.

$$V_{LWG}[cy] = (NV + AOV) * (1 + EF) + \text{ RV} \qquad \text{(Eqn. 5.10-1)}$$

$$V_{EPA}[cy] = (NV)[\text{cy}] * (\text{NR}) \qquad \text{(Eqn. 5.10-2)}$$

Where:

V_{LWG} = Volume in cy as calculated using the LWG method.

V_{EPA} = Volume in cy as calculated using the EPA method.

NV = Neatline Volume in cy

NR = Neat line Ratio (1.5 to 2.0).

RV = Residuals Volume in cy

AOV = Allowable Overdredge Volume in cy

EF = Engineering Factors (30% to 50%)

5.10.2.1 Neatline Volume

The portion of the removal volume which is dependent upon the DOI is defined as the NV above. NV was calculated using the DOI multiplied by the area of the sub-Thiessen. If the bottom of a core associated with a particular sub-Thiessen was impacted (that is, non-impacted sediment did not bound the bottom of the core), an additional 1.0 to 3.0 feet was added to the DOI to account for uncertainty.

$$\text{NV} = (\text{A}_{\text{s}-\text{t}})[\text{ft}^2] * (\text{DOI})\ [\text{ft}] * \left[\frac{1\text{ cy}}{27\text{ ft}^3}\right] \qquad \text{(Eqn. 5.10-3)}$$

Where:

NV = Neatline volume in cy

$A_{s\text{-}t}$ = sub-Thiessen area in square feet (ft^2)

DOI = Depth of impact in feet (ft)

5.10.2.2 Reductions to Neatline Volume

For the LWG method, NVs were reduced for structural considerations as discussed in Section 5.4 and for slope buffer zone areas. Dredging immediately adjacent to structures can potentially impact the structure in a number of ways:

- Removing sediment adjacent to a structure's piling can cause loss of lateral and vertical support which in turn can weaken the structure.

- Many waterfront structures have battered piling to resist lateral loads against a structure. Dredging adjacent to structures can potentially damage battered piling.
- Dredge buckets can strike structures and piling if they are too close to the structure. Offsets prevent unwanted contact.

As part of final remedial design, many of these elements will be investigated in detail potentially modifying or eliminating the need for offsets. A general FS-level assumption of a 5-foot horizontal offset was applied to all dredge areas around structures.

Section 6 describes the evaluation of dredging in/around and under structures in more detail. In summary, extensive dredging under robust structures was generally screened out as a feasible technology for the draft FS. This is explained in more detail in Section 6. Volume calculations consistent with this screening result are described here (Section 5.10).

The slope buffer zone area is defined as the shoreline area where the depth of the dredge cut transitions from zero feet to the full DOI. This transition in the dredge cut is needed to allow for potential slope stability issues that would be created by very steep cuts, and allows for a more realistic and constructible dredge prism. As a conservative FS-level assumption, a 2H:1V dredge prism cut is considered in the volumes for shoreline sub-Thiessens where removal occurs. Figure 5.10-3 illustrates the slope buffer zone area. The slope buffer zones in each SMA are shown in Figure 4 of Appendix G.

5.10.2.3 Allowable Overdredge Volume

For the LWG method, AOV (also known as allowable overdredge) is an estimate of the range of additional depth that would be expected as a result of the contractor’s equipment type, varying operator experience, and site conditions. Allowing overdredge is necessary to account for inaccuracies of the process. For the draft FS, the allowable overdredge was assumed to vary from 0.5 feet to 2.0 feet for low and high volume estimates. The allowable overdredge estimate only applies to the LWG method; for the EPA method, this additional volume is accounted for in the neat line ratio discussed in Section 5.10.1.4.

$$AOV[cy] = (\mathrm{A}_{s-\mathrm{t}})[\mathrm{ft}^2] * \mathrm{D}[\mathrm{ft}] * \frac{1\,cy}{27\,ft\hat{}3} \qquad \text{(Eqn. 5.10-4)}$$

Where:

D = Allowable overdredge of 0.5 to 2 ft

5.10.2.4 Additional Volume for Engineering Factors

For the LWG method, an Engineering Factor (EF) was multiplied by the NV and overdredge volume to account for adjustments to the dredge volume anticipated with final design and construction. As part of remedial design, additional cores will be advanced in the active remediation areas. These additional cores will change the extent of required dredging. In addition, as part of remedial design the engineer will develop dredge prisms that are efficient for the anticipated construction equipment to be used.

This will entail removing extra materials such that the contractor uses longer, flatter dredge cuts to improve efficiency. This optimization of the dredge prism from the GIS-based dredge cuts will increase the dredge volumes. Finally, the volume of additional dredge material associated with the transition slopes between deep and shallow cuts and around the dredge perimeter need to be determined. The EF is established to capture the increased dredge volume for all of the factors mentioned. Based on past FS team experience, the values of EF were set at 0.3 to 0.5

5.10.2.5 Residuals

For the LWG method, the residuals volume is calculated separately from the removal volume associated with the DOI. For the EPA method, the residuals volume is accounted for in the neatline ratio, but the residuals volume is broken out for cost estimates. The residuals volume calculation assumes a 6-inch dredge cut plus a 6-inch overdredge allowance to account for factors similar to those discussed in Section 5.10.2.3.

$$\mathrm{RV} = (\mathrm{A_{s-t}})[\mathrm{ft}^2] * (\mathrm{RD})\ [\mathrm{ft}] * \left[\frac{1\ \mathrm{cy}}{27\ \mathrm{ft}^3}\right] \qquad \text{(Eqn. 5.10-5)}$$

Where:

RV = Residuals volume in cy

RD = Residuals dredge depth in ft, equal to 1 ft

5.10.2.6 Neatline Volume Ratio

EPA directed LWG to account for the factors described in Sections 5.10.2.2 to 5.10.2.4 by using an NV ratio. The NV ratio is a factor applied to the NV as illustrated in Equation 5.10-2. As directed by the EPA, the NV ratio ranges from 1.5 or 2.0 for the low volume and high volume estimates, respectively.

5.10.2.7 Volume Calculation Results

A complete tabulation of removal volumes by sub-Thiessen for the EPA method and a summary by SMA for both LWG and EPA methods can be found in Tables 2 and 3 of Appendix G.

5.11 SMA SENSITIVITIES AND UNCERTAINTIES

The SMA mapping procedures described in the previous sections are used in the draft FS to define spatial boundaries of the alternatives. They contain assumptions that can be varied creating a range of sizes and shapes of the SMAs. Because the SMA mapping procedures involve assumptions that can be changed to other valid assumptions, a sensitivity analysis was conducted to evaluate these assumptions associated with the SMA mapping procedures (Section 5 of Appendix E). The remainder of this section summarizes various key sensitivities associated with these SMA mapping procedures. Details are presented in Appendix E.

The assumptions evaluated included treatment of non-detect values in datasets, handling of data density artifacts and NN contouring procedures, natural recovery of contaminant concentrations over time, mapping of cPAHs/BaPEq in sediment, and the relationship between RGs and RALs.

Results indicate that substantial sensitivity ranges exist with various SMA mapping procedures, and overall these mapping uncertainties were placed in the "medium" uncertainty category discussed in Section 3.6 and Appendix E (Section 6.1). However, these individual mapping uncertainties can have an important additive impact on the footprint of the alternatives. This is particularly true when the discussion is confined to lower RALs, where the combined sensitivities can have large impacts on individual SMAs.

5.11.1 Area Sensitivities and Uncertainties

5.11.1.1 Non-Detect Handling Analysis

The assumed value of non-detects included in sums for classes of contaminants (e.g., total PCBs) can substantially affect the concentration contours used in SMA mapping, which in turn impacts the SMA sizes. The impact of these non-detect assumptions on SMA mapping was quantified using total PCBs as the most relevant example, as it determines the vast majority of SMA size.

In the standard LWG RI/FS calculation of total PCBs for a particular sample, if all PCB congeners in that sample are non-detect, then the highest detection limit is used as the total PCB concentration and the sample is qualified non-detect. If there is at least one detected congener, results for each individual congener are included in the total PCB sum at one half of the detection limit, and the sample is qualified as a detected sample, which could result in relatively high non-detect total PCB sums when summing detection limits in samples with a high percentage of non-detected congeners. This is especially true where Site concentrations are at or near relatively low RGs for total PCBs, such as the human health smallmouth bass EPA point estimate RG (29.5 ppb). High non-detects (defined as non-detect results 25 times above detection limits) were not included in the dataset used to generate NN contour surfaces.

To quantify the uncertainty associated with non-detects, an example total PCB RAL of 75 ppb was mapped using three assumptions for non-detects in the summing process (Figure 5.11-1):

- Zero for non-detects (non-detect = 0 in Figure 5.11-1)
- Full detection limit for non-detects (non-detect = 1 in Figure 5.11-1)
- Historical project approach of assuming one half of the detection limit for non-detects (non-detect = 1/2 in Figure 5.11-1)

Results indicate that the differences in SMA sizes are larger for lower RALs under the various non-detect assumptions (at a RAL of 75 ppb overall SMA acreage differed between 209 and 337 acres as further summarized in Appendix E [Section 5.2]). Thus, the SMA size differences are largest using RALs for Alternatives E and particularly F.

5.11.1.2 Data Density and Natural Neighbors Contouring Analysis

Sensitivities associated with handling of data density artifacts and NN contouring procedures were also evaluated. Figure 5.11-2 shows various data density buffers that could be applied using the example of mapping Alternative F using a total PCB RAL of 75 ppb and standard NN contouring. This example shows buffers as follows:

- No buffers applied. The NN contouring is unrefined.
- The buffer distance is based on the average distance between stations in the navigation channel (206 feet). In this case, only stations in the navigation channel that are more sparsely spread than the average density in the channel are buffered. This is the approach used in this draft FS.
- The buffer distance is based on the average distance between stations in the entire Site (179 feet). Only stations in the navigation channel that are more sparsely spread than the average density for the entire Site are buffered.

As shown in Figure 5.11-2, the buffering assumption makes a moderate difference in SMA size for a few areas in the navigation channel (overall SMA acreage differed between 285 and 311 acres).

The sensitivity to uncertainties in the handling of data density artifacts is an issue that can and will likely affect remedial design on an SMA-specific basis. The shape and size of an SMA is directly the result of the density (number and location) of data within the SMA itself. Thus, assumptions in addressing these data density issues within an SMA may have more of an influence in SMA-specific remedial design than in an evaluation of alternatives for the Site as a whole.

For example, data density assumptions used in the handling of select dioxin/furan results along the boundaries of SMA 13 affect the overall size of the SMA and thus, impact the remedial design for that SMA. This issue becomes more influential on an SMA-specific basis especially for contaminants influencing SMA size that are surrogates for other chemical totals (i.e., PCDF for dioxins/furans for the SMA 13 example). A more detailed analysis of this kind of SMA-specific issue is presented in Section 5.3.2 of Appendix E using SMA 13 as an example. This example illustrates one type of future remedial design uncertainty where extrapolation between data points within an SMA with limited data may cause large differences in SMA size and therefore cleanup volumes and cost, especially if there are only a few data points with results above RALs surrounded by results below RALs (as in the case of the SMA 13 example discussed in Appendix E). Additionally, variations in SMA mapping caused by use of one particular contouring approach (i.e., NN contouring) was evaluated by comparing the contoured surfaces generated with natural log-transformation of the data prior to NN contouring with surfaces generated with no transformation (which is the approach used for draft FS data). Log-transformation is a standard feature in ARC-GIS and is often used to reduce the influence of extreme and isolated values on the resulting contours. These results are detailed in Appendix E; in summary, the log NN contouring creates smaller SMAs in low data density areas such as parts of AOPCs 14, 16, and 18. The resulting decrease in overall SMA size across the entire Site using the log NN approach is approximately 30 percent. It should be noted that a wider range of uncertainty than discussed here exists in SMA mapping procedures based on the contouring method selected that was not quantitatively assessed as part of the sensitivity analysis. All of the uncertainty evaluations regarding SMA mapping conducted in Appendix E use NN contouring as the contouring method, though there are other types of contouring methods that exist (e.g., Kriging and inverse distance weighting) that could be used to generate SMAs. Use of these other techniques would likely create additional differences in SMAs that are not quantified here.

5.11.1.3 Comprehensive Benthic Risk Areas

As discussed in Section 5.3.1, comprehensive benthic risk areas are not mapped using RALs or the above approaches. Multiple lines of bioassay, contaminant concentration, and other evidence are used to define these areas. The natural recovery (or attenuation) of contaminant concentrations over time should be considered for benthic risk areas, but methods to accomplish this are not readily available. To illustrate an example of the uncertainty that may be involved in assessing natural recovery of benthic areas over time, the contaminant concentration data within the comprehensive benthic risk areas were examined (Appendix E). This evaluation found that within these areas, 64 percent of the stations have MQ values below 0.7 and 44 percent have MQ values below 0.3 (as described in Section 4.3.6). Areas within the comprehensive benthic risk areas that are currently below an MQ of 0.7 were excluded from such areas to represent areas that might recover in 5 to 10 years, and the remaining areas were mapped as shown in Figure 5.11-3, which also compares these reduced areas to original areas. As discussed in Section 3.6 and in Appendix E (Section 5.4), as MQs are a measure of the relationship between chemistry and bioassay results, they are used here as an approximate measure of areas that might recover in the future. An MQ value of less than 0.7 (as selected by EPA and further discussed in Section 3.6) is considered a conservative assessment of potential future recovery of benthic SMAs given that, in the absence of bioassay data, an area with an MQ of less than 0.7 would currently be assumed to likely have acceptable levels of benthic risk. As summarized in Figure 5.11-3, the difference between these reduced areas and the original areas is moderate (64 percent difference in overall acres). This analysis suggests that there are considerable portions of the current benthic SMAs that might be considered suitable candidates for either additional bioassay tests or as part of a monitoring program for natural recovery.

5.11.1.4 Uncertainty of Mapping BaPEq

The BaPEq RGs for cancer risk for Tribal fisher direct contact with sediments is based on total cPAHs, expressed as a BaPEq concentration. However, the fate and transport model evaluates BaP as a single contaminant. The toxicity of the same concentration of BaP or BaPEq is essentially equivalent. Thus, any differences in the application of these RGs is related to the variations in concentrations of the single contaminant BaP versus the concentration of all cPAHs including BaP (expressed on a BaPEq basis) present in the same sediment sample. The difference in assumed SMA sizes when mapping BaP and BaPEq is shown in Figure 5.11-4 using a range of theoretical RALs from 50 ppb to 50,000 ppb. This analysis reveals that as the RAL increases, the variability in the sizes of SMAs mapped decreases, similar to the effect of non-detect handling discussed above. Overall, the differences are not large until RALs below about 1,000 ppb are considered (the difference in overall acreage from the current FS approach ranges between approximately 10 and 30 percent between the various RALs as further detailed in Section 5.5 of Appendix E). Given that the lowest RAL for SMA F is 1,500 ppb, the uncertainties caused by mapping BaP results as BaPEq is considered minimal as compared to other SMA uncertainties discussed here.

5.11.1.5 Overall SMA Sensitivity Range

As discussed in Appendix E (Section 6.1) and above, SMA uncertainties (categorized as "medium") are generally smaller than the uncertainties associated with the development of the RGs described in Section 3.6 (categorized as "large") and are similar in size to the uncertainties associated with the development of RALs and as described in Section 4.5 (categorized as "medium"). A wide range of SMAs, with very small to very large footprints, satisfies the human health and ecological protectiveness criterion as summarized in Section 3.6. However, within this overall uncertainty, effects from compounding uncertainties created by RAL application and SMA development may become important. Thus, SMA and RAL mapping uncertainties may not result in an overall range of SMAs that extends from no SMAs to designating entire Study Area as an SMA. However, SMA and RAL mapping uncertainties may result in large differences in SMA sizes within this overall range, and may become particularly important in localized areas such as individual AOPCs. The mapping uncertainties alone can easily cause as much as 50 percent variation in localized SMA sizes (see numerous examples in Section 5 of Appendix E), which clearly could have large impacts on draft FS decisions, and even more impact on SMA-specific remedial designs.

5.11.2 Volume Sensitivity Analysis

As discussed in Section 5.10, EPA directed LWG to use a ratio of 1.5 to 2.0 of the NV to determine the total dredge volume after construction for each alternative (EPA 2011e). LWG compared the EPA directed dredge volume ratio range against more traditional analyses commonly used to determine dredge volumes as part of a sensitivity analyses. EPA's directed volume ratio accounts for the following:

1. Overdredge volumes necessary to ensure removal of the target sediments. Dredging inaccuracies can be associated with equipment type, varying operator experience, and Site conditions (water depth, river currents, weather, surface water conditions, etc.)
2. Dredge volumes associated with the transition slopes between deep and shallow cuts and around the dredge perimeter

3. Volume "creep" associated with going from data at the FS-level to more SMA-specific data available at the design level
4. Dredge volumes associated with a single residual dredge pass after initial cuts are made.

> *It is more accurate for determining total dredge volumes to quantify each item (e.g.overdredge allowances, engineering factors, and residuals) with anticipated ranges than using a ratio factor.*

Given the varying conditions in the Site, it is more accurate for determining total dredge volumes to quantify each item (overdredge allowances, engineering factors (e.g., slope, refined design adjustments, and residuals) with anticipated ranges than using a ratio factor. For item 1, an overdredge allowance of 0.5 to 2.0 feet may adequately capture the range given equipment type, operator uncertainty, and known Site conditions. For items 2 and 3, based on design and construction experience, a volume increase of 30 to 50 percent may bracket the volume increases associated with transition slopes and FS-level data. Finally, for item 4, a dredge cut of 1 foot may adequately represent a single residuals pass.

Figure 5.11-5 graphically presents the difference between the EPA directed approach and LWG's sensitivity analyses. The following conclusions can be drawn by reviewing the figure:

- For DOI in sediment (aka, the NV) between 7 to 9 feet, both approaches generate similar quantities.
- For shallow depths of impacted sediment (0 to 7 feet), the EPA method tends to *underestimate* the likely dredge volume. This is due to the fact that overdredge allowances are commonly a fixed thickness and not a ratio of the DOI. So for a DOI of 1 foot, an overdredge allowance of 0.5 to 2.0 feet would have much more of an impact on the total volume from a percentage standpoint than if the DOI were closer to 10 feet.
- For deeper depths of impacted sediment (greater than 9 feet), the EPA method tends to *overestimate* the likely dredge volume as compared to the LWG method.

Table 5.10-2 presents the average DOI for each SMA by alternative. This table coupled with Figure 5.11-5 allows the reader to identify which SMAs likely have higher dredge volume uncertainty based on a comparison of EPA and LWG methods.

Table 5.11-1 summarizes the dredge volume for each alternative using both methods. The EPA method tends to underestimate the total dredge volume by on average around 10 percent when compared to the LWG method. The difference is as high as 20 percent for Alternative B-i where the average DOI is thinnest, to 6 percent for Alternative F-r where the average DOI is the thickest.[15] Figure 5.11-6 graphically summarizes Table 5.11-1 showing that the thinner the DOI, the higher the likelihood that the EPA directed

[15] The alternatives represented by the "i" and "r" designations are described in Section 7.

dredge volume determination method will under-predict the total dredge volume. In summary, volumes estimated with the LWG method are generally greater than volumes estimated using the EPA method.

5.12 CONCLUSIONS

This section presents the methods and results of the determination of SMAs based on sets of RALs defined in Section 4. These SMAs are used to define a range of alternatives covering progressively larger footprints as discussed more in Section 7. SMA development included definitions of subSMAs that differentiate between various Site characteristics and Site uses that will be relevant to the application of remedial technologies in Section 6 and 7. The extent to which the SMAs address other contaminants potentially posing risk and how these relate to the Site-wide AOPC concept was also presented. It was found that active remediation using the RALs associated with overall SMAs for Alternatives B through F will substantially reduce SWACs for a wide range of contaminants across the Site. An additional finding is that there is generally very little buried contamination above the RALs outside the SMAs designated for active remediation under each alternative. The volumes of contamination associated with each alternative were also defined. These volumes are used to determine the characteristics of the alternatives in Section 7 including remediation sequencing, durations, and volumes.

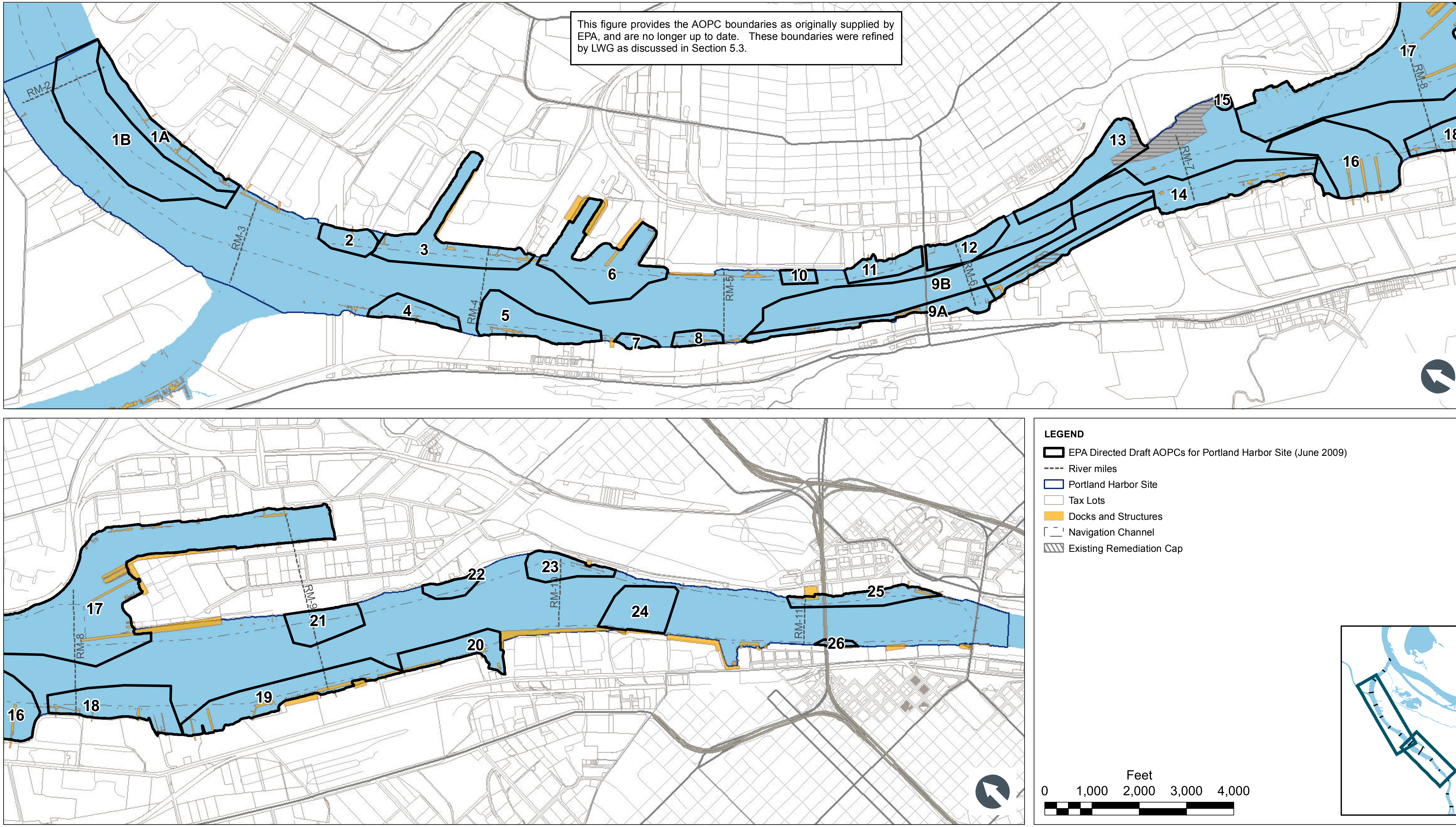

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Figure 5.1-1
Portland Harbor RI/FS
Draft Feasibility Study
EPA Directed Draft AOPCs for Portland Harbor Site

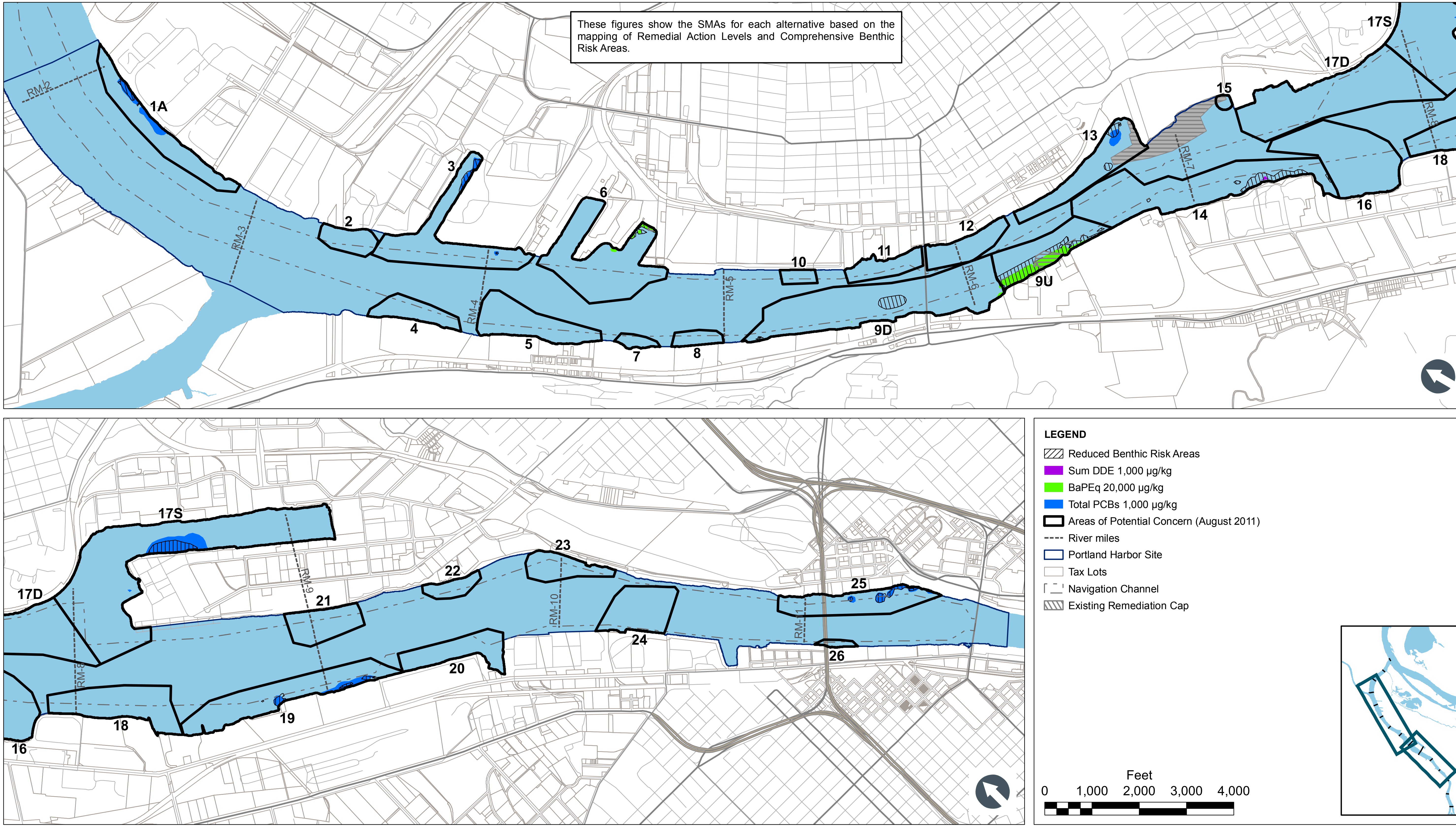

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Figure 5.3-1a
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SMAs Designated by Alternative B

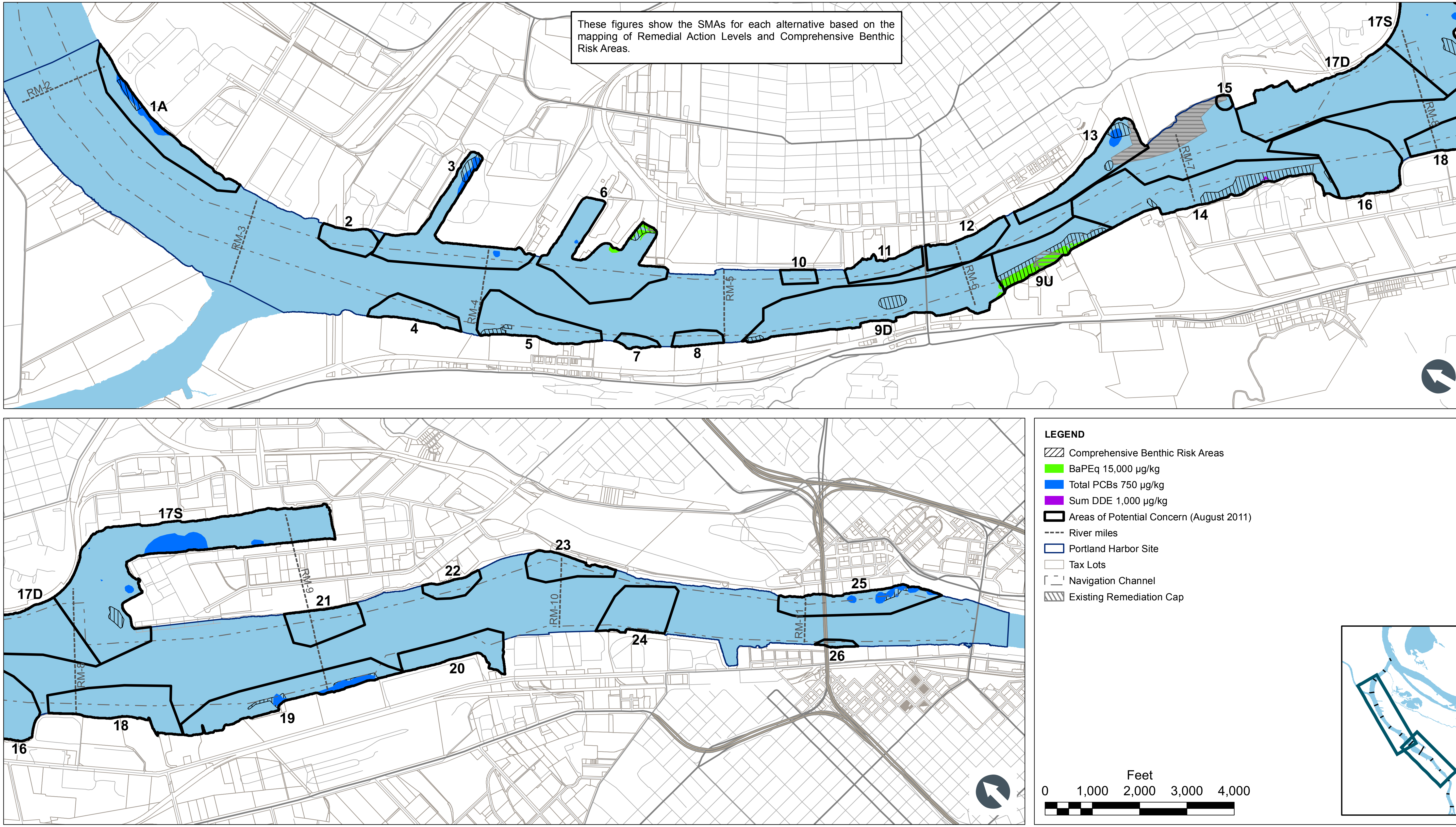

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Figure 5.3-1b
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SMAs Designated by Alternative C

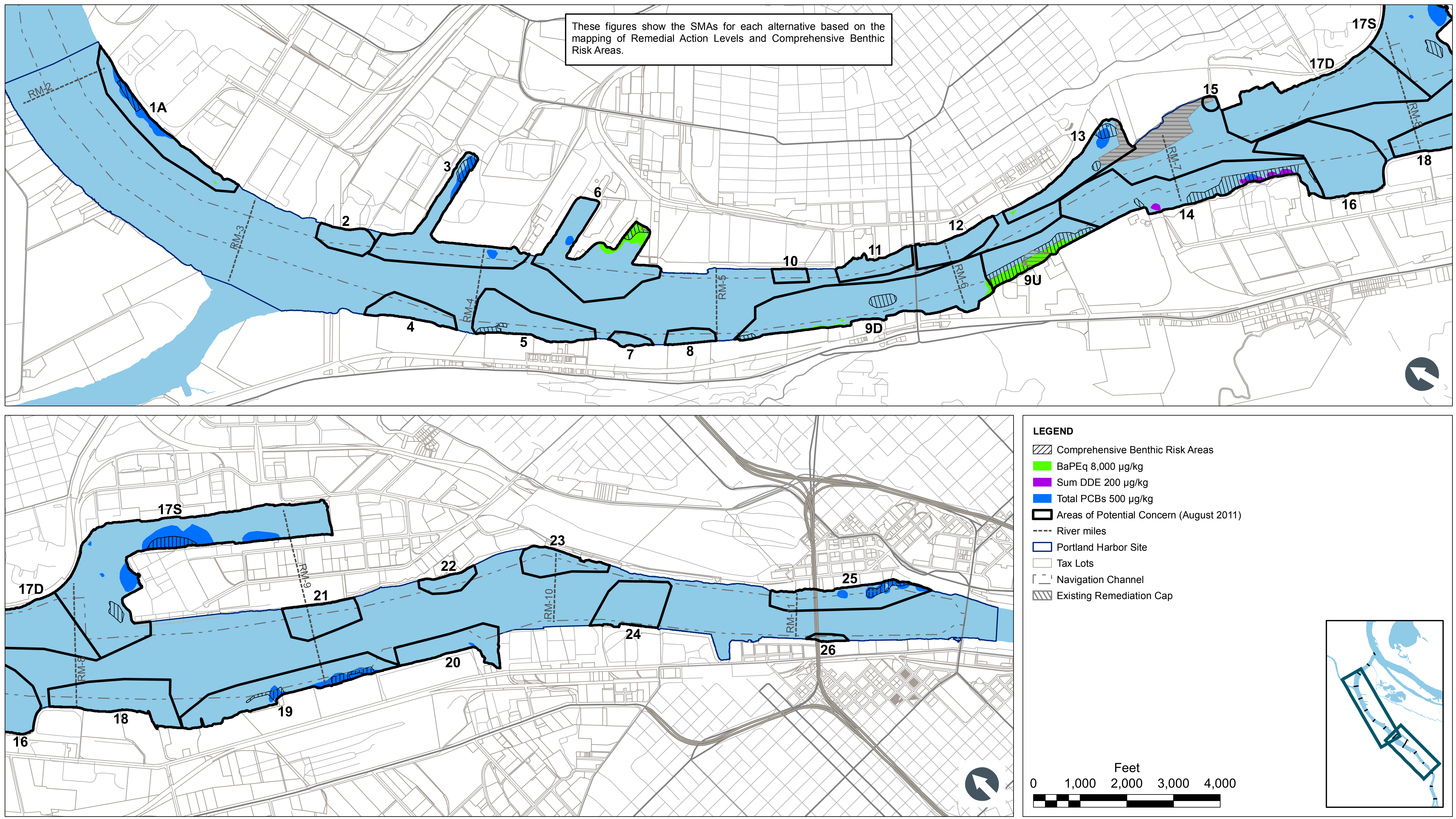

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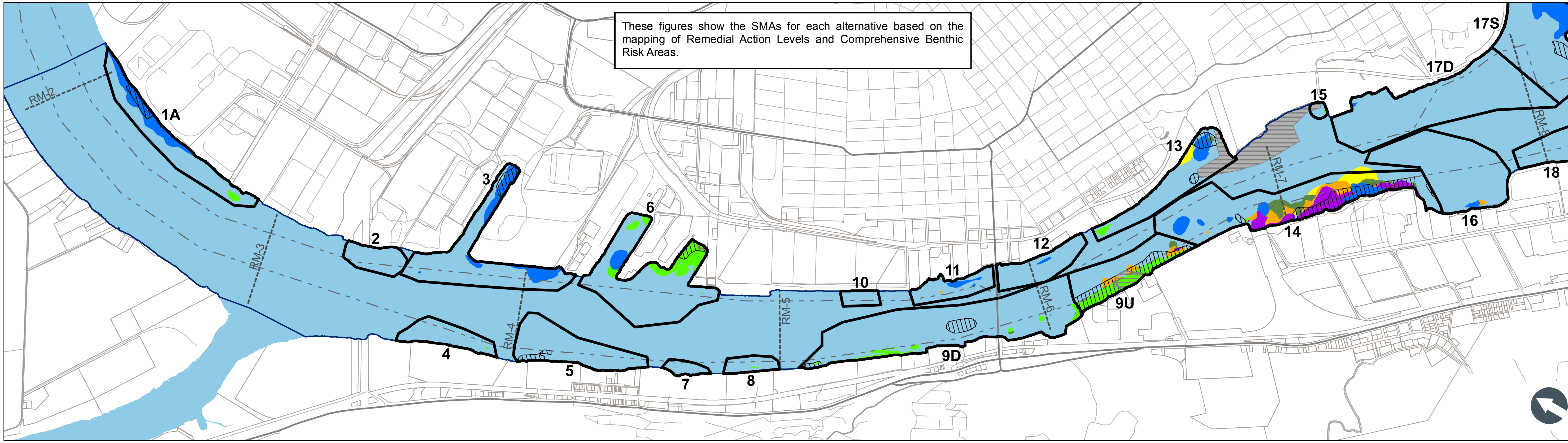
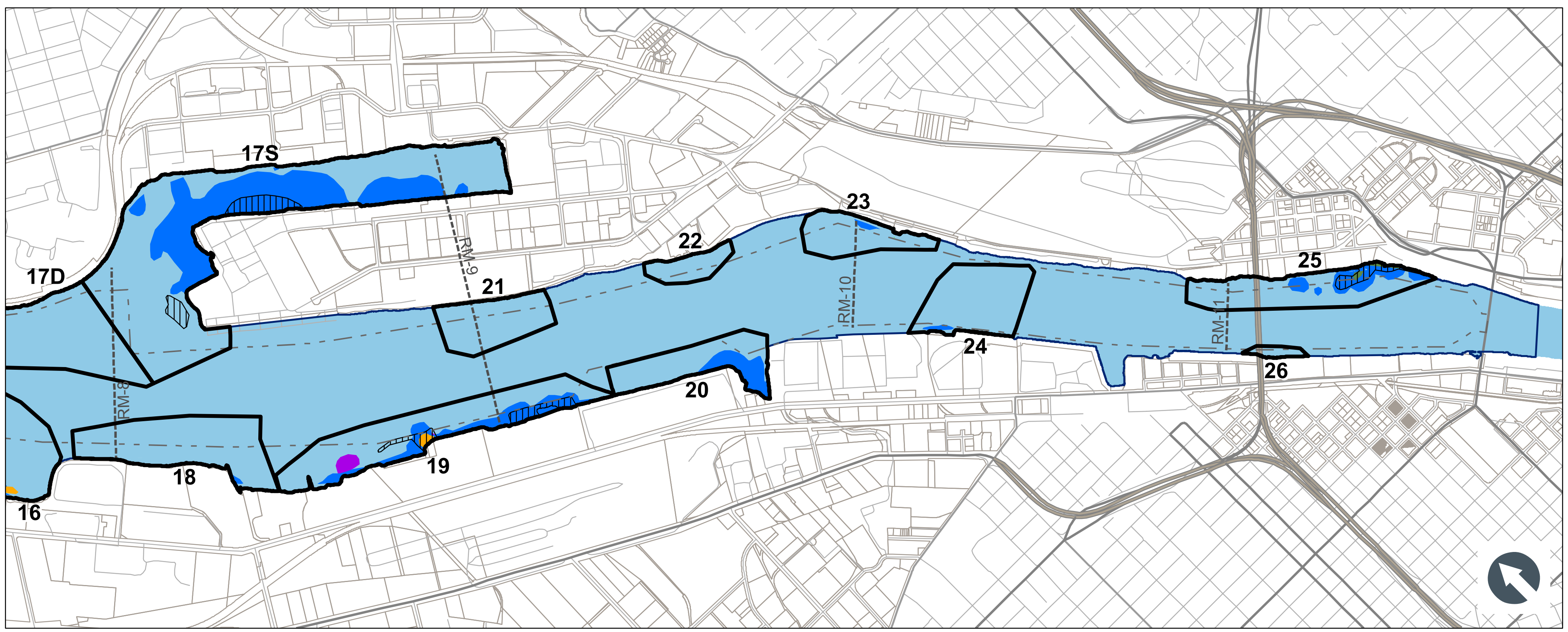
Figure 5.3-1c
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SMAs Designated by Alternative D





LEGEND

- Comprehensive Benthic Risk Areas
- 2,3,4,7,8 PCDF 0.02 µg/kg
- BaPEq 4,000 µg/kg
- Sum DDD 100 µg/kg
- Sum DDE 50 µg/kg
- Sum DDT 150 µg/kg
- Total PCBs 200 µg/kg
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Feet
0 1,000 2,000 3,000 4,000

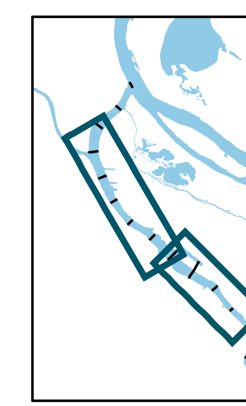


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Figure 5.3-1d
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SMAs Designated by Alternative E

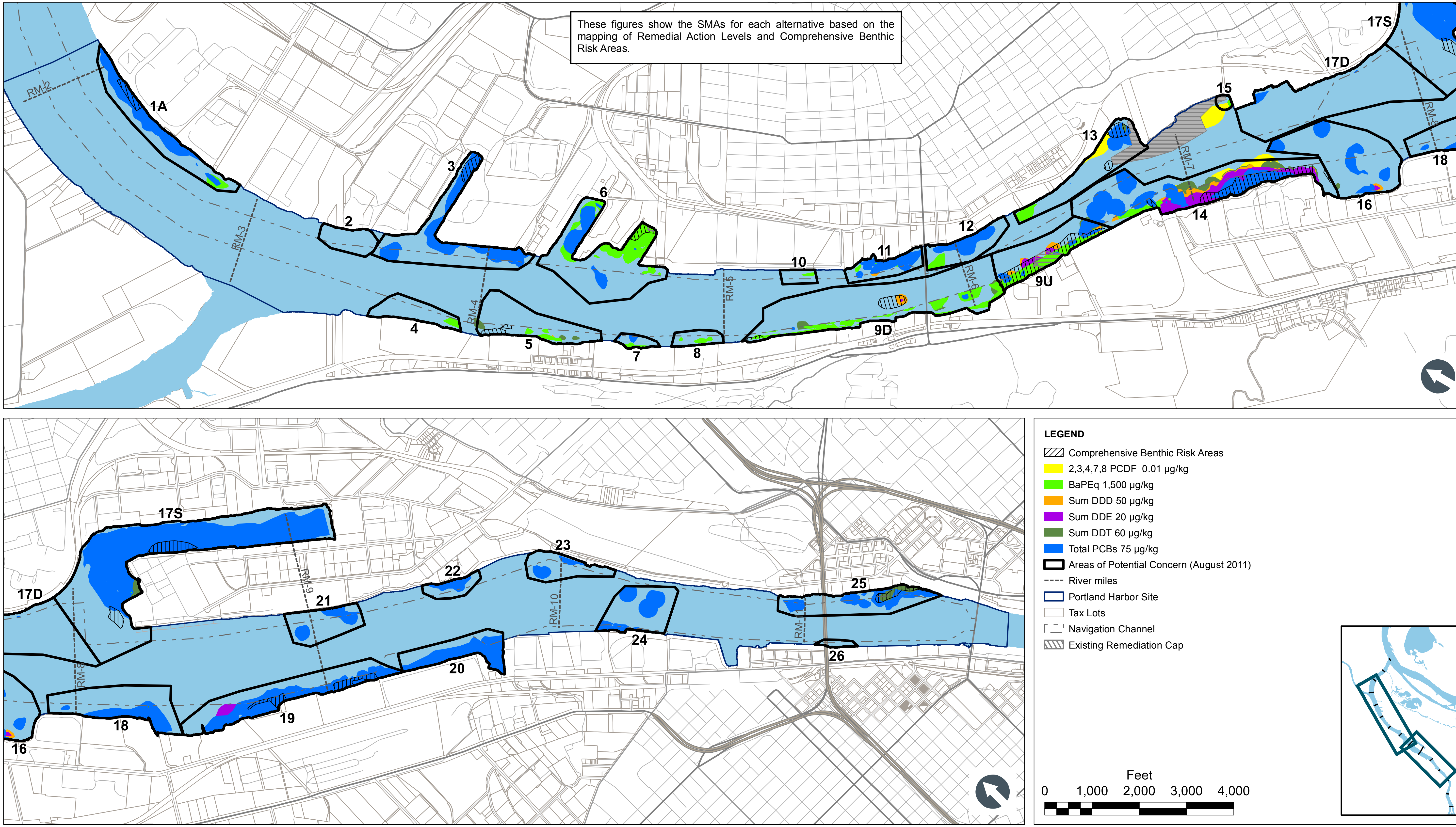

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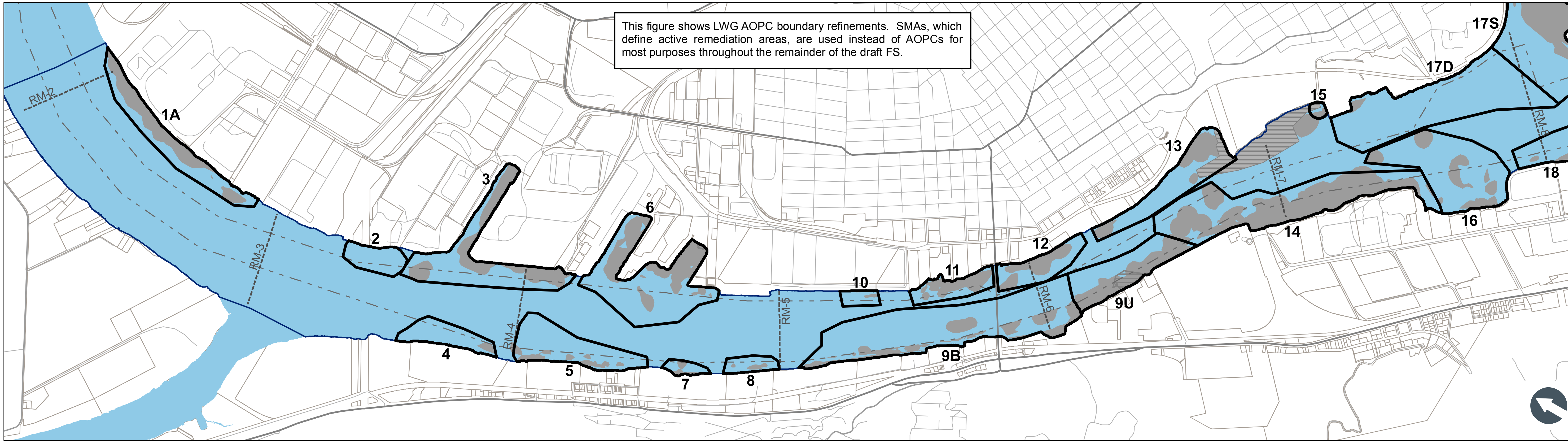
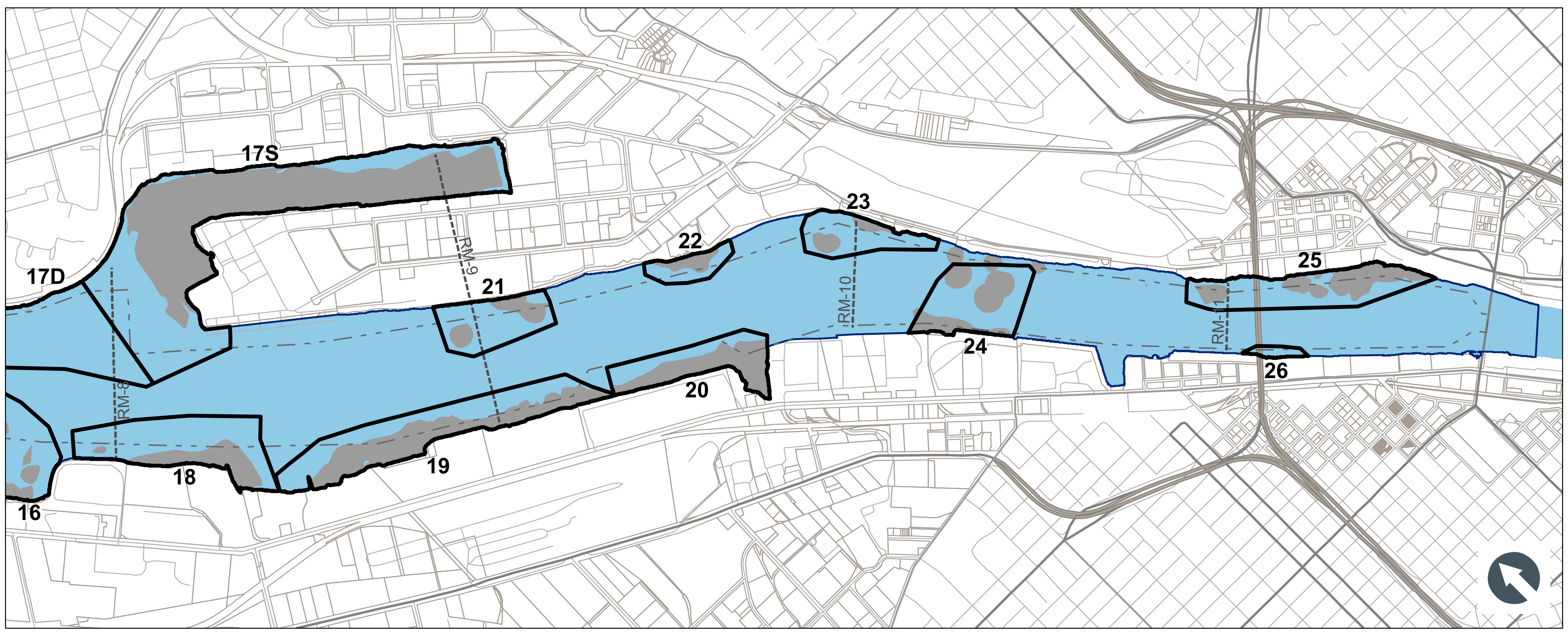
Figure 5.3-1e
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SMAs Designated by Alternative F





LEGEND

- Alternative F
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Feet

0 1,000 2,000 3,000 4,000

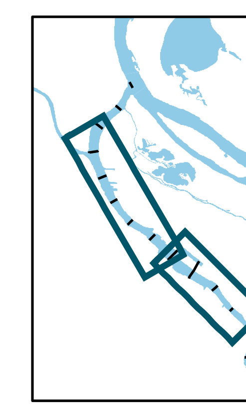


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Figure 5.3-2
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Draft Feasibility Study
Refined AOPC boundaries

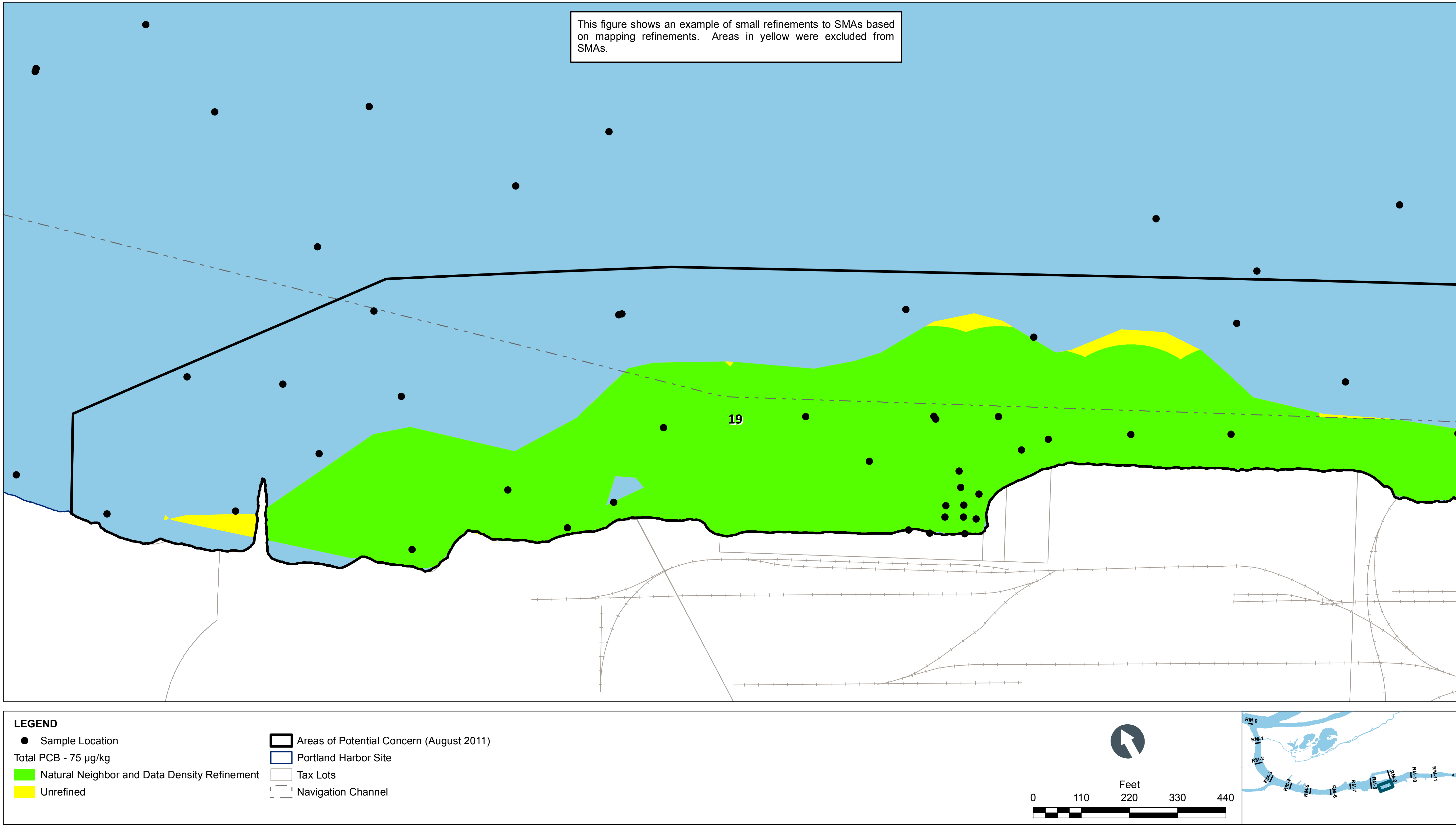

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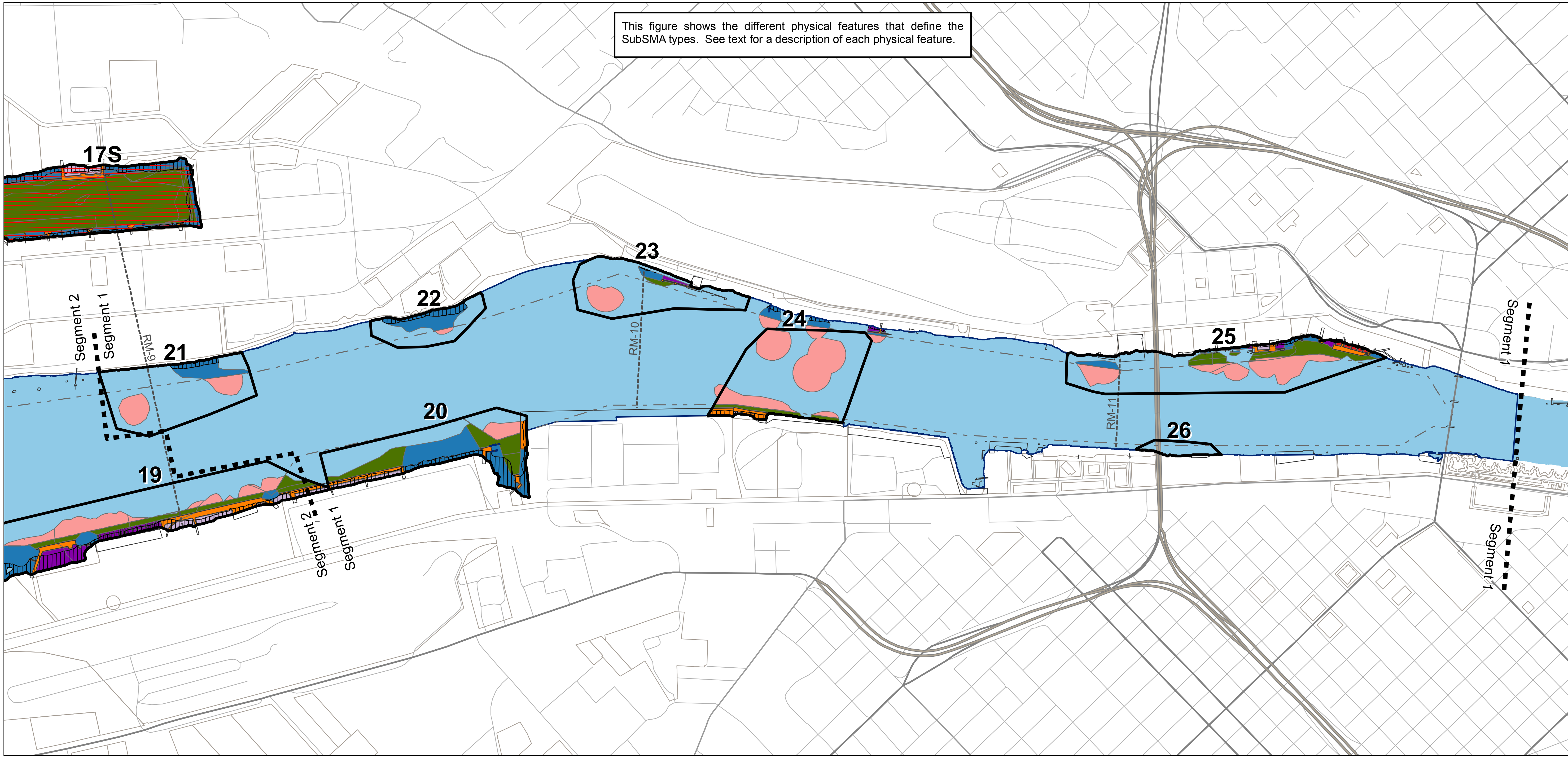
Figure 5.3-3
Portland Harbor RI/FS
Draft Feasibility Study
Example of Data Density and Natural Neighbor Refinements



LEGEND

Areas of Potential Concern (August 2011)
Portland Harbor Site
Federal Navigation Channel
Docks and Structures

Physical Features

Existing Remediation Cap
Potential Future Maintenance Dredge
Navigation Channel
Open Water
Limited Access Structures
Behind Structures with No Access
Under Heavy Structures
Behind Structure - Upland Removal
Existing Remediation Cap
Light Structures
Wave Zone
Potential Disposal Sites CAD/CDF
Segment Boundary
River miles

Feet
0 550 1,100 1,650 2,200

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Figure 5.4-1a
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types (shown for largest SMA Alternative F)
Segment 1: AOPCs 20-26

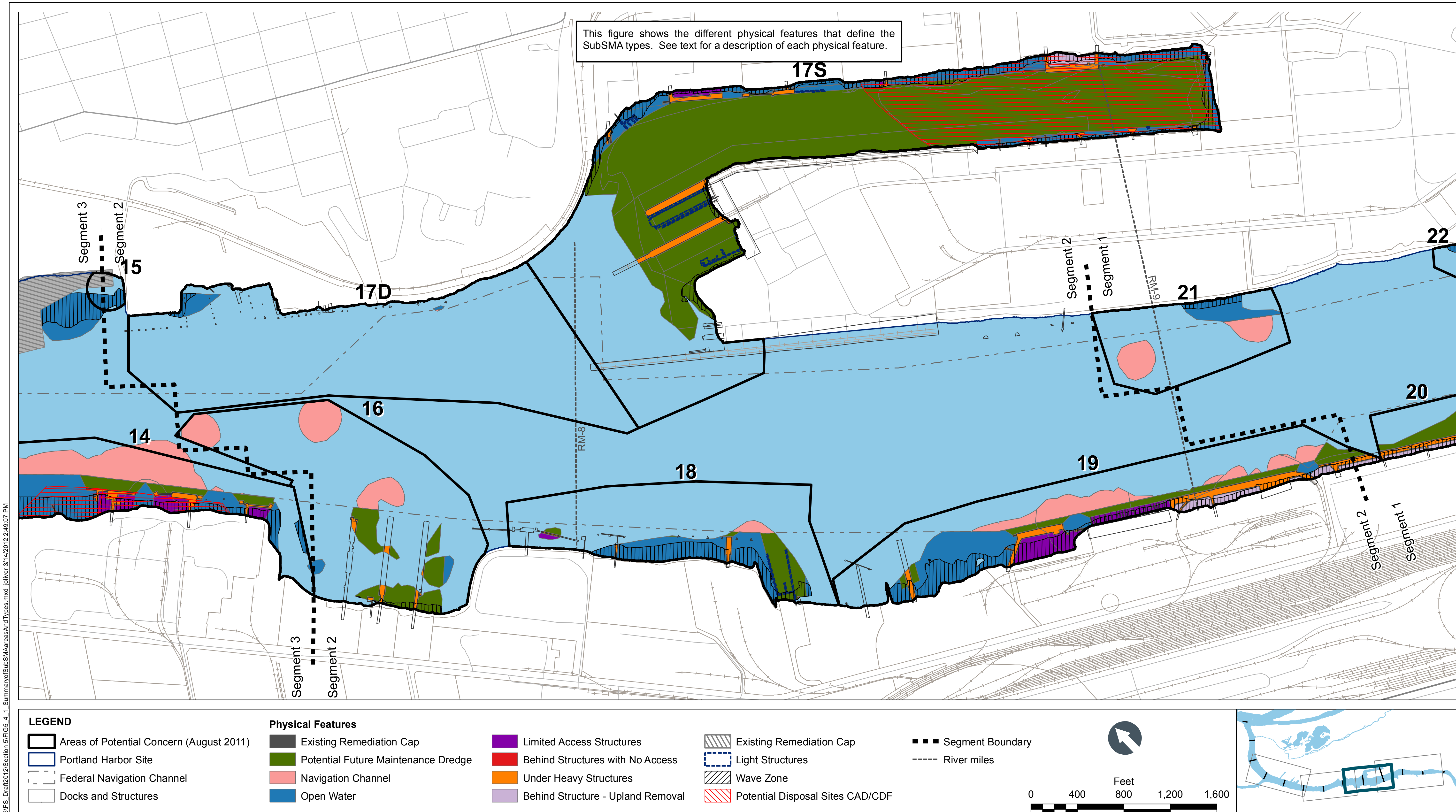

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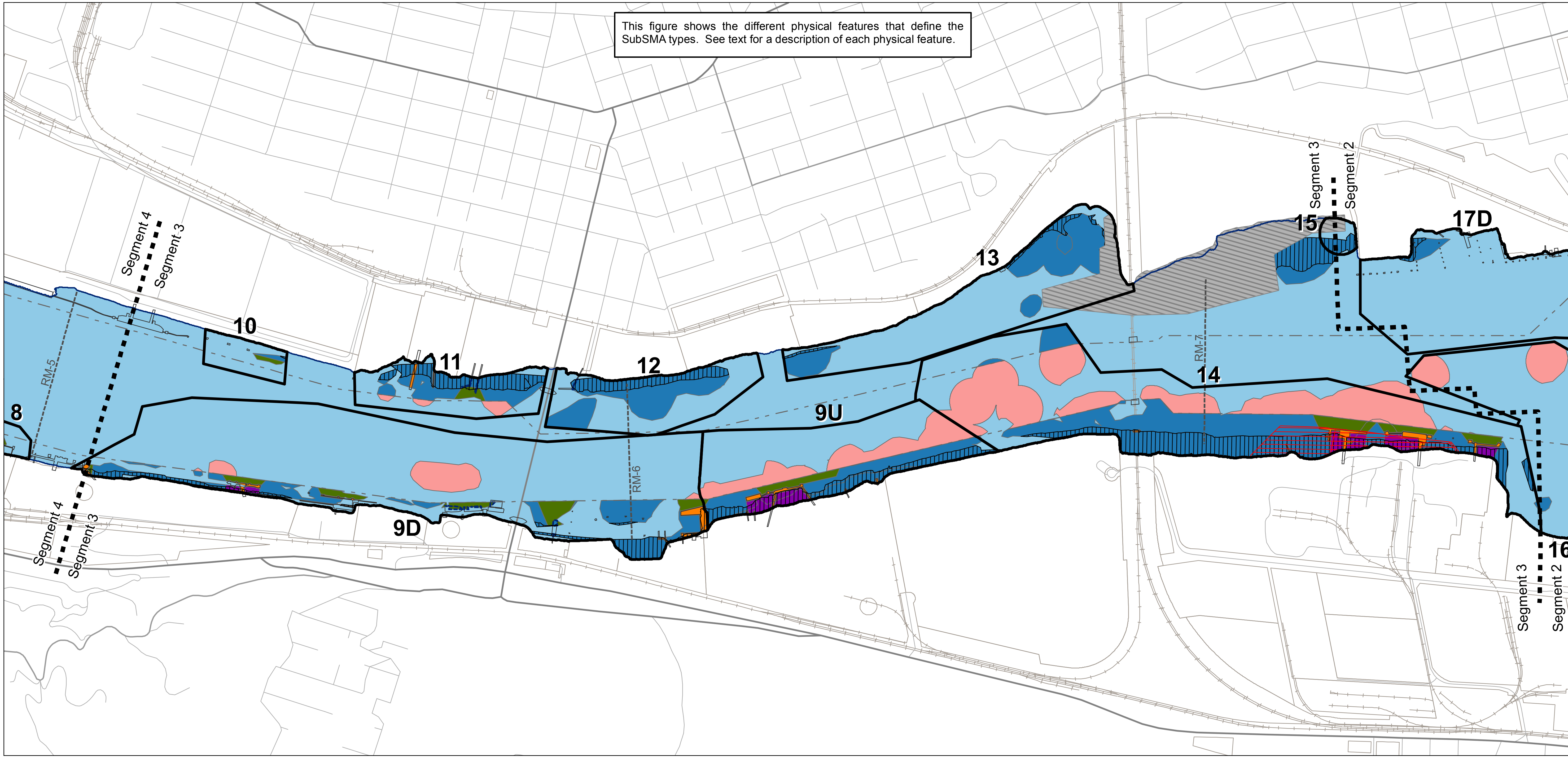
Figure 5.4-1b
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types (shown for largest SMA Alternative F)
Segment 2: AOPCs 15-19



LEGEND

- Areas of Potential Concern (August 2011)
- Portland Harbor Site
- Federal Navigation Channel
- Docks and Structures

Physical Features

- Existing Remediation Cap
- Potential Future Maintenance Dredge
- Navigation Channel
- Open Water
- Limited Access Structures
- Behind Structures with No Access
- Under Heavy Structures
- Behind Structure - Upland Removal
- Existing Remediation Cap
- Light Structures
- Wave Zone
- Potential Disposal Sites CAD/CDF
- Segment Boundary
- River miles

Feet
0 450 900 1,350 1,800

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Figure 5.4-1c
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types (shown for largest SMA Alternative F)
Segment 3: AOPCs 9D - 14

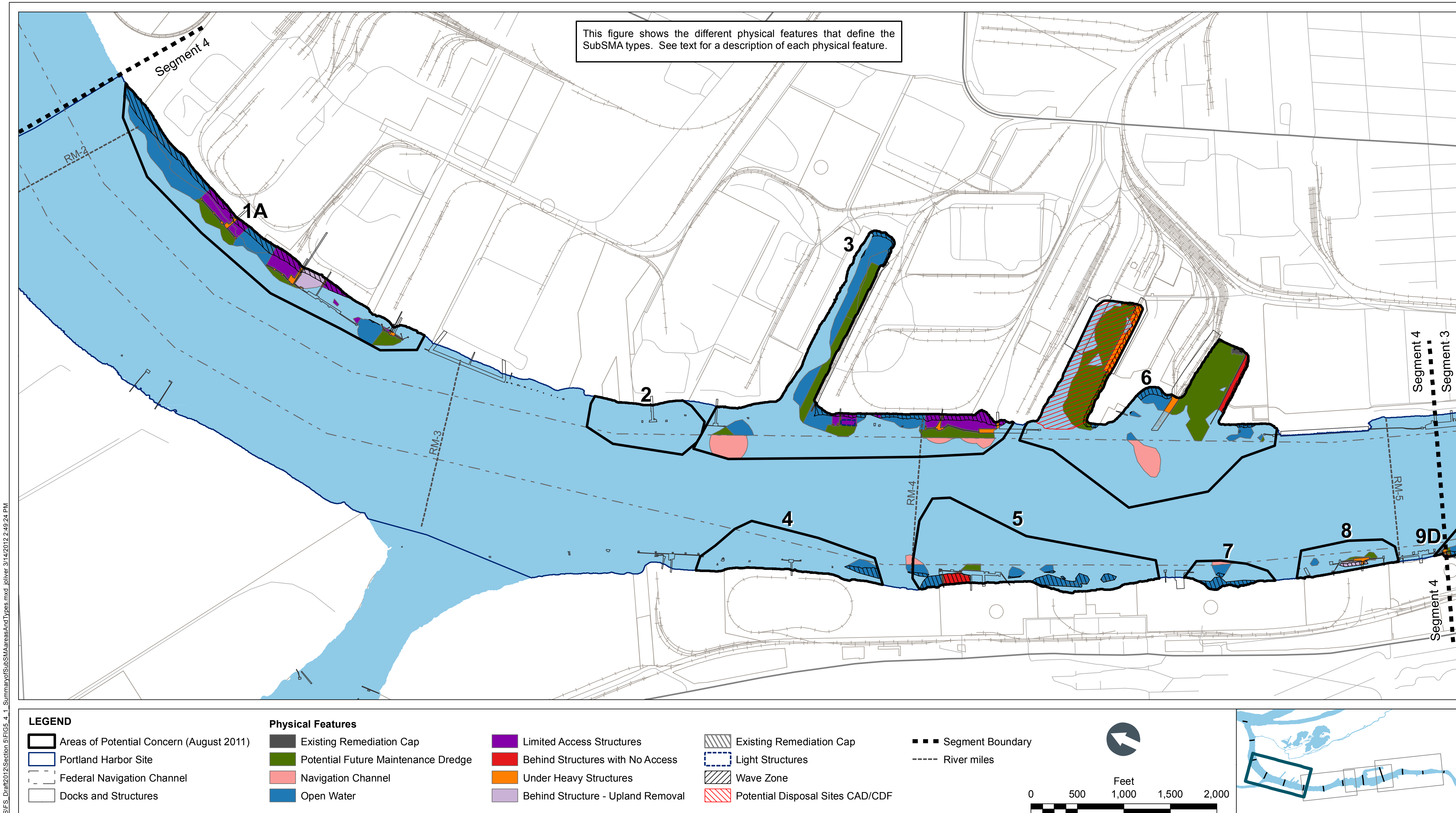

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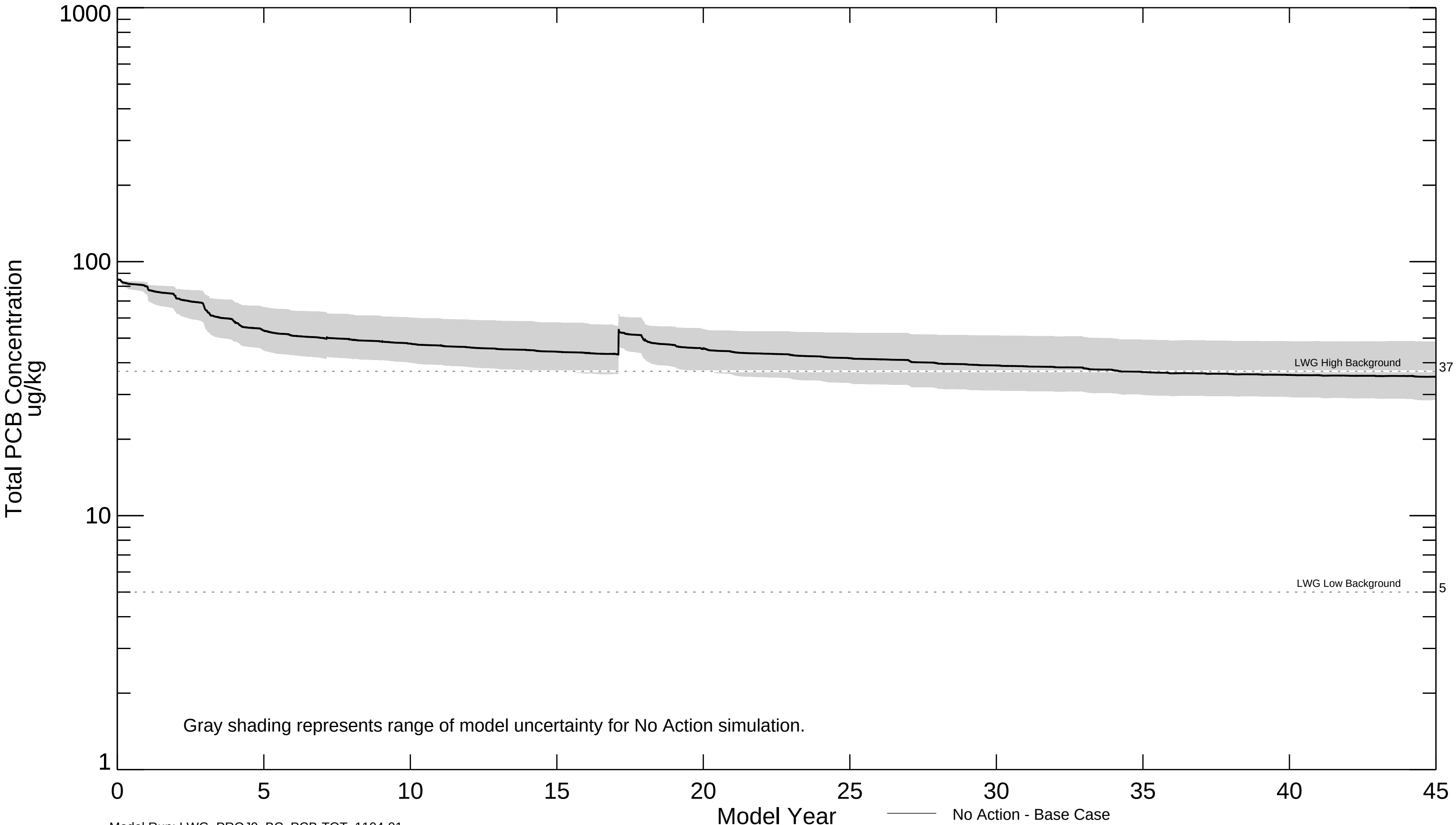
Figure 5.4-1d
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types (shown for largest SMA Alternative F)
Segment 4: AOPCs 1-8

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012\Section 5\FIG5_4_1_SummaryofSubSMAareasAndTypes.mxd joliver 3/14/2012 2:49:24 PM

This figure is an example of the surface sediment changes caused by the flood event at assumed Year 17 and shortly thereafter, including modeling uncertainty bands.



Model Run: LWG_PROJ9_BC_PCB-TOT_1104-01, LWG_PROJ9_LB_PCB-TOT_1105-25, LWG_PROJ9_UB_PCB-TOT_1105-30

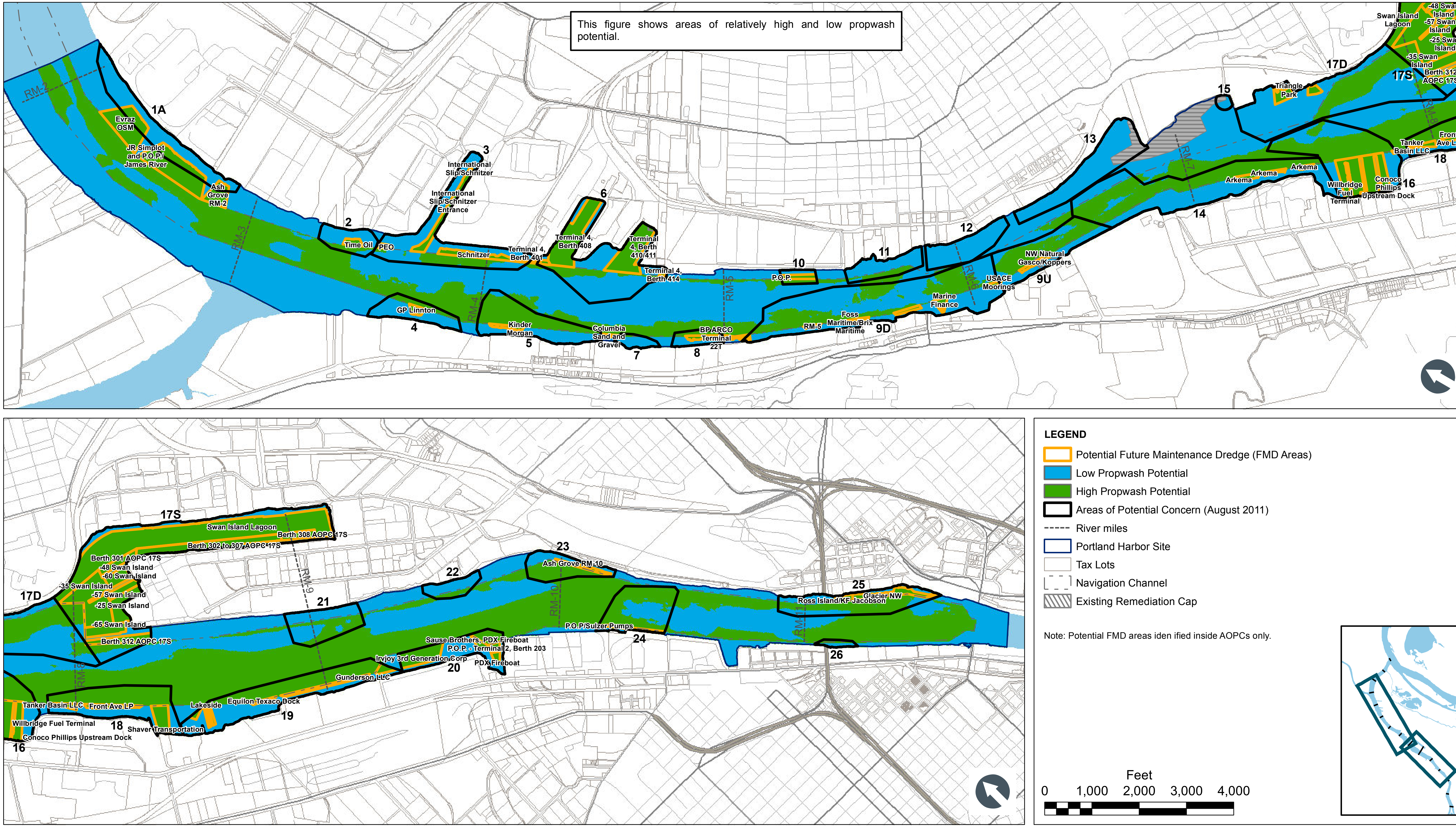
Figure 5.6-1

Portland Harbor RI/FS

Draft Feasibility Study

Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations (Site-wide Average).



Q:\Jobs\010142-01 AQ LWG\Maps\FS\FS Draft2012 EPA\Section 5\FIG5 6 2 BathyPropwashPotential.mxd nkochie 3/14/2012 2:20:43 PM

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Figure 5.6-2
Portland Harbor RI/FS
Draft Feasibility Study
Propwash Modeling Results –
Areas of Relatively High and Low Propwash Potential

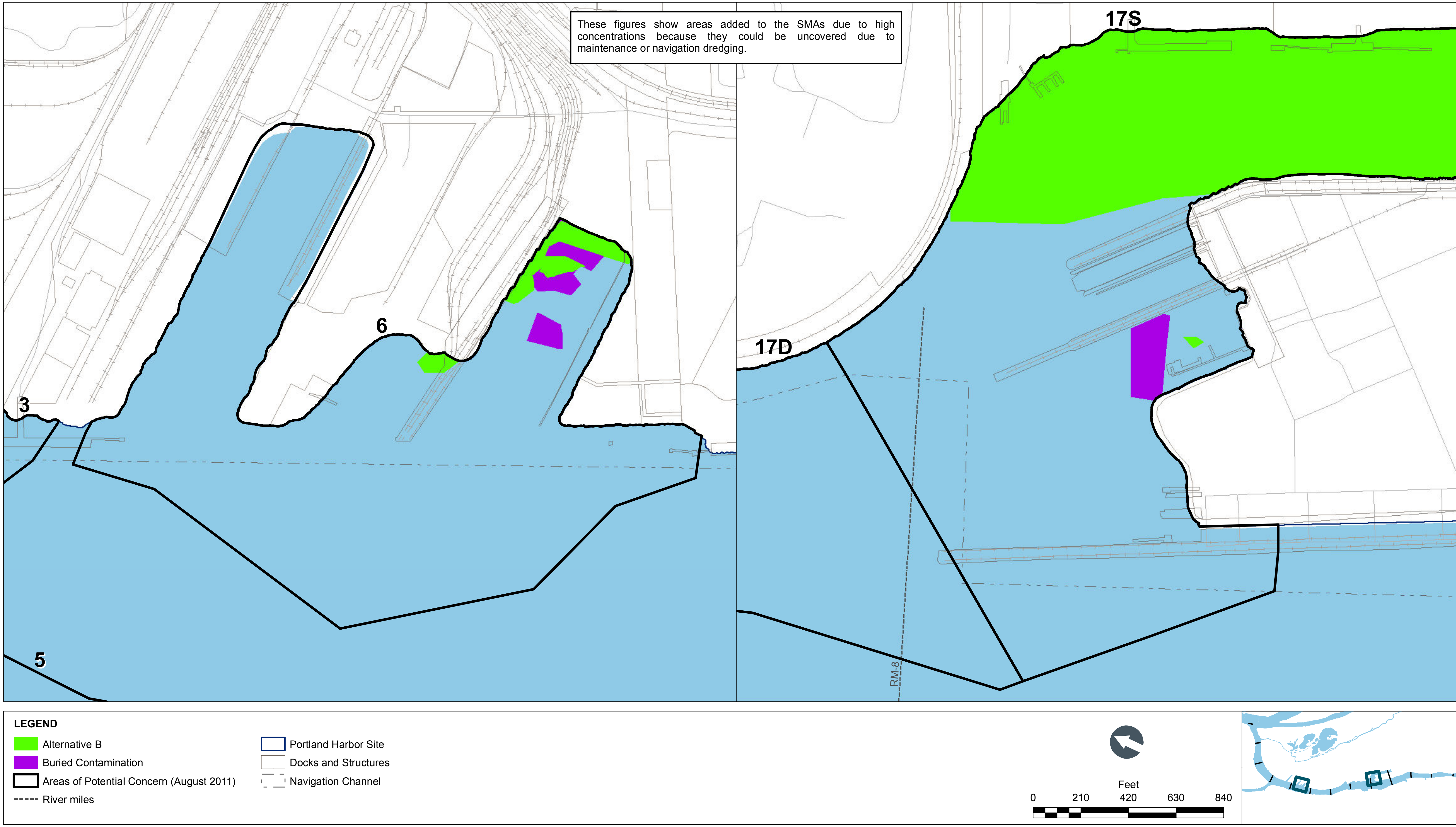

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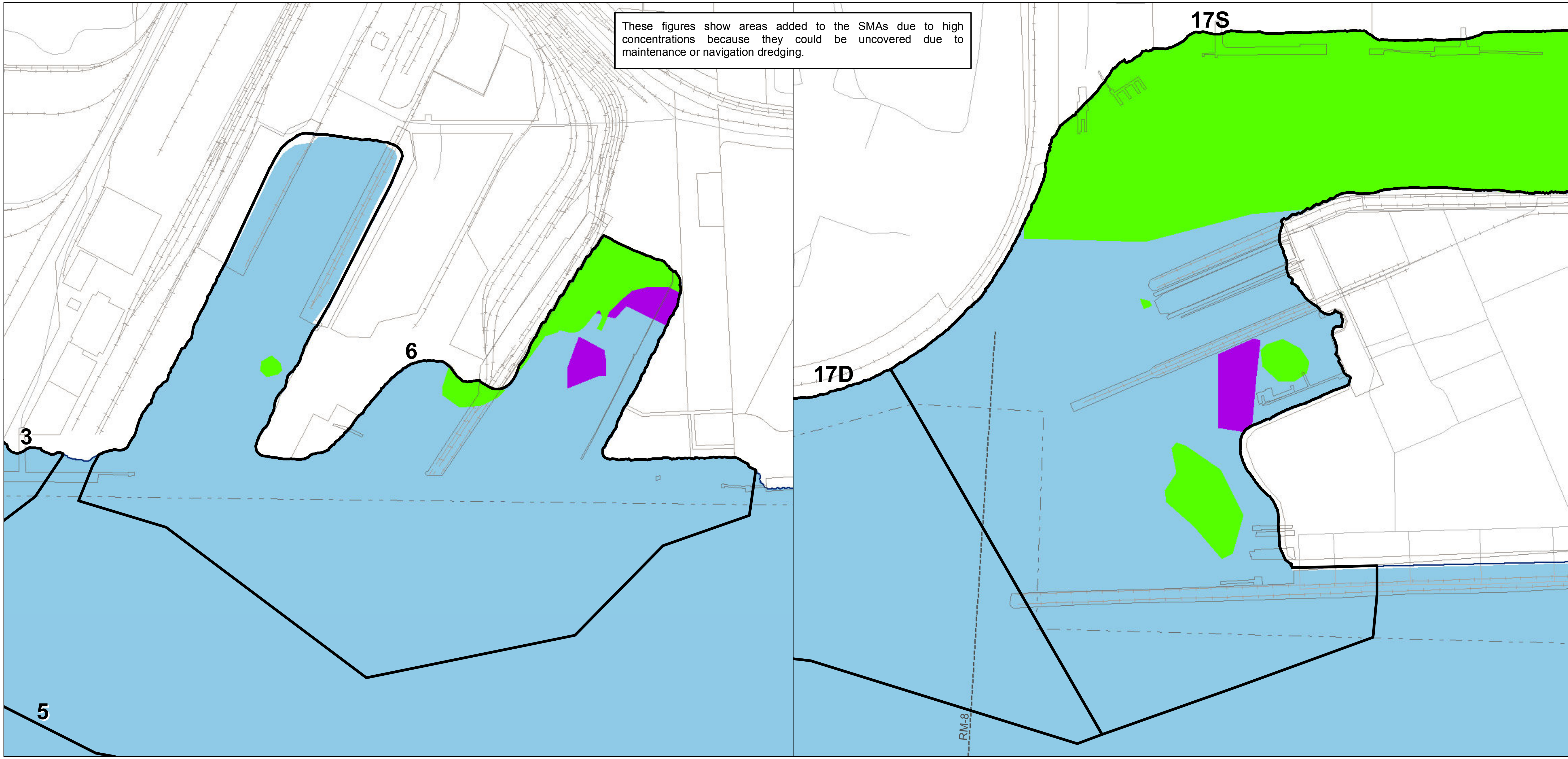
Figure 5.6-3a
Portland Harbor RI/FS
Draft Feasibility Study
Buried Contamination for Alternative B



LEGEND

- Alternative C
- Buried Contamination
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Site
- Docks and Structures
- Navigation Channel

Feet

0 210 420 630 840

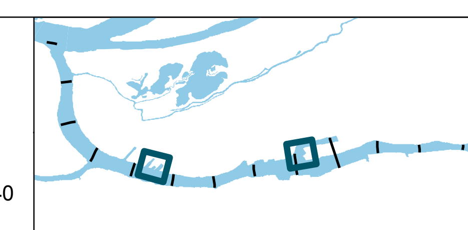


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Figure 5.6-3b
Portland Harbor RI/FS
Draft Feasibility Study
Buried Contamination for Alternative C

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_6_3b_BuriedContaminationAlternativeC.mxd jolliver 3/13/2012 4:19:02 PM

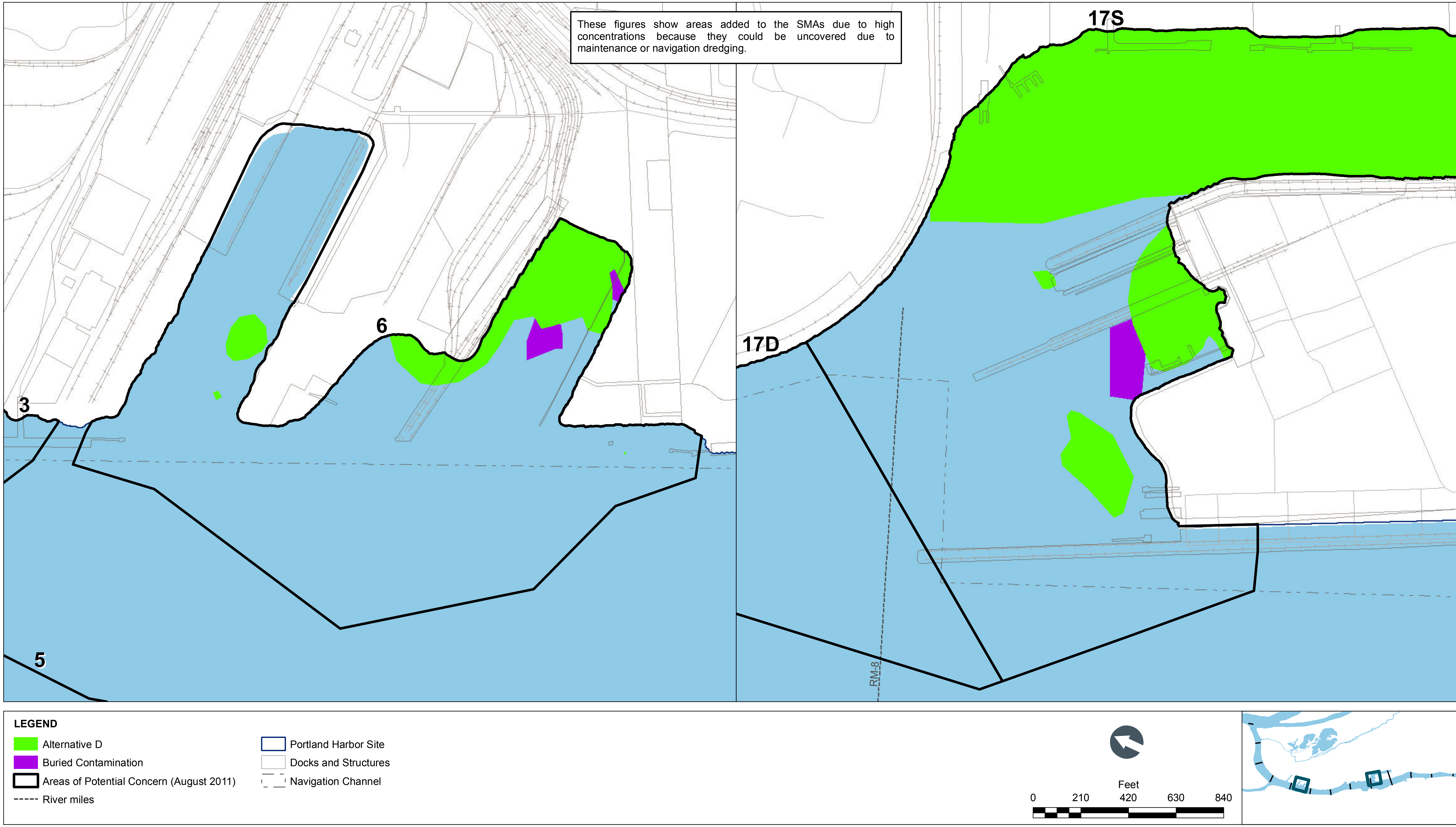

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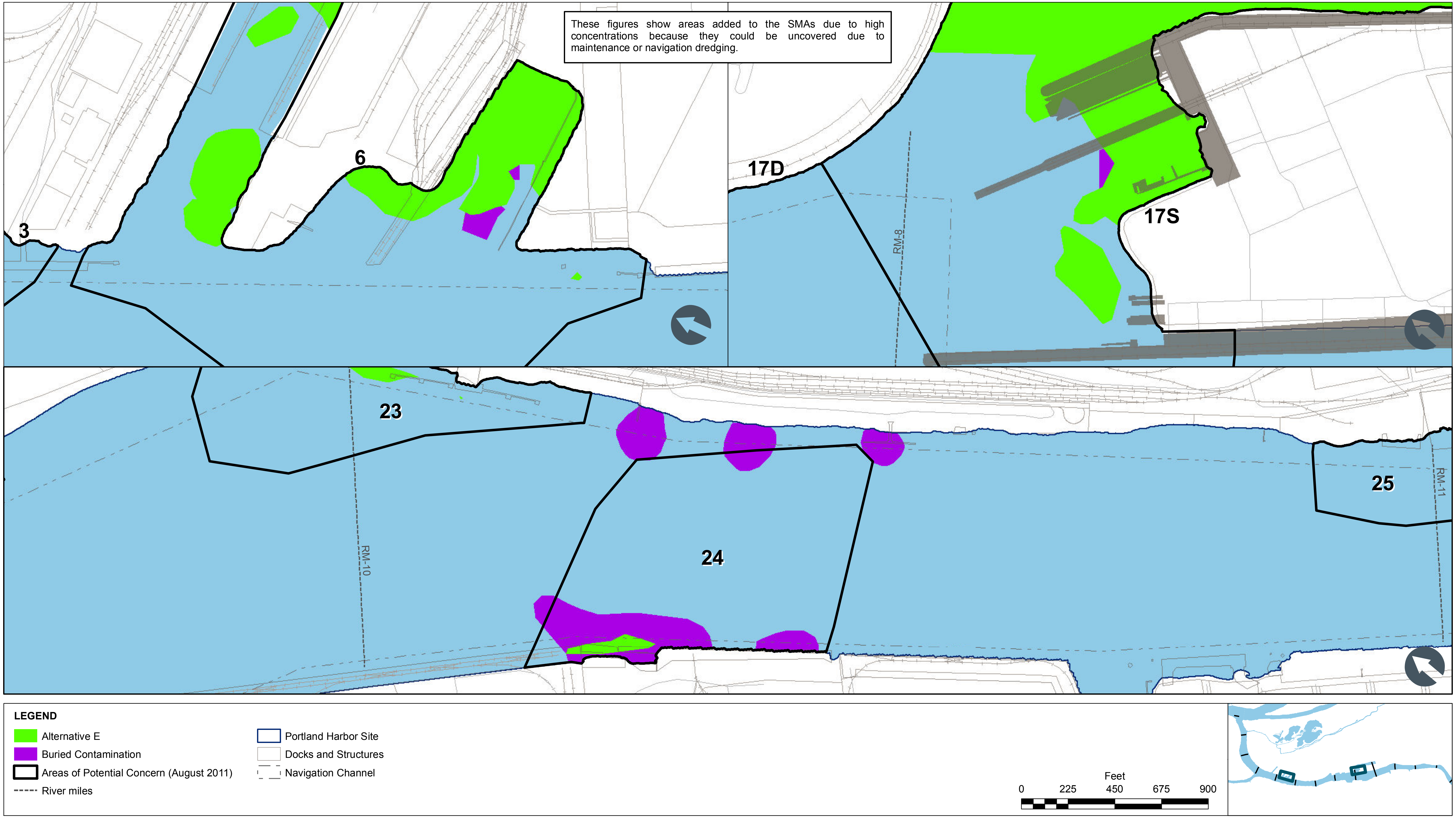
Figure 5.6-3c
Portland Harbor RI/FS
Draft Feasibility Study
Buried Contamination for Alternative D

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_6_3c_BuriedContaminationAlternativeD.mxd joliver 3/13/2012 4:21:43 PM



Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_6_3d_BuriedContaminationAlternativeE.mxd joliver 3/13/2012 4:22:28 PM

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Figure 5.6-3d
Portland Harbor RI/FS
Draft Feasibility Study
Buried Contamination for Alternative E

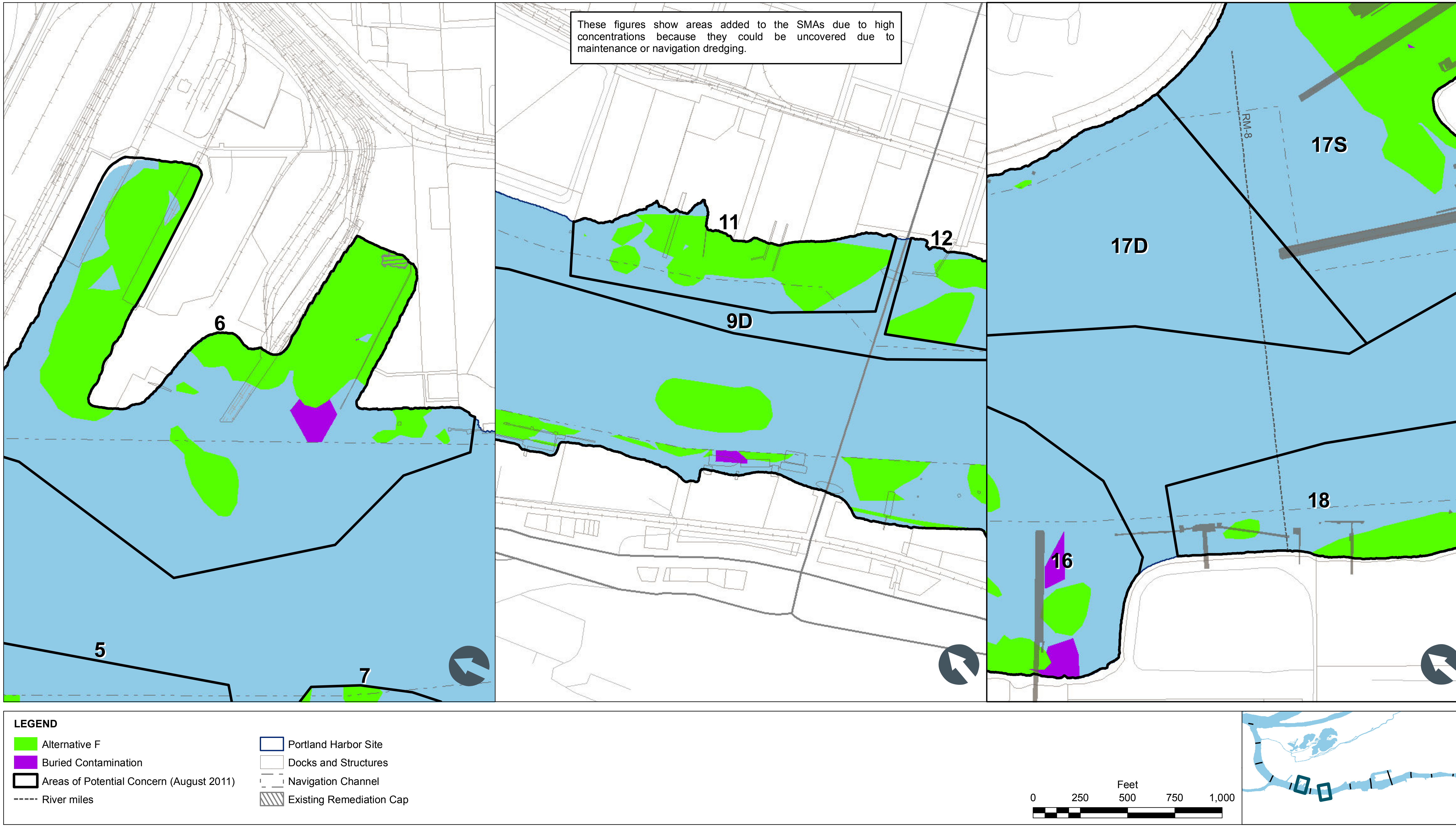

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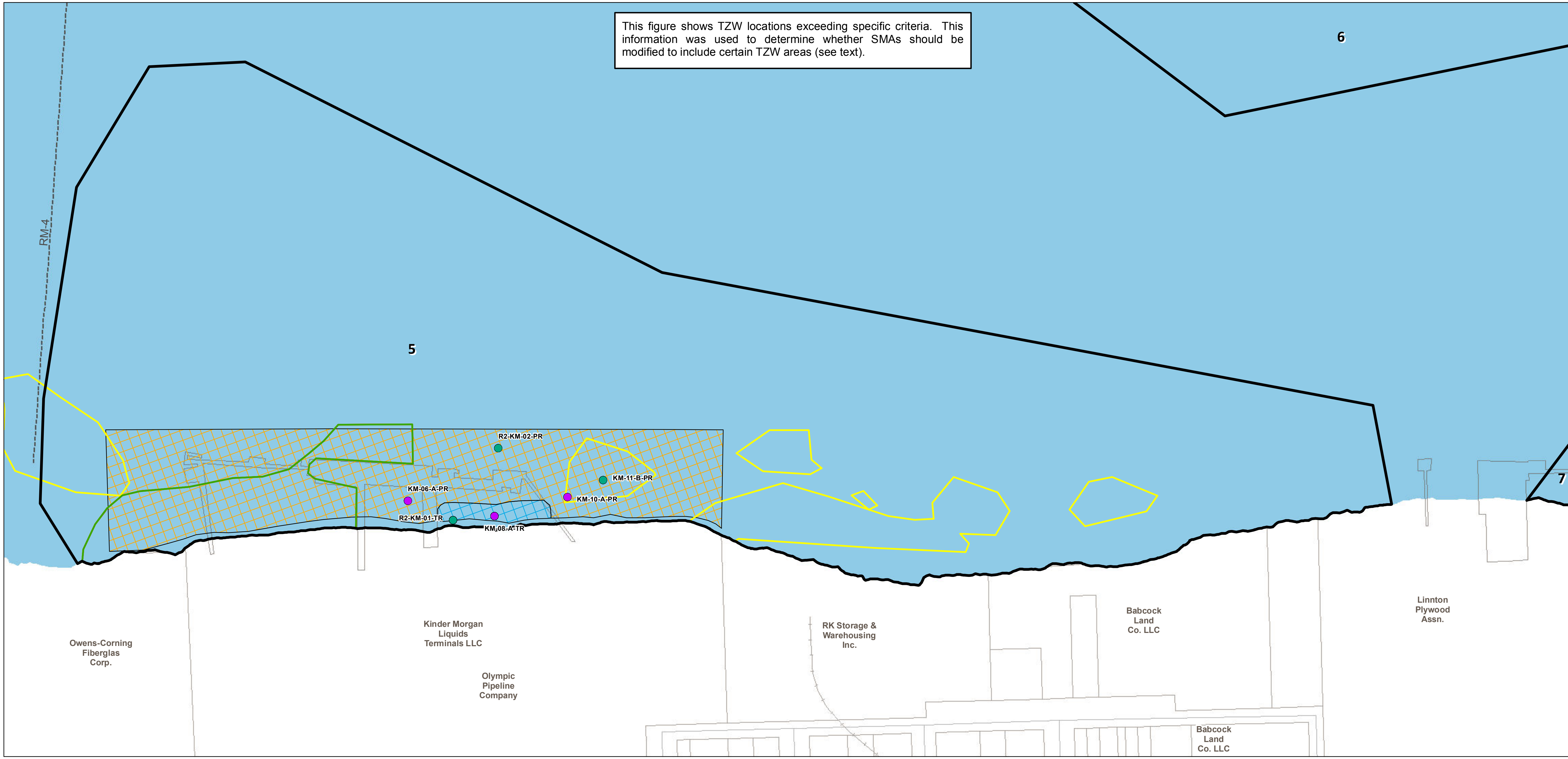
Figure 5.6-3e
Portland Harbor RI/FS
Draft Feasibility Study
Buried Contamination for Alternative F



LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- TZW sample exceeds at least 100x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Ac ive Remediation
- Alternative D - Potential Ac ive Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- Areas of Potential Concern (August 2011)
- River miles
- Docks and Structures
- Tax Lots

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Feet

0 100 200 300 400

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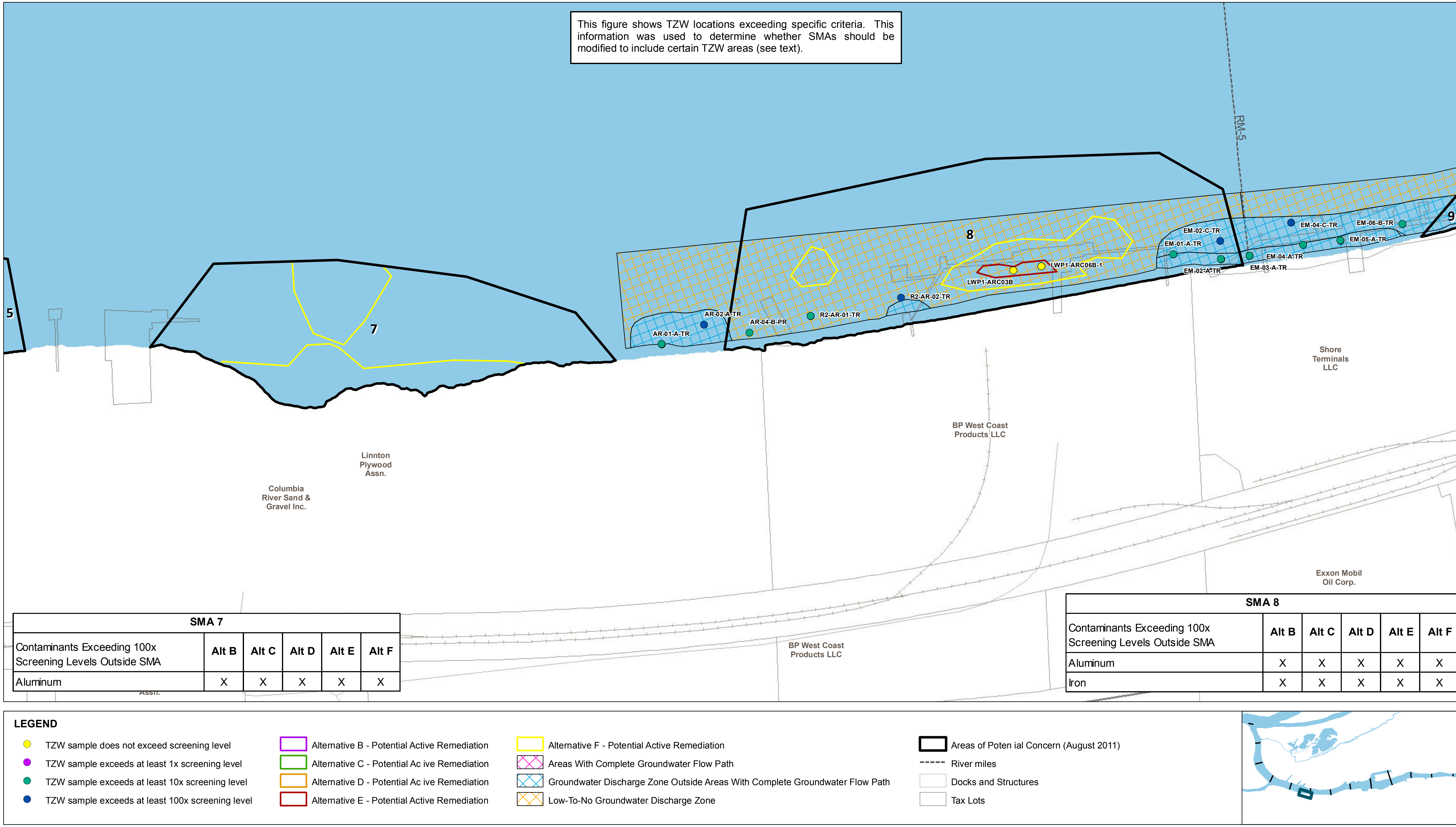
Figure 5.7-1a
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMA5_Aquatic_a.mxd jolivier 3/12/2012 3:32:43 PM



SMA 7

Contaminants Exceeding 100x Screening Levels Outside SMA	Alt B	Alt C	Alt D	Alt E	Alt F
Aluminum	X	X	X	X	X

SMA 8

Contaminants Exceeding 100x Screening Levels Outside SMA	Alt B	Alt C	Alt D	Alt E	Alt F
Aluminum	X	X	X	X	X
Iron	X	X	X	X	X

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LWG Lower Willamette Group

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Figure 5.7-1b
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMA7and8_Aquatic_b.mxd jolliver 3/12/2012 3:33:14 PM

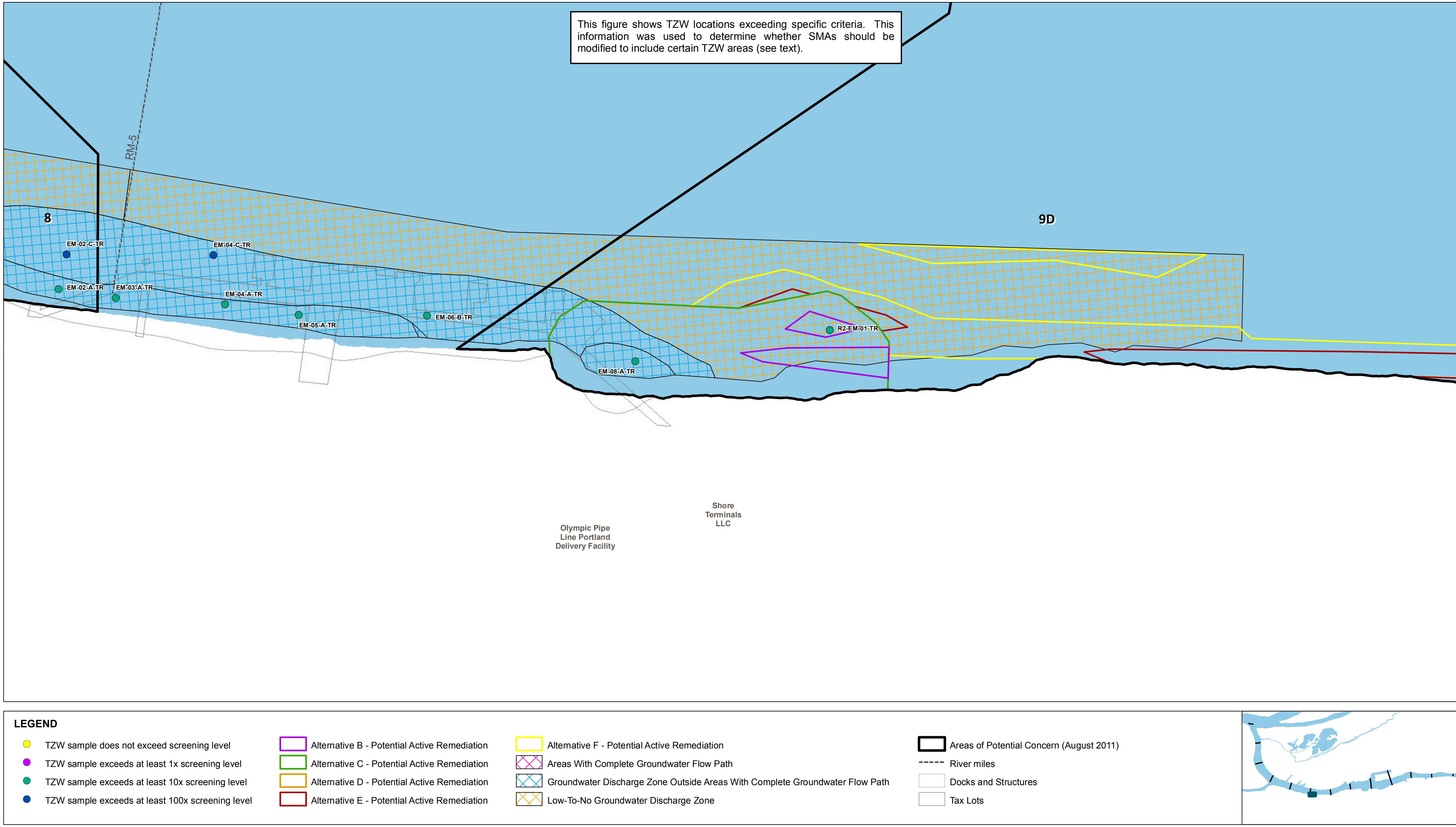

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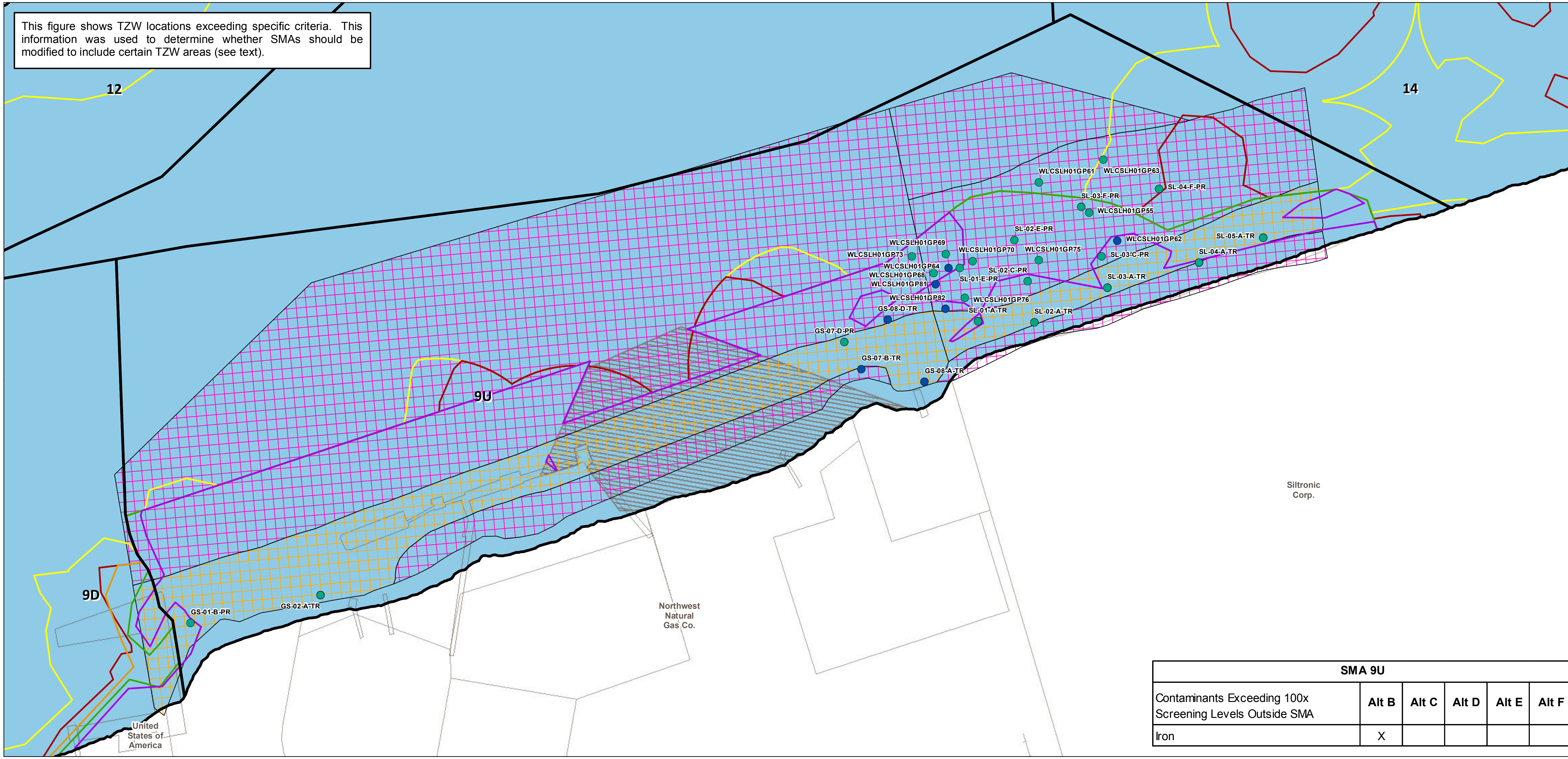
Figure 5.7-1c
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

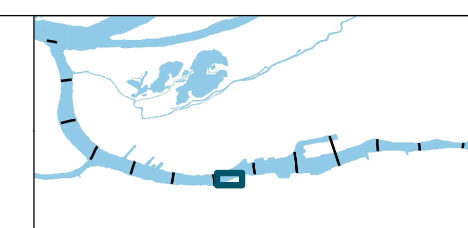
Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMA9D_Aquatic_c.mxd joliver 3/12/2012 3:33:52 PM



SMA 9U					
Contaminants Exceeding 100x Screening Levels Outside SMA	Alt B	Alt C	Alt D	Alt E	Alt F
Iron	X				

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- TZW sample exceeds at least 100x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- Areas of Potential Concern (August 2011)
- River miles
- Existing Remediation Cap
- Docks and Structures
- Tax Lots



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Feet
0 100 200 300 400

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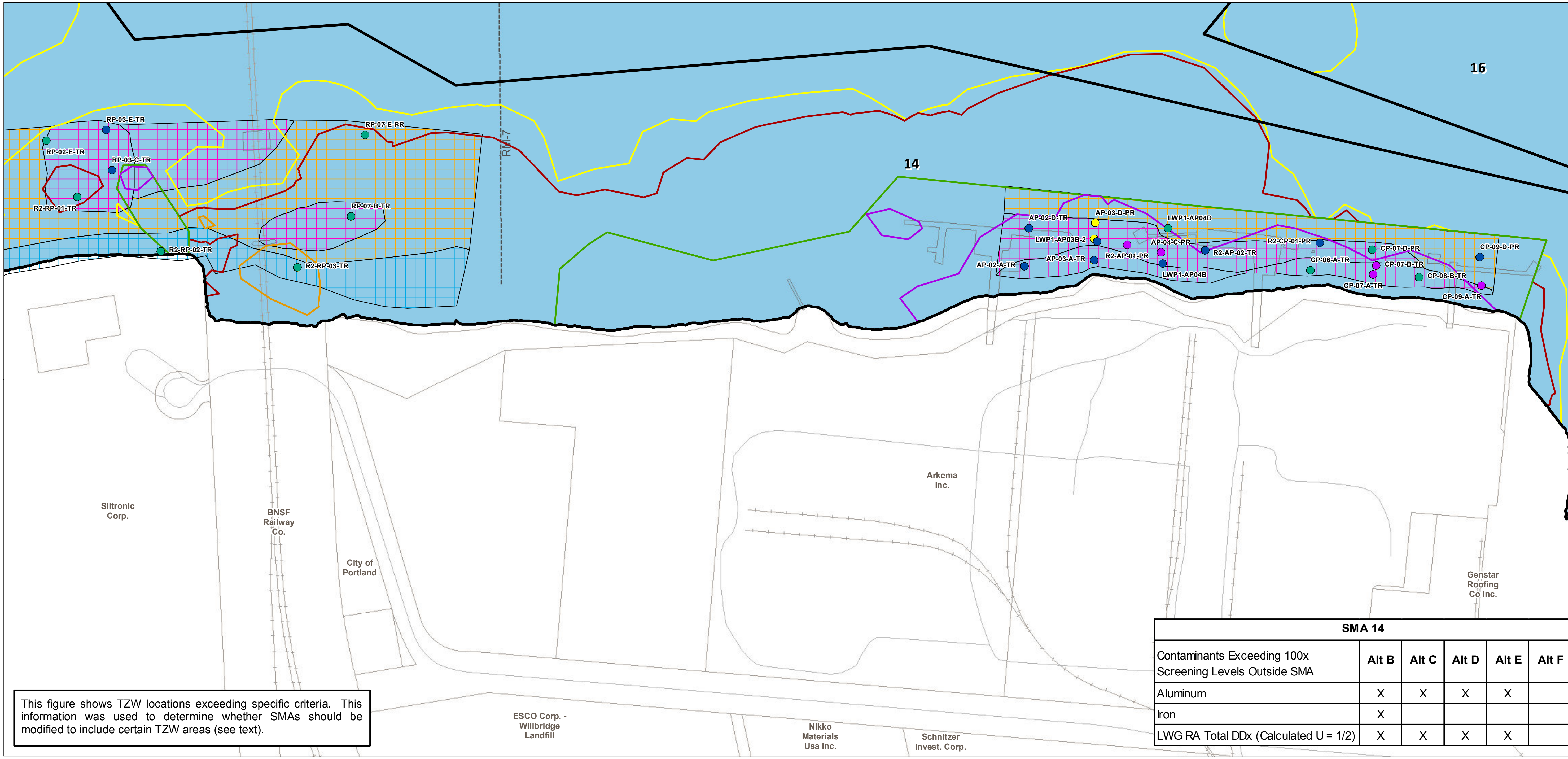
Figure 5.7-1d
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMA9U_Aquatic_d.mxd joliver 3/12/2012 3:47:25 PM

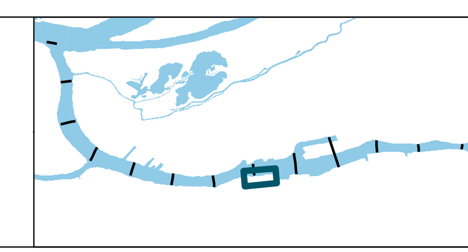


This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 14					
Contaminants Exceeding 100x Screening Levels Outside SMA	Alt B	Alt C	Alt D	Alt E	Alt F
Aluminum	X	X	X	X	
Iron	X				
LWG RA Total DDx (Calculated U = 1/2)	X	X	X	X	

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- TZW sample exceeds at least 100x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- Areas of Potential Concern (August 2011)
- River miles
- Docks and Structures
- Tax Lots



Feet
0 125 250 375 500

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Figure 5.7-1e
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

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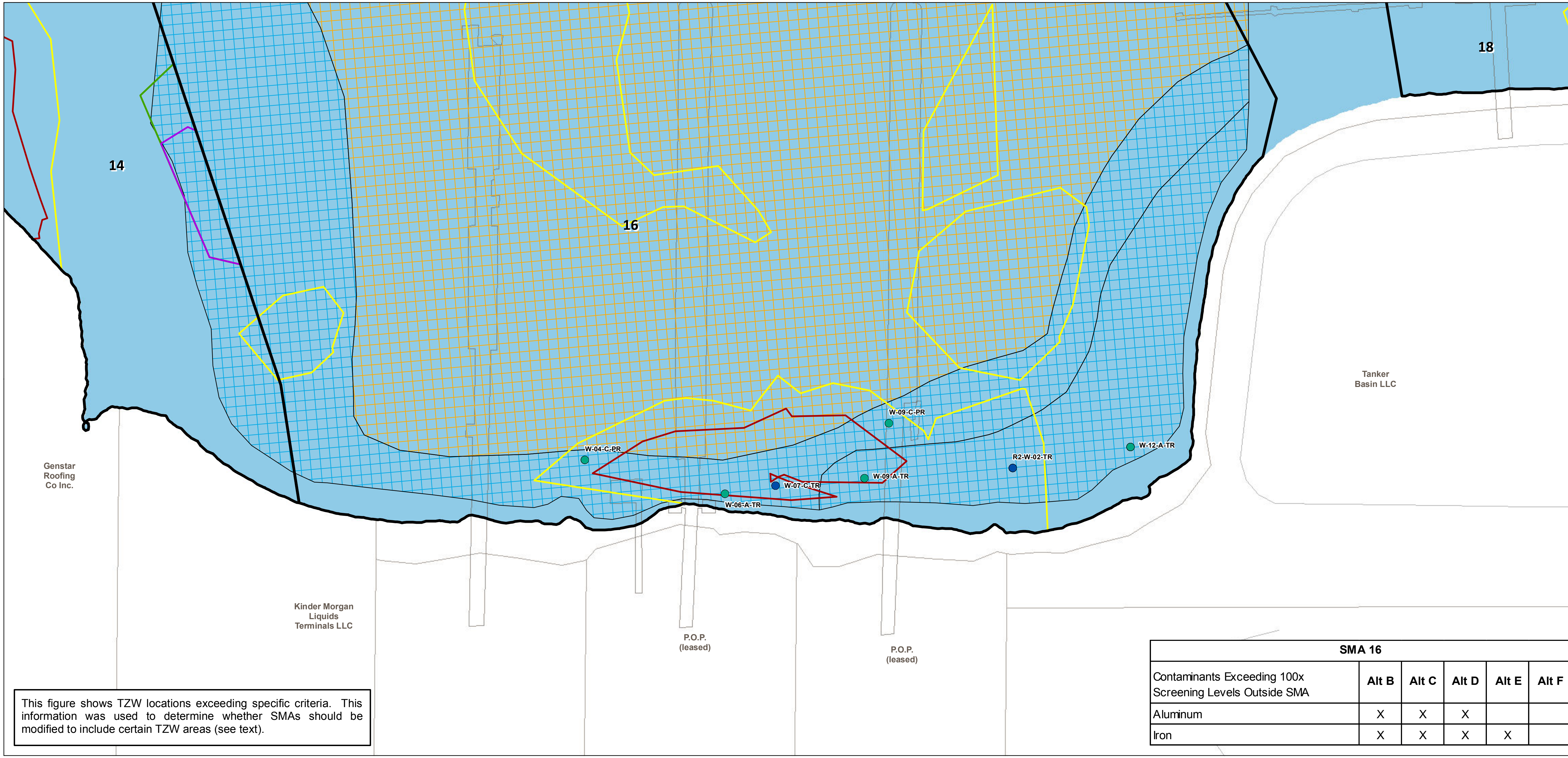
Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMA14_Aquatic_e.mxd joliver 3/12/2012 3:37:30 PM



This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 16					
Contaminants Exceeding 100x Screening Levels Outside SMA	Alt B	Alt C	Alt D	Alt E	Alt F
Aluminum	X	X	X		
Iron	X	X	X	X	

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- TZW sample exceeds at least 100x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- Areas of Potential Concern (August 2011)
- River miles
- Docks and Structures
- Tax Lots

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Feet
0 75 150 225 300

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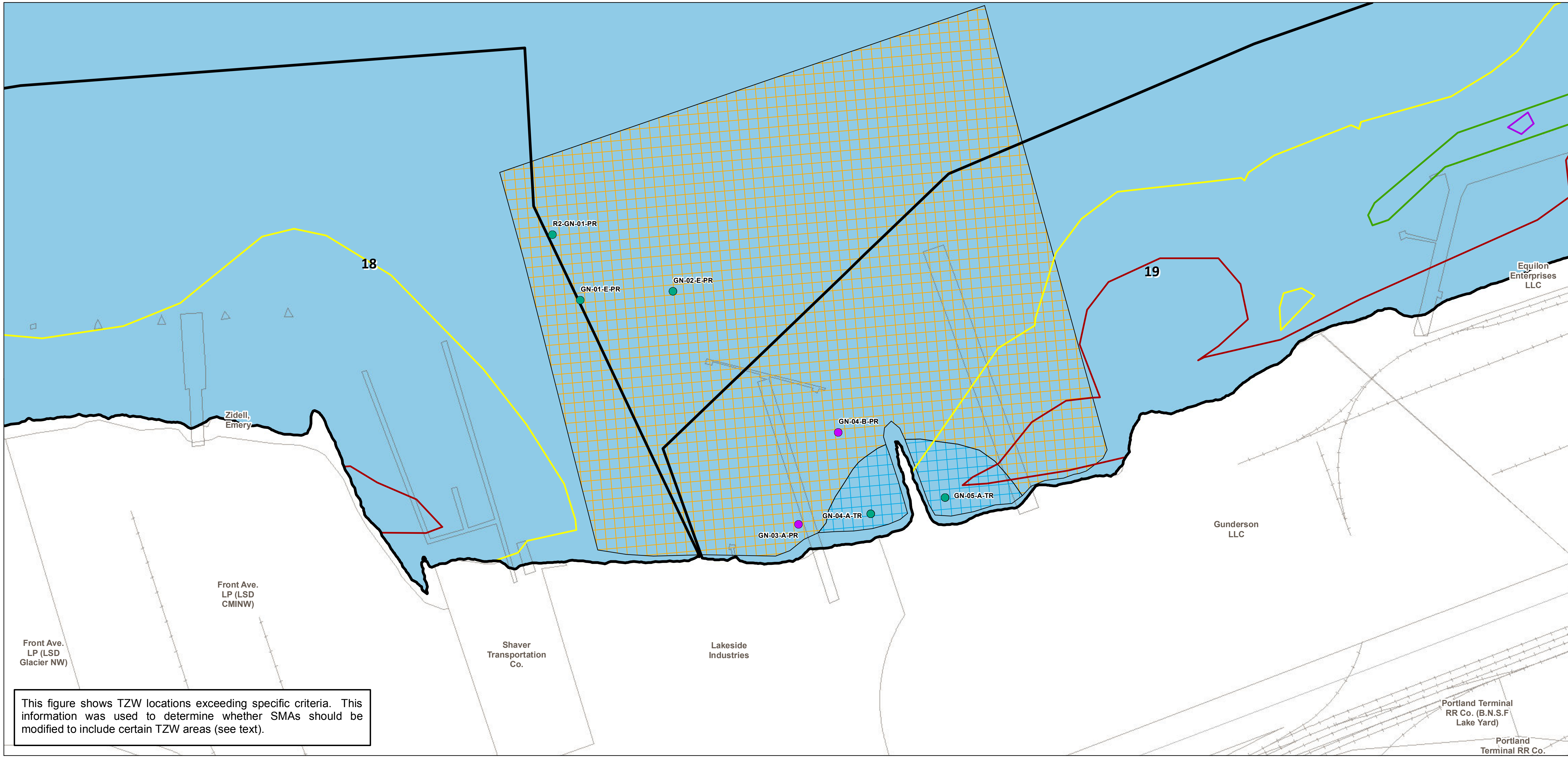
Figure 5.7-1f
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMA16_Aquatic_f.mxd joliver 3/12/2012 3:38:15 PM



LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- TZW sample exceeds at least 100x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- Areas of Potential Concern (August 2011)
- River miles
- Docks and Structures
- Tax Lots

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Feet

0 100 200 300 400

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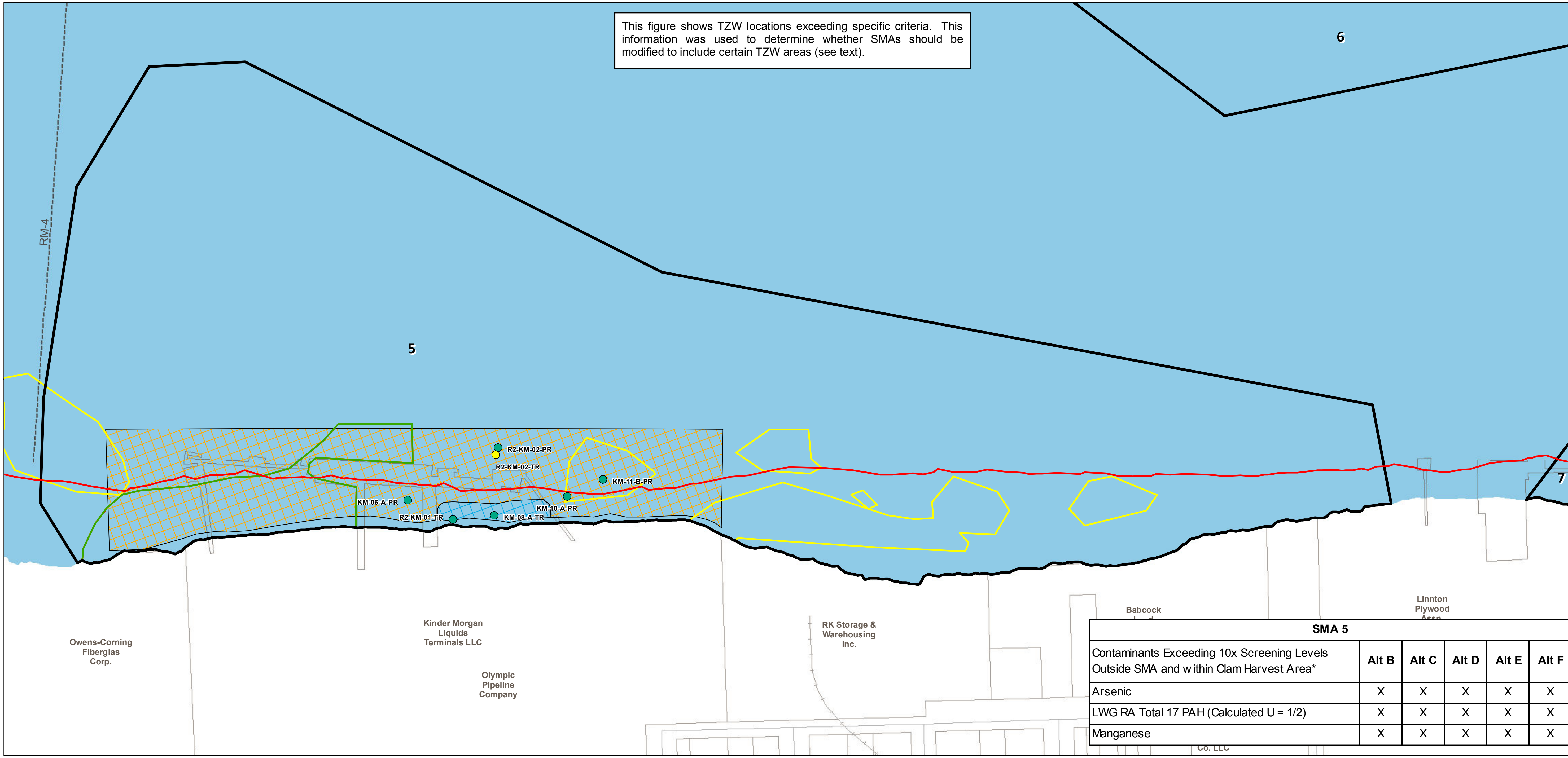
Figure 5.7-1g
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Aquatic Life Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_1_TZW_SMAXand19_Aquatic_g.mxd jolliver 3/12/2012 3:39:05 PM



SMA 5					
Contaminants Exceeding 10x Screening Levels Outside SMA and within Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	X
LWG RA Total 17 PAH (Calculated U = 1/2)	X	X	X	X	X
Manganese	X	X	X	X	X

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Potential Ac ive Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remedia ion
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Potential Concern (August 2011)
- Docks and Structures
- River miles
- Tax Lots

Feet
0 100 200 300 400

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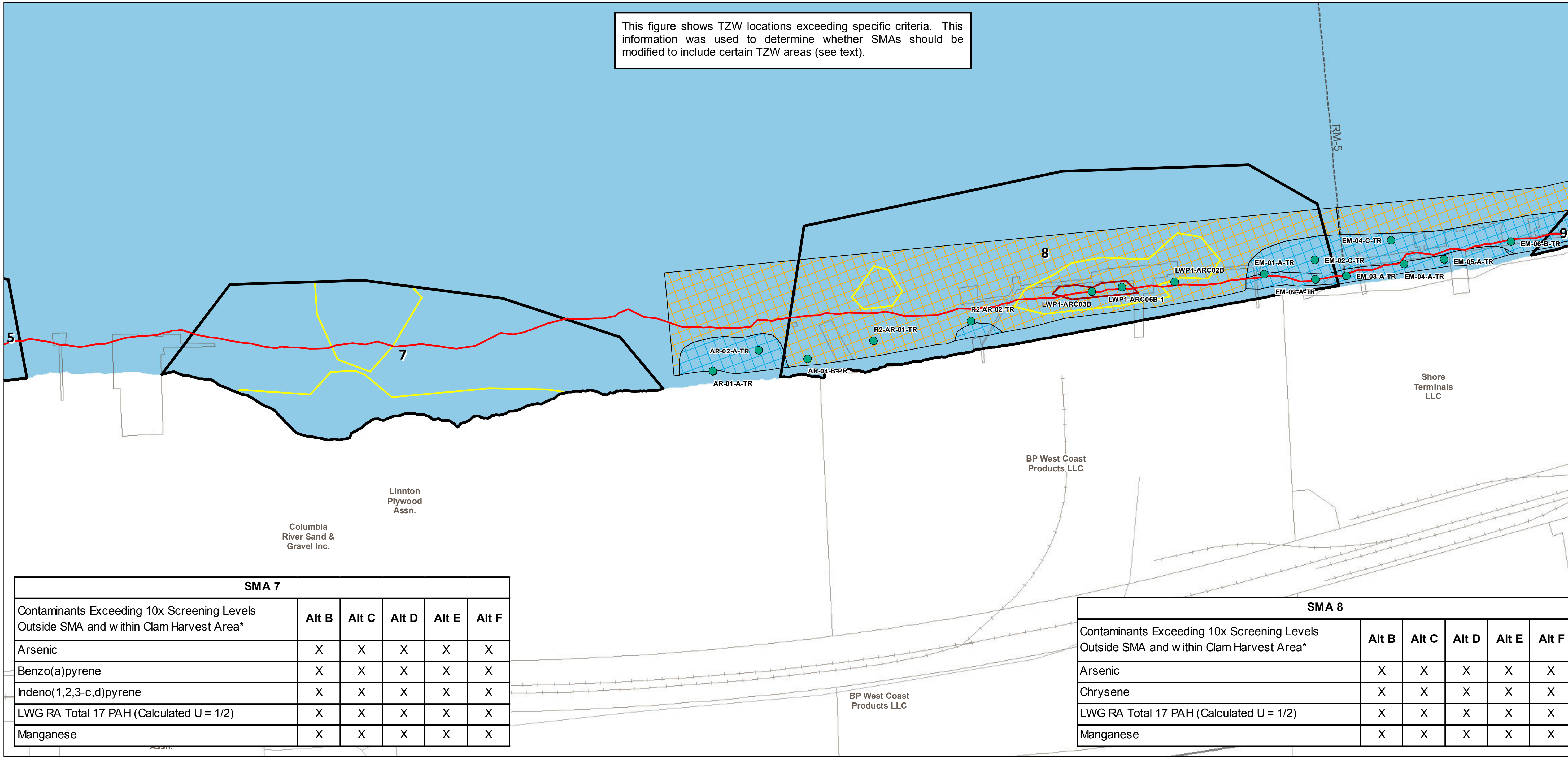
Figure 5.7-2a
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_2_TZW_SMA5_Fish_Consumption_a.mxd jolivier 3/12/2012 3:40:32 PM

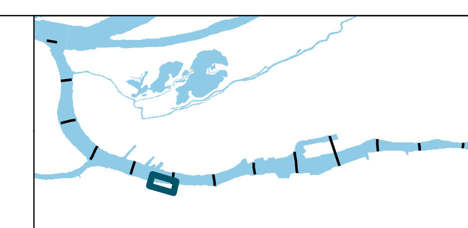


SMA 7					
Contaminants Exceeding 10x Screening Levels Outside SMA and within Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	X
Benzo(a)pyrene	X	X	X	X	X
Indeno(1,2,3-c,d)pyrene	X	X	X	X	X
LWG RA Total 17 PAH (Calculated U = 1/2)	X	X	X	X	X
Manganese	X	X	X	X	X

SMA 8					
Contaminants Exceeding 10x Screening Levels Outside SMA and within Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	X
Chrysene	X	X	X	X	X
LWG RA Total 17 PAH (Calculated U = 1/2)	X	X	X	X	X
Manganese	X	X	X	X	X

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remedia ion
- Areas With Complete Groundwater Flow Pa h
- Groundwater Discharge Zone Outside Areas Wi h Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Potential Concern (August 2011)
- Docks and Structures
- River miles
- Tax Lots



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Feet
0 100 200 300 400

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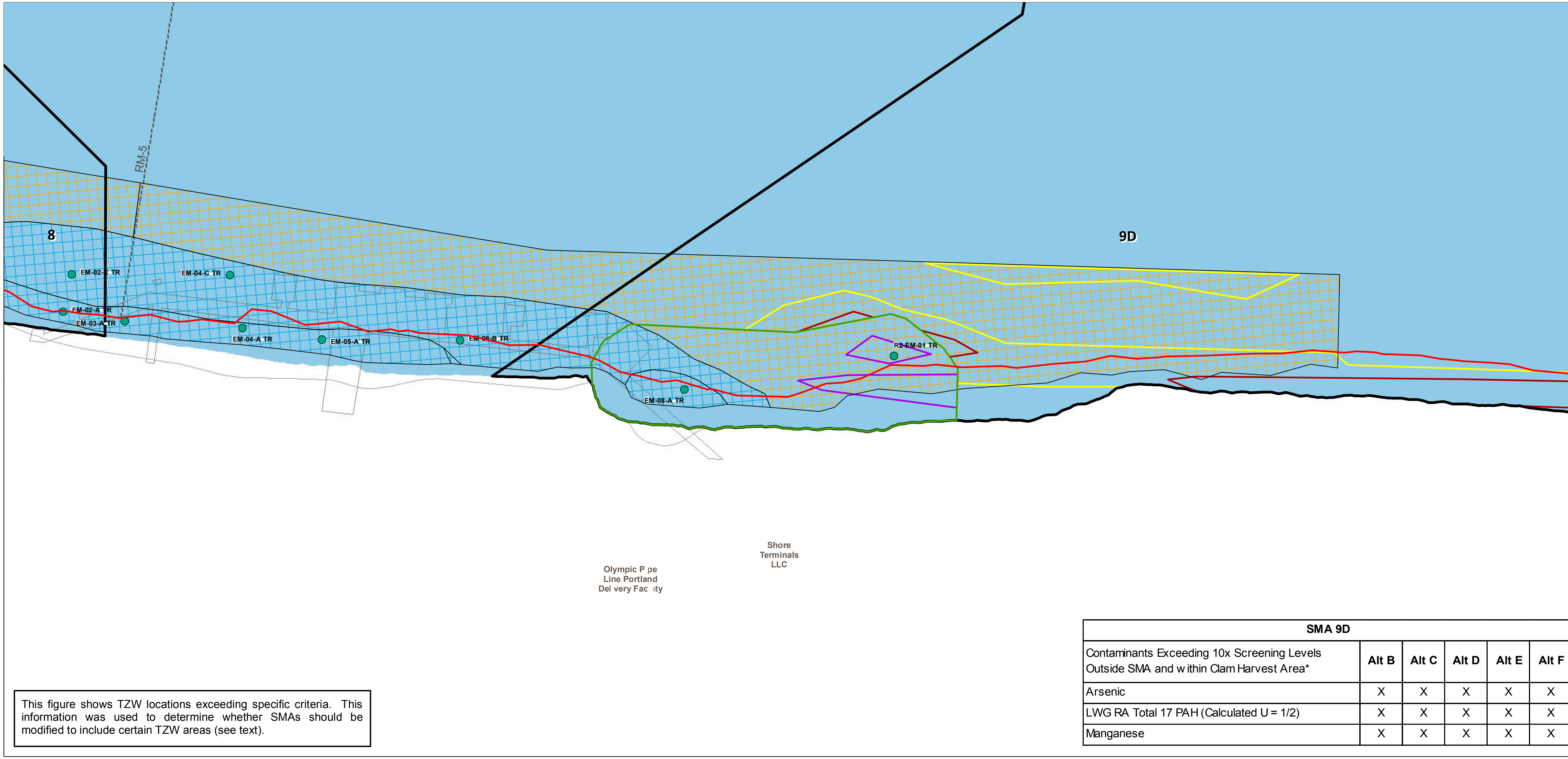
Figure 5.7-2b
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_2_TZW_SMA7and8_Fish_Consumption_b.mxd joliver 3/12/2012 3:41:28 PM

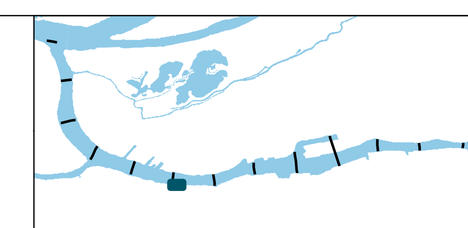


SMA 9D					
Contaminants Exceeding 10x Screening Levels Outside SMA and within Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	X
LWG RA Total 17 PAH (Calculated U = 1/2)	X	X	X	X	X
Manganese	X	X	X	X	X

This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Potential Concern (August 2011)
- Docks and Structures
- River miles
- Tax Lots



Feet
0 50 100 150 200

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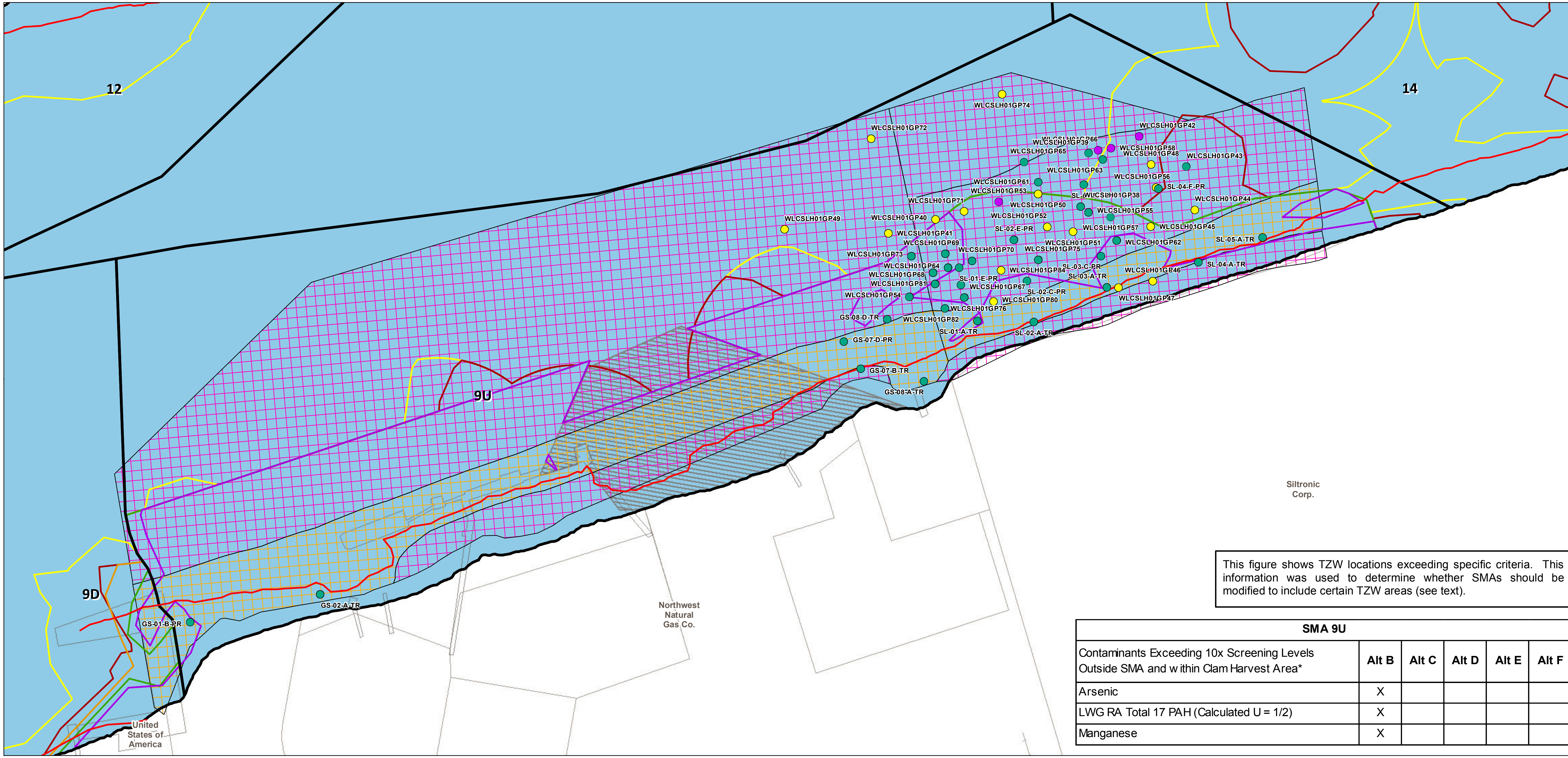
Figure 5.7-2c
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_2_TZW_SMA9D_Fish_Consumption_c.mxd joliver 3/12/2012 3:42:12 PM

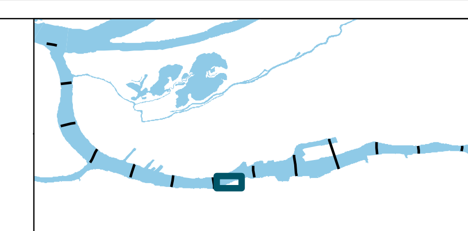


This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 9U					
Contaminants Exceeding 10x Screening Levels Outside SMA and w ithin Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X				
LWG RA Total 17 PAH (Calculated U = 1/2)	X				
Manganese	X				

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Potential Ac ive Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Potential Concern (August 2011)
- Docks and Structures
- Existing Remediation Cap
- River miles
- Tax Lots



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LWG LOWER WILLAMETTE GROUP

Feet
0 100 200 300 400

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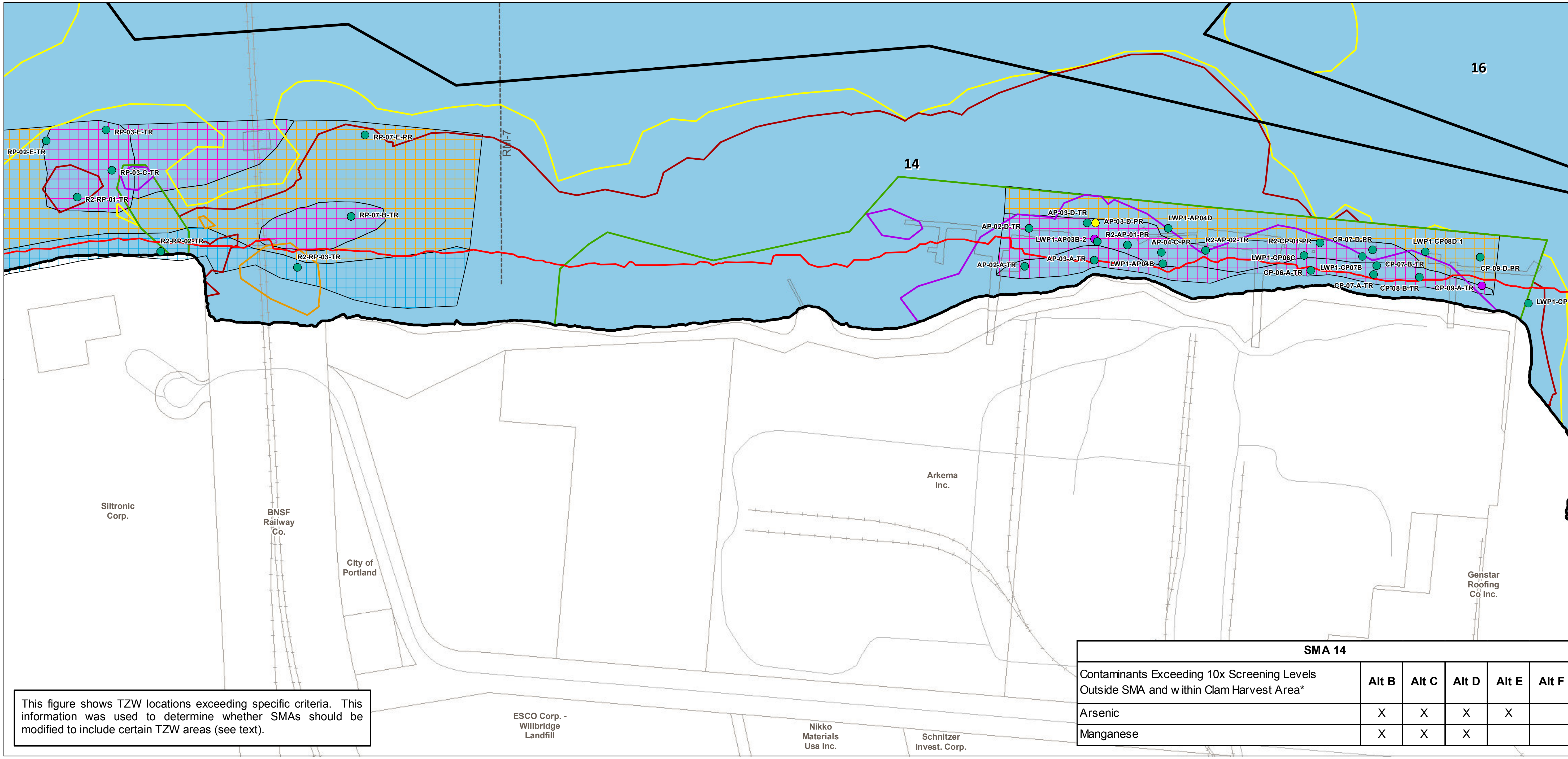
Figure 5.7-2d
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_2_TZW_SMA9U_Fish_Consumption_d.mxd joliver 3/12/2012 3:48:24 PM

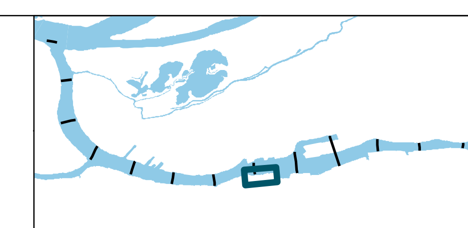


This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 14					
Contaminants Exceeding 10x Screening Levels Outside SMA and w ithin Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	
Manganese	X	X	X		

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Poten ial Active Remediation
- Alterna ive C - Potential Active Remediation
- Alterna ive D - Potential Active Remediation
- Alterna ive E - Potential Active Remediation
- Alterna ive F - Potential Ac ive Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Poten ial Concern (August 2011)
- Docks and Structures
- River miles
- Tax Lots



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Feet

0 125 250 375 500

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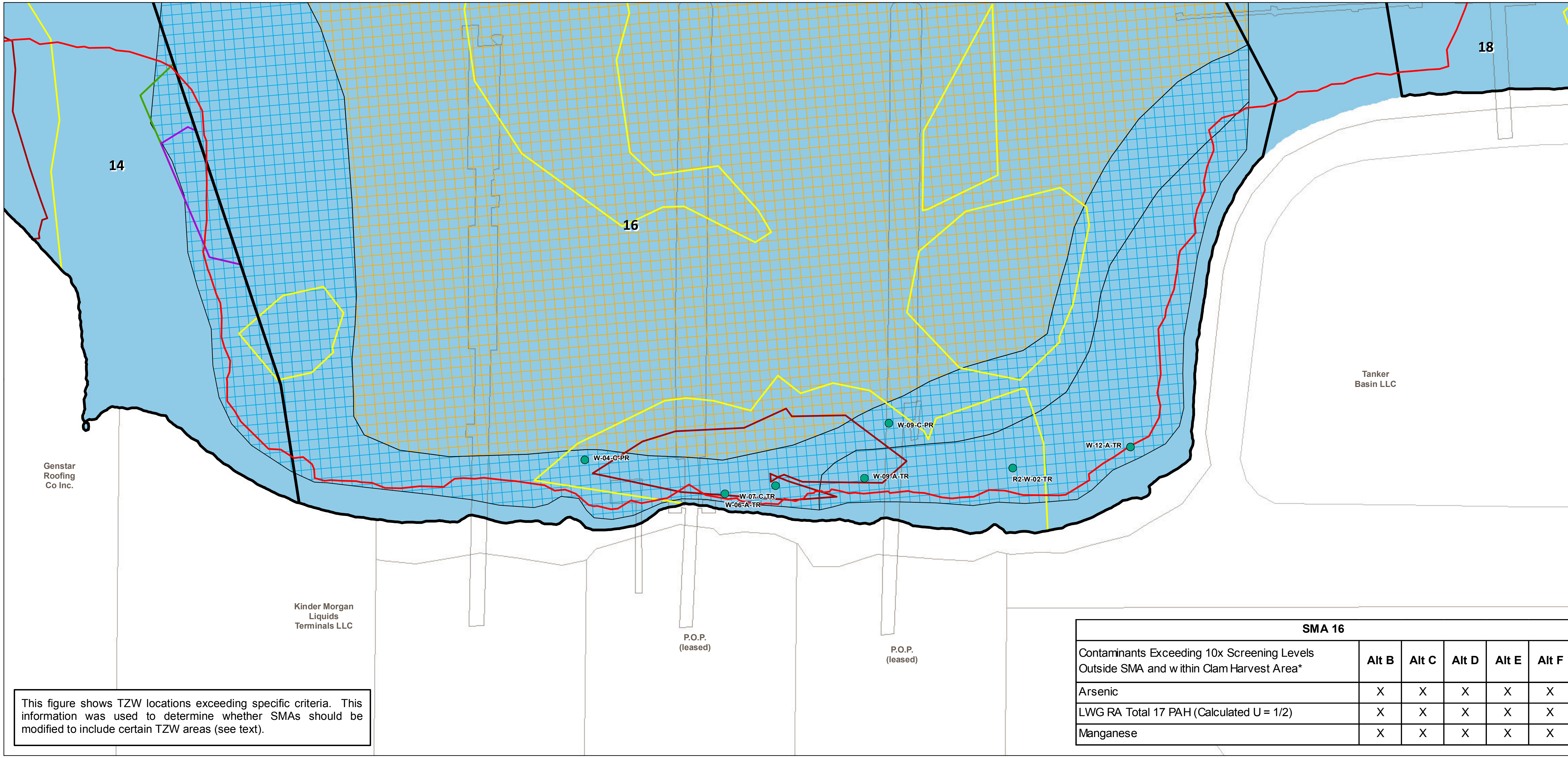
Figure 5.7-2e
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_7_2_TZW_SMA14_Fish_Consumption_e.mxd joliver 3/12/2012 3:46:11 PM



This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 16					
Contaminants Exceeding 10x Screening Levels Outside SMA and within Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	X
LWG RA Total 17 PAH (Calculated U = 1/2)	X	X	X	X	X
Manganese	X	X	X	X	X

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour — +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Potential Concern (August 2011)
- Docks and Structures
- River miles
- Tax Lots

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Feet
0 75 150 225 300

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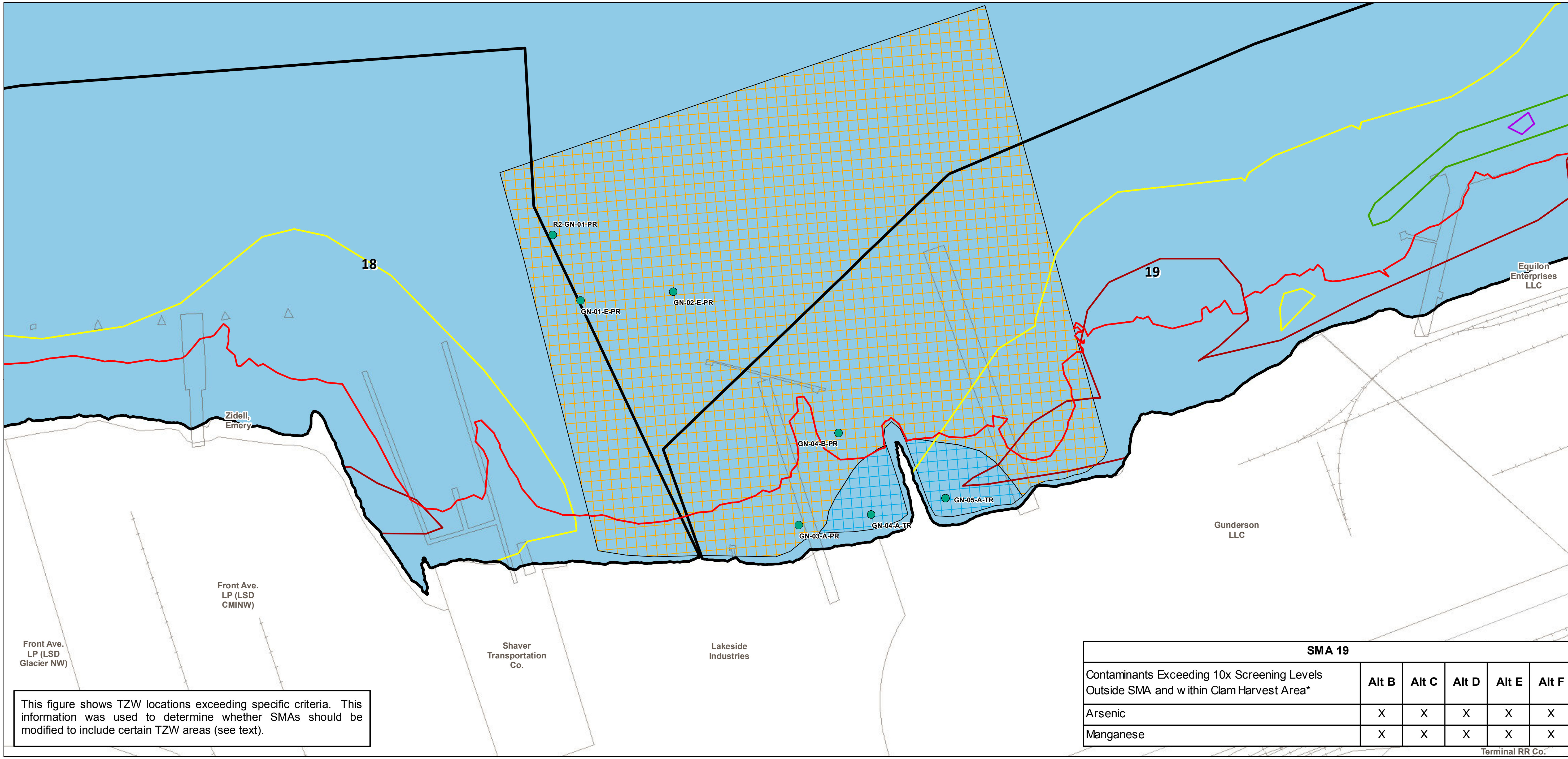
Figure 5.7-2f
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs



This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 19					
Contaminants Exceeding 10x Screening Levels Outside SMA and w ithin Clam Harvest Area*	Alt B	Alt C	Alt D	Alt E	Alt F
Arsenic	X	X	X	X	X
Manganese	X	X	X	X	X

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least 1x screening level
- TZW sample exceeds at least 10x screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Ac ive Remediation
- Alternative F - Poten ial Active Remediation
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- +5.1 ft NAVD88 Contour = Ordinary Low Water (OLW) (*Clam Harvest Area = Area Above OLW)
- Areas of Poten ial Concern (August 2011)
- Docks and Structures
- River miles
- Tax Lots

Feet

0 100 200 300 400

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Figure 5.7-2g
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Fish/Shellfish Consumption Potential ARARs

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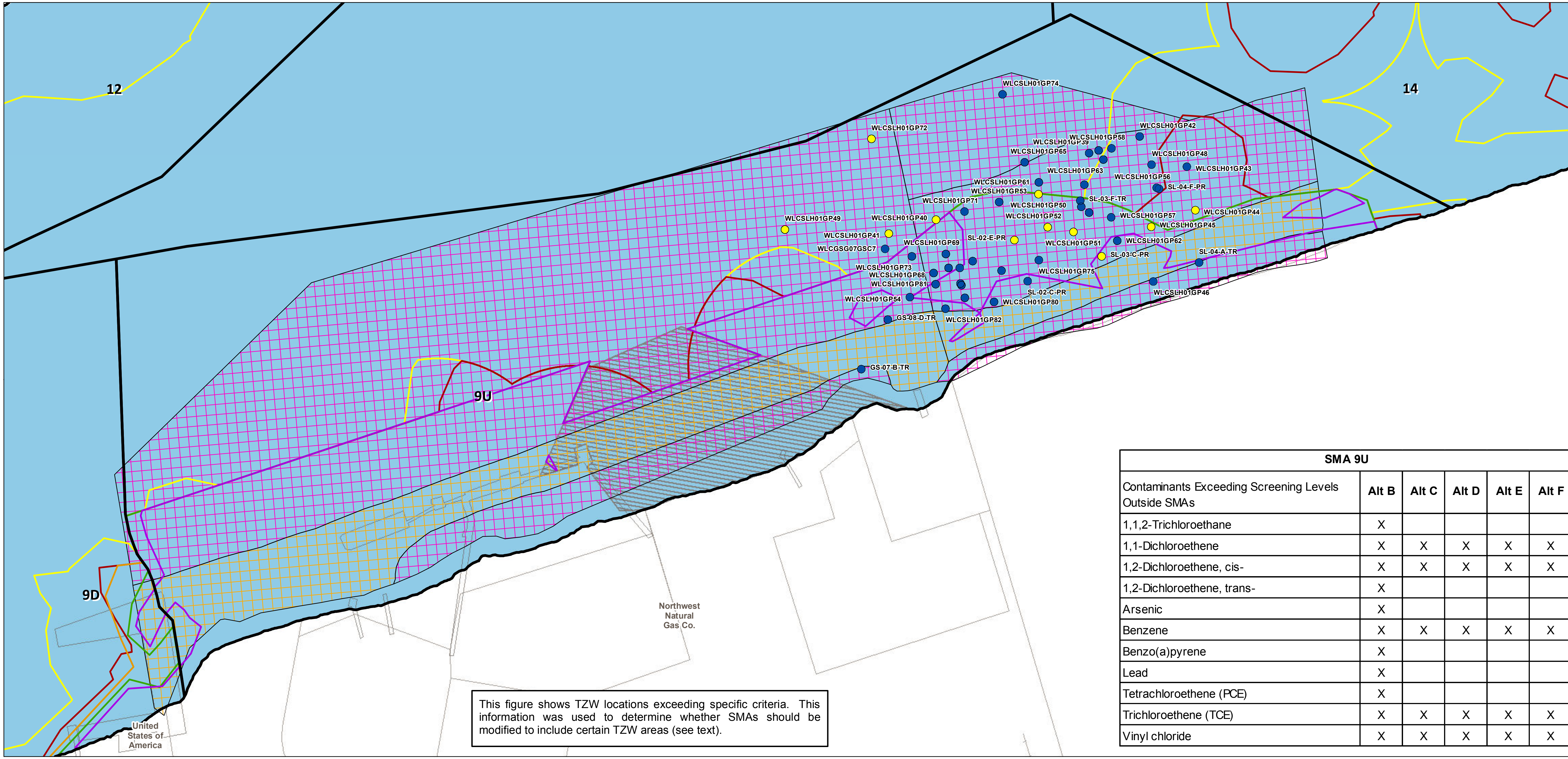
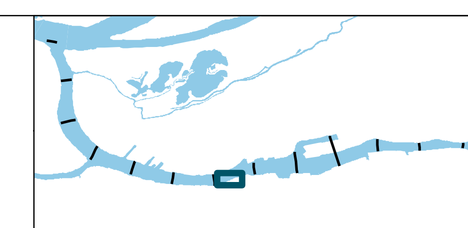


SMA 9U					
Contaminants Exceeding Screening Levels Outside SMAs	Alt B	Alt C	Alt D	Alt E	Alt F
1,1,2-Trichloroethane	X				
1,1-Dichloroethene	X	X	X	X	X
1,2-Dichloroethene, cis-	X	X	X	X	X
1,2-Dichloroethene, trans-	X				
Arsenic	X				
Benzene	X	X	X	X	X
Benzo(a)pyrene	X				
Lead	X				
Tetrachloroethene (PCE)	X				
Trichloroethene (TCE)	X	X	X	X	X
Vinyl chloride	X	X	X	X	X

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least one screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas of Potential Concern (August 2011)
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- Existing Remediation Cap
- River miles
- Docks and Structures
- Tax Lots



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LWG Lower Willamette Group

Feet
0 100 200 300 400

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Figure 5.7-3a
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Drinking Water Potential ARARs

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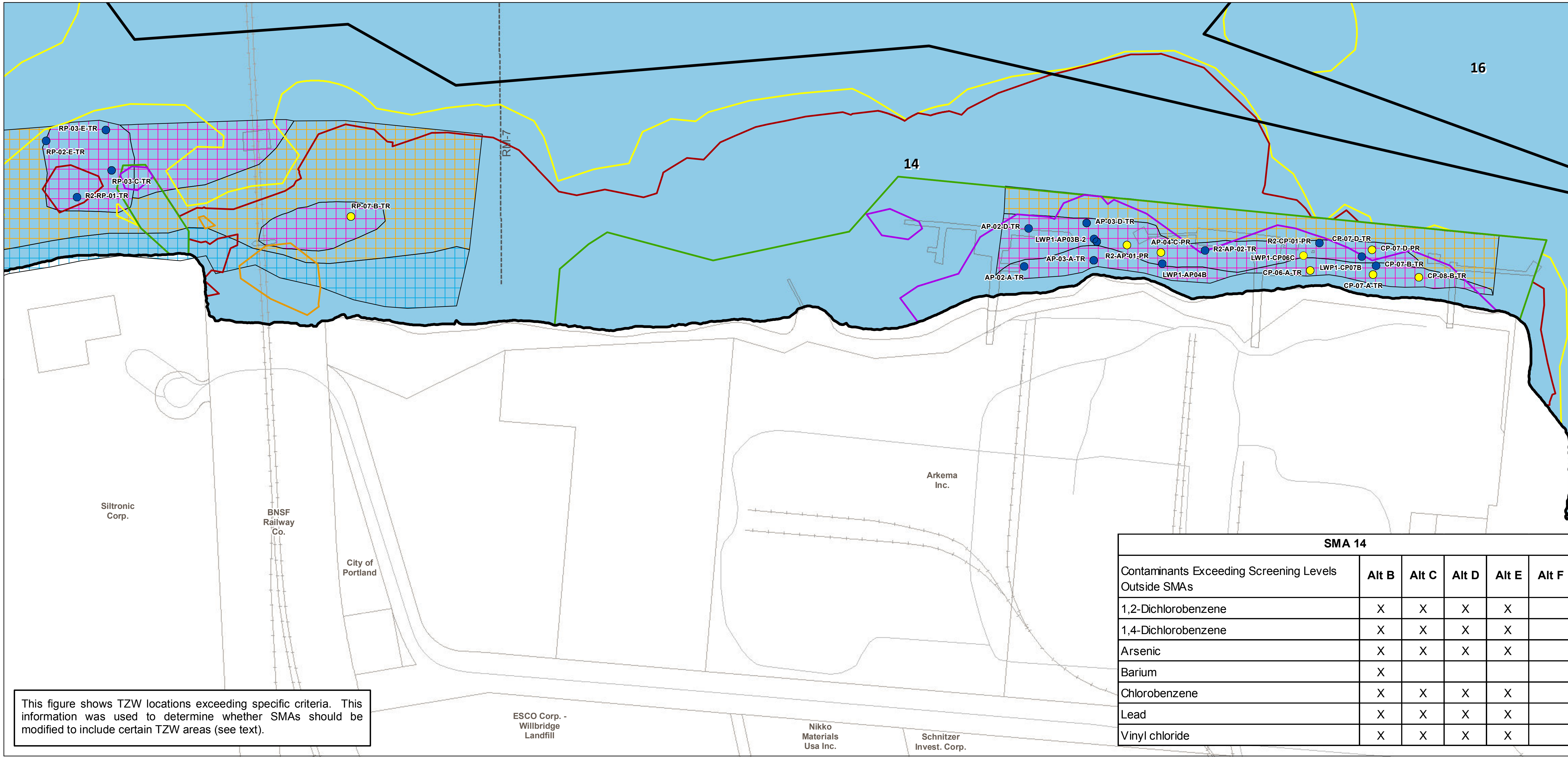
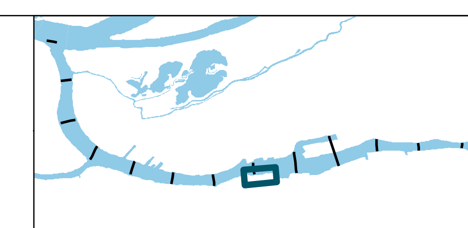


This figure shows TZW locations exceeding specific criteria. This information was used to determine whether SMAs should be modified to include certain TZW areas (see text).

SMA 14					
Contaminants Exceeding Screening Levels Outside SMAs	Alt B	Alt C	Alt D	Alt E	Alt F
1,2-Dichlorobenzene	X	X	X	X	
1,4-Dichlorobenzene	X	X	X	X	
Arsenic	X	X	X	X	
Barium	X				
Chlorobenzene	X	X	X	X	
Lead	X	X	X	X	
Vinyl chloride	X	X	X	X	

LEGEND

- TZW sample does not exceed screening level
- TZW sample exceeds at least one screening level
- Alternative B - Potential Active Remediation
- Alternative C - Potential Active Remediation
- Alternative D - Potential Active Remediation
- Alternative E - Potential Active Remediation
- Alternative F - Potential Active Remediation
- Areas of Potential Concern (August 2011)
- Areas With Complete Groundwater Flow Path
- Groundwater Discharge Zone Outside Areas With Complete Groundwater Flow Path
- Low-To-No Groundwater Discharge Zone
- River miles
- Docks and Structures
- Tax Lots



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LWG LOWER WILLAMETTE GROUP

Feet
0 125 250 375 500

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Figure 5.7-3b
Portland Harbor RI/FS
Draft Feasibility Study
TZW Sample Locations Exceeding Drinking Water Potential ARARs

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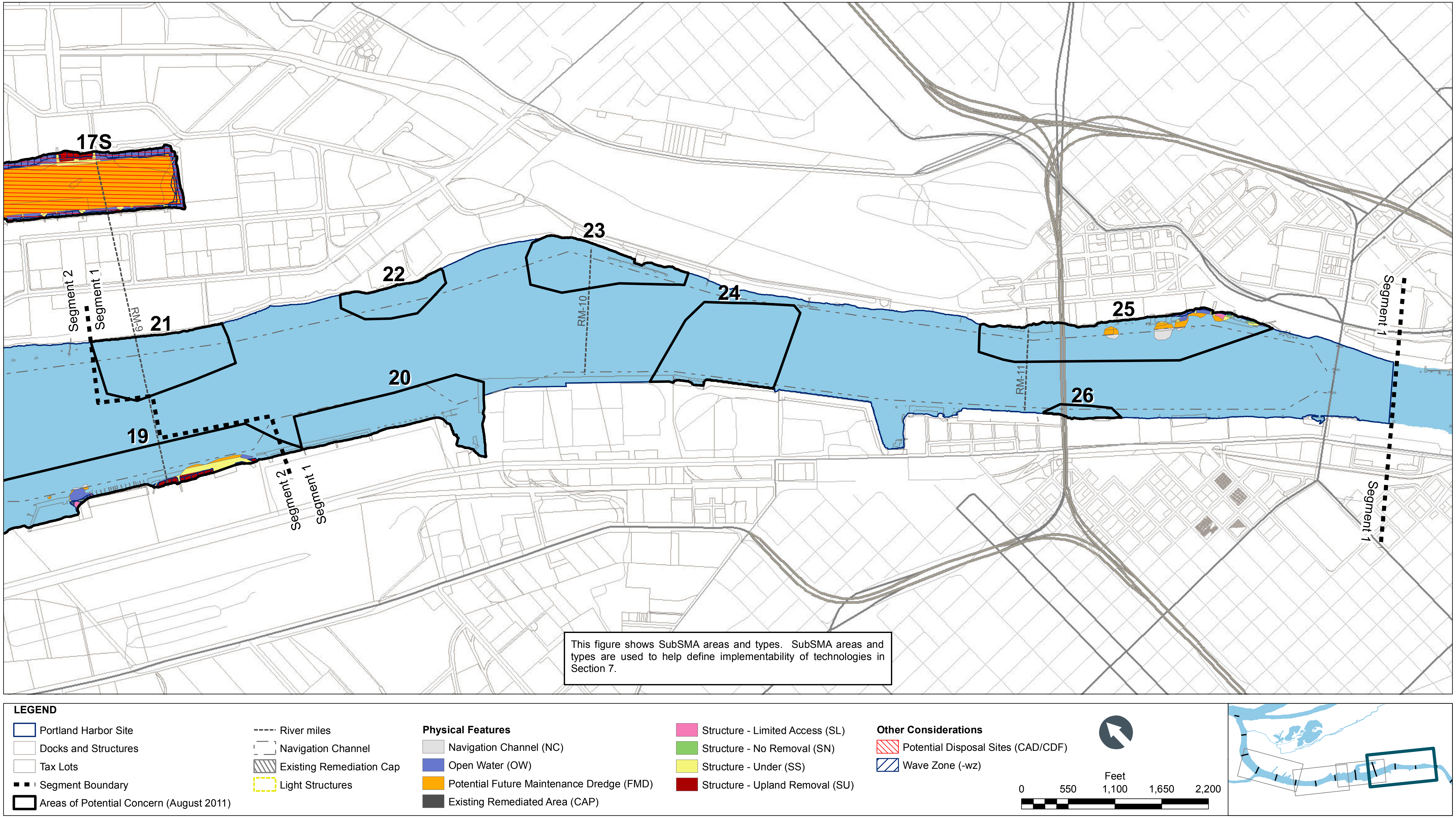

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Figure 5.8-1a
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types - Alternative B
Segment 1: AOPCs 20-26

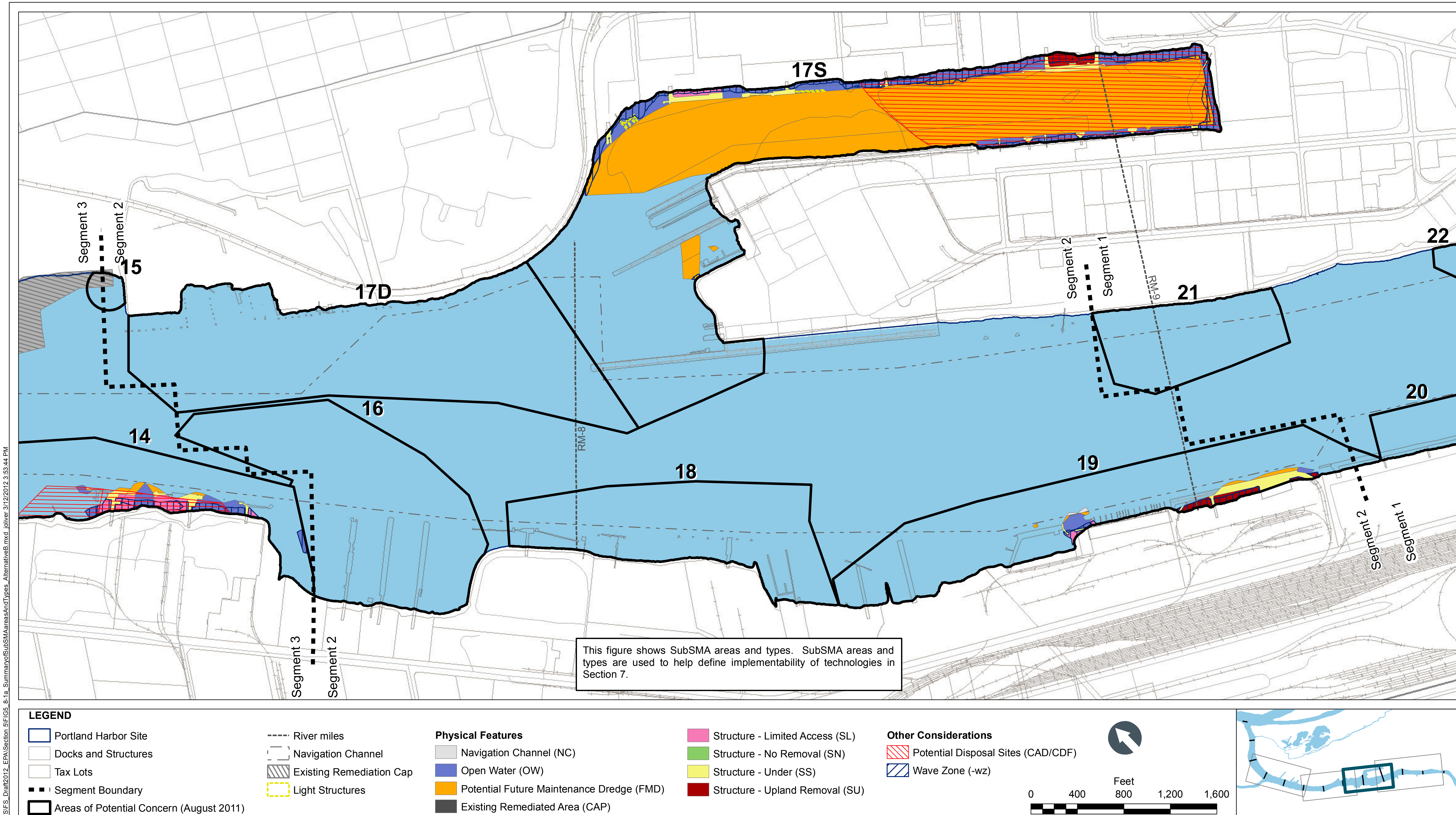

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Figure 5.8-1a
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types - Alternative B
Segment 2: AOPCs 15-19

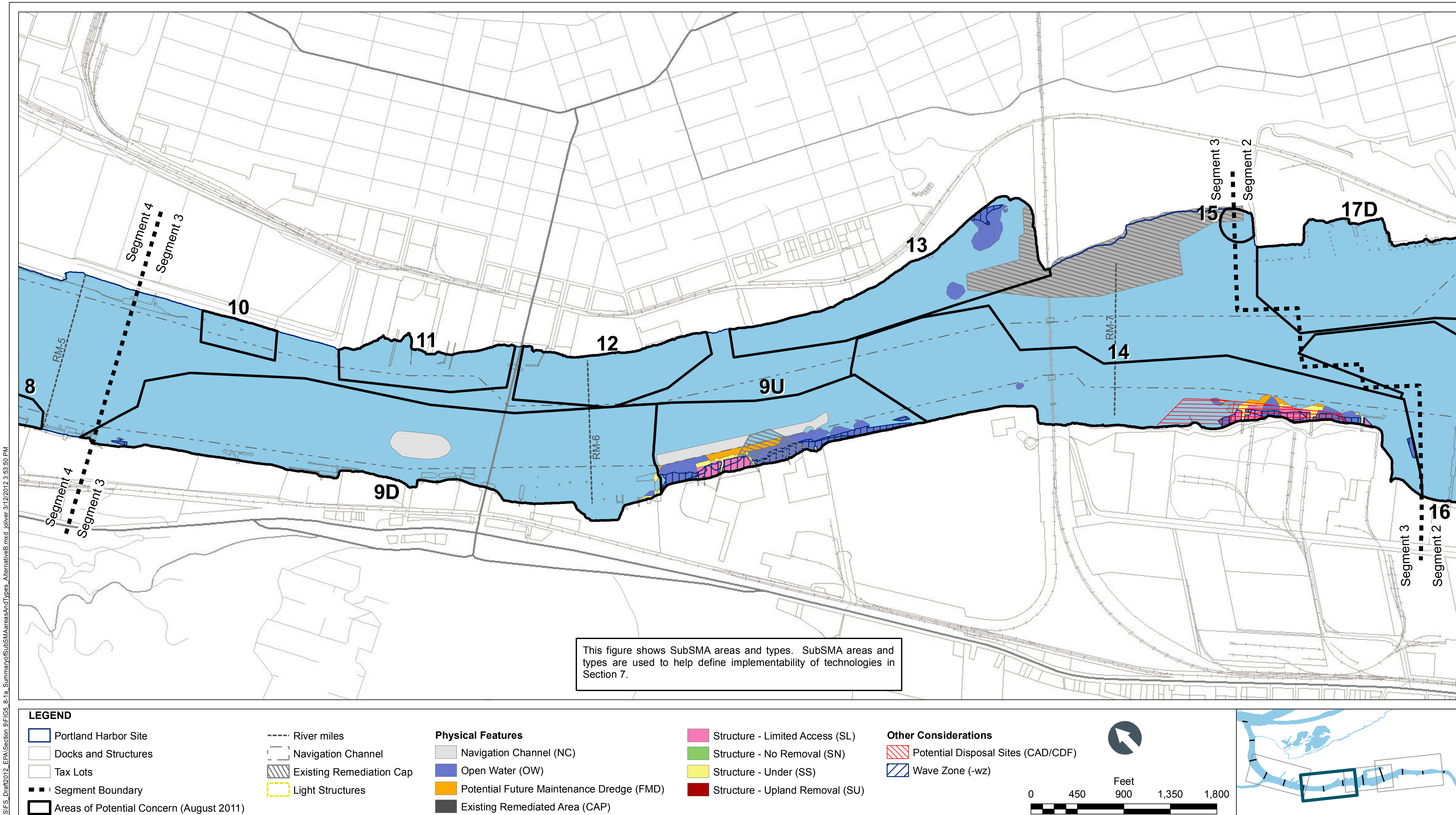

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Figure 5.8-1a
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types - Alternative B
Segment 3: AOPCs 9D - 14

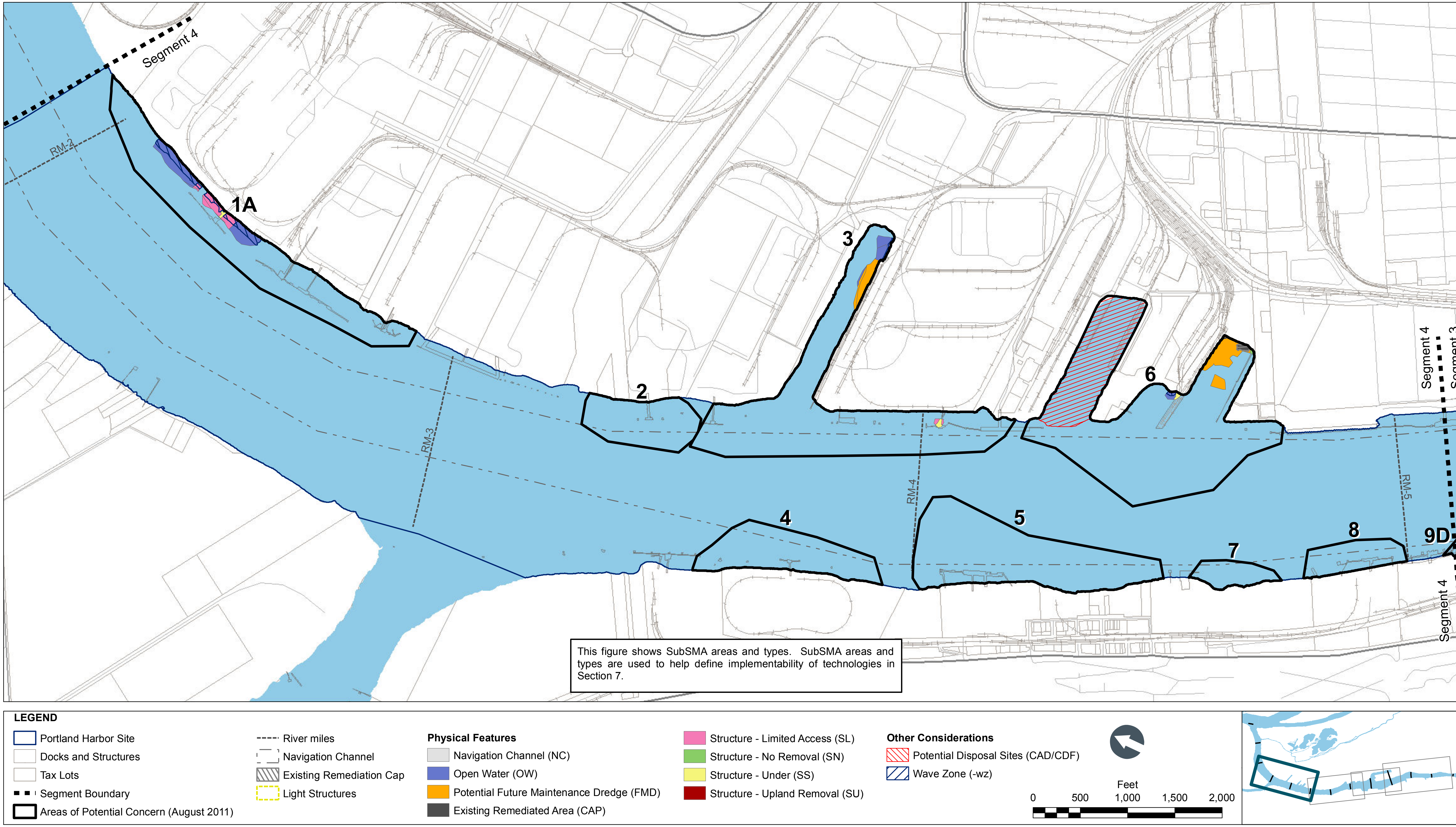

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Figure 5.8-1a
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SubSMA Areas and Types - Alternative B
Segment 4: AOPCs 1-8

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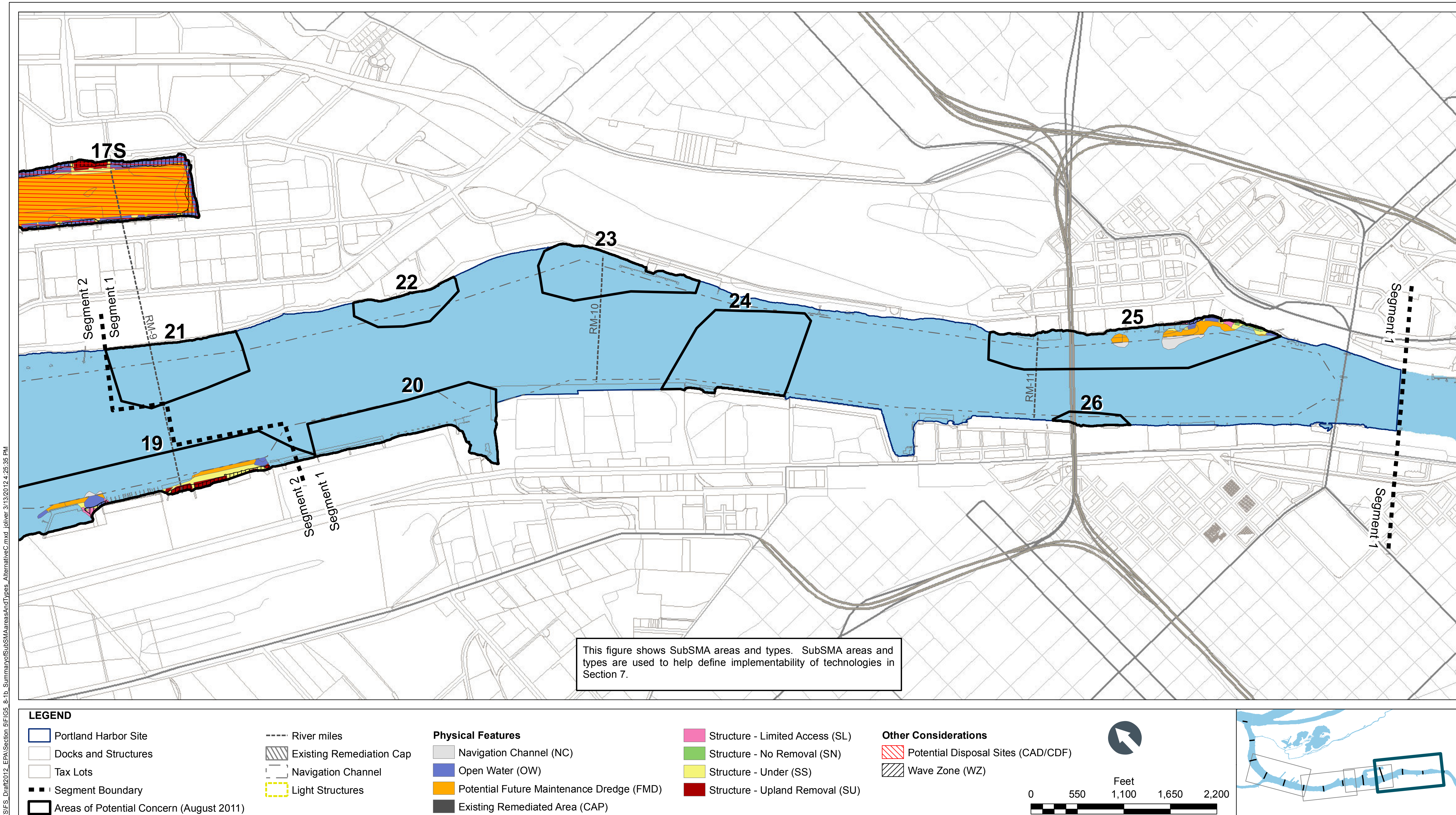

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Figure 5.8-1b
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative C
Segment 1: AOPCs 20-26

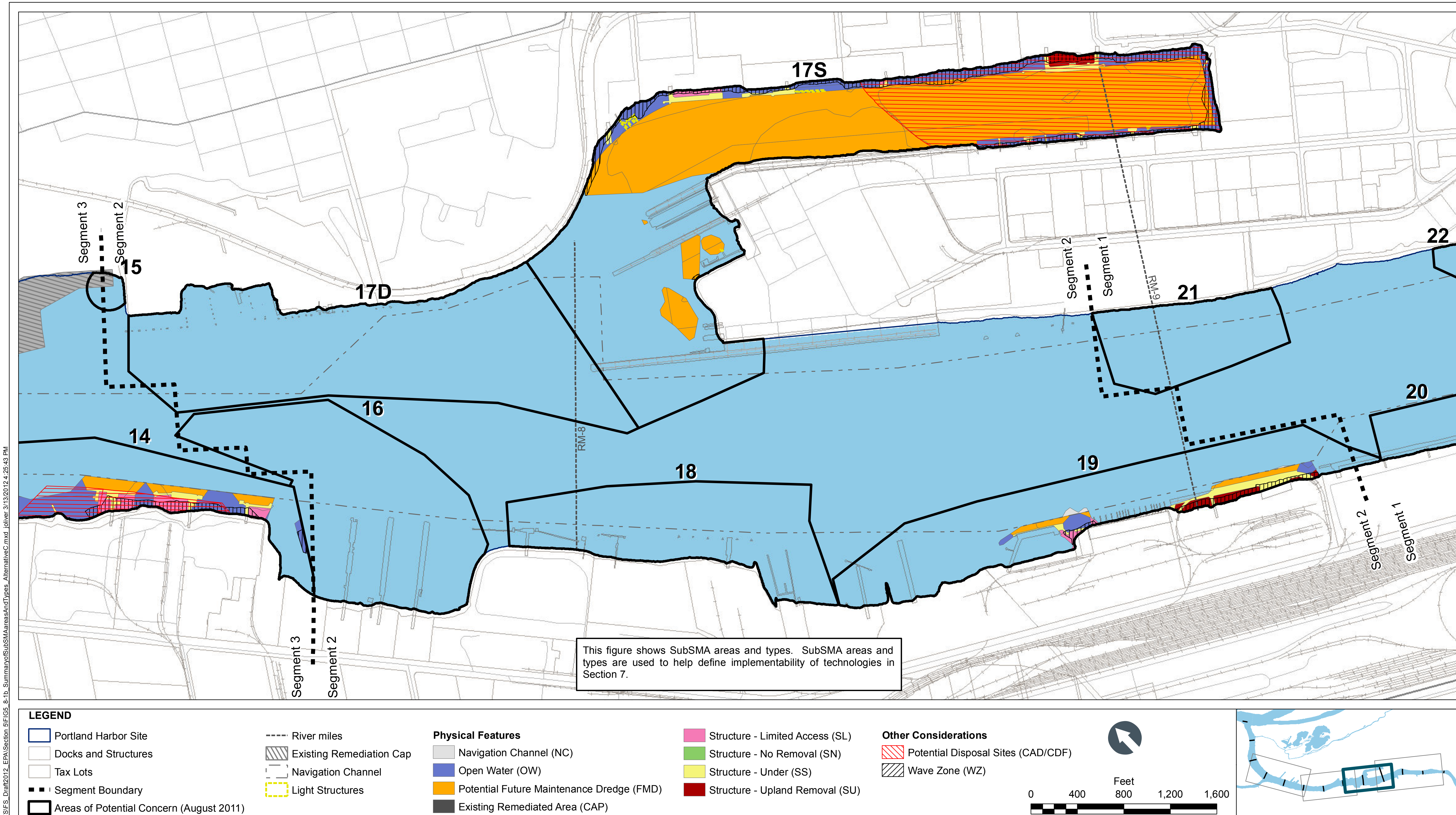

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Figure 5.8-1b
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative C
Segment 2: AOPCs 15-19

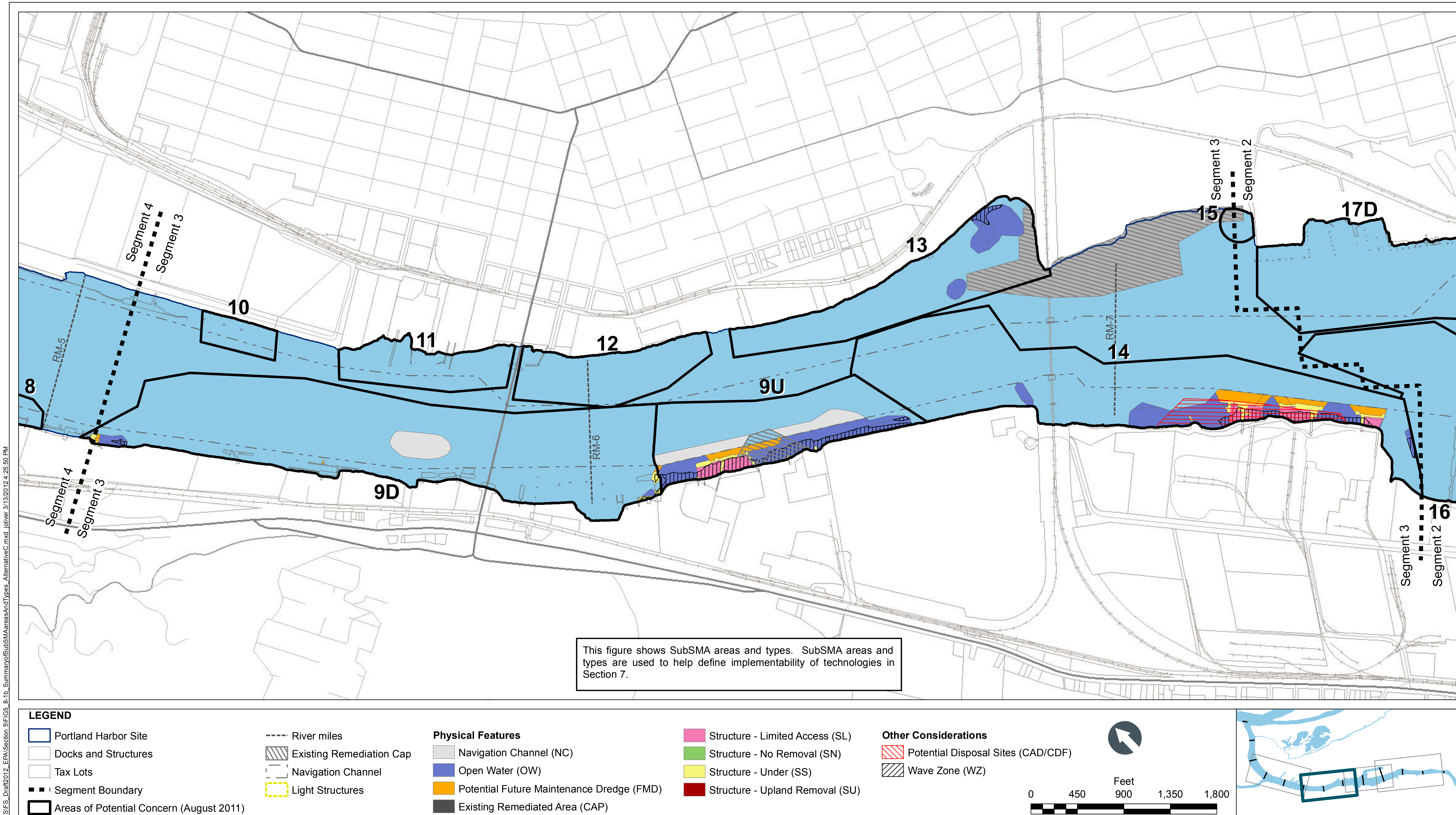

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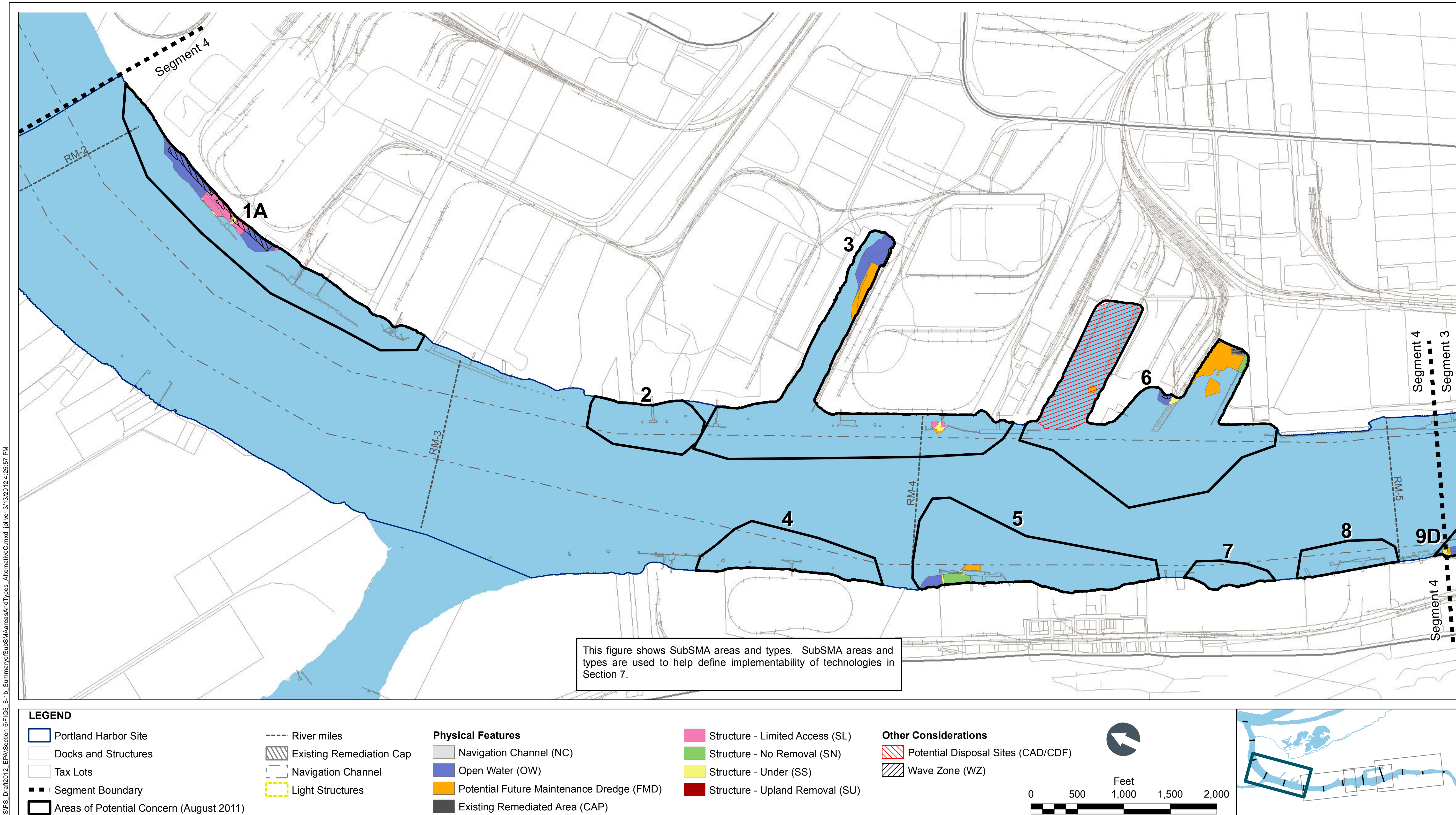
Figure 5.8-1b
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative C
Segment 3: AOPCs 9D - 14



This figure shows SubSMA areas and types. SubSMA areas and types are used to help define implementability of technologies in Section 7.

Q:\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_8-1b_SummaryofSubSMAareasAndTypes_AlternativeC.mxd joliver 3/13/2012 4:25:57 PM

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Figure 5.8-1b
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative C
Segment 4: AOPCs 1-8

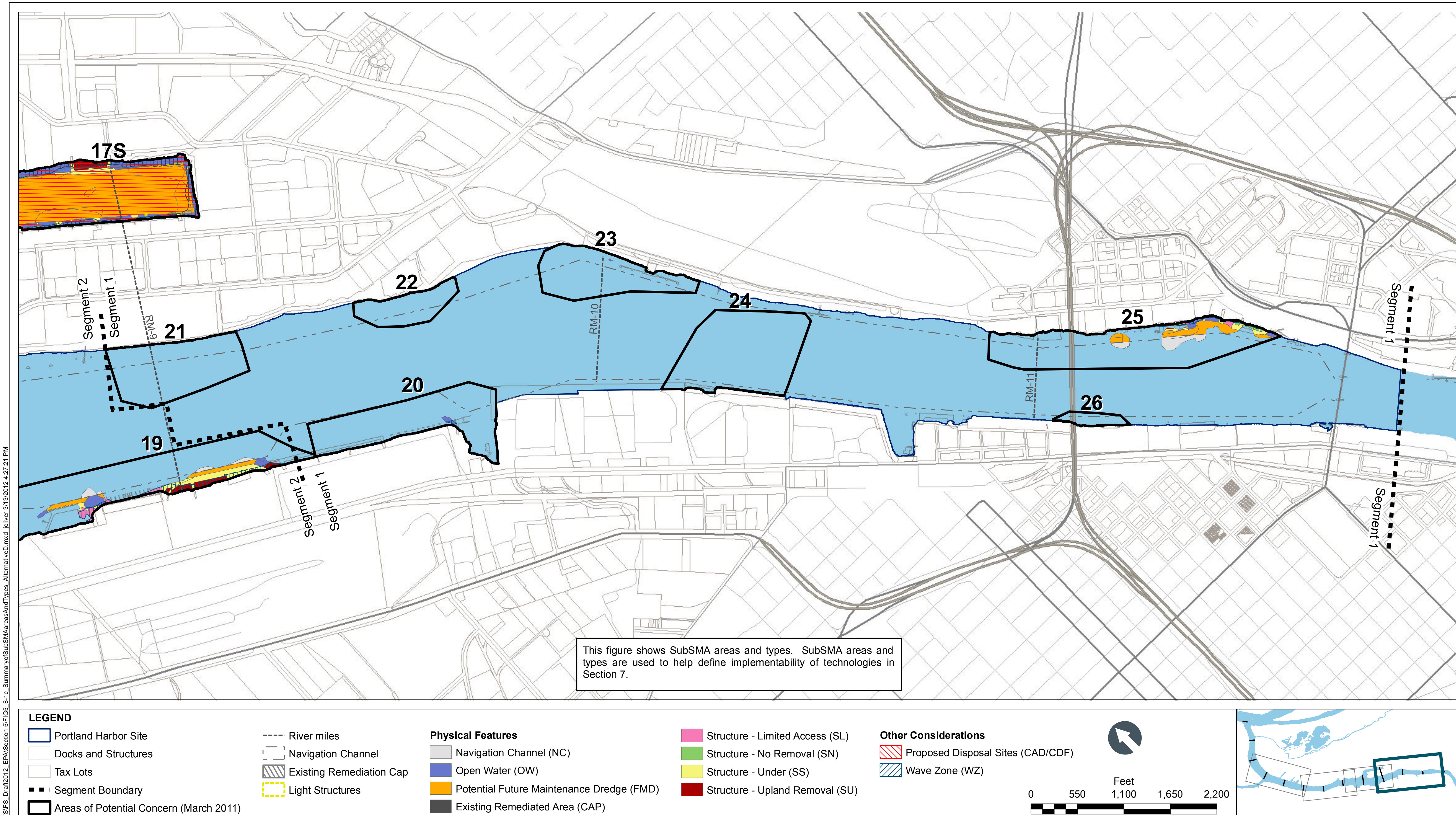

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Figure 5.8-1c
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative D
Segment 1: AOPCs 20-26

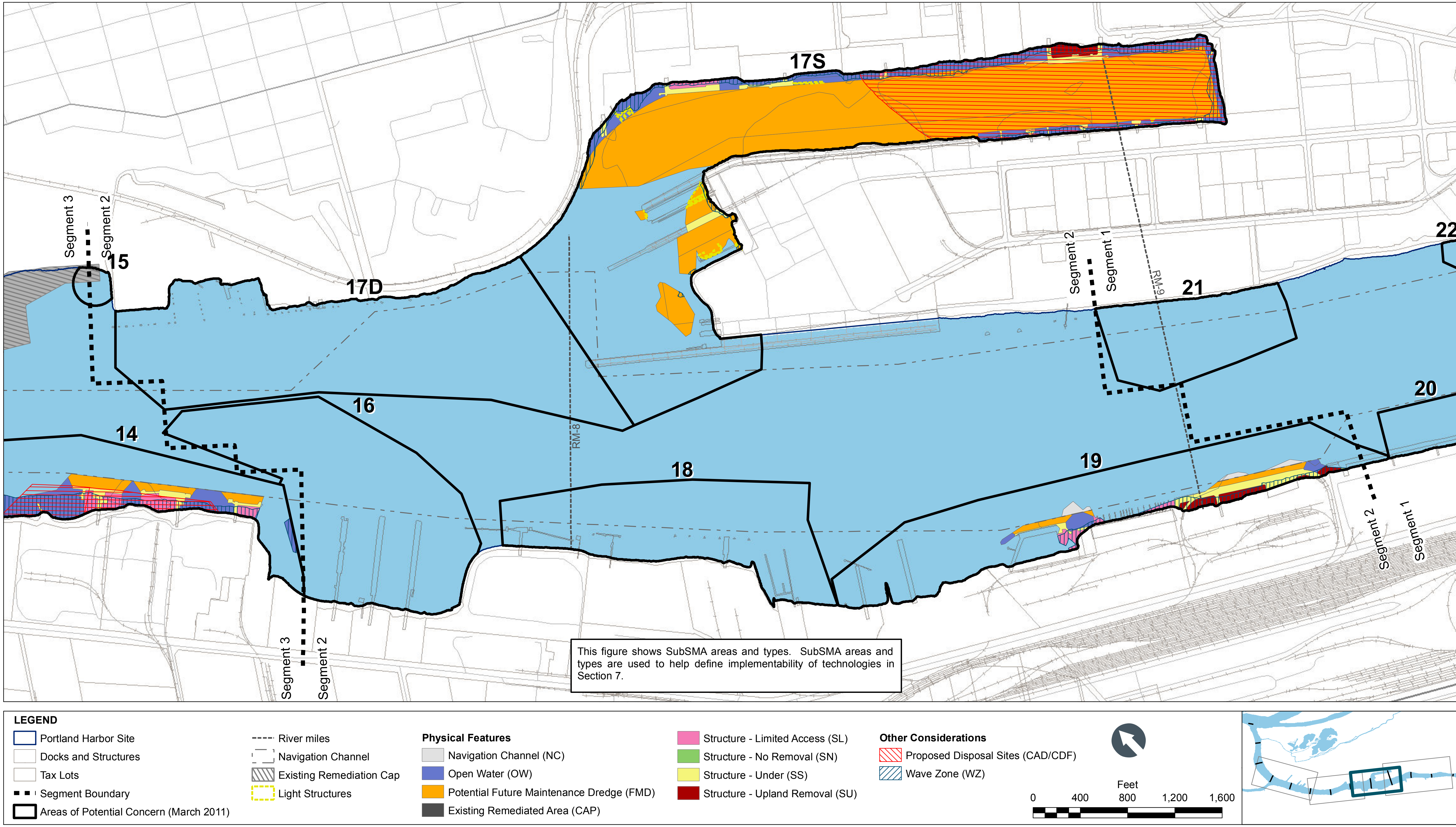

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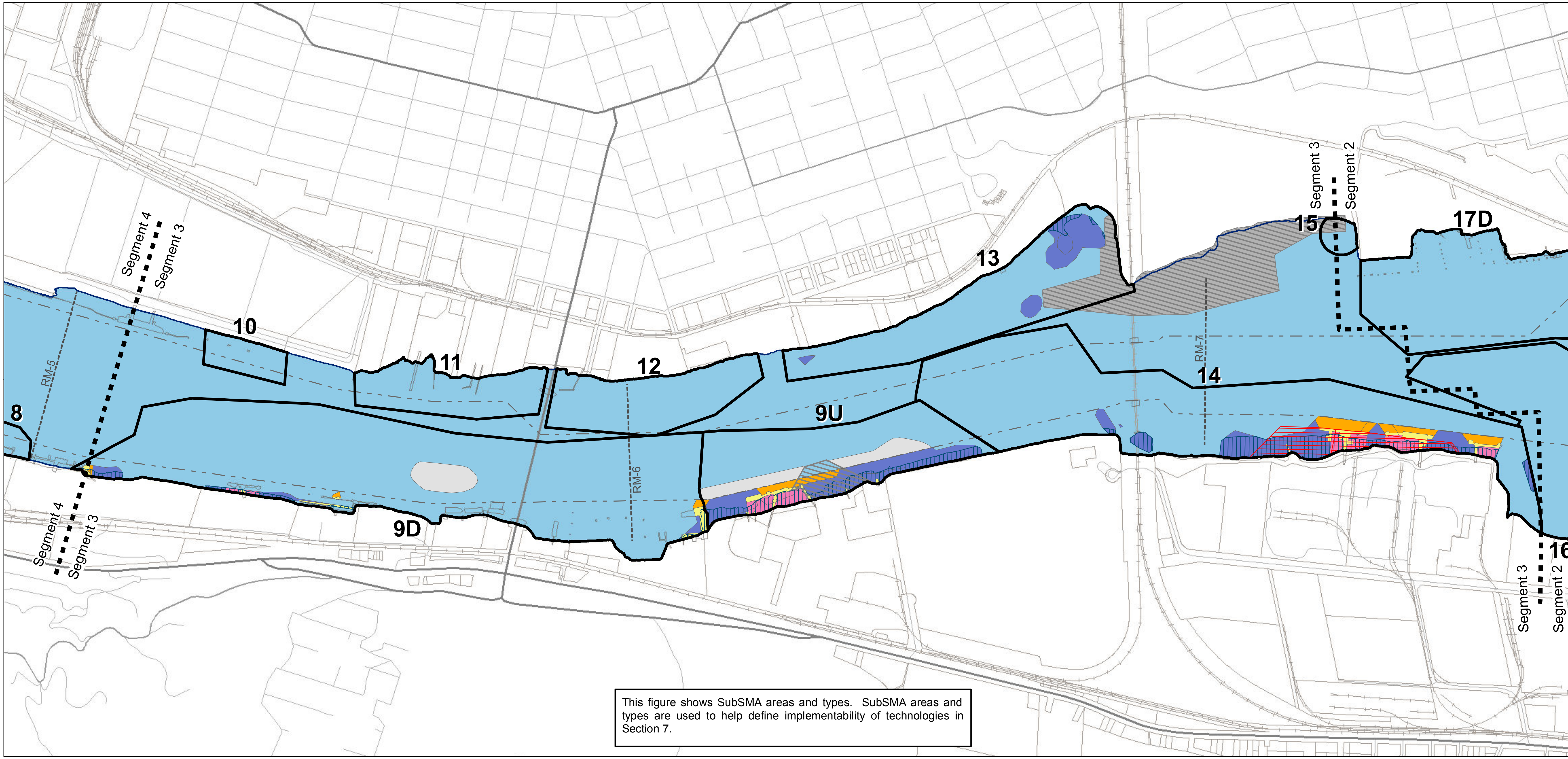
Figure 5.8-1c
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative D
Segment 2: AOPCs 15-19



LEGEND

- Portland Harbor Site
- Docks and Structures
- Tax Lots
- Segment Boundary
- Areas of Potential Concern (March 2011)
- River miles
- Navigation Channel
- Existing Remediation Cap
- Light Structures

Physical Features

- Navigation Channel (NC)
- Open Water (OW)
- Potential Future Maintenance Dredge (FMD)
- Existing Remediated Area (CAP)
- Structure - Limited Access (SL)
- Structure - No Removal (SN)
- Structure - Under (SS)
- Structure - Upland Removal (SU)

Other Considerations

- Proposed Disposal Sites (CAD/CDF)
- Wave Zone (WZ)

Feet

0 450 900 1,350 1,800

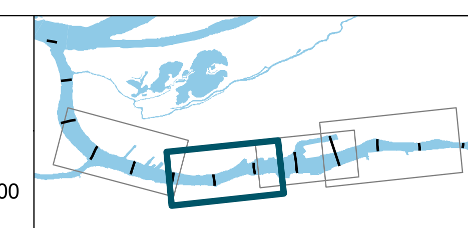


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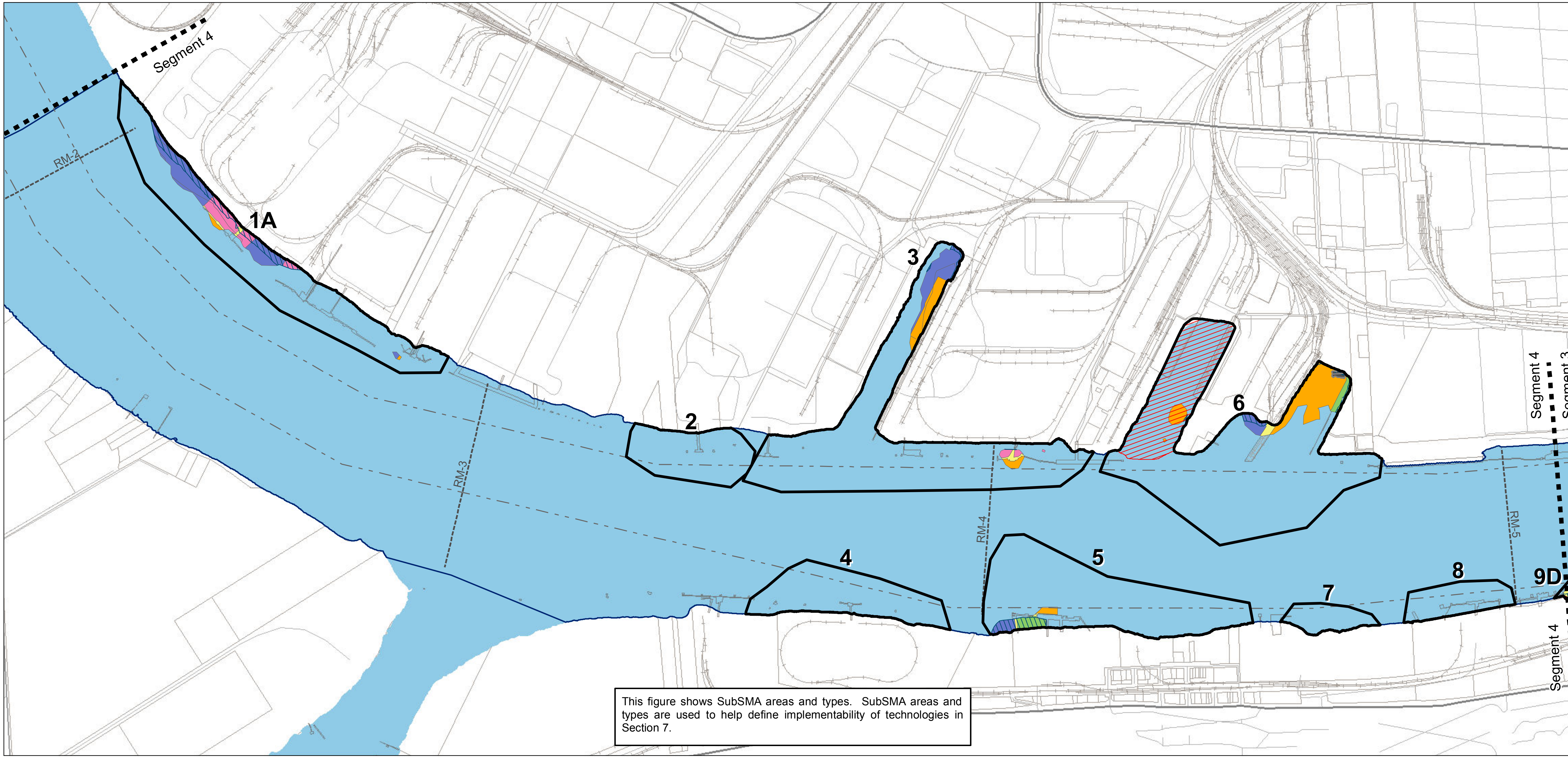
Figure 5.8-1c
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative D
Segment 3: AOPCs 9D - 14



LEGEND

- Portland Harbor Site
- Docks and Structures
- Tax Lots
- Segment Boundary
- Areas of Potential Concern (March 2011)
- River miles
- Navigation Channel
- Existing Remediation Cap
- Light Structures

Physical Features

- Navigation Channel (NC)
- Open Water (OW)
- Potential Future Maintenance Dredge (FMD)
- Existing Remediated Area (CAP)
- Structure - Limited Access (SL)
- Structure - No Removal (SN)
- Structure - Under (SS)
- Structure - Upland Removal (SU)

Other Considerations

- Proposed Disposal Sites (CAD/CDF)
- Wave Zone (WZ)

Feet

0 500 1,000 1,500 2,000

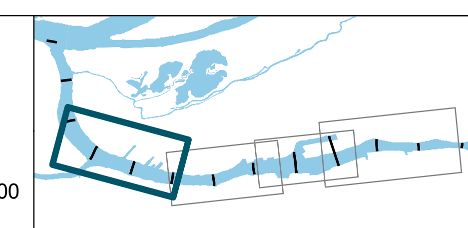


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Figure 5.8-1c
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative D
Segment 4: AOPCs 1-8

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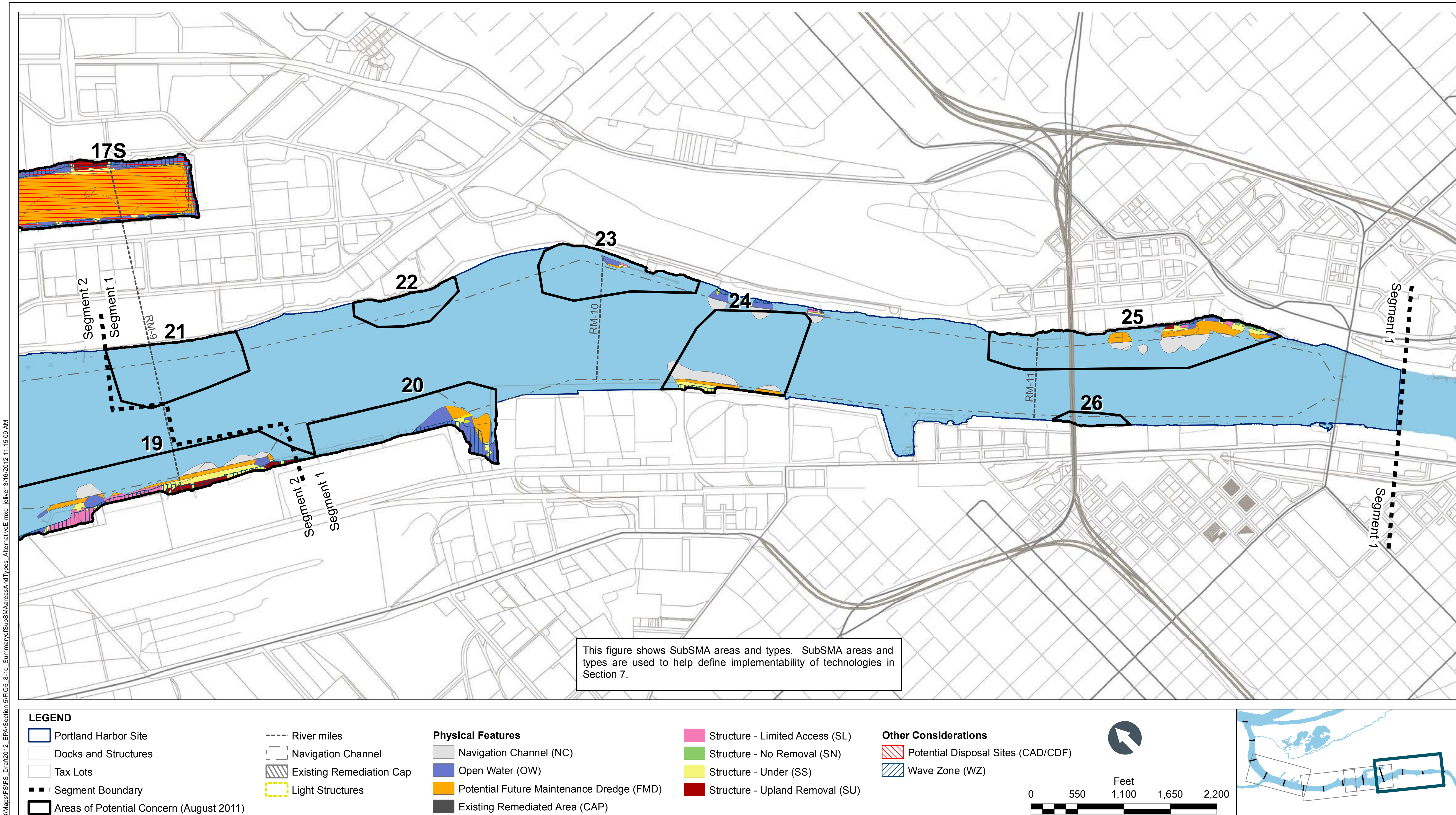

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Figure 5.8-1d
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative E
Segment 1: AOPCs 20-26

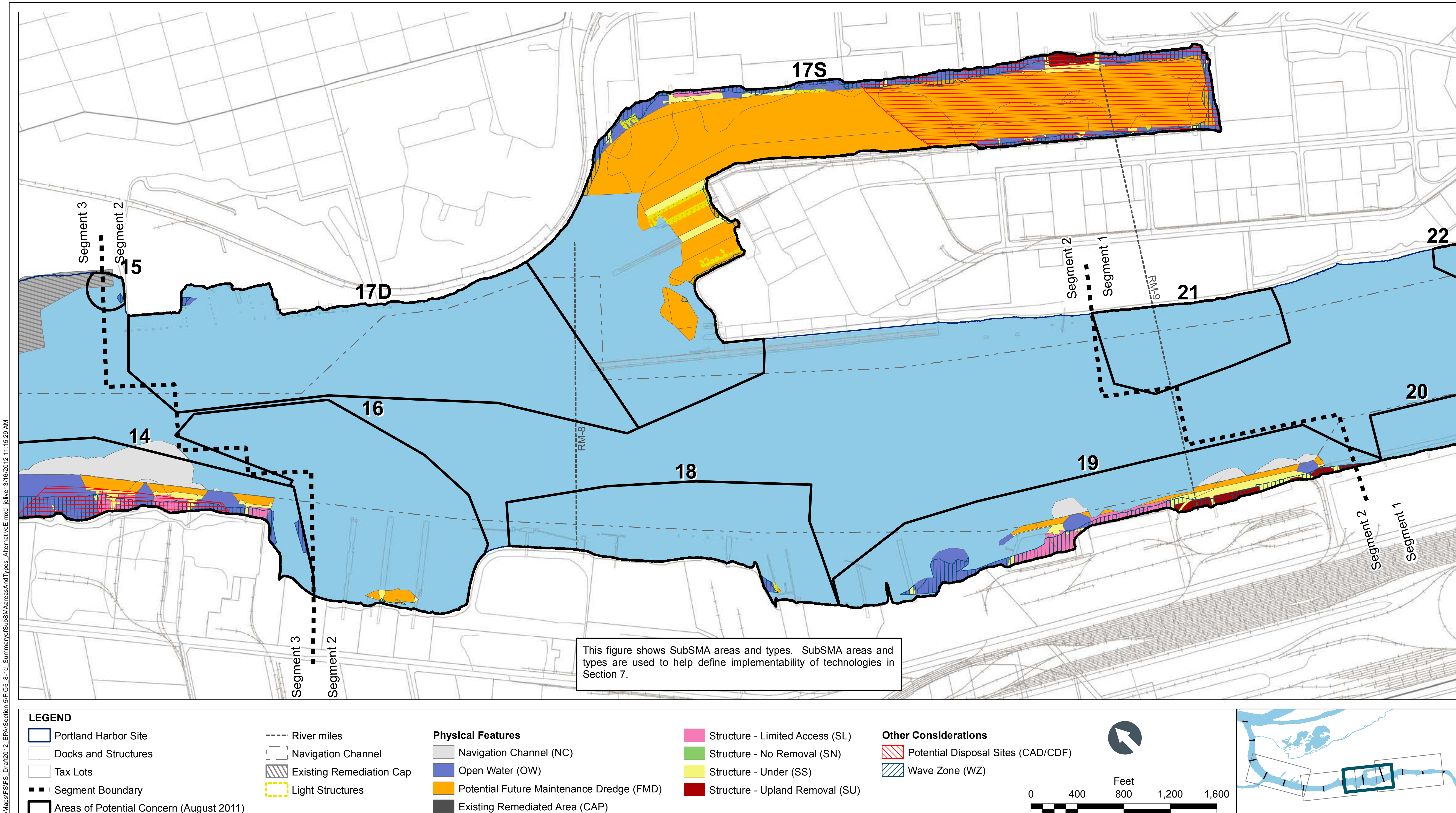

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Figure 5.8-1d
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative E
Segment 2: AOPCs 15-19

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\\Orcas\gis\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_8-1d_SummaryofSubSMAareasAndTypes_AlternativeE.mxd joliver 3/16/2012 11:15:29 AM

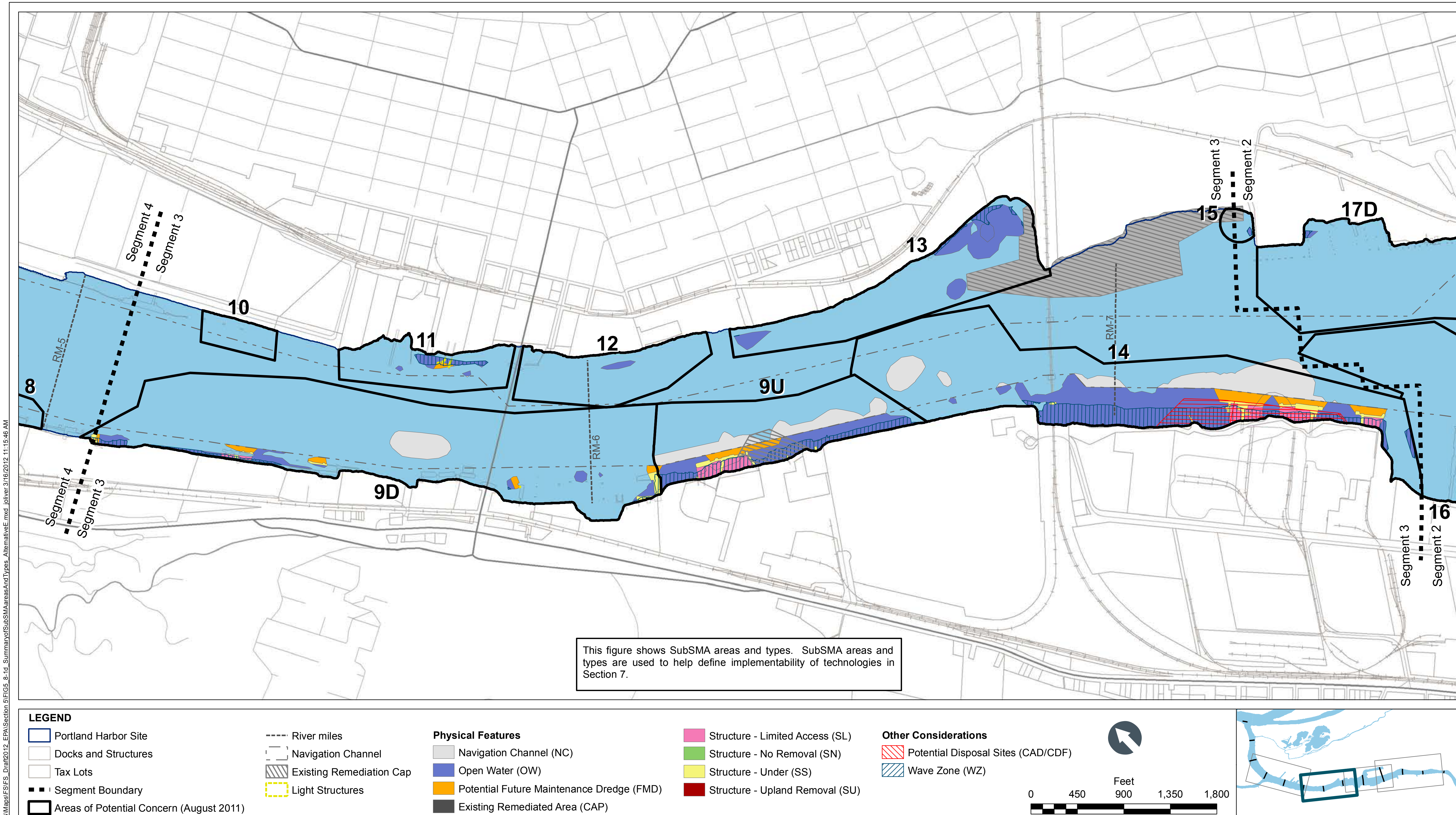

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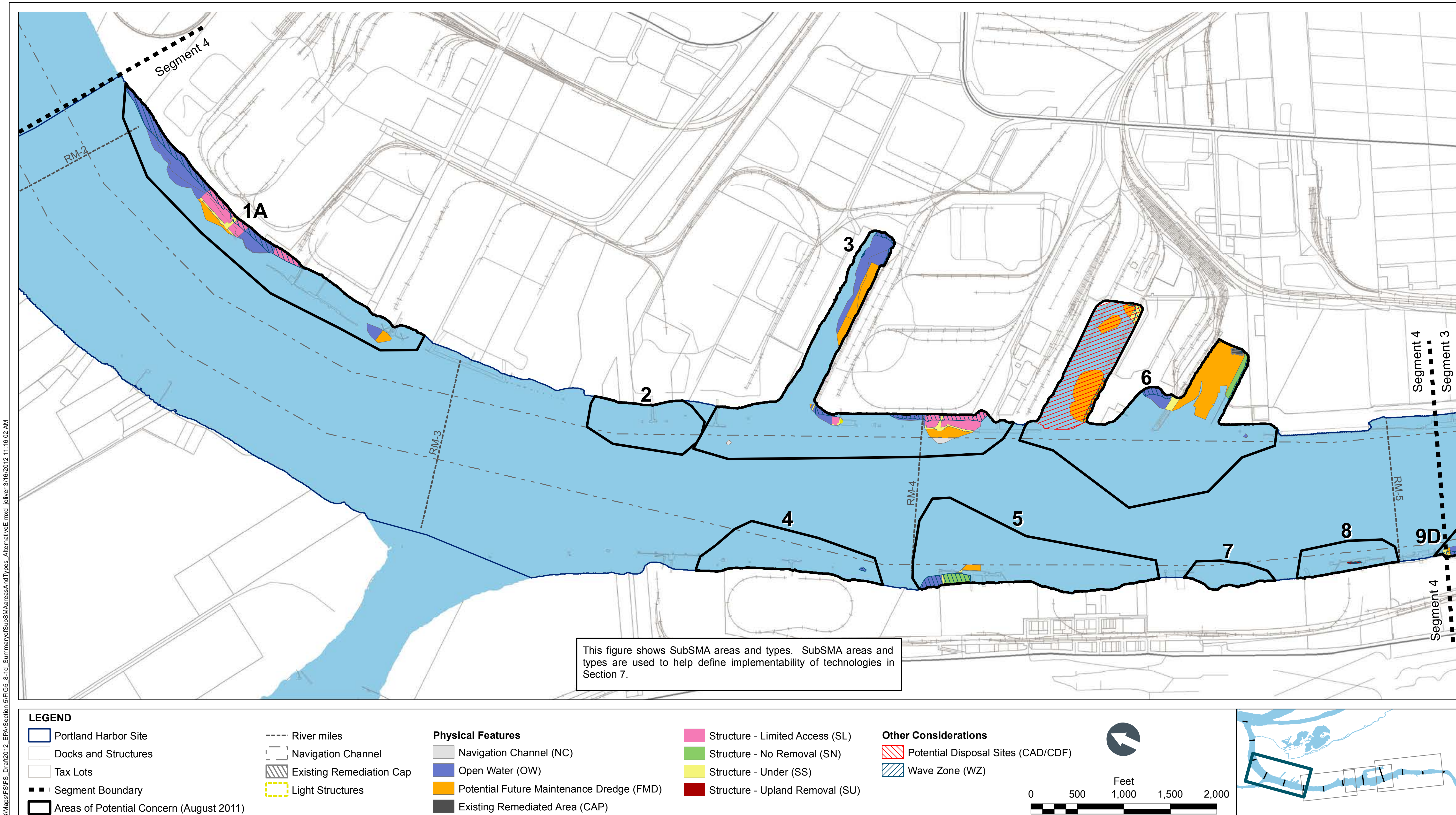
Figure 5.8-1d
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative E
Segment 3: AOPCs 9D - 14



This figure shows SubSMA areas and types. SubSMA areas and types are used to help define implementability of technologies in Section 7.

\\Orcas\gis\Jobs\010142-01_AQ_LWG\Maps\FS\FS_Draft2012_EPA\Section 5\FIG5_8-1d_SummaryofSubSMAareasAndTypes_AlternativeE.mxd joliver 3/16/2012 11:16:02 AM

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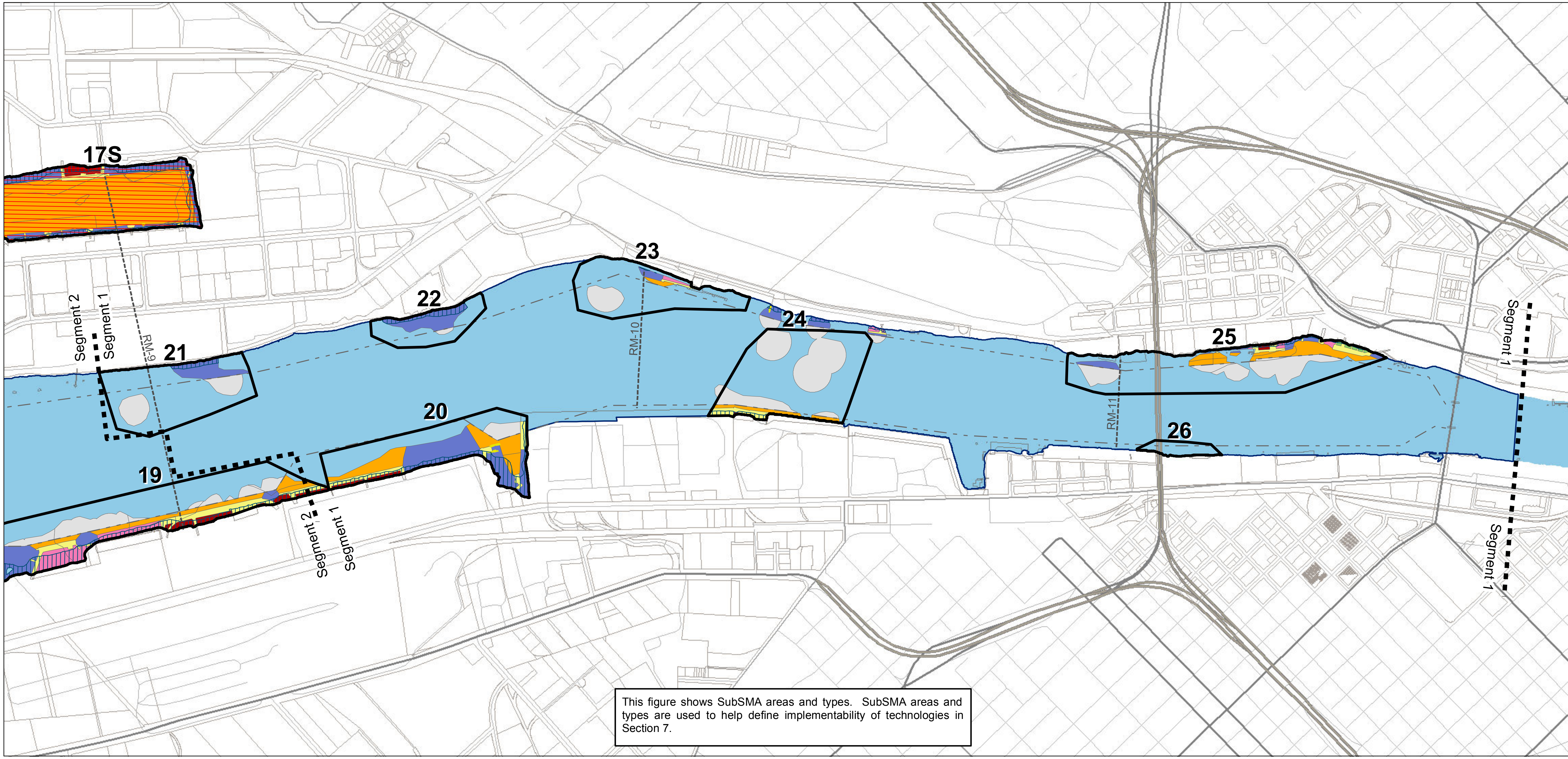
Figure 5.8-1d
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative E
Segment 4: AOPCs 1-8



This figure shows SubSMA areas and types. SubSMA areas and types are used to help define implementability of technologies in Section 7.

LEGEND

- Portland Harbor Site
- Docks and Structures
- Tax Lots
- Segment Boundary
- Areas of Potential Concern (August 2011)
- River miles
- Navigation Channel
- Existing Remediation Cap
- Light Structures

Physical Features

- Navigation Channel (NC)
- Existing Remediated Area (CAP)
- Open Water (OW)
- Potential Future Maintenance Dredge (FMD)
- Structure - Limited Access (SL)
- Structure - No Removal (SN)
- Structure - Under (SS)
- Structure - Upland Removal (SU)

Other Considerations

- Potential Disposal Sites (CAD/CDF)
- Wave Zone (WZ)

Feet
0 550 1,100 1,650 2,200

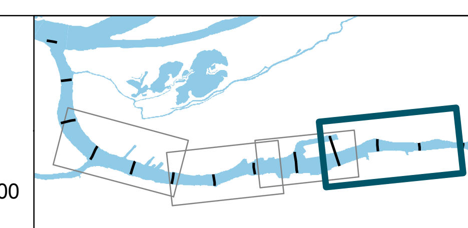


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Figure 5.8-1e
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative F
Segment 1: AOPCs 20-26

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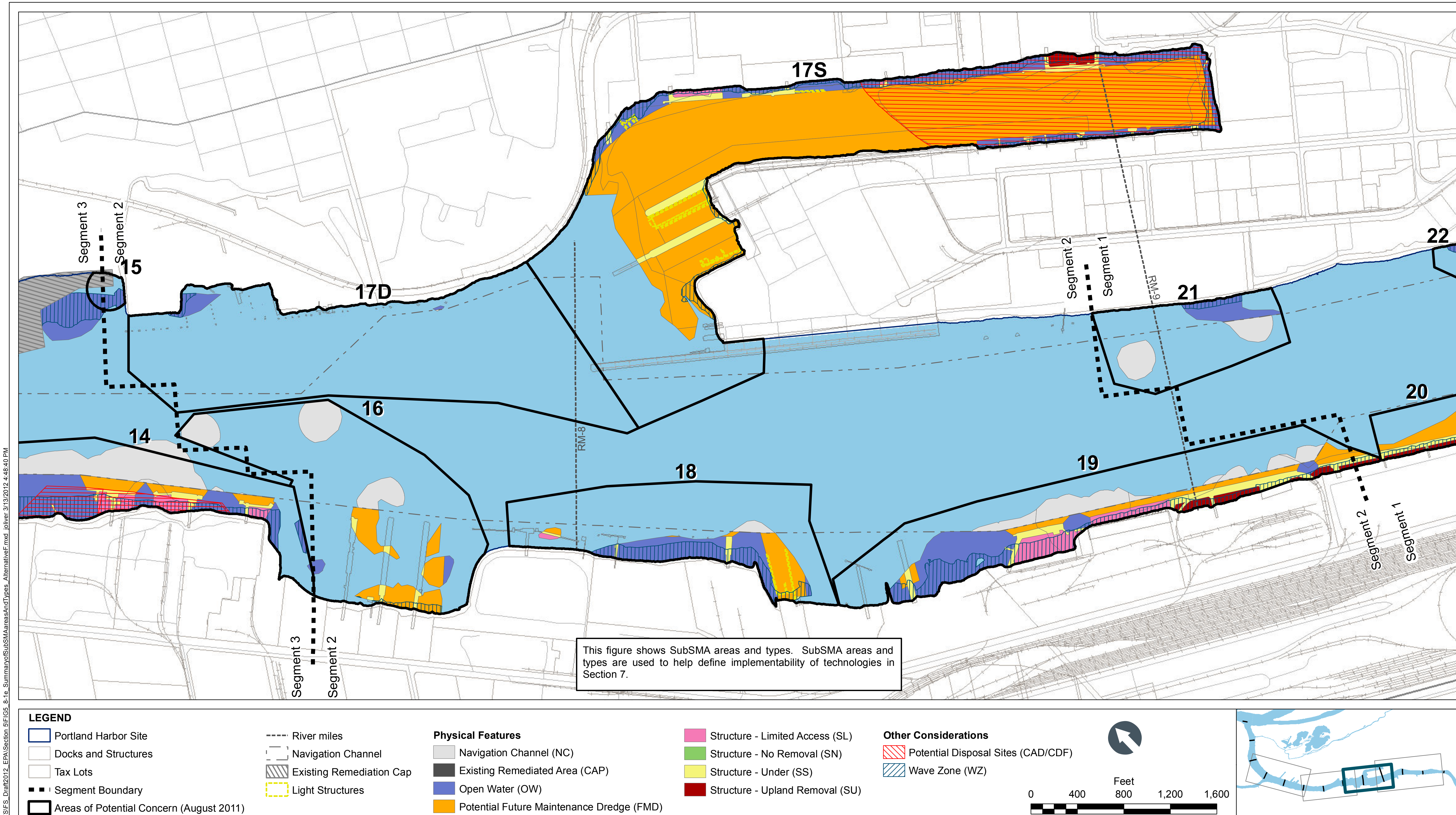

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Figure 5.8-1e
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative F
Segment 2: AOPCs 15-19

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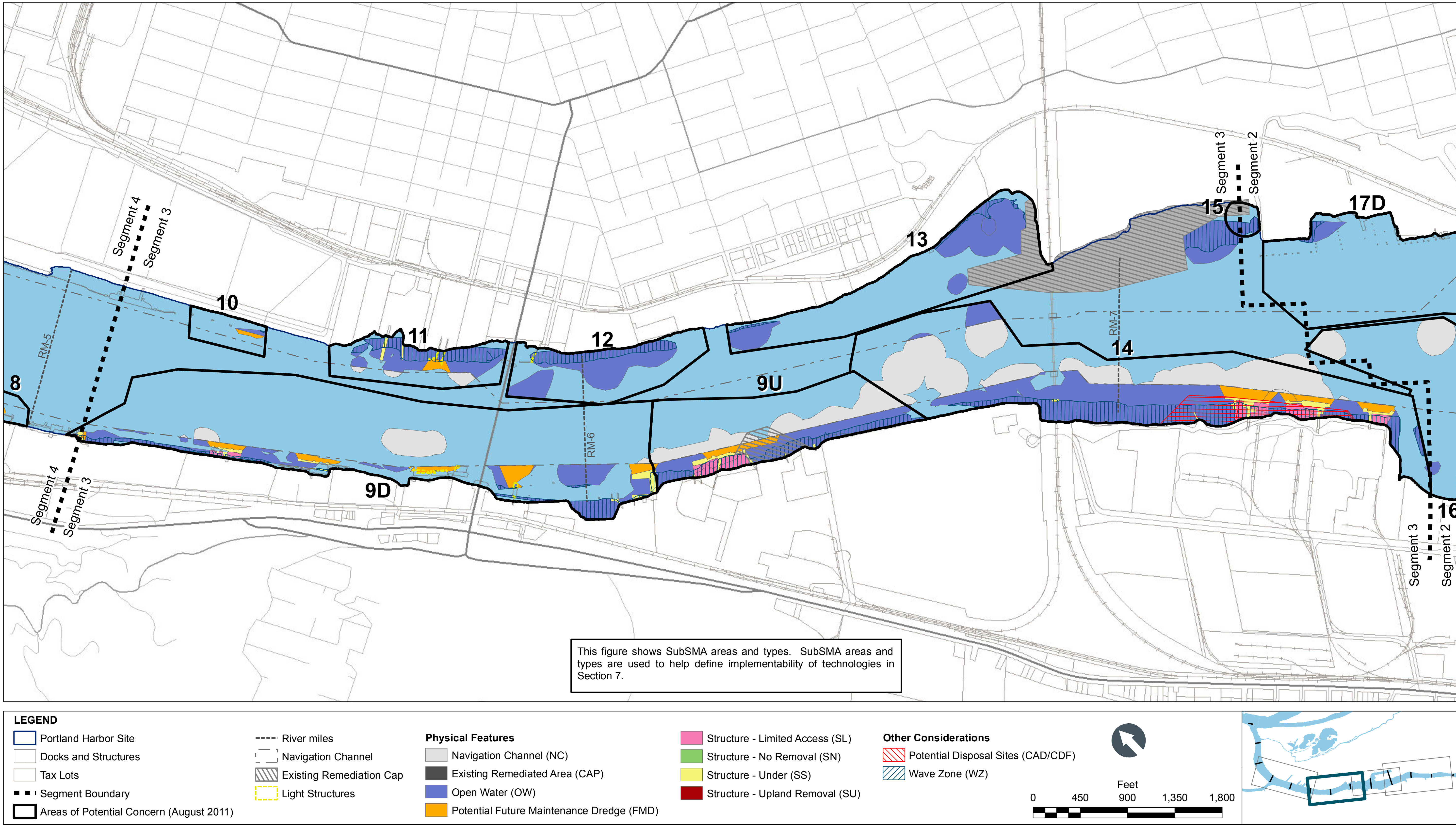

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Figure 5.8-1e
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative F
Segment 3: AOPCs 9D - 14

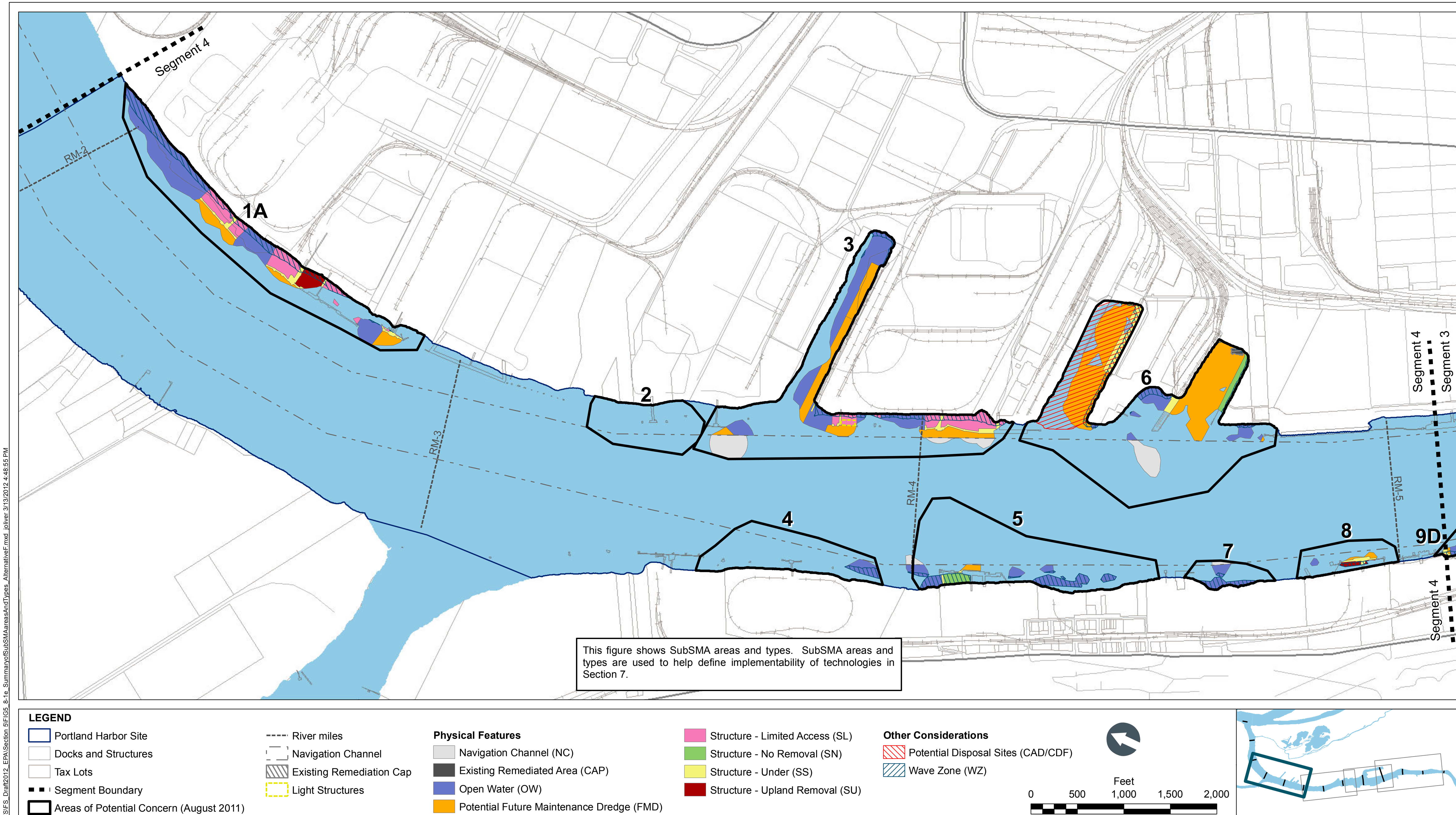

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Figure 5.8-1e
Portland Harbor RI/FS
Draft Feasibility Study
Summary of subSMA Areas and Types - Alternative F
Segment 4: AOPCs 1-8

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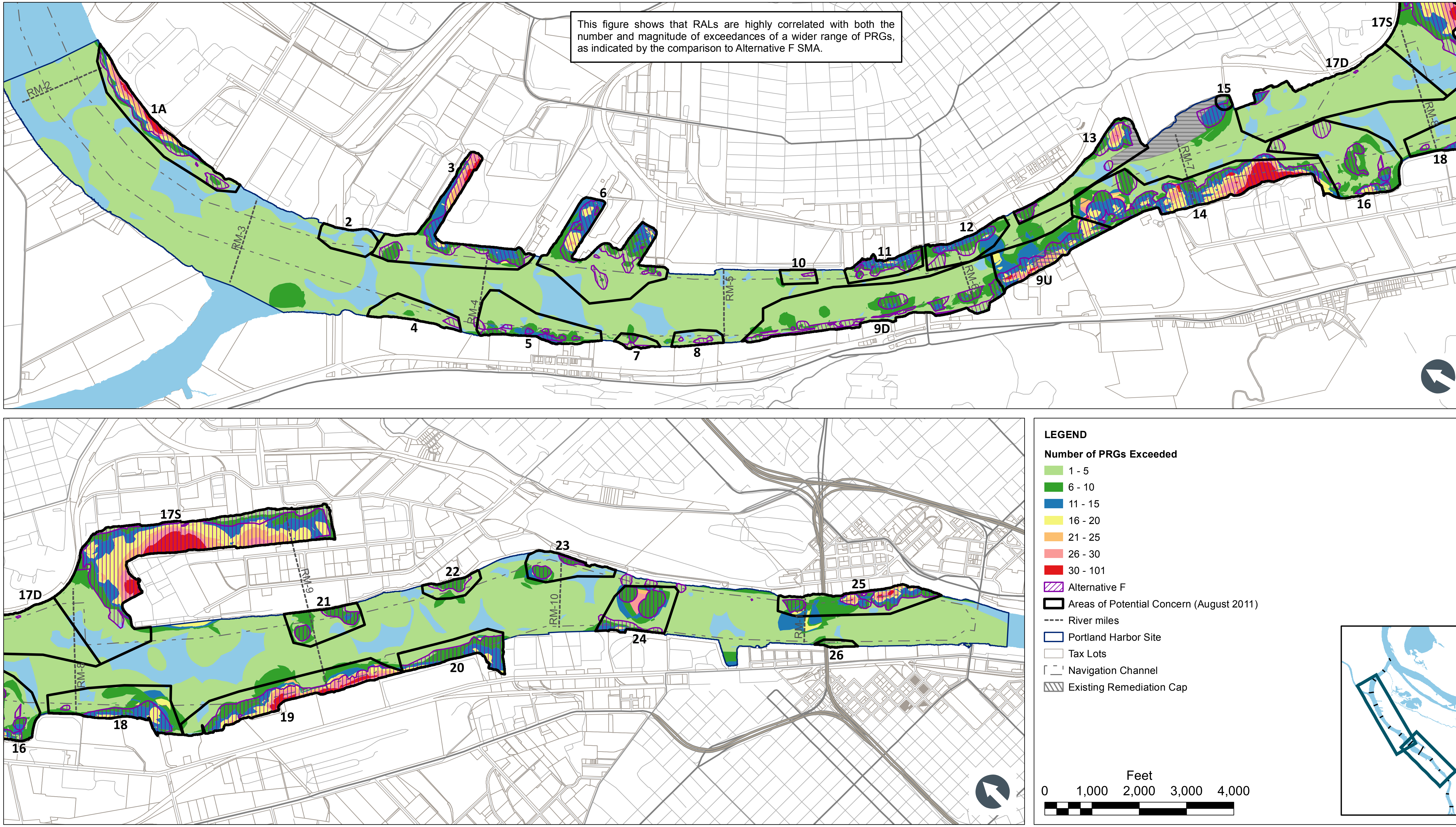

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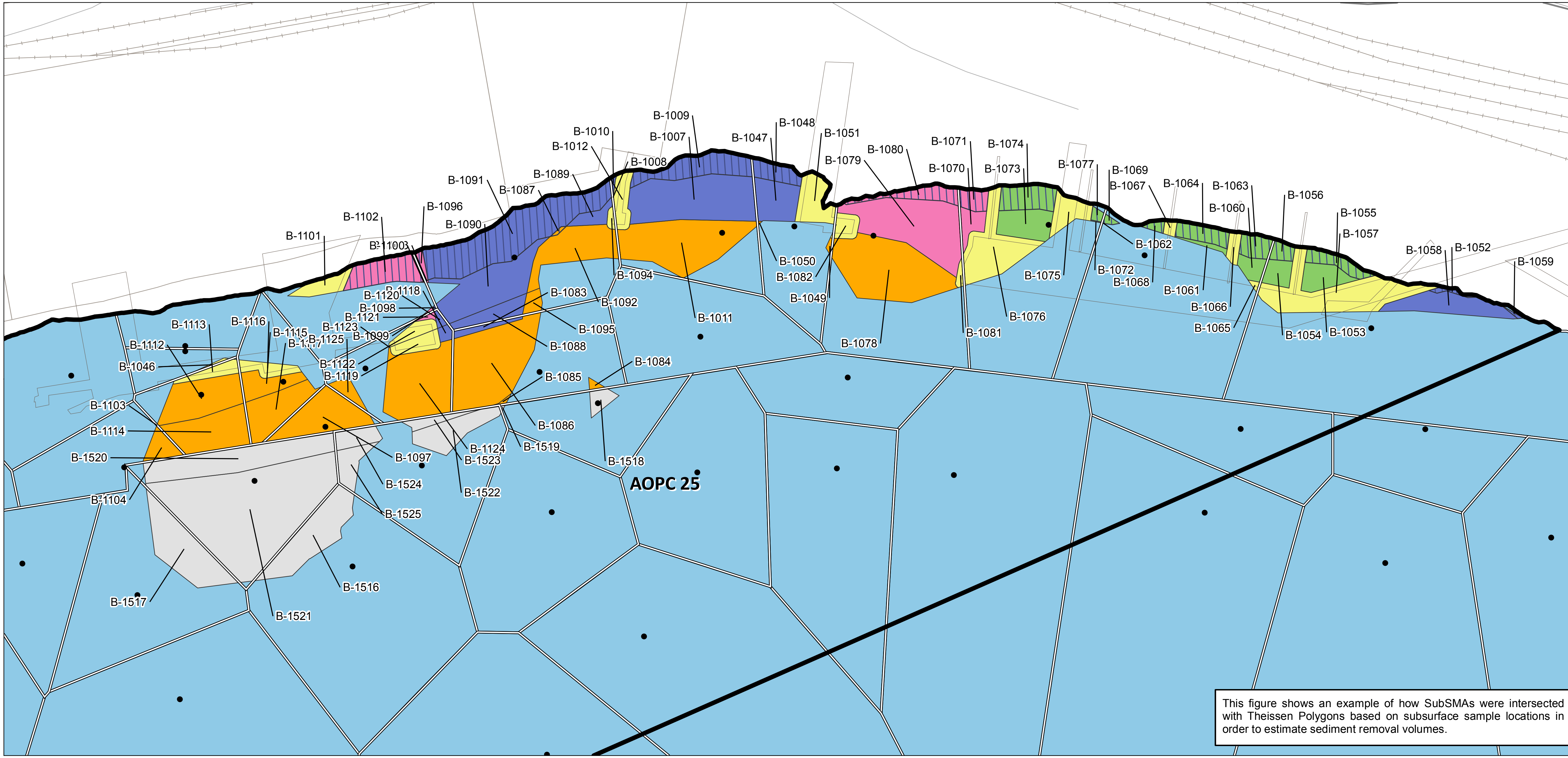
Figure 5.9-1
Portland Harbor RI/FS
Draft Feasibility Study
Mapping of All PRGs Above Background, Above Zero, and Consistent with the Risk Assessment at Time Zero



This figure shows an example of how SubSMAs were intersected with Theissen Polygons based on subsurface sample locations in order to estimate sediment removal volumes.

LEGEND

- Existing Remediation Cap (CAP)
- Potential Future Maintenance Dredge (FMD)
- Navigation Channel (NC)
- Open Water (OW)
- Structure - Limited Access (SL)
- Structure - No Removal (SN)
- Structure - Under (SS)
- Structure - Upland Removal (SU)
- Thiessen Core Location
- Thiessen Polygon
- Wave Zone (-wz)
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Site
- Docks and Structures
- Tax Lots
- Navigation Channel

Feet

0 50 100 150 200

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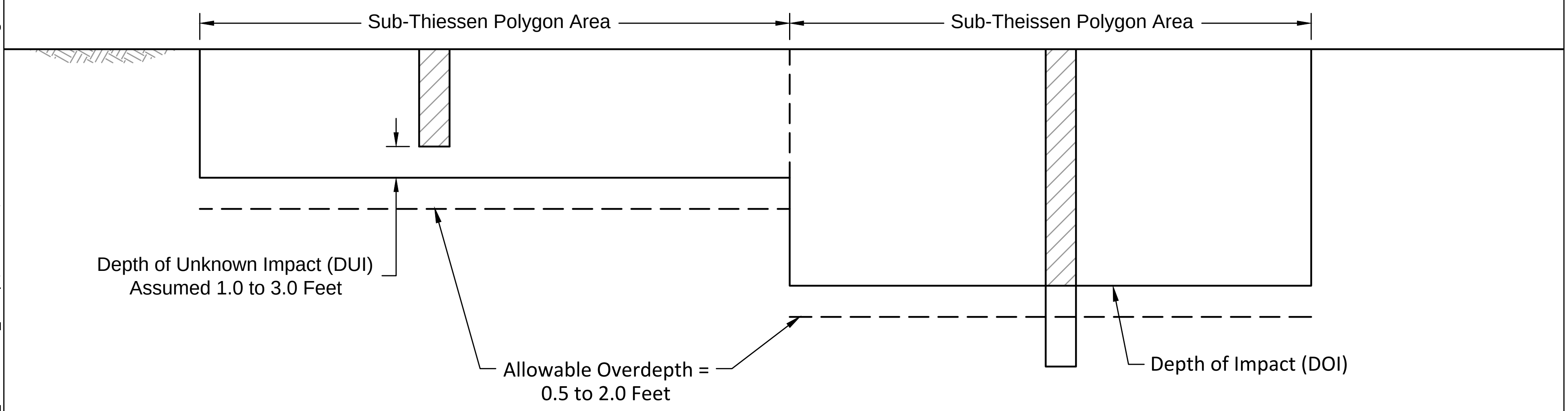
Figure 5.10-1
Portland Harbor RI/FS
Draft Feasibility Study
Example Thiessen Intersections with SubSMAs

This figure shows how volumes were estimated for each Sub-Theissen using both the EPA method and the LWG method.



Profile
Not to Scale

EPA Method
Estimated Volume = (Sub-thiessen Surface Area) x (DOI + DUI) x (NR)
NR = Neat line Ratio = 1.5 to 2.0

LWG Method
Estimated Volume = [(Sub-thiessen Surface Area) x (DOI + DUI + AO)](1+EF) + RV
Engineering Factor (EF) = 0.3 to 0.5 (or 30% to 50%)

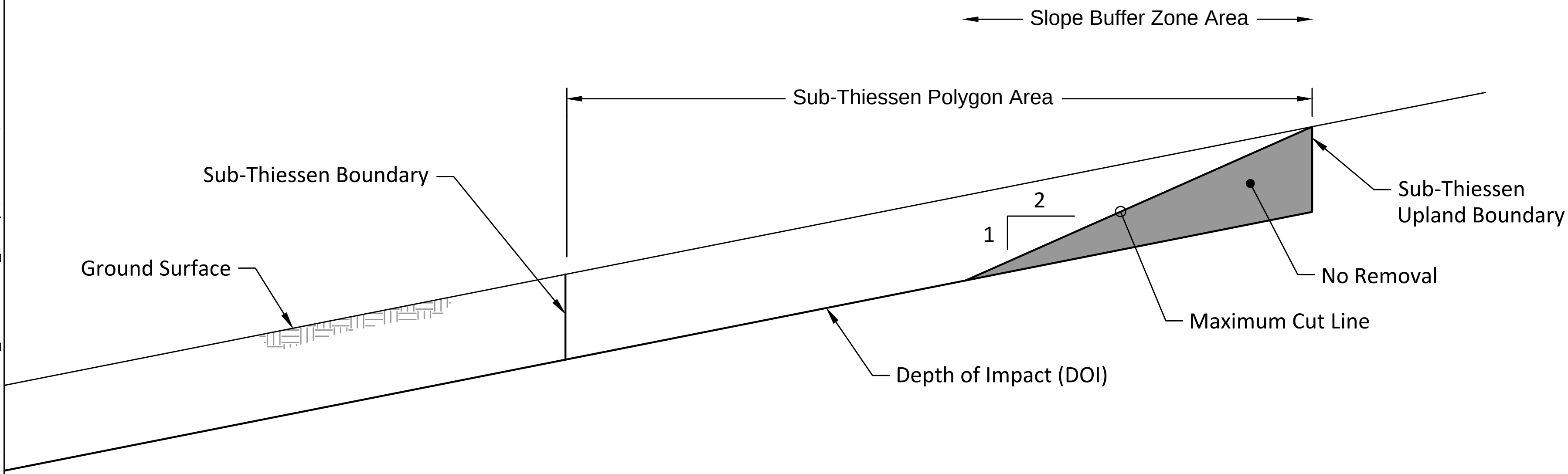
LEGEND:

Impacted Sediment

Non-Impacted Sediment

Figure 5.10-2
Portland Harbor RI/FS
Draft Feasibility Study
Dredge Volume Determination Method

This figure shows how dredge volumes estimates were modified to account for slope buffer zones.



Profile
Not to Scale

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Figure 5.10-3
Portland Harbor RI/FS
Draft Feasibility Study
Slope Buffer Zone Reductions

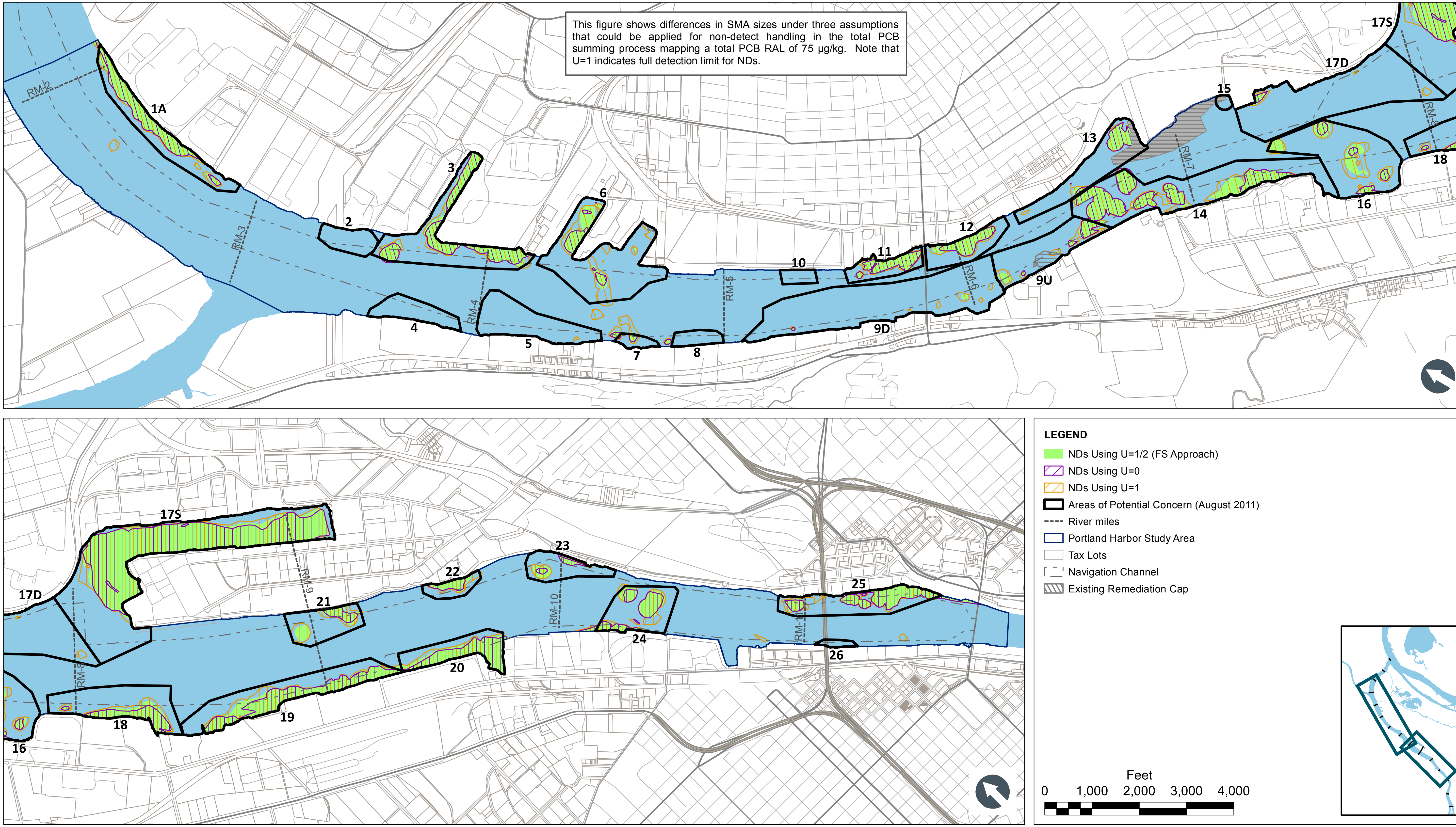

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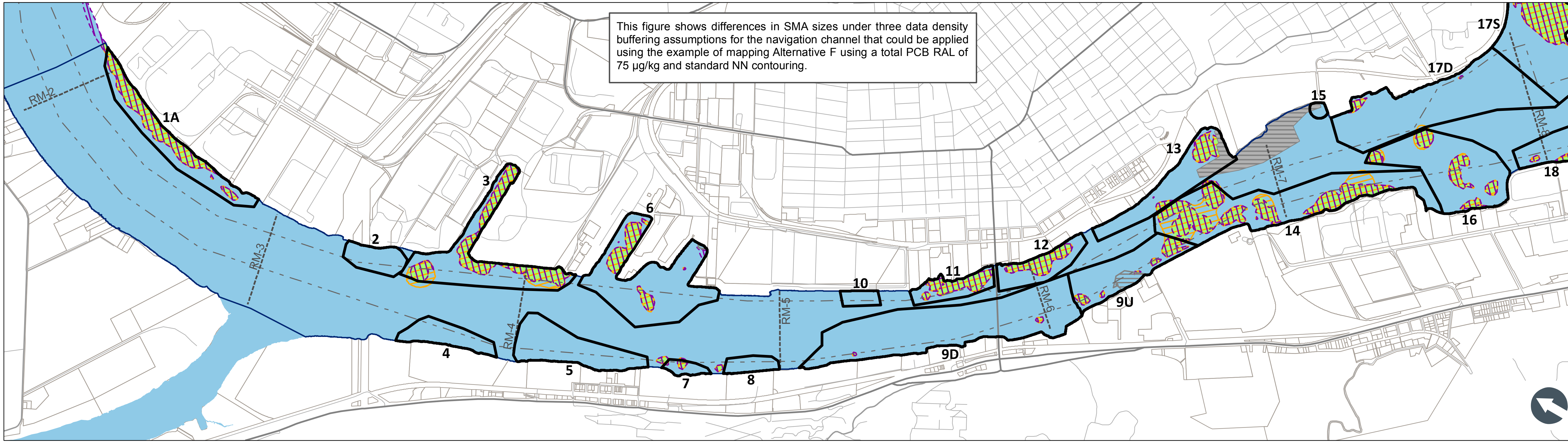
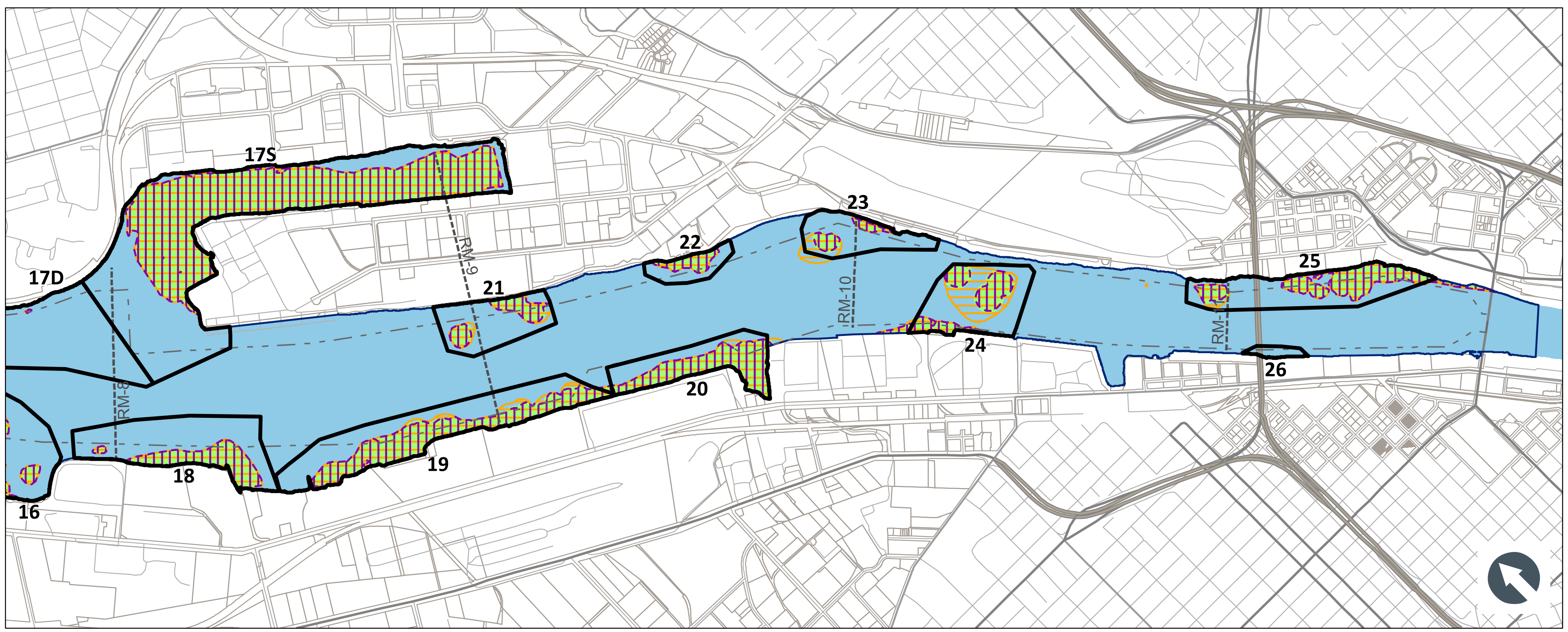
Figure 5.11-1
Portland Harbor RI/FS
Draft Feasibility Study Report
SMA Sensitivities Based on Total PCB Non-Detect Handling Assumptions in Summing Rules Mapping a PCB RAL of 75 µg/kg





LEGEND

- Total PCB RAL 75 µg/kg, Density 206 ft (FS Approach)
- Total PCB RAL 75 µg/kg, Density 179 ft
- Total PCB RAL 75 µg/kg, Unrefined
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Feet
0 1,000 2,000 3,000 4,000

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Figure 5.11-2
Portland Harbor RI/FS
Draft Feasibility Study Report
SMA Sensitivities Based on Data Density Refinements for Mapping a PCB RAL of 75 µg/kg

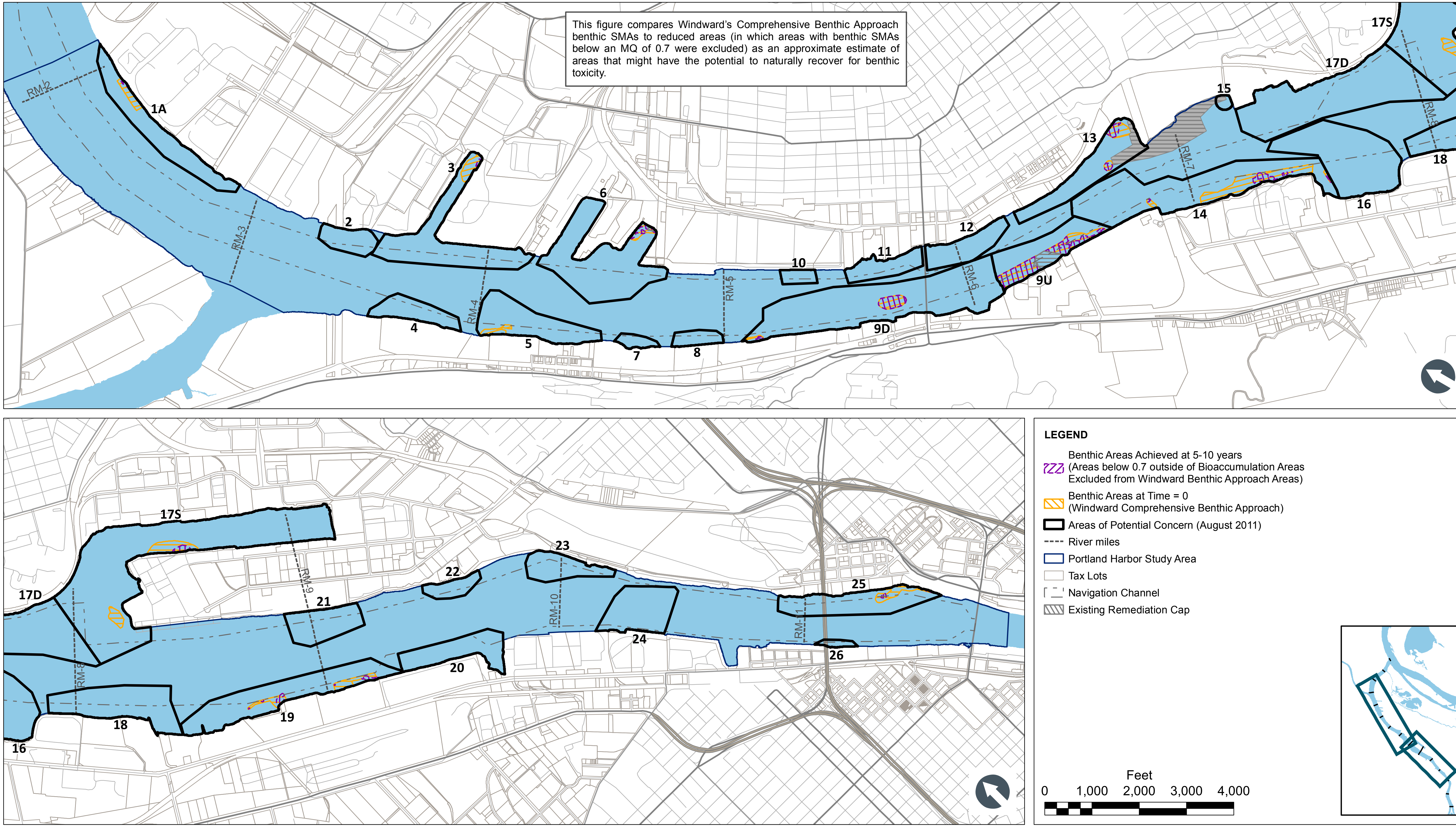

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Figure 5.11-3
Portland Harbor RI/FS
Draft Feasibility Study Report
SMA Sensitivities Comparison of Benthic SMAs Using the Comprehensive Benthic Approach to Benthic SMAs Excluding Areas with an MQ Value Below 0.7

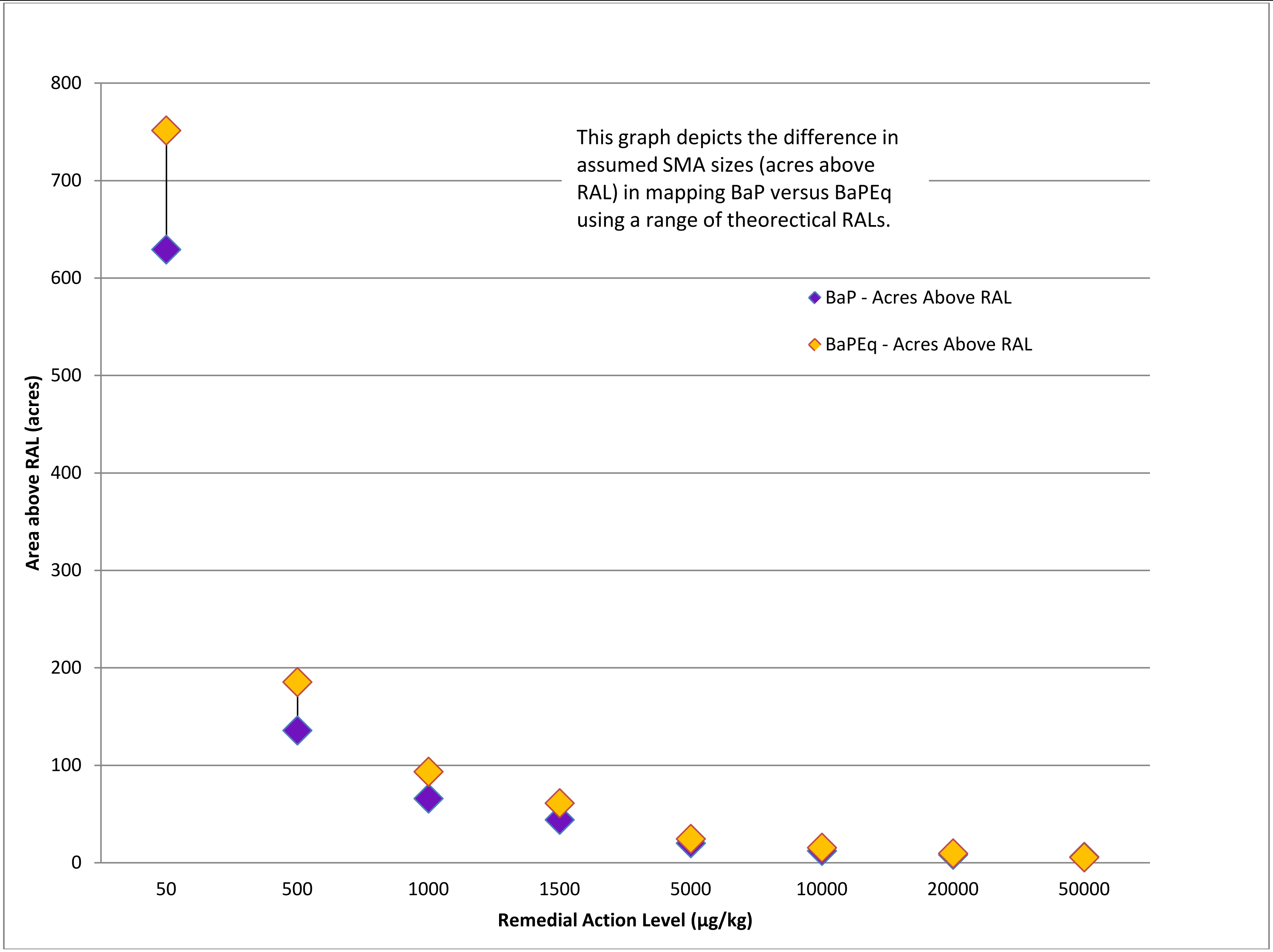

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Figure 5.11-4
Portland Harbor RI/FS
Draft Feasibility Study
Relationship Between RAL Concentration and Difference in Assumed SMA Acreages Using BaP versus BaP Eq Data

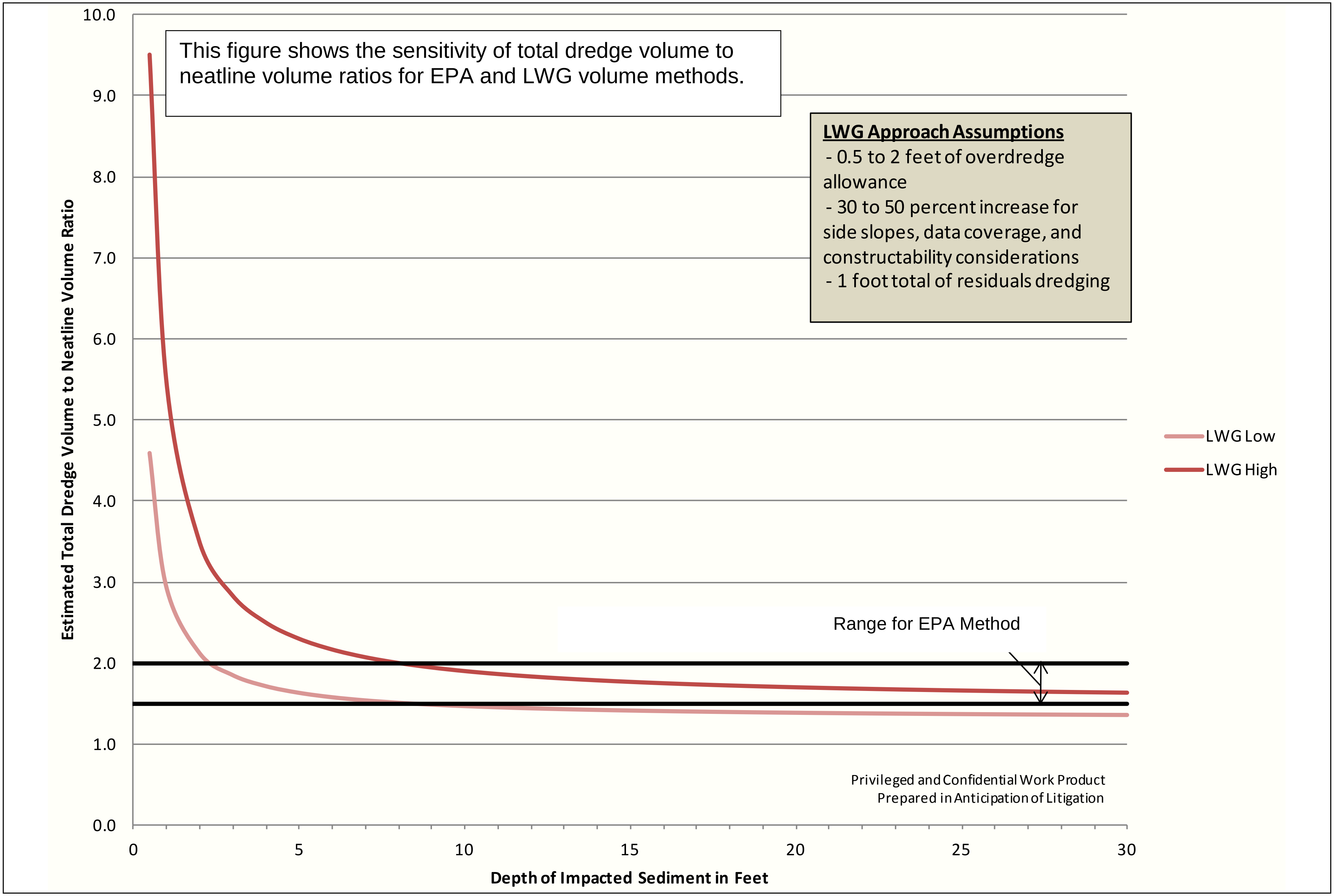

Figure 5.11-5
Portland Harbor RI/FS
Draft Feasibility Study
Sensitivity Analysis of EPA Dredge Volume Calculation

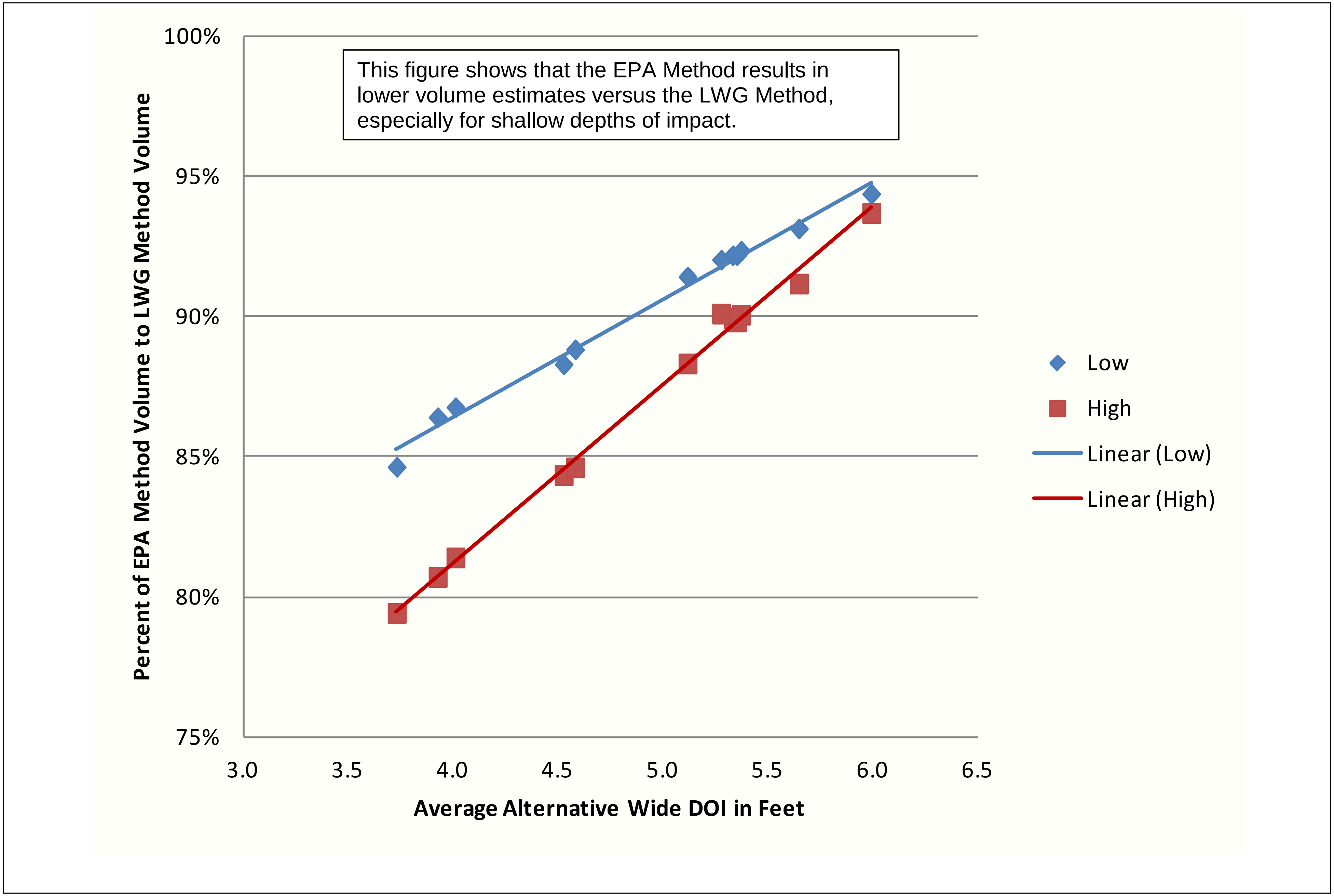

Figure 5.11-6
Portland Harbor RI/FS
Draft Feasibility Study
Sensitivity Analysis of Dredge Volume Determination Method

Table 5.3-1. Grouping of RALs for SMA Determination with Alternative Designations

Alt. No.	SMA Description	PCB RAL (ppb)	BaPEq RAL (ppb)	Sum DDE RAL (ppb)	Sum DDD RAL (ppb)	Sum DDT RAL (ppb)	2,3,4,7,8 PCDF RAL (ppb)	Benthic Toxicity
A	No active remediation (no SMAs)	None	None	None	None	None	None	None
B	Active remediation of highest unacceptable risk areas (RALs high in the zone of maximum incremental reduction)	1,000	20,000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 10 (estimated) MQ > 0.7
C	Active remediation of high unacceptable risk areas (RALs within the zone of maximum incremental reduction)	750	15,000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
D	Active remediation of high unacceptable risk areas (RALs within the zone of maximum incremental reduction)	500	8,000	200	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
E	Active remediation of unacceptable risk areas (RALs at or near the knee of the curve just before the zone of minimal change)	200	4,000[a]	50[b]	100*	150*	0.02*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
F	Active remediation of unacceptable and potentially unacceptable risk areas (RALs within the zone of minimal change)	75	1500	20[c]	50*	60*	0.01*	Comp. Benthic Risk Areas achieved at Year 0 (MQ > 0.7)

*EPA directed RALs.

a - The LWG recommended a BaPEQ value of 8,000 ppb and EPA directed 4,000 ppb.

b - The LWG recommended a sum DDE value of 200 ppb and EPA directed 50 ppb

c - The LWG recommended a sum DDE value of 100 ppb and EPA directed 20 ppb.

BaPEq benzo(a)pyrene equivalent
DDD dichloro-diphenyl-dichloroethane
DDE dichloro-diphenyl-dichloroethene
DDT dichloro-diphenyl-trichloroethane
EPA U.S. Environmental Protection Agency
LWG Lower Willamette Group
MQ Mean Quotient
NA not applicable
PCDF polychlorinated dibenzofuran
ppb parts per billion
RAL remedial action level
SMA sediment management area

Table 5.3-2. Data Density Buffer Distances

Contaminant (μg/kg)	Data Density Buffer (ft)
Total PCBs	206
Sum DDE	226
Sum DDD	238
Sum DDT	255
2,3,4,7,8 PCDF	425*

*Total average distance in shoreline areas outside of the navigation channel. All other buffer distances are based on average distance in the navigation channel.

Table 5.4-1 Summary of sub-SMA Types and Codes Based on Site Uses and Physical Features

Code	Feature	Description
NC	Navigation Channel	Areas within the current federally authorized navigation channel.
FMD	Potential Future Maintenance Dredge Area	Approach areas located between the NC areas and docks where shipping access is needed now or in the future.
SS	Structure - Under	Areas located beneath structures including a 5 foot offset from the structure face. The offset is based on the average depth of contamination across the Study Area and is assumed to minimize dredging related impacts to structures (see Section 5.10).
SL	Structure – Limited Access	Areas where open water equipment is not accessible due to structures. Smaller water-based equipment would have to be used.
SU	Structure – Upland Removal	Areas where no water-based equipment can reach but access from shore is feasible.
SN	Structure – No Removal	Areas where access by water-based equipment is restricted and upland structures, utilities, and/or topography restrict access from shore.
OW	Open Water	Areas where there is no restrictions to dredging or capping type equipment(this includes light structures like floating docks that do not effect removal considerations).
CAP	Remediation Cap	Existing caps at Terminal 4 and McCormick and Baxter.
OTHER CONSIDERATIONS		
Code Suffix	**Feature**	**Description**
-wz	Wave Zone	Area above 0 NAVD88 subject to vessel wake and wind generated wave forces.
-z	Confined Disposal Facilities (CDFs) and Confined Aquatic Disposal (CAD) Footprints	Areas located beneath potential CDF and/or CAD footprints at Termina 4, Arkema, and Swan Island (see Section 6).

Table 5.5-1. Theoretical High Concentration Oregon Hot Spot Values Calculated for All Three Approaches

Human Health Scenario/ Exposure Area	Individual Contaminant	Theoretical Oregon Hot Spot Value Calculated for Approach #1	Theoretical Oregon Hot Spot Value Calculated for Approach #2	Theoretical Oregon Hot Spot Value Calculated for Approach #3
Adult fish consumption, SMB, low IR; river mile	PCB 126	Cancer Risk 10^{-4} (Assuming Whole Body Consumption) = 0.015 µg/kg	100x the Cancer Risk 10^{-4} (Assuming Whole Body Consumption) = 1.5 µg/kg	Cancer Risk 10^{-4} (Assuming Fillet with Skin Consumption) = 0.12 µg/kg
		Non Cancer at HQ=10 (Assuming Whole Body Consumption) = 0.090 µg/kg dw		Non Cancer at HQ=10 (Assuming Fillet with Skin Consumption) = 0.68 µg/kg dw
	PCB 118	Cancer Risk 10^{-4} (Assuming Whole Body Consumption) = 13.8 µg/kg dw	100x the Cancer Risk 10^{-4} (Assuming Whole Body Consumption) = 1,380 µg/kg	Cancer Risk 10^{-4} (Assuming Fillet with Skin Consumption) = NA
		Non Cancer at HQ=10 (Assuming Whole Body Consumption) = 75.2 µg/kg dw		Non Cancer at HQ=10 (Assuming Fillet with Skin Consumption) = NA
	2,3,4,7,8 PCDF	Cancer Risk 10^{-4} (Assuming Whole Body Consumption) = 0.085 µg/kg	100x the Cancer Risk 10^{-4} (Assuming Whole Body Consumption) = 8.5 µg/kg	Cancer Risk 10^{-4} (Assuming Fillet with Skin Consumption) = 0.57 µg/kg
		Non Cancer at HQ=10 (Assuming Whole Body Consumption) = 0.46 µg/kg		Non Cancer at HQ=10 (Assuming Fillet with Skin Consumption) = 3.11 µg/kg

Notes:
HH – Human Health
IR – Ingestion Rate
RM – River Mile
SMB – Smallmouth Bass

Table 5.5-2. Screening Evaluation of Surface Water Data Against Potential ARARs

		Human Health Criteria								Ecological Criteria			
Contaminant	Units	MCL[2]		Oregon-Fish Consumption (2010)[3]		Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[4]		Oregon-Chronic Aquatic[5]		NRWQC-Chronic Aquatic[4]	
1,2,4-Trichlorobenzene	µg/L	7.00E+01				7.00E+00		7.00E+01					
1,2-Dichlorobenzene	µg/L	6.00E+02				1.30E+02		1.30E+03					
1,3-Dichlorobenzene	µg/L					9.60E+01		9.60E+02					
1,4-Dichlorobenzene	µg/L	7.50E+01				1.90E+01		1.90E+02					
2,2-Dichloropropionic acid (Dalapon)	µg/L	2.00E+02											
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	µg/L	3.00E-05		1.40E-08		5.10E-10		5.10E-09					
2,4,5-TP (Silvex)	µg/L	5.00E+01											
2,4,5-Trichlorophenol	µg/L					3.60E+02		3.60E+03	m				
2,4,6-Trichlorophenol	µg/L			3.60E+00		2.40E-01		2.40E+00					
2,4-D (2,4-Dichlorophenoxyacetic acid)	µg/L	7.00E+01											
2,4-Dichlorophenol	µg/L					2.90E+01		2.90E+02					
2,4-Dimethylphenol	µg/L					8.50E+01		8.50E+02					
2,4-Dinitrophenol	µg/L					5.30E+02		5.30E+03					
2,4-Dinitrotoluene	µg/L			9.10E+00		3.40E-01		3.40E+00					
2-Chloronaphthalene	µg/L					1.60E+02		1.60E+03					
2-Chlorophenol	µg/L					1.50E+01		1.50E+02					
3,3'-Dichlorobenzidine	µg/L			2.00E-02		2.80E-03		2.80E-02					
4,4'-DDD (p,p'-DDD)	µg/L					3.10E-05		3.10E-04					
4,4'-DDE (p,p'-DDE)	µg/L					2.20E-05		2.20E-04					
4,4'-DDT (p,p'-DDT)	µg/L					2.20E-05		2.20E-04					
Acenaphthene	µg/L					9.90E+01		9.90E+02					
Aldrin	µg/L			7.90E-05		5.00E-06		5.00E-05					
alpha-Hexachlorocyclohexane	µg/L			3.10E-02		4.90E-04		4.90E-03					
Aluminum	µg/L											8.70E+01	a,m
Anthracene	µg/L					4.00E+03		4.00E+04					
Antimony	µg/L	6.00E+00		4.50E+04		6.40E+01		6.40E+02					
Arsenic	µg/L	1.00E+01		1.75E-02		2.10E+00	f	1.40E-01	f			1.50E+02	b
Benzo(a)anthracene	µg/L					1.80E-03		1.80E-02					
Benzo(a)pyrene	µg/L	2.00E-01				1.80E-03		1.80E-02					
Benzo(b)fluoranthene	µg/L					1.80E-03		1.80E-02					
Benzo(k)fluoranthene	µg/L					1.80E-03		1.80E-02					
beta-Hexachlorocyclohexane	µg/L			5.47E-02		1.70E-03		1.70E-02					
bis(2-Chloroethyl)ether	µg/L			1.36E+00		5.00E-02		5.30E-01					
Bis(2-ethylhexyl) phthalate	µg/L	6.00E+00		5.00E+04		2.20E-01		2.20E+00					
Butylbenzyl phthalate	µg/L					1.90E+02		1.90E+03					
Cadmium	µg/L	5.00E+00								9.37E-02	c,l,n	9.37E-02	b,c
Chromium	µg/L	1.00E+02											
Chromium VI	µg/L									1.10E+01	n		
Chrysene	µg/L					1.80E-03		1.80E-02					
Copper	µg/L	1.30E+03	g							2.74E+00	c,l,n	2.74E+00	b,i
Dibenzo(a,h)anthracene	µg/L					1.80E-03		1.80E-02					
Dieldrin	µg/L			7.60E-05		5.40E-06		5.40E-05		1.90E-03	n	5.60E-02	
Diethyl phthalate	µg/L			1.80E+09		4.40E+03		4.40E+04					
Dimethyl phthalate	µg/L			2.90E+09		1.10E+05		1.10E+06					
Di-n-butyl phthalate	µg/L			1.54E+05		4.50E+02		4.50E+03					
Dinitro-o-cresol (4,6-Dinitro-2-methylphenol)	µg/L			7.65E+02		2.80E+01		2.80E+02					
Dinoseb	µg/L	7.00E+00											
Endosulfan sulfate	µg/L					8.90E+00		8.90E+01					

Table 5.5-2. Screening Evaluation of Surface Water Data Against Potential ARARs

		Number of Samples Exceeding Criterion[1]												
Contaminant	**Units**	**All Criteria**	**MCL**	**Maximum HQ - MCL**	**Oregon-Fish Consumption (2010)**	**HQ - Oregon-Fish Consumption (2010)**	**Oregon-Fish Consumption (2011)**	**HQ - Oregon-Fish Consumption (2011)**	**NRWQC-Fish Consumption**	**HQ - NRWQC-Fish Consumption**	**Oregon-Chronic Aquatic**	**HQ - Oregon-Chronic Aquatic**	**NRWQC-Chronic Aquatic**	**HQ - NRWQC-Chronic Aquatic**
1,2,4-Trichlorobenzene	µg/L	0/40	0/40	--			0/40	--	0/40	--				
1,2-Dichlorobenzene	µg/L	0/40	0/40	--			0/40	--	0/40	--				
1,3-Dichlorobenzene	µg/L	0/40					0/40	--	0/40	--				
1,4-Dichlorobenzene	µg/L	0/40	0/40	--			0/40	--	0/40	--				
2,2-Dichloropropionic acid (Dalapon)	µg/L	0/38	0/38	--										
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	µg/L	3/30	0/30	--	0/30	--	3/30	1.37E+01	2/30	1.4E+00				
2,4,5-TP (Silvex)	µg/L	0/40	0/40	--										
2,4,5-Trichlorophenol	µg/L	0/40					0/40	--	0/40	--				
2,4,6-Trichlorophenol	µg/L	0/40			0/40	--	0/40	--	0/40	--				
2,4-D (2,4-Dichlorophenoxyacetic acid)	µg/L	0/40	0/40	--										
2,4-Dichlorophenol	µg/L	0/40					0/40	--	0/40	--				
2,4-Dimethylphenol	µg/L	0/40					0/40	--	0/40	--				
2,4-Dinitrophenol	µg/L	0/40					0/40	--	0/40	--				
2,4-Dinitrotoluene	µg/L	0/40			0/40	--	0/40	--	0/40	--				
2-Chloronaphthalene	µg/L	0/40					0/40	--	0/40	--				
2-Chlorophenol	µg/L	0/40					0/40	--	0/40	--				
3,3'-Dichlorobenzidine	µg/L	0/36			0/36	--	0/36	--	0/36	--				
4,4'-DDD (p,p'-DDD)	µg/L	24/39					24/39	5.48E+00	0/39	--				
4,4'-DDE (p,p'-DDE)	µg/L	28/39					28/39	9.00E+00	0/39	--				
4,4'-DDT (p,p'-DDT)	µg/L	14/39					14/39	1.46E+01	3/39	1.5E+00				
Acenaphthene	µg/L	0/70					0/70	--	0/70	--				
Aldrin	µg/L	1/39			0/39	--	1/39	1.20E+00	0/39	--				
alpha-Hexachlorocyclohexane	µg/L	0/39			0/39	--	0/39	--	0/39	--				
Aluminum	µg/L	124/134											124/134	2.1E+01
Anthracene	µg/L	0/70					0/70	--	0/70	--				
Antimony	µg/L	0/40	0/40	--	0/40	--	0/40	--	0/40	--				
Arsenic	µg/L	34/198	0/40	--	34/40	3.7E+01	0/40	--	34/40	4.6E+00			0/158	--
Benzo(a)anthracene	µg/L	2/70					2/70	5.56E+00	0/70	--				
Benzo(a)pyrene	µg/L	0/70	0/70	--			0/70	--	0/70	--				
Benzo(b)fluoranthene	µg/L	0/70					0/70	--	0/70	--				
Benzo(k)fluoranthene	µg/L	1/40					1/40	3.72E+00	0/40	--				
beta-Hexachlorocyclohexane	µg/L	0/39			0/39	--	0/39	--	0/39	--				
bis(2-Chloroethyl)ether	µg/L	0/40			0/40	--	0/40	--	0/40	--				
Bis(2-ethylhexyl) phthalate	µg/L	5/49	0/49	--	0/49	--	5/49	7.27E+00	0/49	--				
Butylbenzyl phthalate	µg/L	0/49					0/49	--	0/49	--				
Cadmium	µg/L	0/198	0/40	--							0/158	--	0/158	--
Chromium	µg/L	0/40	0/40	--										
Chromium VI	µg/L	0/20									0/20	--		
Chrysene	µg/L	7/70					7/70	4.28E+00	0/70	--				
Copper	µg/L	0/198	0/40	--							0/158	--	0/158	--
Dibenzo(a,h)anthracene	µg/L	0/70					0/70	--	0/70	--				
Dieldrin	µg/L	30/160			9/39	4.6E+00	30/39	6.48E+01	9/39	6.5E+00	0/160	--	0/160	--
Diethyl phthalate	µg/L	0/49			0/49	--	0/49	--	0/49	--				
Dimethyl phthalate	µg/L	0/49			0/49	--	0/49	--	0/49	--				
Di-n-butyl phthalate	µg/L	0/49			0/49	--	0/49	--	0/49	--				
Dinitro-o-cresol (4,6-Dinitro-2-methylphenol)	µg/L	0/40			0/40	--	0/40	--	0/40	--				
Dinoseb	µg/L	0/38	0/38	--										
Endosulfan sulfate	µg/L	0/39					0/39	--	0/39	--				

Table 5.5-2. Screening Evaluation of Surface Water Data Against Potential ARARs

Contaminant	Units	Human Health Criteria								Ecological Criteria			
		MCL[2]		Oregon-Fish Consumption (2010)[3]		Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[4]		Oregon-Chronic Aquatic[5]		NRWQC-Chronic Aquatic[4]	
Endosulfan-alpha (I)	µg/L					8.90E+00		8.90E+01		5.60E-02	o		
Endosulfan-beta (II)	µg/L					8.90E+00		8.90E+01		5.60E-02	o		
Endrin	µg/L	2.00E+00				2.40E-02		6.00E-02		2.30E-03	n	3.60E-02	
Endrin aldehyde	µg/L					3.00E-02		3.00E-01					
Fluoranthene	µg/L			5.40E+01		1.40E+01		1.40E+02					
Fluorene	µg/L					5.30E+02		5.30E+03					
gamma-Hexachlorocyclohexane (Lindane)	µg/L	2.00E-01		6.25E-02		1.80E-01		1.80E+00		8.00E-02	o		
Heptachlor	µg/L	4.00E-01		2.90E-04		7.90E-06		7.90E-05		3.80E-03	o	3.80E-03	
Heptachlor epoxide	µg/L	2.00E-01				3.90E-06		3.90E-05		3.80E-03	o	3.80E-03	
Hexachlorobenzene	µg/L	1.00E+00		7.40E-04		2.90E-05		2.90E-04					
Hexachlorobutadiene	µg/L			5.00E+01		1.80E+00		1.80E+01					
Hexachlorocyclopentadiene	µg/L	5.00E+01				1.10E+02		1.10E+03					
Hexachloroethane	µg/L			8.74E+00		3.30E-01		3.30E+00					
Indeno(1,2,3-c,d)pyrene	µg/L					1.80E-03		1.80E-02					
Isophorone	µg/L			5.20E+05		9.60E+01		9.60E+02					
Lead	µg/L	1.50E+01	g							5.41E-01	c,l,n	5.41E-01	b,c
LWG RA Sum DDT (Calculated U = 1/2)	µg/L			2.40E-05						1.00E-03	n		
LWG RA Total 17 PAH (Calculated U = 1/2)	µg/L			3.11E-02									
LWG RA Total Chlordane (Calculated U = 1/2)	µg/L	2.00E+00		4.80E-04		8.10E-05		8.10E-04		4.30E-03	o	4.30E-03	
LWG RA Total DDx (Calculated U = 1/2)	µg/L									1.00E-03	o	1.00E-03	
LWG RA Total Endosulfan (Calculated U = 1/2)	µg/L			1.59E+02	j,k					5.60E-02	j,o	5.60E-02	j
LWG RA Total PCB Aroclors (Calculated U = 1/2)	µg/L	5.00E-01		7.90E-05		6.40E-06	e	6.40E-05	e	1.40E-02	e,o	1.40E-02	e
LWG RA Total PCB Congener (Calculated U = 1/2)	µg/L	5.00E-01		7.90E-05		6.40E-06	e	6.40E-05	e	1.40E-02	e,o	1.40E-02	e
Mercury	µg/L	2.00E+00								1.20E-02	b,o	7.70E-01	b
Methoxychlor	µg/L	4.00E+01								3.00E-02	o	3.00E-02	p
Mirex	µg/L									1.00E-03	o	1.00E-03	p
Nickel	µg/L			1.00E+02		1.70E+02		4.60E+03		1.61E+01	c,l,n	1.61E+01	b,c
Nitrobenzene	µg/L					6.90E+01		6.90E+02					
N-Nitrosodimethylamine	µg/L			1.60E+01		3.00E-01		3.00E+00					
N-Nitrosodi-N-propylamine	µg/L					5.10E-02		5.10E-01					
N-Nitrosodiphenylamine	µg/L			1.61E+01		6.00E-01		6.00E+00					
Pentachlorophenol	µg/L	1.00E+00				3.00E-01		3.00E+00		8.18E+00	d,n	8.18E+00	d
Phenol	µg/L					8.60E+04		8.60E+05					
Pyrene	µg/L					4.00E+02		4.00E+03					
Selenium	µg/L	5.00E+01				4.20E+02		4.20E+03		3.50E+01	n	5.00E+00	h
Silver	µg/L									1.20E-01	n		
Thallium	µg/L	2.00E+00		4.80E+01		4.70E-02		4.70E-01					
Toxaphene	µg/L	3.00E+00		7.30E-04		2.80E-05		2.80E-04		2.00E-04	o	2.00E-04	
Tributyltin (ion)	µg/L											7.20E-02	m
Zinc	µg/L					2.60E+03		2.60E+04		3.65E+01	d,l,n	3.65E+01	b,c

Table 5.5-2. Screening Evaluation of Surface Water Data Against Potential ARARs

Contaminant	Units	Number of Samples Exceeding Criterion[1]												
		All Criteria	MCL	Maximum HQ - MCL	Oregon-Fish Consumption (2010)	HQ - Oregon-Fish Consumption (2010)	Oregon-Fish Consumption (2011)	HQ - Oregon-Fish Consumption (2011)	NRWQC-Fish Consumption	HQ - NRWQC-Fish Consumption	Oregon-Chronic Aquatic	HQ - Oregon-Chronic Aquatic	NRWQC-Chronic Aquatic	HQ - NRWQC-Chronic Aquatic
Endosulfan-alpha (I)	µg/L	0/160					0/39	--	0/39	--	0/160	--		
Endosulfan-beta (II)	µg/L	0/160					0/39	--	0/39	--	0/160	--		
Endrin	µg/L	0/147	0/37	--			0/37	--	0/37	--	0/149	--	0/149	--
Endrin aldehyde	µg/L	0/39					0/39	--	0/39	--				
Fluoranthene	µg/L	0/70			0/70	--	0/70	--	0/70	--				
Fluorene	µg/L	0/70					0/70	--	0/70	--				
gamma-Hexachlorocyclohexane (Lindane)	µg/L	0/160	0/39	--	0/39	--	0/39	--	0/39	--	0/160	--		
Heptachlor	µg/L	0/160	0/39	--	0/39	--	0/39	--	0/39	--	0/160	--	0/160	--
Heptachlor epoxide	µg/L	24/160	0/39	--			24/39	6.41E+00	0/39	--	0/160	--	0/160	--
Hexachlorobenzene	µg/L	16/70	0/70	--	0/70	--	16/70	2.52E+00	0/70	--				
Hexachlorobutadiene	µg/L	0/70			0/70	--	0/70	--	0/70	--				
Hexachlorocyclopentadiene	µg/L	0/34	0/34	--			0/34	--	0/34	--				
Hexachloroethane	µg/L	0/40			0/40	--	0/40	--	0/40	--				
Indeno(1,2,3-c,d)pyrene	µg/L	1/70					1/70	4.78E+00	0/70	--				
Isophorone	µg/L	0/40			0/40	--	0/40		0/40	--				
Lead	µg/L	0/198	0/40	--							0/158	--	0/158	--
LWG RA Sum DDT (Calculated U = 1/2)	µg/L	33/160			14/39	1.4E+01					19/160	1.9E+01		
LWG RA Total 17 PAH (Calculated U = 1/2)	µg/L	31/70			31/70	3.2E+00								
LWG RA Total Chlordane (Calculated U = 1/2)	µg/L	1/160	0/39	--	0/39	--	1/39	1.12E+00	0/39	--	0/160	--	0/160	--
LWG RA Total DDx (Calculated U = 1/2)	µg/L	34/160									34/160	2.0E+01	34/160	2.0E+01
LWG RA Total Endosulfan (Calculated U = 1/2)	µg/L	0/160			0/39	--					0/160	--	0/160	--
LWG RA Total PCB Aroclors (Calculated U = 1/2)	µg/L	2/44	0/9	--	1/9	2.2E+02	1/9	2.66E+03	1/9	2.7E+02	2/44	1.2E+00	2/44	1.2E+00
LWG RA Total PCB Congener (Calculated U = 1/2)	µg/L	30/108	0/30	--	29/30	1.6E+01	30/30	2.03E+02	29/30	2.0E+01	0/108	--	0/108	--
Mercury	µg/L	3/198	0/40	--							3/158	1.7E+00	0/158	--
Methoxychlor	µg/L	0/160	0/39	--							0/160	--	0/160	--
Mirex	µg/L	0/49									0/49	--	0/49	--
Nickel	µg/L	0/198			0/40	--	0/40	--	0/40	--	0/158	--	0/158	--
Nitrobenzene	µg/L	0/40					0/40	--	0/40	--				
N-Nitrosodimethylamine	µg/L	0/40			0/40	--	0/40	--	0/40	--				
N-Nitrosodi-N-propylamine	µg/L	0/40					0/40	--	0/40	--				
N-Nitrosodiphenylamine	µg/L	0/40			0/40	--	0/40	--	0/40	--				
Pentachlorophenol	µg/L	0/157	0/40	--			0/40	--	0/40	--	0/157	--	0/157	--
Phenol	µg/L	0/40					0/40	--	0/40	--				
Pyrene	µg/L	0/70					0/70	--	0/70	--				
Selenium	µg/L	0/158	0/40	--			0/40	--	0/40	--	0/158	--	0/158	--
Silver	µg/L	0/158									0/158	--		
Thallium	µg/L	0/6	0/6	--	0/6	--	0/6	--	0/6	--				
Toxaphene	µg/L	0/80	0/9	--	0/9	--	0/9	--	0/9	--	0/80	--	0/80	--
Tributyltin (ion)	µg/L	0/158											0/158	--
Zinc	µg/L	1/198					0/40	--	0/40	--	1/158	1.1E+00	1/158	1.1E+00

Table 5.5-2. Screening Evaluation of Surface Water Data Against Potential ARARs

References:

1 - These columns list a ratio describe the number of samples exceeding each criterion over the number of samples screened against criterion (e.g., "0/62" indicates that 62 samples were screened against the criterion and, of these, 0 samples exceeded the criterion). The samples screened are listed in the draft FS water database and were screened following the approach described in Appendix C.

2 - USEPA. 2009. National Primary Drinking Water Regulations, EPA 816-F-09-004 (MCLs).

3 - DEQ. 2010. Effective Water Quality Criteria for Human Health, Effective June 1, 2010 (superseded)

4 - USEPA. 2009. National Recommended Water Quality Criteria, 4304T (NRWQC).

5 - Oregon Administrative Rules, Division 41: Table 20 and Table 33A; as filed through February 12, 2010.

6 - DEQ. 2011. Table 40: Human Health Water Quality Criteria for Toxic Pollutants, Effective October 17,2011

Notes:

a - This criterion applies at pH range of 6.5-9.0.

b - This criterion is expressed in terms of dissolved metal in the water column and is only applied to results expressed as dissolved metal.

c- This criterion is hardness dependant and is calculated based on a hardness of 25 mg/liter.

d - This criterion is pH dependent and is calculated based on a pH of 7.2.

e - This criterion applies to total PCBs, (e.g., the sum of all congener or all isomer or homolog or aroclor analyses).

f - This criterion applies to inorganic arsenic only.

g - The value shown is an action level. Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% percent of tap water samples exceed the action level, water systems must take additional steps.

h - This criterion for selenium is dependant on the fractions of total selenium that are treated as selenite and selenate. This criterion is based 100% selenium as selenate.

i - Calculated using the Biotic Ligand Model version 2.2.3. Parameters for model inputs are the geometric mean of the water quality results reported for USGS Monitoring Station 14211720 from 10/25/1974 to 3/2/2010, except for pH. PH is 7.2.

j - This criterion is applied as the sum of alpha- and beta-endosulfan.

k - This criterion is the minimum (i.e., the criterion should not be below this value in order to protect aquatic life).

l - Hardness function was not provided in Table 20, the function provided in the NRWQC (EPA 2009) is used to calculate this criterion. This criterion is marked as to be applied on the dissolved basis consistent with the NRWQC.

m - Non-priority chemical NRWQC.

n - DEQ Table 20 water quality criterion.

o - DEQ Table 33a water quality criterion.

Acronymns and abbreviations:

cPAH - Carcinogenic polycyclic aromatic hydrocarbon

EPA - Environmental Protection Agency

Maximum HQ - Hazard Quotient of highest detected sample

MCL - Maximum contaminant level

PAH - Polycyclic aromatic hydrocarbon

PCB - Polychlorinated biphenol

USGS - United States Geological Survey

DEQ - Oregon Department of Environmental Quality

DDx - Sum of DDT and its metabolites

-- - None of the samples screened exceeded this criterion

Table 5.5-3. Comparison of Potential ARAR Values to Site Surface Water Background Concentrations

		Human Health Criteria[b]								Ecological Criteria[b]				Background Levels[r]			
Chemical	Units	MCL[2]		Oregon-Fish Consumption (2010)[4]		Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[1]		Oregon-Chronic[3]		NRWQC-Chronic[1]		Background-Dissolved[5]		Background-Total[5]	
1,1,1-Trichloroethane	µg/L	2.00E+02															
1,1,2,2-Tetrachloroethane	µg/L			1.07E+01		4.00E-01		4.00E+00									
1,1,2-Trichloroethane	µg/L	5.00E+00		4.18E+01		1.60E+00		1.60E+01									
1,1-Dichloroethene	µg/L	7.00E+00				7.10E+02		7.10E+03									
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	ng/L													1.90E-05		3.65E-05	
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (PeCDD)	ng/L													3.63E-06		1.83E-05	
1,2,4-Trichlorobenzene	µg/L	7.00E+01				7.00E+00		7.00E+01									
1,2-Dibromo-3-chloropropane	µg/L	2.00E-01															
1,2-Dibromoethane (Ethylene dibromide)	µg/L	5.00E-02															
1,2-Dichlorobenzene	µg/L	6.00E+02				1.30E+02		1.30E+03									
1,2-Dichloroethane	µg/L	5.00E+00		2.43E+02		3.70E+00		3.70E+01									
1,2-Dichloroethene, cis-	µg/L	7.00E+01															
1,2-Dichloroethene, trans-	µg/L	1.00E+02				1.00E+03		1.00E+04									
1,2-Dichloropropane	µg/L	5.00E+00				1.50E+00		1.50E+01									
1,3-Dichlorobenzene	µg/L					9.60E+01		9.60E+02									
1,4-Dichlorobenzene	µg/L	7.50E+01				1.90E+01		1.90E+02									
2,2-Dichloropropionic acid (Dalapon)	µg/L	2.00E+02															
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	ng/L													3.39E-06		1.55E-05	
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	ng/L													5.06E-06		1.52E-05	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/L	3.00E-02		1.40E-05		**5.10E-07**		**5.10E-06**						8.00E-06	n	8.00E-06	n
2,4,5-TP (Silvex)	µg/L	5.00E+01															
2,4,5-Trichlorophenol	µg/L					3.60E+02		3.60E+03	o								
2,4,6-Trichlorophenol	µg/L			3.60E+00		2.40E-01		2.40E+00									
2,4-D (2,4-Dichlorophenoxyacetic acid)	µg/L	7.00E+01															
2,4-Dichlorophenol	µg/L					2.90E+01		2.90E+02									
2,4-Dimethylphenol	µg/L					8.50E+01		8.50E+02									
2,4-Dinitrophenol	µg/L					5.30E+02		5.30E+03									
2,4-Dinitrotoluene	µg/L			9.10E+00		3.40E-01		3.40E+00									
2-Chlorophenol	µg/L					1.50E+01		1.50E+02									
3,3'-Dichlorobenzidine	µg/L			2.00E-02		2.80E-03		2.80E-02									
4,4'-DDD (p,p'-DDD)	µg/L					**3.10E-05**		3.10E-04						3.45E-05		7.85E-05	
4,4'-DDE (p,p'-DDE)	µg/L					**2.20E-05**		2.20E-04						6.28E-05		1.87E-04	
4,4'-DDT (p,p'-DDT)	µg/L					**2.20E-05**		**2.20E-04**						7.92E-05		2.72E-04	
4-Methylphenol (p-Cresol)	µg/L															2.80E-02	n
Acenaphthene	µg/L					9.90E+01		9.90E+02									
Acrylonitrile	µg/L			6.50E-01		2.50E-02		2.50E-01									
Aldrin	µg/L			7.90E-05		5.00E-06		5.00E-05						2.79E-06		3.85E-06	
alpha-Hexachlorocyclohexane	µg/L			3.10E-02		4.90E-04		4.90E-03									
Aluminum	µg/L											**8.70E+01**	a,o	1.45E+01		1.49E+03	
Anthracene	µg/L					4.00E+03		4.00E+04									
Antimony	µg/L	6.00E+00		4.50E+04		6.40E+01		6.40E+02						3.14E-02		4.41E-02	
Arsenic	µg/L	1.00E+01		**1.75E-02**		2.10E+00	h	**1.40E-01**	h			1.50E+02	c	4.46E-01		5.36E-01	
Benzene	µg/L	5.00E+00		4.00E+01		1.40E+00		5.10E+01									

Table 5.5-3. Comparison of Potential ARAR Values to Site Surface Water Background Concentrations

		Human Health Criteria[b]								Ecological Criteria[b]				Background Levels[r]			
Chemical	**Units**	**MCL[2]**		**Oregon-Fish Consumption (2010)[4]**		**Oregon-Fish Consumption (2011)[6]**		**NRWQC-Fish Consumption[1]**		**Oregon-Chronic[3]**		**NRWQC-Chronic[1]**		**Background-Dissolved[5]**		**Background-Total[5]**	
Benzo(a)anthracene	µg/L					1.80E-03		1.80E-02						8.50E-05		3.53E-04	
Benzo(a)pyrene	µg/L	2.00E-01				1.80E-03		1.80E-02						3.19E-05		5.04E-04	
Benzo(b)fluoranthene	µg/L					1.80E-03		1.80E-02						3.60E-05		5.93E-04	
Benzo(j,k)fluoranthene	µg/L													3.15E-05		4.64E-04	
Benzo(k)fluoranthene	µg/L					**1.80E-03**		1.80E-02								5.50E-03	n
Benzyl alcohol	µg/L															5.50E-01	n
beta-Hexachlorocyclohexane	µg/L			5.47E-02		1.70E-03		1.70E-02									
bis(2-Chloroethyl)ether	µg/L			1.36E+00		5.00E-02		5.30E-01									
Bis(2-ethylhexyl) phthalate	µg/L	6.00E+00		5.00E+04		**2.20E-01**		2.20E+00						1.71E-02	n	1.51E+00	
Bromodichloromethane	µg/L							1.70E+01									
Bromoform (Tribromomethane)	µg/L					1.40E+01		1.40E+02									
Bromomethane (Methyl Bromide)	µg/L							1.50E+03									
Butylbenzyl phthalate	µg/L					1.90E+02		1.90E+03									
Cadmium	µg/L	5.00E+00								9.37E-02	c,d,v,p	9.37E-02	c,d	1.00E-02	n	1.00E-02	n
Carbazole	µg/L															7.50E-03	n
Carbon tetrachloride (Tetrachloromethane)	µg/L	5.00E+00		6.94E+00		1.60E-01		1.60E+00									
Chlorobenzene	µg/L	1.00E+02				1.60E+02		1.60E+03									
Chloroform	µg/L			1.57E+01		1.10E+03		4.70E+02									
Chromium	µg/L	1.00E+02												5.42E-01		1.48E+00	
Chromium VI	µg/L									1.10E+01	p	1.10E+01	c				
Chrysene	µg/L					1.80E-03		1.80E-02						3.27E-04		6.94E-04	
Copper	µg/L	1.30E+03	i							2.74E+00	c,d,m,p	2.74E+00	c,k	1.40E+00		3.07E+00	
delta-Hexachlorocyclohexane	µg/L													1.19E-06		1.26E-06	
Dibenzo(a,h)anthracene	µg/L					1.80E-03		1.80E-02						1.08E-03	n	8.96E-05	
Dibromochloromethane	µg/L							1.30E+01									
Dichloromethane (Methylene chloride)	µg/L	5.00E+00				5.90E+01		5.90E+02									
Dieldrin	µg/L			**7.60E-05**		**5.40E-06**		**5.40E-05**		1.90E-03	p	5.60E-02		2.15E-04		2.50E-04	
Diethyl phthalate	µg/L			1.80E+09		4.40E+03		4.40E+04						2.31E-03	n	3.93E-02	
Dimethyl phthalate	µg/L			2.90E+09		1.10E+05		1.10E+06									
Di-n-butyl phthalate	µg/L			1.54E+05		4.50E+02		4.50E+03									
Dinitro-o-cresol (4,6-Dinitro-2-methylphenol)	µg/L			7.65E+02		2.80E+01		2.80E+02									
Dinoseb	µg/L	7.00E+00															
Endosulfan sulfate	µg/L					8.90E+00		8.90E+01									
Endosulfan-alpha (I)	µg/L					8.90E+00		8.90E+01		5.60E-02	l,q	5.60E-02	l				
Endosulfan-beta (II)	µg/L					8.90E+00		8.90E+01		5.60E-02	l,q	5.60E-02	l				
Endrin	µg/L	2.00E+00				2.40E-02		6.00E-02		2.30E-03	p	3.60E-02		1.23E-06		1.05E-06	
Endrin aldehyde	µg/L					3.00E-02		3.00E-01									
Endrin ketone	µg/L													3.15E-06		3.25E-06	
Ethylbenzene	µg/L	7.00E+02		3.28E+03		2.10E+02		2.10E+03									
Fluoranthene	µg/L			5.40E+01		1.40E+01		1.40E+02									
Fluorene	µg/L					5.30E+02		5.30E+03									
gamma-Hexachlorocyclohexane (Lindane)	µg/L	2.00E-01		6.25E-02		1.80E-01		1.80E+00		8.00E-02	q			3.71E-05		3.72E-05	
Heptachlor	µg/L	4.00E-01		2.90E-04		7.90E-06		7.90E-05		3.80E-03	l,q	3.80E-03	q	6.31E-07		7.22E-07	

Table 5.5-3. Comparison of Potential ARAR Values to Site Surface Water Background Concentrations

		Human Health Criteria[b]								Ecological Criteria[b]				Background Levels[r]			
Chemical	Units	MCL[2]		Oregon-Fish Consumption (2010)[4]		Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[1]		Oregon-Chronic[3]		NRWQC-Chronic[1]		Background-Dissolved[5]		Background-Total[5]	
Heptachlor epoxide	µg/L	2.00E-01				**3.90E-06**		3.90E-05		3.80E-03	l,q	3.80E-03	q	2.13E-05	c	2.30E-05	
Hexachlorobenzene	µg/L	1.00E+00		7.40E-04		**2.90E-05**		2.90E-04						5.03E-05	c	6.36E-05	
Hexachlorobutadiene	µg/L			5.00E+01		1.80E+00		1.80E+01									
Hexachlorocyclopentadiene	µg/L	5.00E+01				1.10E+02		1.10E+03									
Hexachloroethane	µg/L			8.74E+00		3.30E-01		3.30E+00									
Indeno(1,2,3-c,d)pyrene	µg/L					1.80E-03		1.80E-02						9.00E-04	n	3.18E-04	
Isophorone	µg/L			5.20E+05		9.60E+01		9.60E+02									
Lead	µg/L	1.50E+01	i							5.41E-01	c,d,m,p	5.41E-01	c,d	3.23E-02	c	6.93E-01	
LWG RA Sum DDD (Calculated U = 1/2)	µg/L													4.53E-05		9.83E-05	
LWG RA Sum DDE (Calculated U = 1/2)	µg/L													6.46E-05		1.92E-04	
LWG RA Sum DDT (Calculated U = 1/2)	µg/L			**2.40E-05**						1.00E-03	p			9.72E-05		3.13E-04	
LWG RA Total 17 PAH (Calculated U = 1/2)	µg/L			**3.11E-02**										5.30E-02		5.51E-02	
LWG RA Total 7 of 17 LPAH (Calculated U = 1/2)	µg/L													5.09E-02		5.11E-02	
LWG RA Total Chlordane (Calculated U = 1/2)	µg/L	2.00E+00		4.80E-04		8.10E-05		8.10E-04		4.30E-03	q	4.30E-03		4.80E-05		7.85E-05	
LWG RA Total cPAH TEQ (EPA 1993) (Calculated U = 1/2)	µg/L													1.02E-03		1.11E-03	
LWG RA Total DDx (Calculated U = 1/2)	µg/L									1.00E-03	q	1.00E-03		1.94E-04		5.93E-04	
LWG RA Total Dioxin/Furan TEQ 2005 (Mammal) (Calculated U = 1/2)	ng/L													4.36E-05		9.78E-05	
LWG RA Total Endosulfan (Calculated U = 1/2)	µg/L			1.59E+02						5.60E-02	q						
LWG RA Total PCB Congener (Calculated U = 1/2)	ng/L	5.00E+02		**7.90E-02**		**6.40E-03**	f	**6.40E-02**	f	1.40E+01	f,q	1.40E+01	f	1.96E-01		3.89E-01	
LWG RA Total PCB Congener TEQ 2005 (Mammal) (Calculated U = 1/2)	ng/L													4.50E-06		6.28E-06	
LWG RA Total Xylene (Calculated U = 1/2)	µg/L	1.00E+04															
Mecoprop (MCPP)	µg/L															1.40E+01	n
Mercury	µg/L	2.00E+00								**1.20E-02**	c,q	7.70E-01	c	4.00E-02	n	3.39E-02	
Methoxychlor	µg/L	4.00E+01								3.00E-02	q	3.00E-02	o				
Mirex	µg/L									1.00E-03	q	1.00E-03	o				
Naphthalene	µg/L													2.41E-02		2.42E-02	
Nickel	µg/L			1.00E+02		1.70E+02		4.60E+03		1.61E+01	c,d,m,p	1.61E+01	c,d	8.47E-01	c	1.66E+00	
Nitrobenzene	µg/L					6.90E+01		6.90E+02									
N-Nitrosodimethylamine	µg/L			1.60E+01		3.00E-01		3.00E+00									
N-Nitrosodi-N-propylamine	µg/L					5.10E-02		5.10E-01									
N-Nitrosodiphenylamine	µg/L			1.61E+01		6.00E-01		6.00E+00									
PCB-077	ng/L													2.44E-04		5.63E-04	
PCB-081	ng/L													7.50E-05	n	1.55E-05	
PCB-105	ng/L													1.32E-03		3.43E-03	
PCB-118	ng/L													3.44E-03		9.22E-03	
PCB-126	ng/L													3.75E-05	n	4.66E-05	
PCB-156/157	ng/L													2.34E-04	c	1.16E-03	
PCB-169	ng/L													3.18E-05		2.79E-05	
Pentachlorophenol	µg/L	1.00E+00				3.00E-01		3.00E+00		8.18E+00	f,p	8.18E+00	e				
Phenol	µg/L					8.60E+04		8.60E+05								3.00E-02	n
Pyrene	µg/L					4.00E+02		4.00E+03									
Selenium	µg/L	5.00E+01				4.20E+02		4.20E+03		3.50E+01	p	5.00E+00	g,j	3.32E-01		3.75E-01	
Silver	µg/L									1.20E-01	p			4.50E-03	n	1.00E-02	n

Table 5.5-3. Comparison of Potential ARAR Values to Site Surface Water Background Concentrations

Chemical	Units	Human Health Criteria[b]								Ecological Criteria[b]				Background Levels[r]			
		MCL[2]		Oregon-Fish Consumption (2010)[4]		Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[1]		Oregon-Chronic[3]		NRWQC-Chronic[1]		Background-Dissolved[5]		Background-Total[5]	
Styrene	µg/L	1.00E+02															
Tetrachloroethene (PCE)	µg/L	5.00E+00		8.85E+00		3.30E-01		3.30E+00									
Thallium	µg/L	2.00E+00		4.80E+01		4.70E-02		4.70E-01									
Toluene	µg/L	1.00E+03		4.24E+05		1.50E+03		1.50E+04									
Toxaphene	µg/L	3.00E+00		7.30E-04		2.80E-05		2.80E-04		2.00E-04	q	2.00E-04					
Tributyltin (ion)	µg/L											7.20E-02	o		n	7.00E-03	n
Trichloroethene (TCE)	µg/L	5.00E+00		8.07E+01		3.00E+00		3.00E+01									
Vinyl chloride	µg/L	2.00E+00		5.25E+02		2.40E-01		2.40E+00									
Zinc	µg/L					2.60E+03		2.60E+04		3.65E+01	c,d,m,p	3.65E+01	c,d	1.87E+00	c	6.38E+00	

Table 5.5-3. Comparison of Potential ARAR Values to Site Surface Water Background Concentrations

References:

1 EPA. 2009a. National Recommended Water Quality Criteria, 4304T (NRWQC).
2 EPA. 2009b. National Primary Drinking Water Regulations, EPA 816-F-09-004.
3 Oregon Administrative Rules, Division 41: Table 20 and Table 33A; as filed through February 12, 2010.
4 DEQ. 2010. Effective Water Quality Criteria for Human Health, Effective June 1, 2010 (superseded)
5 Integral et. al. 2011. Tables 7.4-4a and 7.4-4b of the Portland Harbor RI/FS Draft Final Remedial Investigation Report.
6 DEQ. 2011. Table 40: Human Health Water Quality Criteria for Toxic Pollutants, Effective October 17,2011

Sample result qualifiers:

J estimated value
T calculated
A result count is lower than expected
U non detect
R rejected
N Identity of the analyte is presumptive and not definitive.

Notes:

Sample results were compared to the listed screening levels per the methodology presented in Appendix C.
Bold indicates criterion is below background
Totals were calculated consistent with the approach used in Appendix F (BHHRA) of the Portland Harbor RI/FS Draft Final Remedial Investigation Report.
Sample results are from the Portland Harbor nature and extent database.
a This criterion applies at pH range of 6.5-9.0.
b All criteria applied on a totals basis unless otherwise indicated.
c This criterion is applies on a dissolved basis.
d This criterion is hardness dependant and is calculated based on a hardness of 25 ppm.
e This criterion is pH dependent and is calculated based on a pH of 7.2.
f This criterion applies to total PCBs, (e.g., the sum of all congener or all isomer or homolog or aroclor analyses).
g It is scientifically acceptable to use the conversion factor (.996-CMC or .992-CCC) that was used in the GLC to convert this to a value that is expressed in terms of dissolved metal.
h This criterion applies to inorganic arsenic only.
i The value shown is an action level. Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% percent of tap water samples exceed the action level, water systems must take additional steps.
j This criterion for selenium is dependant on the fractions of total selenium that are treated as selenite and selenate. This criterion is based 100% selenium as selenate.
k Calculated using the Biotic Ligand Model version 2.2.3. Parameters for model inputs are the geometric mean of the water quality results reported for USGS Monitoring Station 14211720 from 10/25/1974 to 3/2/2010, except for pH. PH is 7.2.
l This criterion is derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, this criterion should be divided by 2.
m Hardness function was not provided in Table 20, the function provided in the NRWQC (EPA 2009a) is used to calculate this criterion. This criterion is marked as to be applied on the dissolved basis consistent with EPA 2009.
n 95th percentile value used because a UPL could not be calculated
o Non-priority chemical NRWQC.
p DEQ Table 20 water quality criterion.
q DEQ Table 33a water quality criterion.
r Upper prediction limit (UPL) value used for background unless otherwise indicated. However the LWG believes that mean background concentration values are more appropriate for comparison to potential ARAR values.

Acronymns and abbreviations:

µg/L - Micrograms per liter
ARAR - Applicable or relevant and appropriate requirement
BHHRA - Baseline Human Health Risk Assessment
cm - centimeter
cPAH - Carcinogenic polycyclic aromatic hydrocarbon
DEQ - Oregon Department of Environmental Protection
EPA - Environmental Protection Agency
HH COC - Chemical of concern for the protection of Human Health
HPAH - Heavy polycyclic aromatic hydrocarbon
HQ - Hazard Quotient
LPAH - Light polycyclic aromatic hydrocarbon
MCL - Maximum contaminant level
mg/L - Milligrams per liter
NA - Not available
NC - Not calculated
ng/L- Nanograms per liter
NRWQC-Chronic - National Recommended Water Quality Criteria, freshwater chronic
NRWQC-Fish Consumption - National Recommended Water Quality Criteria for the protection of human health, fish consumption only.
Oregon Chronic - ODEQ freshwater aquatic chronic water quality criteria
Oregon-Fish Consumption - ODEQ effective water quality criteria for the protection of human healt, fish consumption only
PAH - Polycyclic aromatic hydrocarbon
PCB - Polychlorinated biphenol
SMA - Sediment management area
TEQ - Toxicity equivelency quotient
TZW - Transition zone water
USGS - United States Geological Survey
WS - Surface water
WSXAD - XAD column + filter surface water
WSXADC - XAD column surface water

Table 5.5-4. Evaluation of RGs for Human Health Cancer Risk >10^{-3} for Principal Threat High Concentration Analysis

Contaminant	RG Type	Scenario/ Receptor	Exposure Area	Cancer Risk > 10^{-3} (max value) for Contaminant	Meets Principal Threat High Concentration Criteria?
BaP	PRG	HH Clam Consumption, High Consumption Rate 18 g/day, 10^$^{-5}$	One river mile, shoreline only	NO ($4X10^{-4}$)	NO
BaPEq	RG	HH Tribal Fisher In-water Direct Contact 10^$^{-6}$ (cPAH)	Shoreline half river mile	NO ($2X10^{-4}$)	NO
BaPEq	RG	HH HF Fisher Beach Sediment Direct Contact 10^$^{-6}$ (cPAH)	Beach Type	NO ($3X10^{-6}$)	NO
Total PCBs	RG	HH Adult Fish Consumption - Small Mouth Bass - Low IR - 10^$^{-4}$	One river mile	NO ($1X10^{-3}$)	YES - Risk is equal to but not greater than ($1X10^{-3}$)
Total PCBs	Focused PRG	Background DW UPL[1]	Site-wide	NA	NA
2,3,4,7,8 PCDF (as surrogate for Total Dioxin/Furan TEQ)[2]	RG	HH Adult Fish Consumption, Small Mouth Bass Low IR, 10^$^{-4}$	One river mile	NO ($7X10^{-4}$)	NO
Total Chlordane	Focused PRG	HH Fish Consumption - Large Home Range Single Species High IR, Low BA 10^$^{-6}$	Study Area	NO ($3X10^{-6}$)	NO
Sum DDE	RG	HH adult fish consumption, 10-6 large home range fish, low BA, low IR	Study Area	NO ($3X10^{-6}$)	NO

1 - Because this PRG is not based on a risk level, a value meeting PTM risk levels cannot be defined. PCB PTM areas are determined using the human health smallmouth bass total PCBs RG.
2 - The RG is based on 2,3,4,7,8 PCDF but developed to be protective of total dioxin furan risks.

Table 5.5-5. TCLP Leachate Data

Sample ID / Chemical Name	Unit	TCLP Leachate Screening Level (mg/L)	LWM-TCLPC1	LWM-TCLPC7	LWM-TCLPC11A	LWM-TCLPC11B	LWM-TCLPC11C	LWM-TCLPC14A	LWM-TCLPC14B	LWM-TCLPC15	LWM-TCLPC18	LWM-TCLPC19	LWM-TCLPC23
1,1-Dichloroethene	µg/L	0.7	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloroethane	µg/L	0.5	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	µg/L	7.5	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	µg/L	400	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
2,4,6-Trichlorophenol	µg/L	2	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
2,4-D	µg/L	10	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2,4-Dinitrotoluene	µg/L	0.13	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
2-Methylphenol	µg/L	200	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methylphenol[1]	µg/L	200	10 U	10 U	10 U	53	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Arsenic	mg/L	5	0.2 UT	0.2 U	0.2 UT	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UT	0.2 U
Barium	mg/L	100	0.365 T	0.29	0.38 T	0.4	0.29	1.67	0.29	0.34	0.39	0.445 T	0.4
Benzene	µg/L	0.5	10 U	10 U	10 U	2900	13	10 U	10 U	10 U	10 U	10 U	10 U
Cadmium	mg/L	1	0.01 UT	0.01 U	0.01 UT	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 UT	0.01 U
Carbon tetrachloride	µg/L	0.5	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chlordane[2]	µg/L	0.03	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	µg/L	100	10 U	10 U	10 U	10 U	10 U	10 U	8900	10 U	10 U	10 U	10 U
Chloroform	µg/L	6	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chromium	mg/L	5	0.02 UT	0.02 U	0.02 UT	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 UT	0.02 U
cis-Chlordane	µg/L	0.03	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cresol[3]	µg/L	200	10 U	10 U	10 U	53	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Endrin	µg/L	0.02	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
gamma-Hexachlorocyclohexane	µg/L	0.4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Heptachlor	µg/L	0.008	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Heptachlor epoxide	µg/L	0.008	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Heptachlor and its epoxide	µg/L	0.008	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Hexachlorobenzene	µg/L	0.13	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	µg/L	0.5	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	µg/L	3	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 UJ
Lead	mg/L	5	0.1 UT	0.1 U	0.1 UT	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.13 T	0.1 U
Mercury	mg/L	0.2	0.0001 UT	0.0001 U	0.0001 UT	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 UT	0.0001 U
Methoxychlor	µg/L	10	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Methylethyl ketone	µg/L	200	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Nitrobenzene	µg/L	2	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Pentachlorophenol	µg/L	100	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Phenol	µg/L	NA	10 U	10 U	10 U	21	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Pyridine	µg/L	5	50 UJ	50 UJ	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 UJ
Selenium	mg/L	1	0.2 UT	0.2 U	0.2 UT	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UT	0.2 U
Silver	mg/L	5	0.02 UT	0.02 U	0.02 UJT	0.02 UJ	0.02 UJ	0.02 U	0.02 U	0.02 U	0.02 U	0.02 UT	0.02 U
Silvex	µg/L	1	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U
Tetrachloroethene	µg/L	0.7	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toxaphene	µg/L	0.5	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
trans-Chlordane	µg/L	0.03	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene	µg/L	0.5	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl chloride	µg/L	0.2	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U

Notes:

**Sums of non-detect values were performed by reporting the highest non-detect value in a given sum.

1 - 3-methylphenol coelutes with 4-methylphenol.

2 - Chlordane is the sum of cis-chlordane and trans-chlordane.

3 - Cresol is the sum of 2-methylphenol, 3-methylphenol, and 4-methylphenol.

Exceeds TCLP regulatory leachate screening level

Table 5.7-1. Transition Zone Water Potential ARARs Screening Results

			Human Health Criteria						Ecological Criteria				Number of Samples Exceeding Criterion[1]												
Contaminant	Units	Fraction	MCL[2]		Oregon-Fish Consumption (2010)[3]	Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[4]		Oregon-Chronic Aquatic[5]		NRWQC-Chronic Aquatic[4]		All Criteria	MCL	Maximum HQ - MCL	Oregon-Fish Consumption (2010)	Maximum HQ - Oregon-Fish Consumption (2010)	Oregon-Fish Consumption (2011)	Maximum HQ - Oregon-Fish Consumption (2011)	NRWQC-Fish Consumption	Maximum HQ - NRWQC-Fish Consumption	Oregon-Chronic Aquatic	Maximum HQ - Oregon-Chronic Aquatic	NRWQC-Chronic Aquatic	Maximum HQ - NRWQC-Chronic Aquatic
1,1,1-Trichloroethane	µg/L	Total	2 00E+02											0/162	0/162	--										
1,1,2,2-Tetrachloroethane	µg/L	Total			1 07E+01	4 00E-01		4 00E+00						0/148			0/148	--	0/148	--	0/148	--				
1,1,2-Trichloroethane	µg/L	Total	5 00E+00		4 18E+01	1 60E+00		1 60E+01						5/233	5/162	8 00E+01	1/148	8 61E+00	3/148	2 25E+02	1/148	2 25E+01				
1,1-Dichloroethene	µg/L	Total	7 00E+00			7 10E+02		7 10E+03						7/233	7/162	4 04E+01			0/148	--	0/148	--				
1,2,4-Trichlorobenzene	µg/L	Total	7 00E+01			7 00E+00		7 00E+01						0/225	0/159	--			0/140	--	0/140	--				
1,2-Dibromo-3-chloropropane	µg/L	Total	2 00E-01											0/95	0/95	--										
1,2-Dibromoethane (Ethylene dibromide)	µg/L	Total	5 00E-02											0/162	0/162	--										
1,2-Dichlorobenzene	µg/L	Total	6 00E+02			1 30E+02		1 30E+03						2/225	1/159	1 07E+00			2/140	4 92E+00	0/140	--				
1,2-Dichloroethane	µg/L	Total	5 00E+00		2 43E+02	3 70E+00		3 70E+01						3/233	3/162	1 54E+02	1/148	3 17E+00	2/148	2 08E+02	2/148	2 08E+01				
1,2-Dichloroethene, cis-	µg/L	Total	7 00E+01											27/138	27/138	8 20E+03										
1,2-Dichloroethene, trans-	µg/L	Total	1 00E+02			1 00E+03		1 00E+04						2/233	2/162	1 76E+01			0/148	--	0/148	--				
1,2-Dichloropropane	µg/L	Total	5 00E+00			1 50E+00		1 50E+01						2/233	2/162	1 22E+01			2/148	4 07E+01	1/148	4 07E+00				
1,3-Dichlorobenzene	µg/L	Total				9 60E+01		9 60E+02						0/158					0/140	--	0/140	--				
1,4-Dichlorobenzene	µg/L	Total	7 50E+01			1 90E+01		1 90E+02						3/221	3/150	3 20E+00			2/140	1 26E+01	1/140	1 26E+00				
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	µg/L	Filtered	3 00E-05		1 40E-08	5 10E-10		5 10E-09						0/3	0/3	--	0/3	--	0/3	--	0/3	--				
(TCDD)	µg/L	Total	3 00E-05		1 40E-08	5 10E-10		5 10E-09						0/3	0/3	--	0/3	--	0/3	--	0/3	--				
2,4,5-TP (Silvex)	µg/L	Filtered	5 00E+01											0/5	0/5	--										
2,4,5-TP (Silvex)	µg/L	Total	5 00E+01											0/7	0/7	--										
2,4-D (2,4-Dichlorophenoxyacetic acid)	µg/L	Filtered	7 00E+01											0/5	0/5	--										
2,4-D (2,4-Dichlorophenoxyacetic acid)	µg/L	Total	7 00E+01											0/7	0/7	--										
4,4'-DDD (p,p'-DDD)	µg/L	Filtered				3 10E-05		3 10E-04						1/8					1/8	8 06E+02	1/8	8 06E+01				
4,4'-DDD (p,p'-DDD)	µg/L	Total				3 10E-05		3 10E-04						8/18					8/18	4 19E+04	8/18	4 19E+03				
4,4'-DDE (p,p'-DDE)	µg/L	Filtered				2 20E-05		2 20E-04						1/8					1/8	3 82E+02	1/8	3 82E+01				
4,4'-DDE (p,p'-DDE)	µg/L	Total				2 20E-05		2 20E-04						7/18					7/18	1 09E+04	7/18	1 09E+03				
4,4'-DDT (p,p'-DDT)	µg/L	Filtered				2 20E-05		2 20E-04						0/8					0/8	--	0/8	--				
4,4'-DDT (p,p'-DDT)	µg/L	Total				2 20E-05		2 20E-04						8/18					8/18	8 18E+04	8/18	8 18E+03				
Acenaphthene	µg/L	Filtered				9 90E+01		9 90E+02						0/37					0/37	--	0/37	--				
Acenaphthene	µg/L	Total				9 90E+01		9 90E+02						8/76					8/76	4 03E+00	0/76	--				
Acrolein	µg/L	Total			7 80E+02	9 30E-01		9 00E+00				3 00E+00		1/5			0/5	--	1/5	1 94E+00	0/5	--			0/5	--
Acrylonitrile	µg/L	Total			6 50E-01	2 50E-02		2 50E-01						0/88			0/88	--	0/88	--	0/88	--				
Aluminum	µg/L	Filtered										8 70E+01	b,p	5/55											5/55	3 57E+00
Aluminum	µg/L	Total										8 70E+01	b,p	46/93											46/93	4 71E+02
Anthracene	µg/L	Filtered				4 00E+03		4 00E+04						0/37					0/37	--	0/37	--				
Anthracene	µg/L	Total				4 00E+03		4 00E+04						0/76					0/76	--	0/76	--				
Antimony	µg/L	Filtered	6 00E+00		4 50E+04	6 40E+01		6 40E+02						0/58	0/18	--	0/55	--	0/55	--	0/55	--				
Antimony	µg/L	Total	6 00E+00		4 50E+04	6 40E+01		6 40E+02						1/118	1/55	4 20E+00	0/106	--	0/106	--	0/106	--				
Arsenic	µg/L	Filtered	1 00E+01		1 75E-02	2 10E+00	h	1 40E-01	h			1 50E+02	c	54/61	5/18	2 70E+00	53/58	4 39E+03	46/58	3 66E+01	53/58	5 49E+02			0/58	--
Arsenic	µg/L	Total	1 00E+01		1 75E-02	2 10E+00	h	1 40E-01	h					97/125	11/55	3 76E+00	95/113	2 93E+03	77/113	2 44E+01	95/113	3 66E+02				
Barium	µg/L	Filtered	2 00E+03											1/18	1/18	1 06E+00										
Barium	µg/L	Total	2 00E+03											2/42	2/42	1 34E+00										
Benzene	µg/L	Total	5 00E+00		4 00E+01	1 40E+00		5 10E+01						86/236	61/162	1 10E+03	14/151	9 60E+01	48/151	2 74E+03	12/151	7 53E+01				
Benzo(a)anthracene	µg/L	Filtered				1 80E-03		1 80E-02						8/37					8/37	1 22E+02	2/37	1 22E+01				
Benzo(a)anthracene	µg/L	Total				1 80E-03		1 80E-02						43/76					43/76	1 79E+04	35/76	1 79E+03				
Benzo(a)pyrene	µg/L	Filtered	2 00E-01			1 80E-03		1 80E-02						4/37	0/2	--			4/37	6 11E+01	2/37	6 11E+00				
Benzo(a)pyrene	µg/L	Total	2 00E-01			1 80E-03		1 80E-02						47/92	21/39	3 75E+02			38/76	2 10E+04	33/76	2 10E+03				
Benzo(b)fluoranthene	µg/L	Filtered				1 80E-03		1 80E-02						4/37					4/37	4 83E+01	3/37	4 83E+00				
Benzo(b)fluoranthene	µg/L	Total				1 80E-03		1 80E-02						31/76					31/76	1 85E+04	28/76	1 85E+03				
Benzo(k)fluoranthene	µg/L	Filtered				1 80E-03		1 80E-02						4/37					4/37	5 56E+01	3/37	5 56E+00				
Benzo(k)fluoranthene	µg/L	Total				1 80E-03		1 80E-02						25/76					25/76	5 00E+03	23/76	5 00E+02				
Beryllium	µg/L	Filtered	4 00E+00											0/18	0/18	--										
Beryllium	µg/L	Total	4 00E+00											0/42	0/42	--										
Bromodichloromethane	µg/L	Total				1 70E+00		1 70E+01						2/148					2/148	1 71E+02	1/148	1 71E+01				
Bromoform (Tribromomethane)	µg/L	Total				1 40E+01		1 40E+02						0/148					0/148	--	0/148	--				
Bromomethane (Methyl Bromide)	µg/L	Total				1 50E+02		1 50E+03						0/148					0/148	--	0/148	--				
Cadmium	µg/L	Filtered	5 00E+00							9 37E-02	c,d,o,q	9 37E-02	c,d	10/58	0/18	--							10/55	5 55E+00	10/55	5 55E+00
Cadmium	µg/L	Total	5 00E+00											1/42	1/42	7 20E+00										

Table 5.7-1. Transition Zone Water Potential ARARs Screening Results

			Human Health Criteria							Ecological Criteria				Number of Samples Exceeding Criterion[1]												
Contaminant	Units	Fraction	MCL[2]		Oregon-Fish Consumption (2010)[3]	Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[4]		Oregon-Chronic Aquatic[5]		NRWQC-Chronic Aquatic[4]		All Criteria	MCL	Maximum HQ - MCL	Oregon-Fish Consumption (2010)	Maximum HQ - Oregon-Fish Consumption (2010)	Oregon-Fish Consumption (2011)	Maximum HQ - Oregon-Fish Consumption (2011)	NRWQC-Fish Consumption	Maximum HQ - NRWQC-Fish Consumption	Oregon-Chronic Aquatic	Maximum HQ - Oregon-Chronic Aquatic	NRWQC-Chronic Aquatic	Maximum HQ - NRWQC-Chronic Aquatic
Carbon tetrachloride (Tetrachloromethane)	µg/L	Total	5 00E+00		6 94E+00	1 60E-01		1 60E+00						0/233	0/162	--	0/148	--	0/148	--	0/148	--				
Chlorobenzene	µg/L	Total	1 00E+02			1 60E+02		1 60E+03						10/233	9/162	3 00E+02			5/148	7 50E+01	2/148	7 50E+00				
Chloroform	µg/L	Total			1 57E+01	1 10E+03		4 70E+02						7/148			7/148	4 90E+04	3/148	7 00E+02	4/148	1 64E+03				
Chromium	µg/L	Filtered	1 00E+02											0/22	0/22	--										
Chromium	µg/L	Total	1 00E+02											4/62	4/62	1 47E+00										
Chrysene	µg/L	Filtered				1 80E-03		1 80E-02						10/37					10/37	1 72E+02	4/37	1 72E+01				
Chrysene	µg/L	Total				1 80E-03		1 80E-02						42/76					42/76	1 92E+04	35/76	1 92E+03				
Copper	µg/L	Filtered	1 30E+03	i						2 74E+00	c,d,o,q	2 74E+00	c,l	1/51	0/10	--							Jan-48	1 33E+00	1/48	1 33E+00
Copper	µg/L	Total	1 30E+03	i										0/40	0/40	--										
Cyanide	µg/L	Total				1 30E+02		1 40E-04						15/38					13/34	1 78E+02	12/34	1 65E+02				
Cyanide, free	µg/L	Total	2 00E-04							5 20E-06	r	5 20E-06		0/13	0/13	--							0/13	--		--
Dibenzo(a,h)anthracene	µg/L	Filtered				1 80E-03		1 80E-02						1/37					1/37	1 33E+00	0/37	--				
Dibenzo(a,h)anthracene	µg/L	Total				1 80E-03		1 80E-02						29/76					29/76	2 06E+03	15/76	2 06E+02				
Dibromochloromethane	µg/L	Total				1 30E+00		1 30E+01						0/148					0/148	--	0/148	--				
Dichloromethane (Methylene chloride)	µg/L	Total	5 00E+00			5 90E+01		5 90E+02						12/233	12/162	1 04E+05			3/148	8 81E+03	3/148	8 81E+02				
Ethylbenzene	µg/L	Total	7 00E+02		3 28E+03	2 10E+02		2 10E+03						3/236	0/162	--	0/151	--	3/151	1 98E+00	0/151	--				
Fluoranthene	µg/L	Filtered			5 40E+01	1 40E+01		1 40E+02						0/37			0/37	--	0/37	--	0/37	--				
Fluoranthene	µg/L	Total			5 40E+01	1 40E+01		1 40E+02						8/76			2/76	1 96E+00	8/76	7 57E+00	0/76					
Fluorene	µg/L	Filtered				5 30E+02		5 30E+03						0/37					0/37	--	0/37	--				
Fluorene	µg/L	Total				5 30E+02		5 30E+03						0/76					0/76	--	0/76	--				
Hexachlorobutadiene	µg/L	Total			5 00E+01	1 80E+00		1 80E+01						0/140			0/140	--	0/140	--	0/140	--				
Indeno(1,2,3-c,d)pyrene	µg/L	Filtered				1 80E-03		1 80E-02						3/37					3/37	1 28E+01	2/37	1 28E+00				
Indeno(1,2,3-c,d)pyrene	µg/L	Total				1 80E-03		1 80E-02						40/76					40/76	9 39E+03	34/76	9 39E+02				
Iron	µg/L	Filtered								1 00E+03	c,r	1 00E+03	p	47/55									47/55	1 22E+02	47/55	1 22E+02
Iron	µg/L	Total										1 00E+03		101/106											101/106	2 52E+02
Lead	µg/L	Filtered	1 50E+01	i						5 41E-01	c,d,o,q	5 41E-01	c,d	4/61	0/18	--							4/58	2 98E+00	4/58	2 98E+00
Lead	µg/L	Total	1 50E+01	i										9/55	9/55	8 73E+00										
LWG RA Sum DDT (Calculated U = 1/2)	µg/L	Filtered			2 40E-05					1 00E-03	q			1/8			1/8	4 17E+02					1/8	1 00E+01		
LWG RA Sum DDT (Calculated U = 1/2)	µg/L	Total			2 40E-05					1 00E-03	q			9/18			9/18	7 92E+04					9/18	1 90E+03		
LWG RA Total 17 PAH (Calculated U = 1/2)	µg/L	Filtered			3 11E-02									35/37			35/37	3 86E+04								
LWG RA Total 17 PAH (Calculated U = 1/2)	µg/L	Total			3 11E-02									73/76			73/76	4 47E+04								
LWG RA Total DDx (Calculated U = 1/2)	µg/L	Filtered								1 00E-03	r	1 00E-03		5/8									5/8	1 60E+02	5/8	1 60E+02
LWG RA Total DDx (Calculated U = 1/2)	µg/L	Total								1 00E-03	r	1 00E-03		12/18									12/18	3 10E+03	12/18	3 10E+03
LWG RA Total Xylene (Calculated U = 1/2)	µg/L	Total	1 00E+04											0/162	0/162	--										
Manganese	µg/L	Filtered			1 00E+02			1 00E+02	p					63/67			63/67	3 35E+02			63/67	3 35E+02				
Manganese	µg/L	Total			1 00E+02			1 00E+02	p					121/122			121/122	6 62E+02			121/122	6 62E+02				
Mercury	µg/L	Filtered	2 00E+00							1 20E-02	c,r	7 70E-01	c	5/58	0/18	--							5/55	3 00E+01	0/55	--
Mercury	µg/L	Total	2 00E+00											0/42	0/42	--										
Nickel	µg/L	Filtered			1 00E+02	1 70E+02		4 60E+03		1 61E+01	c,d,o,q	1 61E+01	c,d	3/55			0/55	--	0/55	--	0/55	--	3/55	1 58E+00	3/55	1 58E+00
Nickel	µg/L	Total			1 00E+02	1 70E+02		4 60E+03						1/106			1/106	1 42E+00	0/106	--	0/106	--				
Nitrate as nitrogen	µg/L	Total	1 00E-02	j										0/49	0/49	--										
Nitrite as nitrogen	µg/L	Total	1 00E-03	j										0/49	0/49	--										
Pyrene	µg/L	Filtered				4 00E+02		4 00E+03						0/37					0/37	--	0/37	--				
Pyrene	µg/L	Total				4 00E+02		4 00E+03						0/76					0/76	--	0/76	--				
Selenium	µg/L	Filtered	5 00E+01			4 20E+02		4 20E+03		3 50E+01	q	5 00E+00	k	0/58	0/18	--			0/55	--	0/55	--	0/55	--	0/55	--
Selenium	µg/L	Total	5 00E+01			4 20E+02		4 20E+03		3 50E+01	q	5 00E+00	k	0/118	0/55	--			0/106	--	0/106	--	0/106	--	0/106	--
Silver	µg/L	Filtered								1 20E-01	q			0/55									0/55	--		
Silver	µg/L	Total								1 20E-01	q			13/102									13/102	2 17E+01		
Styrene	µg/L	Total	1 00E+02											0/162	0/162	--										
Tetrachloroethene (PCE)	µg/L	Total	5 00E+00		8 85E+00	3 30E-01		3 30E+00						10/233	6/162	2 40E+03	3/148	1 58E+02	7/148	4 24E+03	3/148	4 24E+02				
Thallium	µg/L	Filtered	2 00E+00		4 80E+01	4 70E-02		4 70E-01						1/58	0/18	--	0/55	--	1/55	3 64E+00	0/55	--				
Thallium	µg/L	Total	2 00E+00		4 80E+01	4 70E-02		4 70E-01						8/105	0/42	--	0/93	--	8/93	1 39E+01	1/93	1 39E+00				
Toluene	µg/L	Total	1 00E+03		4 24E+05	1 50E+03		1 50E+04						0/236	0/162	--	0/151	--	0/151	--	0/151	--				
Trichloroethene (TCE)	µg/L	Total	5 00E+00		8 07E+01	3 00E+00		3 00E+01						20/233	19/162	1 17E+05	2/148	1 10E+03	10/148	2 95E+04	6/148	2 95E+03				

Table 5.7-1. Transition Zone Water Potential ARARs Screening Results

Contaminant	Units	Fraction	Human Health Criteria: MCL[2]		Oregon-Fish Consumption (2010)[3]	Oregon-Fish Consumption (2011)[6]		NRWQC-Fish Consumption[4]		Ecological Criteria: Oregon-Chronic Aquatic[5]		NRWQC-Chronic Aquatic[4]	
Vinyl chloride	µg/L	Total	2 00E+00		5 25E+02	2 40E-01		2 40E+00					
Zinc	µg/L	Filtered				2 60E+03		2 60E+04		3 65E+01	c,d,o,q	3 65E+01	c,d
Zinc	µg/L	Total				2 60E+03		2 60E+04					

Number of Samples Exceeding Criterion[1]

Contaminant	Units	Fraction	All Criteria	MCL	Maximum HQ - MCL	Oregon-Fish Consumption (2010)	Maximum HQ - Oregon-Fish Consumption (2010)	Oregon-Fish Consumption (2011)	Maximum HQ - Oregon-Fish Consumption (2011)	NRWQC-Fish Consumption	Maximum HQ - NRWQC-Fish Consumption	Oregon-Chronic Aquatic	Maximum HQ - Oregon-Chronic Aquatic	NRWQC-Chronic Aquatic	Maximum HQ - NRWQC-Chronic Aquatic
Vinyl chloride	µg/L	Total	80/233	52/162	1 45E+04	5/148	8 19E+00	50/148	1 79E+04	22/148	1 79E+03				
Zinc	µg/L	Filtered	1/58					0/58	--	0/58	--	1/58	1 44E+01	1/58	1 44E+01
Zinc	µg/L	Total	0/113					0/113	--	0/113	--				

References:

1 - These columns list a ratio describe the number of samples exceeding each criterion over the number of samples screened against criterion (e g , "0/62" indicates that 62 samples were screened against the criterion and, of these, 0 samples exceeded the criterion) The samples screened are listed in the FS water database and were screened following the approach described in Appendix C
2 - USEPA 2009 National Primary Drinking Water Regulations, EPA 816-F-09-004 (MCLs)
3 - DEQ 2010 Effective Water Quality Criteria for Human Health, Effective June 1, 2010 (superseded)
4 - USEPA 2009 National Recommended Water Quality Criteria, 4304T (NRWQC)
5 - Oregon Administrative Rules, Division 41: Table 20 and Table 33A; as filed through February 12, 2010
6 - DEQ 2011 Table 40: Human Health Water Quality Criteria for Toxic Pollutants, Effective October 17,2011

Notes:

a - All criteria are expressed in terms of total analyte in the water column, but appled to results expressed as dissolved or total analyte unless otherwise specified (note c)
b - This criterion applies at pH range of 6 5-9 0
c - This criterion is expressed in terms of dissolved metal in the water column and is only applied to results expressed as dissolved metal
d - This criterion is hardness dependant and is calculated based on a hardness of 25 mg/liter
e - This criterion is applied to free cyanide
f - This criterion is pH dependent and is calculated based on a pH of 7 2
g - This criterion applies to total PCBS, (e g , the sum of all congener or all isomer or homolog or aroclor analyses)
h - This criterion applies to inorganic arsenic only
i - The value shown is an action level Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water If more than 10% percent of tap water samples exceed the action level, water systems must take additional steps
j - This criterion is measured as nitrogen
k - This criterion for selenium is dependant on the fractions of total selenium that are treated as selenite and selenate This criterion is based 100% selenium as selenate
l - Calculated using the Biotic Ligand Model version 2 2 3 Parameters for model inputs are the geometric mean of the water quality results reported for USGS Monitoring Station 14211720 from 10/25/1974 to 3/2/2010, except for pH PH is 7 2
m - This criterion is applied as the sum of alpha- and beta-endosulfan
n - This criterion is the minimum (i e , the criterion should not be below this value in order to protect aquatic life)
o - Hardness function was not provided in Table 20, the function provided in the NRWQC (EPA 2009) is used to calculate this criterion This criterion is marked as to be applied on the dissolved basis consistent with the NRWQC
p - Non-priority chemical NRWQC
q - EQ Table 20 water quality criterion
r - ODEQ Table 33a water quality criterion

Acronymns and abbreviations:

cPAH - Carcenogenic polycyclic aromatic hydrocarbon
MCL - Maximum contaminate level
PAH - Polycyclic aromatic hydrocarbon
PCB - Polychlorinated biphenol
USGS - United States Geological Survey
DEQ - Oregon Department of Environmental Quality
EPA - United States Environmental Protection Agency
DDx - Sum of DDT and its metabolites
-- - None of the samples screened exceeded this criterion

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
LW2-C009	1A	1	5	5	5	5
LW2-C011	1A	1	4	4	11	11
LW2-C011-2	1A	4	4	8	8	8
LW2-C015	1A	4	4	4	4	4
LW2-C019	1A	9	9	9	9	9
LW2-C019-2	1A	5	5	5	5	5
LW2-C020	1A	8	8	8	8	8
LW2-C022	1A	--	--	--	--	11
LW2-C025	1A	1	1	1	1	1
LW2-C025-2	1A	1	1	1	1	5
LW2-C027	1A	1	1	1	1	5
LW2-C034	1A	--	--	--	--	1
LW2-C038	1A	--	--	--	1	1
LW3-C600	1A	--	1	1	9	9
LW3-C602	1A	--	--	1	1	10
LW3-C604	1A	--	--	1	1	11
LW3-C605	1A	1	1	1	1	11
LW3-C608	1A	--	--	--	1	1
LW3-C609	1A	--	--	1	1	9
LW3-DC01-1	1A	--	--	--	1	7
LW3-DC01-2	1A	--	--	--	6	8
LWM-C1	1A	1	1	1	1	12
LWM-TCLP1	1A	1	1	1	1	1
WLCACF05C123	1A	--	--	--	1	1
WLCOSJ00RB13	1A	2	2	2	2	2
LW2-C067	3	--	--	--	--	13
LW2-C073	3	--	--	--	--	10
LW2-C078	3	--	--	--	--	1
LW2-C079	3	--	--	--	1	1
LW2-C080	3	--	--	1	1	1
LW2-C082	3	--	--	--	1	1
LW2-C082-2	3	--	--	--	1	1
LW2-C083	3	--	--	--	6	6
LW2-C084	3	1	1	1	2	2
LW2-C087	3	--	--	--	4	4
LW2-C088	3	--	--	--	--	5
LW2-C089	3	3	3	3	3	3
LW2-C090	3	--	1	1	4	4
LW2-C091	3	1	1	1	7	7
LW2-C092	3	7	7	7	7	9
LW2-C094	3	2	2	2	2	2
LW2-C096	3	--	--	--	5	5
LW2-C099	3	--	--	--	10	10
LW2-C103	3	--	--	--	--	12
LW2-C106	3	--	--	--	15	15
LW2-C109	3	--	--	--	12	12
LW2-C111	3	1	1	1	5	8
LW2-C111-2	3	--	--	1	14	14
LW2-C112	3	1	1	1	9	14

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
LW3-C614	3	--	--	--	1	11
LWM-C3	3	13	13	13	13	13
WLCDRD05VC005	3	--	--	--	--	1
WLCDRD05VC007	3	--	--	1	1	7
WLCITG08SED01	3	5	5	7	7	7
WLCITG08SED02	3	9	9	9	9	9
WLCITG08SED10	3	1	1	1	1	3
WLCITG08SED11	3	3	3	3	3	3
WLCITG08SED14	3	4	4	4	4	4
WLCT0I98B401C1	3	--	--	--	3	3
WLCT4C04VC01	3	--	--	1	1	3
WLCT4C04VC02	3	--	--	--	--	3
WR-WSI98SD013	3	--	--	--	1	1
LW2-C105	4	--	--	--	1	1
LW2-C121	4	--	--	--	--	8
LW2-C121	5	--	1	1	8	8
LW2-C122	5	--	1	1	6	6
LW2-C127	5	--	--	--	--	6
LW2-C130	5	--	--	--	--	2
LW2-C522	5	--	--	--	--	3
LW3-C626	5	--	--	--	--	17
WLCDRD05VC010	5	--	--	--	--	8
WLCDRD05VC012	5	--	1	1	1	6
WLCDRD05VC014	5	--	1	1	1	7
WLCGXV99S1	5	--	1	1	1	1
WLCGXV99S3	5	--	--	--	--	1
WR-WSI98SD017	5	--	3	3	3	3
LW3-C630	6	--	--	--	--	1
WLCDRD05VC011	6	--	--	--	--	1
WLCT4C04PS12	6	--	--	1	1	1
WLCT4C04PS17	6	--	--	--	--	1
WLCT4C04PS20	6	--	--	--	--	17
WLCT4C04PS21	6	--	--	--	--	1
WLCT4C04PS22	6	--	--	1	1	1
WLCT4C04PS28	6	--	--	1	1	1
WLCT4C04PS31	6	--	--	--	--	1
WLCT4C04PS32	6	--	--	--	1	1
WLCT4C04UP10	6	--	--	1	1	1
WLCT4C04VC05	6	--	--	--	1	3
WLCT4C04VC06	6	--	--	--	1	1
WLCT4C04VC07	6	--	--	--	--	5
WLCT4C04VC08	6	--	--	--	--	1
WLCT4C04VC09	6	--	--	--	5	5
WLCT4C04VC10	6	--	--	--	--	1
WLCT4C04VC11	6	--	--	--	1	5
WLCT4C04VC12	6	--	--	1	1	5
WLCT4C04VC13	6	--	1	1	1	1
WLCT4C04VC14	6	--	--	--	1	7
WLCT4C04VC15	6	--	--	--	3	3

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
WLCT4C04VC16	6	--	--	--	1	1
WLCT4C04VC18	6	--	--	--	--	5
WLCT4C04VC19	6	--	--	3	3	5
WLCT4C04VC20	6	--	--	--	--	13
WLCT4C04VC21	6	--	--	--	--	13
WLCT4C04VC22	6	11	11	11	11	11
WLCT4C04VC23	6	--	1	1	1	1
WLCT4C04VC26	6	--	--	--	--	7
WLCT4C04VC27	6	--	--	--	--	1
WLCT4C04VC28	6	--	--	1	1	1
WLCT4C04VC29	6	3	3	3	5	5
WLCT4C04VC31	6	--	--	--	--	9
WLCT4C04VC32	6	--	1	5	5	5
WLCT4G06T4B41106	6	10	10	10	10	10
WLCT4G06T4B41402	6	--	--	--	1	1
WLCT4G06T4B41403	6	--	--	--	--	2
WLCT4G06T4B41404	6	--	--	--	--	1
WLCT4G06T4PI09	6	--	--	--	--	2
WLCT4G06T4S301	6	9	9	9	9	9
WLCT4G06T4S302	6	6	6	6	6	6
WLCT4G06T4S303	6	--	2	2	2	2
WLCT4G06T4S305	6	8	8	8	8	8
WLCT4G06T4S306	6	--	1	1	1	1
WLCT4G06T4S307	6	--	--	--	4	4
WLCT4G06T4S308	6	1	1	1	2	2
WLCT4J98HCS07	6	4	4	4	4	4
WLCT4J98HCS11	6	4	4	4	4	4
WLCT4J98HCS13	6	--	--	1	1	1
WLCT4J98HCS22	6	--	--	1	1	1
WLCT4J98HCS27	6	--	--	--	3	3
WLCT4J98HCS32	6	--	--	--	1	1
WLCT4J98HCS39	6	--	--	--	1	1
WLCT4J98HCS42	6	4	4	4	4	4
WR-WSI98SD023	6	--	--	--	1	1
WR-WSI98SD031	6	3	3	3	3	3
LW2-C138	7	--	--	--	--	1
LW2-C139	7	--	--	--	--	1
LW2-C142	7	--	--	--	--	9
LW2-NA1A	7	--	--	--	--	1
LW2-NA1B	7	--	--	--	--	3
WLCDRD05VC024	7	--	--	--	--	1
WR-WSI98SD035	7	--	--	--	--	3
LW2-C148	8	--	--	--	--	8
LW2-C157	8	--	--	--	--	5
LW2-C158	8	--	--	--	--	10
LW2-C160	8	--	--	--	1	1
LW2-C163	8	--	--	--	--	1
LW2-C163-2	8	--	--	--	--	1
LWM-C6	8	--	--	--	--	1

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
WLCBPE06SGP06	8	--	--	--	--	1
WLCBPE06SGP10	8	--	--	--	--	1
WLCBPE06SGP13	8	--	--	--	--	1
WLCBPE06SGP14	8	--	--	--	4	4
WLCBPE06SGP15	8	--	--	--	--	4
WLCBPE06SGP16	8	--	--	--	--	4
LW2-C176	9D	--	1	1	1	1
LW2-C179	9D	11	11	11	11	11
LW2-C182	9D	--	--	--	11	11
LW2-C184	9D	--	--	--	9	9
LW2-C185	9D	--	--	--	8	8
LW2-C187	9D	--	--	6	6	6
LW2-C210	9D	--	1	1	1	1
LW2-C213	9D	--	--	1	--	1
LW2-C220	9D	1	1	1	1	1
LW2-C221	9D	5	5	5	5	5
LW2-C227	9D	--	--	--	--	6
LW2-C228	9D	--	--	--	--	5
LW2-C231	9D	--	--	--	--	5
LW2-C240	9D	--	--	--	10	10
LW2-C245	9D	--	--	--	--	6
LW2-C252	9D	--	--	--	1	8
LW2-C263	9D	12	12	12	12	12
LW2-C527	9D	--	16	16	16	16
LW2-C528	9D	--	13	13	13	13
LW2-C529	9D	--	--	--	--	18
LW2-C530	9D	--	--	--	18	18
LW2-C531	9D	--	--	--	12	12
LW3-C640	9D	--	--	1	1	1
LW3-C645	9D	1	1	1	1	1
WLCDRD05VC036	9D	--	--	--	--	1
WLCMFH00SD04	9D	--	--	--	1	2
WLCMFH00SD05	9D	--	--	--	2	2
WLCMFH00SD06	9D	--	--	--	--	1
WLCMRD08SDDA17SB	9D	7	7	7	7	7
WLCMRD08SDDA18SB	9D	--	--	--	--	11
WLCMRD08SDDA19SB	9D	--	--	--	--	14
WLCMRD08SDDB21SB	9D	--	--	--	--	1
WLCMRD08SDDB22SB	9D	1	1	1	11	11
WLCMRD08SDDC23SB	9D	--	17	17	17	17
WLCMRD08SDDC24SB	9D	15	15	15	15	15
WLCMRD08SDDC25SB	9D	12	12	12	12	12
WLCMRD08SDOF28SB	9D	--	--	--	--	1
WLCMRD08SDUD1SB	9D	20	20	20	20	20
WLCMRD08SDUD26SB	9D	--	1	1	1	6
WLCMRD08SDUD27SB	9D	6	6	6	6	6
WLCMRD08SDUD2SB	9D	1	1	1	1	1
WLCMRI02CS001	9D	--	3	3	3	3
WLCMRI02CS002	9D	--	--	--	--	3

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
WLCMRI02CS003	9D	--	--	--	3	3
WR-WSI98SD048	9D	--	--	--	--	3
WR-WSI98SD055C	9D	--	--	--	--	3
WR-WSI98SD057	9D	--	--	--	--	3
LW2-C252	9U	1	1	1	1	8
LW2-C258	9U	10	10	10	10	10
LW2-C263	9U	12	12	12	12	12
LW2-C264	9U	7	7	7	7	7
LW2-C269	9U	18	18	18	18	18
LW2-C270	9U	6	6	6	6	6
LW2-C273	9U	12	12	12	12	12
LW2-C283	9U	8	8	8	8	8
LW2-C289	9U	7	7	7	7	7
LW2-C299	9U	8	8	8	8	8
LW2-C301	9U	17	17	17	17	17
LW2-C302	9U	11	11	11	11	11
LW2-C305	9U	--	5	5	7	7
LW2-C305-2	9U	--	8	8	8	8
LW2-C311	9U	5	5	5	5	17
LW2-C312	9U	--	--	--	5	5
LW2-C521	9U	9	9	9	9	9
LW2-C525	9U	11	11	11	11	11
LW3-C662	9U	11	11	11	11	11
LWM-C11	9U	13	13	13	13	13
LWM-TCLP11A	9U	1	1	1	1	1
LWM-TCLP11B	9U	1	1	1	1	1
LWM-TCLP11C	9U	1	1	1	1	1
WLCDRD05VC052	9U	3	3	3	3	3
WLCDRD05VC054	9U	--	7	7	7	7
WLCDRD05VC056	9U	--	--	--	--	9
WLCGSD01AN0101	9U	1	1	1	1	1
WLCGSD01AN0102	9U	1	1	1	1	1
WLCGSD01AN0103	9U	1	1	1	1	1
WLCGSD01AN0105	9U	--	--	--	--	1
WLCGSD01AN0205	9U	1	1	1	1	1
WLCGSG04RAA17	9U	20	20	20	20	20
WLCGSG07GSB2	9U	7	7	7	7	15
WLCGSG07GSB5	9U	7	7	7	7	7
WLCGSG07GSB7	9U	15	15	15	15	15
WLCGSG07GSC2	9U	7	7	7	7	7
WLCGSG07GSC5	9U	1	1	1	1	1
WLCGSG07GSC7	9U	7	7	7	7	7
WLCGSJ06GS04	9U	1	1	1	1	1
WLCGSJ06GS05	9U	11	11	11	11	11
WLCGSJ06GS06	9U	11	11	11	11	23
WLCGSJ06GS07	9U	27	27	27	27	27
WLCGSJ06GS08	9U	1	1	1	1	1
WLCGSJ06GS09	9U	27	27	27	27	27
WLCMRD08SDDA17SB	9U	7	7	7	7	7

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
WLCMRD08SDUD1SB	9U	20	20	20	20	20
WLCMRD08SDUD27SB	9U	--	--	--	6	6
WLCMRD08SDUD2SB	9U	1	1	1	1	1
WLCSLH01GP25	9U	32	32	32	32	32
WLCSLH01GP26	9U	24	24	24	24	24
WLCSLH01GP27	9U	--	16	16	16	16
WLCSLH01GP28	9U	31	31	31	31	31
WLCSLH01GP29	9U	--	13	13	13	13
WLCSLH01GP30	9U	19	19	19	19	19
WLCSLH01GP31	9U	13	13	13	13	13
WLCSLH01GP32	9U	--	7	7	7	7
WR-WSI98SD072	9U	3	3	3	3	3
LW2-C192	10	--	--	--	--	8
WR-WSI98SD049	10	--	--	--	--	3
LW2-C192	11	--	--	--	--	8
LW2-C196	11	--	--	--	--	1
LW2-C197	11	--	--	--	--	7
LW2-C199	11	--	--	--	--	6
LW2-C202	11	--	--	--	--	6
LW2-C203	11	--	--	--	--	7
LW2-C206	11	--	--	--	4	4
LW2-C207	11	--	--	--	5	5
LW2-C207-2	11	--	--	--	--	5
LW2-C215	11	--	--	--	1	1
LW3-C644-1	11	--	--	--	1	1
LW3-C644-2	11	--	--	--	--	1
LW3-C651	11	--	--	--	--	4
LWM-C7	11	--	--	--	1	1
LWM-TCLP7	11	--	--	--	9	9
WR-WSI98SD053	11	--	--	--	1	1
LW2-C232	12	--	--	--	1	1
LW2-C244	12	--	--	--	9	9
LW2-C247	12	--	--	--	--	1
LW3-C651	12	--	--	--	--	4
LW2-C254	13	--	--	1	2	2
LW2-C277	13	--	--	--	11	11
LW2-C280	13	4	4	4	4	4
LW2-C282	13	1	1	1	1	1
LW2-C291	13	1	1	9	9	9
LW2-C293	13	9	9	9	9	9
LW2-C293-2	13	5	5	5	5	5
LW2-C295	13	8	8	8	8	8
LW2-C296	13	--	1	1	1	5
LW2-C303	13	--	--	--	--	3
LW2-C524	13	1	1	1	1	1
LW2-C533	13	1	1	1	1	1
LW2-NA2A	13	--	--	--	1	1
LW2-NA2B	13	1	1	1	1	1
LW3-C665	13	--	--	--	12	12

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative B	Alternative C	Alternative D	Alternative E	Alternative F
LWM-C13	13	1	1	1	1	13
WR-WSI98SD074	13	--	1	1	1	1
LW2-C290	14	--	--	--	--	3
LW2-C293-2	14	--	--	--	--	5
LW2-C300-2	14	--	--	--	5	5
LW2-C312	14	--	--	--	--	5
LW2-C313	14	--	--	--	--	1
LW2-C314	14	--	--	--	--	11
LW2-C316	14	--	--	--	11	11
LW2-C321	14	--	--	--	1	1
LW2-C321-2	14	--	--	--	1	5
LW2-C323	14	--	--	--	--	4
LW2-C324	14	1	1	1	1	11
LW2-C326	14	--	--	--	--	2
LW2-C327	14	1	1	1	6	10
LW2-C329	14	--	--	12	12	12
LW2-C331	14	--	1	1	1	1
LW2-C332	14	--	--	--	6	6
LW2-C333	14	--	--	1	1	3
LW2-C334	14	--	--	--	4	4
LW2-C335	14	--	--	1	2	2
LW2-C341	14	--	--	--	1	1
LW2-C348	14	--	8	8	8	8
LW2-C349	14	--	--	--	--	1
LW2-C351	14	3	3	3	3	3
LW2-C356	14	8	8	8	11	11
LW2-C358	14	--	1	1	1	10
LW2-C359	14	12	12	12	12	12
LW2-C360	14	1	1	1	7	7
LW2-C360-2	14	10	10	10	10	19
LW2-C361	14	--	1	1	1	5
LW2-C362	14	1	1	1	1	5
LW2-C366	14	1	15	15	15	15
LW2-C366-2	14	3	3	3	9	9
LW2-C368	14	1	1	1	4	8
LW2-C371	14	--	1	1	5	5
LW2-C377	14	1	1	1	16	16
LW2-C523	14	--	--	--	--	4
LW3-C664	14	--	--	--	4	4
LW3-C679	14	--	--	--	10	10
LW3-C688	14	1	1	9	9	9
LW3-C690	14	--	--	--	--	15
LWM-C14	14	12	12	12	12	12
LWM-TCLP14A	14	--	--	--	--	7
LWM-TCLP14B	14	1	1	1	1	1
WLCDRD05VC056	14	--	--	--	--	9
WLCDRD05VC058	14	--	--	--	1	1
WLCDRD05VC060	14	--	--	--	1	1
WLCDRD05VC062	14	--	--	--	1	5

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
WLCDRD05VC064	14	--	--	--	1	1
WLCDRD05VC066	14	--	--	--	1	1
WLCDRD05VC068	14	--	--	--	1	8
WLCDRD05VC070	14	--	--	--	9	9
WLCDRD05VC072	14	--	1	1	1	9
WLCEAF02WB08	14	9	9	9	16	16
WLCEAF02WB09	14	10	10	10	34	34
WLCEAF02WB10	14	17	17	17	17	17
WLCEAF02WB11	14	15	15	15	15	15
WLCEAF02WB12	14	--	1	1	1	2
WLCEAF02WB13	14	17	17	17	17	17
WLCEAF02WB14	14	2	2	2	2	2
WLCEAF02WB15	14	--	1	1	2	2
WLCEAF02WB16	14	1	1	1	1	2
WLCEAF02WB17	14	2	2	2	2	2
WLCEAF02WB18	14	8	8	8	20	20
WLCEAF02WB19	14	--	1	1	1	1
WLCEAF02WB20	14	--	--	--	1	2
WLCEAF02WB21	14	--	--	--	1	1
WLCEAF02WB22	14	--	--	--	1	1
WLCEAF02WB23	14	1	1	1	7	7
WLCEAF02WB24	14	19	19	19	19	19
WLCEAF02WB25	14	2	2	2	2	2
WLCMBI02SED02	14	--	--	--	--	1
WLR0797WRGC24	14	--	1	1	1	6
WLR0797WRGC25	14	--	--	--	--	2
WLRELF99OSS001	14	2	2	2	2	2
WLRELF99OSS002	14	3	3	3	3	3
WLRELF99OSS003	14	1	1	1	1	1
WLRELF99OSS004	14	2	2	2	2	2
WLRELF99OSS005	14	1	1	1	3	3
WLRELF99OSS006	14	1	1	1	1	1
WLRELF99RB2	14	1	1	1	1	1
WLRELF99RB6	14	--	1	1	2	2
WR-WSI98SD072	14	--	--	--	--	3
WR-WSI98SD081C	14	--	--	--	3	3
WR-WSI98SD084	14	--	3	3	3	3
WR-WSI98SD090	14	1	1	1	3	3
WR-WSI98SD092	14	3	3	3	3	3
WR-WSI98SD100	14	--	1	1	1	1
LW3-C676	15	--	--	--	--	2
LW3-C678	15	--	--	--	--	8
LWM-TCLP15	15	--	--	--	1	1
WLCMBI02SED08	15	--	--	--	--	1
LW2-C349	16	--	--	--	--	1
LW2-C357	16	--	--	--	--	1
LW2-C358	16	--	--	--	--	10
LW2-C361	16	--	--	--	--	5
LW2-C377	16	--	--	--	--	16

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
LW2-C381	16	--	--	--	--	1
LW2-C401	16	--	--	--	--	12
LW2-C532	16	--	--	--	--	10
LW2-NA3A	16	--	--	--	--	1
LW2-NA3B	16	--	--	--	--	1
LW3-C688	16	--	--	--	--	9
LW3-C690	16	--	--	--	--	15
PSYSEA98PSY39C	16	--	--	--	--	4
TOSCO99DMMU1	16	--	--	--	--	10
WLCCWI08DMMU1A	16	--	--	--	1	1
WLCCWI08DMMU1C	16	--	--	--	--	1
WLCCWI08DMMU2A	16	--	--	--	1	1
WLCCWI08DMMU2C	16	--	--	--	--	1
WLCCWI08DMMU3A	16	--	--	--	1	1
WLCCWI08DMMU3ABDE	16	--	--	--	3	3
WLCCWI08DMMU3B	16	--	--	--	3	3
WLCCWI08DMMU3D	16	--	--	--	1	1
WLCCWI08DMMU3E	16	--	--	--	1	1
WLCDRD05VC072	16	--	--	--	--	9
WLCDRI03C07-08	16	--	--	--	--	1
WLCPWL09APS-1	16	--	--	--	1	1
WLCPWL09APS-2	16	--	--	--	--	1
WLCPWL09APS-3	16	--	--	--	--	4
WLCPWL09URB-1	16	--	--	--	--	11
WLCPWL09URB-2	16	--	--	--	--	5
WLCPWL09URB-3	16	--	--	--	--	1
WLCPWL09URB-D	16	--	--	--	--	6
WR-WSI98SD117	16	--	--	--	--	3
LW2-C342	17D	--	--	--	--	7
LW3-C686	17D	--	--	--	--	1
WLCDRD05VC031	17D	--	--	--	--	1
WR-WSI98SD096	17D	--	--	--	3	3
WR-WSI98SD106	17D	--	--	--	--	3
LW2-C364	17S	--	--	--	2	2
LW2-C372	17S	--	--	--	1	3
LW2-C379	17S	1	5	5	6	6
LW2-C380	17S	1	1	1	1	1
LW2-C382	17S	1	1	1	5	5
LW2-C383	17S	--	1	1	2	2
LW2-C384	17S	4	4	4	4	7
LW2-C388	17S	1	1	1	1	1
LW2-C392	17S	--	2	2	2	2
LW2-C393	17S	1	1	1	5	5
LW2-C396	17S	--	--	--	1	1
LW2-C397	17S	1	1	9	11	11
LW2-C402	17S	1	1	1	2	2
LW2-C405	17S	--	--	--	--	4
LW2-C415	17S	--	1	1	1	1
LW2-C417	17S	--	--	--	--	12

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative B	Alternative C	Alternative D	Alternative E	Alternative F
LW2-C421	17S	--	--	2	4	4
LW2-C425	17S	--	--	--	--	1
LW2-C425-2	17S	--	--	--	--	10
LW2-C426	17S	--	--	--	1	4
LW2-C430	17S	--	--	--	--	17
LW2-NA4A	17S	--	--	--	1	1
LW2-NA4B	17S	--	--	--	1	3
LW3-C702	17S	--	--	--	--	9
LW3-C703	17S	--	--	--	--	5
LW3-C706	17S	--	1	1	1	1
LW3-C708	17S	--	--	8	8	10
LWM-C21/LWM-C23	17S	--	--	--	1	12
LWM-TCLP23	17S	--	--	--	--	1
PSYD&M97DM20	17S	--	1	1	4	4
PSYD&M97DM24	17S	--	--	1	1	1
PSYSEA98PSY01C	17S	--	--	--	--	7
PSYSEA98PSY07C	17S	--	--	1	7	7
PSYSEA98PSY11C	17S	1	1	1	1	4
PSYSEA98PSY16C	17S	--	--	--	4	8
PSYSEA98PSY18C	17S	--	1	4	4	4
PSYSEA98PSY20C	17S	--	--	--	4	4
PSYSEA98PSY23C	17S	--	4	4	4	4
PSYSEA98PSY27C	17S	--	4	4	4	4
PSYSEA98PSY30C	17S	--	5	5	5	5
WLCPSK09DMMU1	17S	--	--	1	11	11
WLCPSK09DMMU5	17S	--	1	1	1	1
WR-WSI98SD133	17S	3	3	3	3	3
WR-WSI98SD136	17S	--	1	1	1	1
WR-WSI98SD141	17S	--	--	1	1	3
LW2-C413	18	--	--	--	--	10
LW2-C413-2	18	--	--	--	--	11
LW2-C431	18	--	--	--	6	6
LW2-C434	18	--	--	--	--	5
LW2-C437	18	--	--	--	--	1
LW3-C698	18	--	--	--	--	1
LW3-C701	18	--	--	--	--	12
LW3-C704	18	--	--	--	--	8
LW3-C709	18	--	--	--	--	1
LW3-C712	18	--	--	--	--	1
LWM-TCLP18	18	--	--	--	1	1
WLCDRI03C15-17	18	--	--	--	--	1
WR-WSI98SD135	18	--	--	--	--	1
LW2-C440	19	--	--	--	8	12
LW2-C441	19	--	--	--	1	5
LW2-C441-2	19	--	--	--	5	5
LW2-C444	19	--	--	--	7	7
LW2-C445	19	--	--	--	--	17
LW2-C447	19	--	--	--	4	4
LW2-C448	19	1	1	1	12	12

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
LW2-C449	19	1	1	1	1	1
LW2-C450	19	8	8	8	8	8
LW2-C453	19	5	5	9	9	9
LW2-C455	19	5	5	9	9	9
LW2-C456	19	1	1	1	7	7
LW2-C457	19	--	--	1	1	6
LW2-C458	19	--	--	--	--	1
LW2-C458-2	19	--	--	--	--	9
LW2-C461	19	1	1	1	9	12
LW2-C462	19	--	1	1	1	1
LW2-C468	19	1	1	1	1	9
LW2-C471	19	--	--	--	--	1
LW2-C474	19	--	1	1	1	1
LW2-C477	19	1	1	4	4	7
LW3-C721	19	--	--	--	1	12
LW3-C724	19	1	1	1	1	4
LWM-TCLP19	19	12	12	12	12	12
WLCGNG03HA37	19	1	1	1	1	1
WLCGNG03HA38	19	1	1	1	1	1
WLCGNG03HA42	19	2	2	2	2	2
WLCGNG03HA43	19	3	3	3	3	3
WLR0499WRVC05	19	--	--	--	--	1
WLR0499WRVC06	19	--	1	1	1	1
WLR0499WRVC09	19	--	--	--	--	1
WLR1199WRVC04	19	1	1	1	1	1
WR-WSI98SD143	19	3	3	3	3	3
WR-WSI98SD151	19	1	1	1	1	3
LW2-C477	20	--	--	--	--	7
LW2-C492	20	--	--	--	1	1
LW3-C735	20	--	--	--	1	5
LW3-C738	20	--	--	4	4	17
LW3-C739	20	--	--	--	--	17
LWM-C24	20	--	--	--	12	12
WLCDRI03HCVC53	20	--	--	--	--	1
LW3-C733	21	--	--	--	--	1
PSYSEA98PSY50C	21	--	--	--	--	8
WLCDRI03C30-32	21	--	--	--	--	1
WLCDRI03C33-35	21	--	--	--	--	1
WR-WSI98SD150	21	--	--	--	--	3
LW2-C454	22	--	--	--	--	1
LW3-C742	22	--	--	--	--	9
WLCDRD05VC037	22	--	--	--	--	1
WLCDRD05VC039	22	--	--	--	--	1
LW3-C746	23	--	--	--	--	1
LW3-C749	23	--	--	--	--	4
WLCAYH00SD04	23	--	--	1	1	1
WLCDRD05VC045	23	--	--	--	--	1
WLR0797WRGC32	23	--	--	--	--	1
LW3-C747	24	--	--	--	5	8

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
LW3-C749	24	--	--	--	1	4
LW3-C752	24	--	--	--	11	11
LW3-C753	24	--	--	--	--	1
LW3-C757	24	--	--	--	7	7
LW3-C773-2	24	--	--	--	1	11
WLCAYH00SD02	24	--	--	--	1	1
WLCDRD05VC049	24	--	--	--	8	8
WLCDRD05VC051	24	--	--	--	4	4
WLCDRD05VC053	24	--	--	--	--	1
WLCDRD05VC055	24	--	--	--	1	9
WLCDRD05VC106	24	--	--	--	8	8
WLCDRD05VC108	24	--	--	--	8	8
WLCDRD05VC110	24	--	--	--	6	6
LW3-C777	25	--	--	--	--	1
LW3-C778	25	1	1	1	1	1
LW3-C779	25	--	--	--	1	3
LW3-RC02-2	25	--	--	--	--	1
LW3-UC01	25	1	1	1	3	3
LW3-UC02	25	1	1	1	1	1
LW3-UC03	25	4	4	4	4	8
RM11E-C001	25	--	--	--	--	1
RM11E-C002	25	--	--	--	--	3
RM11E-C003	25	--	6	6	6	6
RM11E-C004	25	1	1	1	1	1
RM11E-C005	25	1	1	1	1	1
RM11E-C006	25	1	1	1	1	1
RM11E-C007	25	1	1	1	1	1
RM11E-C008	25	1	1	1	1	1
RM11E-C009	25	--	--	--	1	3
RM11E-C010-R2	25	1	1	1	1	1
RM11E-C011	25	1	1	1	1	1
RM11E-C012	25	--	--	1	1	3
RM11E-C013	25	--	--	--	--	1
RM11E-C014	25	--	--	--	1	1
RM11E-C015	25	--	1	1	1	5
RM11E-C016	25	1	1	1	1	1
RM11E-C017	25	1	1	1	1	1
RM11E-C018	25	--	--	--	1	1
RM11E-C019	25	7	7	7	7	7
RM11E-C020	25	1	1	1	3	3
RM11E-C021	25	1	1	1	1	1
RM11E-C022	25	5	5	5	5	5
RM11E-C023	25	7	7	10	10	10
RM11E-C024	25	--	1	1	1	1
RM11E-C025	25	1	1	1	1	1
RM11E-C026	25	--	1	1	1	1
RM11E-C027	25	--	--	1	1	1
RM11E-C028	25	--	--	--	--	1

Table 5.10-1. Summary of Depth of Impact by Alternative (in feet)

Core ID	SMA	Alternative				
		B	C	D	E	F
RM11E-C029	25	1	1	1	1	1
RM11E-C031	25	--	--	--	--	1
RM11E-C032	25	1	1	1	1	1
RM11E-C034	25	--	--	--	1	1
RM11E-C035	25	1	1	1	1	1
RM11E-C038	25	1	1	1	1	1
RM11E-C047	25	1	1	1	3	5
RM11E-C048-R1	25	--	4	4	4	4
RM11E-C048-R2	25	1	1	1	3	3
WLCAYH00SD01	25	--	--	--	--	1
WLCAYH00SD02	25	--	--	--	--	1
WLCDRD05VC061	25	--	--	--	--	1
WLCDRD05VC122	25	--	--	--	--	1
WLCGWF03GNVC01	25	1	3	3	3	3
WLCGWF03GNVC0103	25	1	3	3	3	3
WLCGWF03GNVC03	25	1	1	1	1	3
WLR0797WRCD40	25	--	--	--	--	2

Notes:
All depths are in feet
-- = No depth of impact because the theissen for this core does not overlap the footprint for this alternative.
SMA = Sediment Management Area

Table 5.10-2. Summary of Average Depth of Impact for Each SMA by Alternative (in feet)

SMA	Alternative				
	B	**C**	**D**	**E**	**F**
1A	2.8	3.2	3.0	3.4	6.2
2	--	--	--	--	--
3	3.8	3.6	3.1	5.0	6.1
4	--	--	--	1.0	4.5
5	--	1.3	1.3	3.4	5.7
6	5.7	4.3	3.4	2.9	3.7
7	--	--	--	--	2.7
8	--	--	--	2.5	3.2
9D	7.7	7.6	6.9	7.6	7.1
9U	9.9	9.8	9.8	9.7	10.2
10	--	--	--	--	5.6
11	--	--	--	3.2	4.2
12	--	--	--	4.9	3.8
13	3.3	2.9	3.4	4.4	5.2
14	4.9	4.3	4.5	5.5	6.2
15	--	--	--	1.0	3.0
16	--	--	--	1.5	4.6
17D	--	--	--	3.0	3.0
17S	1.5	2.0	2.4	3.3	4.8
18	--	--	--	3.4	4.5
19	2.7	2.5	2.9	4.1	5.5
20	--	--	3.8	4.5	8.6
21	--	--	--	--	2.7
22	--	--	--	--	3.0
23	--	--	1.0	1.0	1.7
24	--	--	--	5.1	6.3
25	1.7	1.9	1.9	2.0	2.2

Notes

Depths are in feet

-- = No depth of impact under this alternative

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

				RAL Exceedance Factor							
Alt	SMA	Core ID	DoI (cm)	2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
B	13	LW2-C280	137	--	1.1	--	ND	--	0.0	ND	--
B	13	LW2-C293	272	--	2.2	--	0.0	--	0.0	--	0.3
B	13	LW2-C293-2	152	--	2.7	--	0.0	--	0.0	--	0.4
B	13	LW2-C295	256	--	2.9	--	0.1	--	0.1	0.2	--
B	14	LW2-C351	80	--	2.2	--	0.1	--	0.1	0.1	--
B	14	LW2-C356	256	--	19.2	--	1.4	--	0.0	--	--
B	14	LW2-C359	378	--	3.4	--	0.2	--	0.0	0.1	--
B	14	LW2-C360-2	299	--	1.9	--	0.2	--	--	ND	--
B	14	LW2-C366-2	100	--	1.0	--	0.2	--	0.0	ND	--
B	14	LWM-C14	376	--	8.7	--	ND	--	0.1	--	1.0
B	14	WLCEAF02WB08	284	--	740.0	--	9.0	--	--	--	--
B	14	WLCEAF02WB09	305	--	519.6	--	24.0	--	--	--	--
B	14	WLCEAF02WB10	518	--	1443.7	--	ND	--	--	--	--
B	14	WLCEAF02WB11	442	--	1562.9	--	ND	--	--	--	--
B	14	WLCEAF02WB13	518	--	1.1	--	ND	--	--	--	--
B	14	WLCEAF02WB14	61	--	1.4	--	0.2	--	--	--	--
B	14	WLCEAF02WB17	61	--	1.3	--	ND	--	--	--	--
B	14	WLCEAF02WB18	244	--	7.7	--	0.7	--	--	--	--
B	14	WLCEAF02WB24	567	--	2.6	--	ND	--	--	--	--
B	14	WLCEAF02WB25	52	--	18.7	--	ND	--	--	--	--
B	14	WLRELF99OSS001	70	--	1.3	--	0.2	--	0.0	--	--
B	14	WLRELF99OSS002	90	--	3.9	--	0.4	--	0.0	--	--
B	14	WLRELF99OSS004	50	--	13.8	--	1.8	--	0.8	--	--
B	14	WLRELF99OSS006	30	--	3.2	--	1.2	--	0.0	--	--
B	14	WR-WSI98SD092	90	--	12.8	--	ND	--	0.1	ND	--
B	17S	LW2-C384	128	--	2.4	--	0.0	--	0.1	--	11.0
B	17S	WR-WSI98SD133	90	--	1.1	--	--	--	0.1	2.4	--
B	19	LW2-C450	245	--	0.5	--	0.1	--	0.0	2.2	--
B	19	LW2-C453	152	--	1.5	--	0.4	--	0.0	--	6.0
B	19	LW2-C455	152	--	6.7	--	2.8	--	0.0	--	37.0
B	19	LWM-TCLP19	374	--	2.1	--	--	--	--	--	--
B	19	WLCGNG03HA42	61	--	6.5	--	--	--	0.1	--	--
B	19	WLCGNG03HA43	76	--	22.4	--	--	--	0.8	--	--
B	19	WR-WSI98SD143	90	--	1.9	--	--	--	ND	--	--
B	1A	LW2-C011-2	137	--	0.9	--	ND	--	0.0	8.2	--
B	1A	LW2-C015	107	--	0.3	--	ND	--	0.0	--	1.1
B	1A	LW2-C019	264	--	0.2	--	ND	--	ND	--	1.1
B	1A	LW2-C019-2	153	--	1.1	--	--	--	--	--	1.1
B	1A	LW2-C020	232	--	0.3	--	0.0	--	0.0	1.7	--
B	1A	WLCOSJ00RB13	60	--	1.0	--	--	--	ND	1.9	--
B	25	LW3-UC03	120	--	0.6	--	ND	--	--	2.4	--
B	25	RM11E-C019	213	--	1.3	--	ND	--	0.0	9.0	--
B	25	RM11E-C022	140	--	3.6	--	ND	--	0.0	2.8	--
B	25	RM11E-C023	213	--	2.2	--	--	--	--	2.2	--
B	3	LW2-C089	98	--	0.5	--	ND	--	0.0	3.3	--
B	3	LW2-C092	212	--	3.0	--	ND	--	0.2	15.0	--
B	3	LW2-C094	72	--	0.4	--	0.0	--	0.0	2.1	--
B	3	LWM-C3	382	--	1.1	--	ND	--	0.0	--	5.0
B	3	WLCITG08SED01	152	--	40.5	--	--	--	0.4	14.0	--
B	3	WLCITG08SED02	259	--	7.4	--	--	--	0.1	1.2	--
B	3	WLCITG08SED11	76	--	3.0	--	--	--	0.1	2.0	--
B	3	WLCITG08SED14	107	--	1.3	--	--	--	0.1	1.1	--
B	6	WLCT4C04VC22	335	--	1.6	--	ND	--	ND	ND	--
B	6	WLCT4C04VC29	91	--	0.7	--	ND	--	0.7	1.3	--
B	6	WLCT4G06T4B41106	305	--	1.5	--	ND	--	1.5	0.1	--
B	6	WLCT4G06T4S301	274	--	2.4	--	--	--	0.8	--	--
B	6	WLCT4G06T4S302	183	--	1.3	--	--	--	0.5	--	--
B	6	WLCT4G06T4S305	244	--	2.1	--	--	--	0.9	--	--
B	6	WLCT4J98HCS07	128	--	3.6	--	--	--	0.8	--	--
B	6	WLCT4J98HCS11	121	--	2.0	--	--	--	1.3	--	--
B	6	WLCT4J98HCS42	121	--	1.5	--	--	--	1.7	--	--
B	6	WR-WSI98SD031	90	--	1.3	--	--	--	1.3	--	--
B	9D	LW2-C179	346	--	1.2	--	ND	--	0.3	ND	--
B	9D	LW2-C221	150	--	1.6	--	ND	--	--	0.0	--
B	9D	LW2-C263	376	--	8.1	--	0.0	--	2.0	ND	--
B	9D	WLCMRD08SDDA17SB	213	--	4.4	--	ND	--	1.3	ND	--
B	9D	WLCMRD08SDDC24SB	457	--	11.9	--	ND	--	1.4	0.3	--
B	9D	WLCMRD08SDDC25SB	366	--	2.4	--	ND	--	1.4	0.2	--
B	9D	WLCMRD08SDUD1SB	610	--	1.1	--	ND	--	ND	ND	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
B	9D	WLCMRD08SDUD27SB	183	--	3.9	--	ND	--	1.2	ND	--
B	9U	LW2-C258	304	--	1.6	--	--	--	--	--	--
B	9U	LW2-C263	376	--	8.1	--	0.0	--	2.0	ND	--
B	9U	LW2-C264	220	--	3.2	--	ND	--	3.7	0.1	--
B	9U	LW2-C269	541	--	3.5	--	ND	--	1.1	ND	--
B	9U	LW2-C270	182	--	3.4	--	0.0	--	1.2	ND	--
B	9U	LW2-C273	355	--	2.5	--	ND	--	0.6	--	--
B	9U	LW2-C283	258	--	9.1	--	ND	--	1.7	ND	--
B	9U	LW2-C289	206	--	10.8	--	--	--	--	--	--
B	9U	LW2-C299	230	--	106.1	--	ND	--	--	ND	--
B	9U	LW2-C301	516	--	28.2	--	0.0	--	4.6	ND	--
B	9U	LW2-C302	348	--	1379.9	--	ND	--	24.0	ND	--
B	9U	LW2-C311	153	--	2.9	--	0.0	--	0.8	0.0	--
B	9U	LW2-C521	280	--	40.3	--	ND	--	--	ND	--
B	9U	LW2-C525	341	--	11.6	--	ND	--	2.9	ND	--
B	9U	LW3-C662	327	--	14.2	--	ND	--	1.8	ND	--
B	9U	LWM-C11	386	--	249.0	--	ND	--	12.5	--	0.1
B	9U	WLCDRD05VC052	88	--	15.6	--	ND	--	--	0.4	--
B	9U	WLCGSD01AN0101	40	--	11.9	--	--	--	0.7	--	--
B	9U	WLCGSD01AN0102	40	--	31.6	--	--	--	1.3	--	--
B	9U	WLCGSD01AN0103	40	--	642.6	--	--	--	8.5	--	--
B	9U	WLCGSG04RAA17	610	--	39.3	--	--	--	8.0	--	--
B	9U	WLCGSG07GSB2	213	--	3.5	--	--	--	1.1	--	--
B	9U	WLCGSG07GSB5	213	--	4.3	--	--	--	1.3	--	--
B	9U	WLCGSG07GSB7	457	--	88.9	--	--	--	10.0	--	--
B	9U	WLCGSG07GSC2	213	--	1.8	--	--	--	--	--	--
B	9U	WLCGSG07GSC7	213	--	61.0	--	--	--	--	--	--
B	9U	WLCGSJ06GS05	335	--	5.8	--	--	--	0.4	--	--
B	9U	WLCGSJ06GS06	335	--	1.7	--	--	--	0.3	--	--
B	9U	WLCGSJ06GS07	823	--	117.1	--	--	--	6.5	--	--
B	9U	WLCGSJ06GS09	823	--	12.1	--	--	--	0.7	--	--
B	9U	WLCMRD08SDDA17SB	213	--	4.4	--	ND	--	1.3	ND	--
B	9U	WLCMRD08SDUD1SB	610	--	1.1	--	ND	--	ND	ND	--
B	9U	WLCSLH01GP25	960	--	4.5	--	--	--	0.9	--	--
B	9U	WLCSLH01GP26	716	--	1.1	--	--	--	0.1	--	--
B	9U	WLCSLH01GP28	930	--	1.9	--	--	--	0.7	--	--
B	9U	WLCSLH01GP30	564	--	1.3	--	--	--	ND	--	--
B	9U	WLCSLH01GP31	381	--	13.9	--	--	--	--	--	--
B	9U	WR-WSI98SD072	90	--	2.2	--	0.0	--	0.1	0.1	--
C	13	LW2-C280	137	--	1.1	--	ND	--	0.0	ND	--
C	13	LW2-C293	272	--	2.2	--	0.0	--	0.0	--	0.4
C	13	LW2-C293-2	152	--	2.7	--	0.0	--	0.0	--	0.5
C	13	LW2-C295	256	--	2.9	--	0.1	--	0.2	0.2	--
C	14	LW2-C348	240	--	28.4	--	1.3	--	0.1	ND	--
C	14	LW2-C351	80	--	2.2	--	0.1	--	0.1	0.1	--
C	14	LW2-C356	256	--	19.2	--	1.4	--	0.0	--	--
C	14	LW2-C359	378	--	3.4	--	0.2	--	0.0	0.2	--
C	14	LW2-C360-2	299	--	1.9	--	0.2	--	--	ND	--
C	14	LW2-C366	464	--	0.1	--	ND	--	ND	1.1	--
C	14	LW2-C366-2	100	--	1.0	--	0.2	--	0.0	ND	--
C	14	LWM-C14	376	--	8.7	--	ND	--	0.1	--	1.3
C	14	WLCEAF02WB08	284	--	740.0	--	9.0	--	--	--	--
C	14	WLCEAF02WB09	305	--	519.6	--	24.0	--	--	--	--
C	14	WLCEAF02WB10	518	--	1443.7	--	ND	--	--	--	--
C	14	WLCEAF02WB11	442	--	1562.9	--	ND	--	--	--	--
C	14	WLCEAF02WB13	518	--	1.1	--	ND	--	--	--	--
C	14	WLCEAF02WB14	61	--	1.4	--	0.2	--	--	--	--
C	14	WLCEAF02WB17	61	--	1.3	--	ND	--	--	--	--
C	14	WLCEAF02WB18	244	--	7.7	--	0.7	--	--	--	--
C	14	WLCEAF02WB24	567	--	2.6	--	ND	--	--	--	--
C	14	WLCEAF02WB25	52	--	18.7	--	ND	--	--	--	--
C	14	WLRELF99OSS001	70	--	1.3	--	0.2	--	0.0	--	--
C	14	WLRELF99OSS002	90	--	3.9	--	0.4	--	0.0	--	--
C	14	WLRELF99OSS004	50	--	13.8	--	1.8	--	1.0	--	--
C	14	WLRELF99OSS006	30	--	3.2	--	1.2	--	0.0	--	--
C	14	WR-WSI98SD084	90	--	2.6	--	ND	--	0.1	ND	--
C	14	WR-WSI98SD092	90	--	12.8	--	ND	--	0.2	ND	--
C	17S	LW2-C379	152	--	0.3	--	0.0	--	ND	1.3	--
C	17S	LW2-C384	128	--	2.4	--	0.0	--	0.2	--	14.7

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
C	17S	LW2-C392	76	--	0.4	--	0.0	--	0.1	1.2	--
C	17S	PSYSEA98PSY23C	121	--	0.6	--	--	--	0.0	2.3	--
C	17S	PSYSEA98PSY27C	121	--	1.2	--	--	--	ND	ND	--
C	17S	PSYSEA98PSY30C	152	--	1.0	--	--	--	--	--	--
C	17S	WR-WSI98SD133	90	--	1.1	--	--	--	0.1	3.2	--
C	19	LW2-C450	245	--	0.5	--	0.1	--	0.0	3.0	--
C	19	LW2-C453	152	--	1.5	--	0.4	--	0.0	--	8.0
C	19	LW2-C455	152	--	6.7	--	2.8	--	0.0	--	49.3
C	19	LWM-TCLP19	374	--	2.1	--	--	--	--	--	--
C	19	WLCGNG03HA42	61	--	6.5	--	--	--	0.1	--	--
C	19	WLCGNG03HA43	76	--	22.4	--	--	--	1.1	--	--
C	19	WR-WSI98SD143	90	--	1.9	--	--	--	ND	--	--
C	1A	LW2-C009	153	--	0.1	--	ND	--	0.0	1.0	--
C	1A	LW2-C011	127	--	0.2	--	ND	--	0.0	1.3	--
C	1A	LW2-C011-2	137	--	0.9	--	ND	--	0.0	10.9	--
C	1A	LW2-C015	107	--	0.3	--	ND	--	0.0	--	1.5
C	1A	LW2-C019	264	--	0.2	--	ND	--	ND	--	1.5
C	1A	LW2-C019-2	153	--	1.1	--	--	--	--	--	1.5
C	1A	LW2-C020	232	--	0.3	--	0.0	--	0.0	2.3	--
C	1A	WLCOSJ00RB13	60	--	1.0	--	--	--	ND	2.5	--
C	25	LW3-UC03	120	--	0.6	--	ND	--	--	3.2	--
C	25	RM11E-C003	172	--	1.2	--	ND	--	0.0	1.3	--
C	25	RM11E-C019	213	--	1.3	--	ND	--	0.0	12.0	--
C	25	RM11E-C022	140	--	3.6	--	ND	--	0.0	3.7	--
C	25	RM11E-C023	213	--	2.2	--	--	--	--	2.9	--
C	25	RM11E-C048-R1	134	--	1.3	--	ND	--	0.0	0.1	--
C	25	WLCGWF03GNVC01	85	--	0.9	--	--	--	--	1.2	--
C	25	WLCGWF03GNVC0103	88	--	0.9	--	--	--	--	1.2	--
C	3	LW2-C089	98	--	0.5	--	ND	--	0.0	4.4	--
C	3	LW2-C092	212	--	3.0	--	ND	--	0.2	20.0	--
C	3	LW2-C094	72	--	0.4	--	0.0	--	0.1	2.8	--
C	3	LWM-C3	382	--	1.1	--	ND	--	0.0	--	6.7
C	3	WLCITG08SED01	152	--	40.5	--	--	--	0.6	18.7	--
C	3	WLCITG08SED02	259	--	7.4	--	--	--	0.2	1.6	--
C	3	WLCITG08SED11	76	--	3.0	--	--	--	0.2	2.7	--
C	3	WLCITG08SED14	107	--	1.3	--	--	--	0.1	1.5	--
C	5	WR-WSI98SD017	90	--	1.6	--	--	--	0.3	--	--
C	6	WLCT4C04VC22	335	--	1.6	--	ND	--	ND	ND	--
C	6	WLCT4C04VC29	91	--	0.7	--	ND	--	0.9	1.7	--
C	6	WLCT4G06T4B41106	305	--	1.5	--	ND	--	2.0	0.2	--
C	6	WLCT4G06T4S301	274	--	2.4	--	--	--	1.1	--	--
C	6	WLCT4G06T4S302	183	--	1.3	--	--	--	0.7	--	--
C	6	WLCT4G06T4S303	61	--	1.2	--	--	--	0.6	--	--
C	6	WLCT4G06T4S305	244	--	2.1	--	--	--	1.2	--	--
C	6	WLCT4J98HCS07	128	--	3.6	--	--	--	1.1	--	--
C	6	WLCT4J98HCS11	121	--	2.0	--	--	--	1.7	--	--
C	6	WLCT4J98HCS42	121	--	1.5	--	--	--	2.2	--	--
C	6	WR-WSI98SD031	90	--	1.3	--	--	--	1.7	--	--
C	9D	LW2-C179	346	--	1.2	--	ND	--	0.5	ND	--
C	9D	LW2-C221	150	--	1.6	--	ND	--	--	0.0	--
C	9D	LW2-C263	376	--	8.1	--	0.0	--	2.6	ND	--
C	9D	LW2-C527	482	--	1.5	--	0.1	--	0.3	0.5	--
C	9D	LW2-C528	386	--	2.0	--	0.2	--	0.3	0.3	--
C	9D	WLCMRD08SDDA17SB	213	--	4.4	--	ND	--	1.7	ND	--
C	9D	WLCMRD08SDDC23SB	518	--	1.3	--	0.0	--	0.3	ND	--
C	9D	WLCMRD08SDDC24SB	457	--	11.9	--	ND	--	1.8	0.4	--
C	9D	WLCMRD08SDDC25SB	366	--	2.4	--	ND	--	1.9	0.3	--
C	9D	WLCMRD08SDUD1SB	610	--	1.1	--	ND	--	ND	ND	--
C	9D	WLCMRD08SDUD27SB	183	--	3.9	--	ND	--	1.6	ND	--
C	9D	WLCMRI02CS001	91	--	4.3	--	0.0	--	1.1	ND	--
C	9U	LW2-C258	304	--	1.6	--	--	--	--	--	--
C	9U	LW2-C263	376	--	8.1	--	0.0	--	2.6	ND	--
C	9U	LW2-C264	220	--	3.2	--	ND	--	4.9	0.1	--
C	9U	LW2-C269	541	--	3.5	--	ND	--	1.4	ND	--
C	9U	LW2-C270	182	--	3.4	--	0.0	--	1.6	ND	--
C	9U	LW2-C273	355	--	2.5	--	ND	--	0.7	--	--
C	9U	LW2-C283	258	--	9.1	--	ND	--	2.2	ND	--
C	9U	LW2-C289	206	--	10.8	--	--	--	--	--	--
C	9U	LW2-C299	230	--	106.1	--	ND	--	--	ND	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
C	9U	LW2-C301	516	--	28.2	--	0.0	--	6.1	ND	--
C	9U	LW2-C302	348	--	1379.9	--	ND	--	32.0	ND	--
C	9U	LW2-C305	160	--	5.5	--	0.0	--	--	0.3	--
C	9U	LW2-C305-2	240	--	9.0	--	0.0	--	--	0.2	--
C	9U	LW2-C311	153	--	2.9	--	0.0	--	1.1	0.1	--
C	9U	LW2-C521	280	--	40.3	--	ND	--	--	ND	--
C	9U	LW2-C525	341	--	11.6	--	ND	--	3.8	ND	--
C	9U	LW3-C662	327	--	14.2	--	ND	--	2.3	ND	--
C	9U	LWM-C11	386	--	249.0	--	ND	--	16.7	--	0.1
C	9U	WLCDRD05VC052	88	--	15.6	--	ND	--	--	0.5	--
C	9U	WLCDRD05VC054	201	--	2.4	--	ND	--	--	0.3	--
C	9U	WLCGSD01AN0101	40	--	11.9	--	--	--	0.9	--	--
C	9U	WLCGSD01AN0102	40	--	31.6	--	--	--	1.7	--	--
C	9U	WLCGSD01AN0103	40	--	642.6	--	--	--	11.3	--	--
C	9U	WLCGSG04RAA17	610	--	39.3	--	--	--	10.7	--	--
C	9U	WLCGSG07GSB2	213	--	3.5	--	--	--	1.5	--	--
C	9U	WLCGSG07GSB5	213	--	4.3	--	--	--	1.7	--	--
C	9U	WLCGSG07GSB7	457	--	88.9	--	--	--	13.3	--	--
C	9U	WLCGSG07GSC2	213	--	1.8	--	--	--	--	--	--
C	9U	WLCGSG07GSC7	213	--	61.0	--	--	--	--	--	--
C	9U	WLCGSJ06GS05	335	--	5.8	--	--	--	0.5	--	--
C	9U	WLCGSJ06GS06	335	--	1.7	--	--	--	0.4	--	--
C	9U	WLCGSJ06GS07	823	--	117.1	--	--	--	8.7	--	--
C	9U	WLCGSJ06GS09	823	--	12.1	--	--	--	0.9	--	--
C	9U	WLCMRD08SDDA17SB	213	--	4.4	--	ND	--	1.7	ND	--
C	9U	WLCMRD08SDUD1SB	610	--	1.1	--	ND	--	ND	ND	--
C	9U	WLCSLH01GP25	960	--	4.5	--	--	--	1.1	--	--
C	9U	WLCSLH01GP26	716	--	1.1	--	--	--	0.1	--	--
C	9U	WLCSLH01GP27	472	--	1.1	--	--	--	--	--	--
C	9U	WLCSLH01GP28	930	--	1.9	--	--	--	0.9	--	--
C	9U	WLCSLH01GP29	381	--	1.8	--	--	--	--	--	--
C	9U	WLCSLH01GP30	564	--	1.3	--	--	--	ND	--	--
C	9U	WLCSLH01GP31	381	--	13.9	--	--	--	--	--	--
C	9U	WLCSLH01GP32	198	--	43.6	--	--	--	--	--	--
C	9U	WR-WSI98SD072	90	--	2.2	--	0.0	--	0.1	0.2	--
D	13	LW2-C280	137	--	1.1	--	ND	--	0.0	ND	--
D	13	LW2-C291	289	--	0.3	--	0.0	--	0.0	--	1.5
D	13	LW2-C293	272	--	2.2	--	0.1	--	0.1	--	0.6
D	13	LW2-C293-2	152	--	2.7	--	0.1	--	0.1	--	0.8
D	13	LW2-C295	256	--	2.9	--	0.3	--	0.3	0.3	--
D	14	LW2-C329	359	--	9.3	--	ND	--	0.5	ND	--
D	14	LW2-C348	240	--	28.4	--	6.5	--	0.1	ND	--
D	14	LW2-C351	80	--	2.2	--	0.7	--	0.2	0.1	--
D	14	LW2-C356	256	--	19.2	--	7.0	--	0.0	--	--
D	14	LW2-C359	378	--	3.4	--	1.2	--	0.0	0.2	--
D	14	LW2-C360-2	299	--	1.9	--	1.0	--	--	ND	--
D	14	LW2-C366	464	--	0.1	--	ND	--	ND	1.7	--
D	14	LW2-C366-2	100	--	1.0	--	0.9	--	0.0	ND	--
D	14	LW3-C688	281	--	0.3	--	2.3	--	0.0	--	0.5
D	14	LWM-C14	376	--	8.7	--	ND	--	0.2	--	2.0
D	14	WLCEAF02WB08	284	--	740.0	--	45.0	--	--	--	--
D	14	WLCEAF02WB09	305	--	519.6	--	120.0	--	--	--	--
D	14	WLCEAF02WB10	518	--	1443.7	--	ND	--	--	--	--
D	14	WLCEAF02WB11	442	--	1562.9	--	ND	--	--	--	--
D	14	WLCEAF02WB13	518	--	1.1	--	ND	--	--	--	--
D	14	WLCEAF02WB14	61	--	1.4	--	0.8	--	--	--	--
D	14	WLCEAF02WB17	61	--	1.3	--	ND	--	--	--	--
D	14	WLCEAF02WB18	244	--	7.7	--	3.3	--	--	--	--
D	14	WLCEAF02WB24	567	--	2.6	--	ND	--	--	--	--
D	14	WLCEAF02WB25	52	--	18.7	--	ND	--	--	--	--
D	14	WLRELF99OSS001	70	--	1.3	--	1.1	--	0.1	--	--
D	14	WLRELF99OSS002	90	--	3.9	--	1.8	--	0.1	--	--
D	14	WLRELF99OSS004	50	--	13.8	--	9.2	--	1.9	--	--
D	14	WLRELF99OSS006	30	--	3.2	--	5.9	--	0.0	--	--
D	14	WLRELF99RB2	23	--	0.4	--	1.6	--	0.0	--	--
D	14	WR-WSI98SD084	90	--	2.6	--	ND	--	0.2	ND	--
D	14	WR-WSI98SD092	90	--	12.8	--	ND	--	0.3	ND	--
D	17S	LW2-C379	152	--	0.3	--	0.0	--	0.0	1.9	--
D	17S	LW2-C384	128	--	2.4	--	0.1	--	0.4	--	22.0

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
D	17S	LW2-C392	76	--	0.4	--	0.0	--	0.1	1.8	--
D	17S	LW2-C397	271	--	0.3	--	0.0	--	0.0	--	1.1
D	17S	LW2-C421	61	--	0.4	--	ND	--	0.1	2.6	--
D	17S	LW3-C708	236	--	7.5	--	ND	--	0.6	--	13.8
D	17S	PSYSEA98PSY18C	121	--	0.4	--	--	--	0.1	1.3	--
D	17S	PSYSEA98PSY23C	121	--	0.6	--	--	--	0.1	3.4	--
D	17S	PSYSEA98PSY27C	121	--	1.2	--	--	--	0.0	ND	--
D	17S	PSYSEA98PSY30C	152	--	1.0	--	--	--	--	--	--
D	17S	WR-WSI98SD133	90	--	1.1	--	--	--	0.2	4.8	--
D	19	LW2-C450	245	--	0.5	--	0.4	--	0.0	4.5	--
D	19	LW2-C453	270	--	0.7	--	1.2	--	0.0	0.7	--
D	19	LW2-C455	274	--	0.7	--	1.9	--	0.0	--	1.2
D	19	LW2-C477	123	--	0.2	--	0.0	--	0.0	--	1.0
D	19	LWM-TCLP19	374	--	2.1	--	--	--	--	--	--
D	19	WLCGNG03HA42	61	--	6.5	--	--	--	0.1	--	--
D	19	WLCGNG03HA43	76	--	22.4	--	--	--	2.1	--	--
D	19	WR-WSI98SD143	90	--	1.9	--	--	--	ND	--	--
D	1A	LW2-C009	153	--	0.1	--	ND	--	0.0	1.5	--
D	1A	LW2-C011	127	--	0.2	--	ND	--	0.0	1.9	--
D	1A	LW2-C011-2	256	--	0.2	--	0.0	--	0.0	1.2	--
D	1A	LW2-C015	107	--	0.3	--	0.0	--	0.0	--	2.2
D	1A	LW2-C019	264	--	0.2	--	0.0	--	0.0	--	2.2
D	1A	LW2-C019-2	153	--	1.1	--	--	--	--	--	2.2
D	1A	LW2-C020	232	--	0.3	--	0.0	--	0.0	3.4	--
D	1A	WLCOSJ00RB13	60	--	1.0	--	--	--	0.0	3.8	--
D	20	LW3-C738	115	--	0.2	--	0.0	--	0.1	--	1.3
D	25	LW3-UC03	120	--	0.6	--	ND	--	--	4.8	--
D	25	RM11E-C003	172	--	1.2	--	ND	--	0.0	1.9	--
D	25	RM11E-C019	213	--	1.3	--	ND	--	0.0	18.0	--
D	25	RM11E-C022	140	--	3.6	--	0.0	--	0.0	5.6	--
D	25	RM11E-C023	301	--	0.2	--	0.0	--	0.0	1.3	--
D	25	RM11E-C048-R1	134	--	1.3	--	0.0	--	0.0	0.1	--
D	25	WLCGWF03GNVC01	85	--	0.9	--	--	--	--	1.8	--
D	25	WLCGWF03GNVC0103	88	--	0.9	--	--	--	--	1.7	--
D	3	LW2-C089	98	--	0.5	--	ND	--	0.0	6.6	--
D	3	LW2-C092	212	--	3.0	--	ND	--	0.4	30.0	--
D	3	LW2-C094	72	--	0.4	--	0.1	--	0.1	4.2	--
D	3	LWM-C3	382	--	1.1	--	ND	--	0.1	--	10.0
D	3	WLCITG08SED01	198	--	0.8	--	--	--	0.1	1.2	--
D	3	WLCITG08SED02	259	--	7.4	--	--	--	0.3	2.4	--
D	3	WLCITG08SED11	76	--	3.0	--	--	--	0.3	4.0	--
D	3	WLCITG08SED14	107	--	1.3	--	--	--	0.3	2.2	--
D	5	WR-WSI98SD017	90	--	1.6	--	--	--	0.6	--	--
D	6	WLCT4C04VC19	91	--	0.6	--	0.0	--	2.3	0.2	--
D	6	WLCT4C04VC22	335	--	1.6	--	ND	--	ND	ND	--
D	6	WLCT4C04VC29	91	--	0.7	--	0.0	--	1.6	2.6	--
D	6	WLCT4C04VC32	152	--	0.4	--	0.0	--	1.4	0.2	--
D	6	WLCT4G06T4B41106	305	--	1.5	--	ND	--	3.8	0.3	--
D	6	WLCT4G06T4S301	274	--	2.4	--	--	--	2.0	--	--
D	6	WLCT4G06T4S302	183	--	1.3	--	--	--	1.2	--	--
D	6	WLCT4G06T4S303	61	--	1.2	--	--	--	1.1	--	--
D	6	WLCT4G06T4S305	244	--	2.1	--	--	--	2.3	--	--
D	6	WLCT4J98HCS07	128	--	3.6	--	--	--	2.0	--	--
D	6	WLCT4J98HCS11	121	--	2.0	--	--	--	3.1	--	--
D	6	WLCT4J98HCS42	121	--	1.5	--	--	--	4.1	--	--
D	6	WR-WSI98SD031	90	--	1.3	--	--	--	3.1	--	--
D	9D	LW2-C179	346	--	1.2	--	ND	--	0.9	ND	--
D	9D	LW2-C187	197	--	1.2	--	ND	--	1.4	0.1	--
D	9D	LW2-C221	150	--	1.6	--	ND	--	--	0.0	--
D	9D	LW2-C263	376	--	8.1	--	0.1	--	4.9	ND	--
D	9D	LW2-C527	482	--	1.5	--	0.6	--	0.6	0.7	--
D	9D	LW2-C528	386	--	2.0	--	0.9	--	0.6	0.4	--
D	9D	WLCMRD08SDDA17SB	213	--	4.4	--	ND	--	3.3	ND	--
D	9D	WLCMRD08SDDC23SB	518	--	1.3	--	0.2	--	0.5	ND	--
D	9D	WLCMRD08SDDC24SB	457	--	11.9	--	ND	--	3.4	0.5	--
D	9D	WLCMRD08SDDC25SB	366	--	2.4	--	ND	--	3.5	0.5	--
D	9D	WLCMRD08SDUD1SB	610	--	1.1	--	ND	--	ND	ND	--
D	9D	WLCMRD08SDUD27SB	183	--	3.9	--	ND	--	3.0	ND	--
D	9D	WLCMRI02CS001	91	--	4.3	--	0.0	--	2.0	ND	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
D	9U	LW2-C258	304	--	1.6	--	--	--	--	--	--
D	9U	LW2-C263	376	--	8.1	--	0.1	--	4.9	ND	--
D	9U	LW2-C264	220	--	3.2	--	0.0	--	9.1	0.1	--
D	9U	LW2-C269	541	--	3.5	--	0.0	--	2.6	ND	--
D	9U	LW2-C270	182	--	3.4	--	0.2	--	3.0	ND	--
D	9U	LW2-C273	355	--	2.5	--	ND	--	1.4	--	--
D	9U	LW2-C283	258	--	9.1	--	0.0	--	4.1	ND	--
D	9U	LW2-C289	206	--	10.8	--	--	--	--	--	--
D	9U	LW2-C299	230	--	106.1	--	ND	--	--	ND	--
D	9U	LW2-C301	516	--	28.2	--	0.1	--	11.4	ND	--
D	9U	LW2-C302	348	--	1379.9	--	ND	--	60.0	ND	--
D	9U	LW2-C305	160	--	5.5	--	0.1	--	--	0.4	--
D	9U	LW2-C305-2	240	--	9.0	--	0.2	--	--	0.2	--
D	9U	LW2-C311	153	--	2.9	--	0.1	--	2.0	0.1	--
D	9U	LW2-C521	280	--	40.3	--	ND	--	--	ND	--
D	9U	LW2-C525	341	--	11.6	--	ND	--	7.1	ND	--
D	9U	LW3-C662	327	--	14.2	--	0.0	--	4.4	ND	--
D	9U	LWM-C11	386	--	249.0	--	ND	--	31.3	--	0.2
D	9U	WLCDRD05VC052	88	--	15.6	--	ND	--	--	0.8	--
D	9U	WLCDRD05VC054	201	--	2.4	--	ND	--	--	0.4	--
D	9U	WLCGSD01AN0101	40	--	11.9	--	--	--	1.6	--	--
D	9U	WLCGSD01AN0102	40	--	31.6	--	--	--	3.1	--	--
D	9U	WLCGSD01AN0103	40	--	642.6	--	--	--	21.3	--	--
D	9U	WLCGSG04RAA17	610	--	39.3	--	--	--	20.0	--	--
D	9U	WLCGSG07GSB2	213	--	3.5	--	--	--	2.8	--	--
D	9U	WLCGSG07GSB5	213	--	4.3	--	--	--	3.1	--	--
D	9U	WLCGSG07GSB7	457	--	88.9	--	--	--	25.0	--	--
D	9U	WLCGSG07GSC2	213	--	1.8	--	--	--	--	--	--
D	9U	WLCGSG07GSC7	213	--	61.0	--	--	--	--	--	--
D	9U	WLCGSJ06GS05	335	--	5.8	--	--	--	1.0	--	--
D	9U	WLCGSJ06GS06	335	--	1.7	--	--	--	0.7	--	--
D	9U	WLCGSJ06GS07	823	--	117.1	--	--	--	16.3	--	--
D	9U	WLCGSJ06GS09	823	--	12.1	--	--	--	1.8	--	--
D	9U	WLCMRD08SDDA17SB	213	--	4.4	--	ND	--	3.3	ND	--
D	9U	WLCMRD08SDUD1SB	610	--	1.1	--	ND	--	ND	ND	--
D	9U	WLCSLH01GP25	960	--	4.5	--	--	--	2.1	--	--
D	9U	WLCSLH01GP26	716	--	1.1	--	--	--	0.2	--	--
D	9U	WLCSLH01GP27	472	--	1.1	--	--	--	--	--	--
D	9U	WLCSLH01GP28	930	--	1.9	--	--	--	1.8	--	--
D	9U	WLCSLH01GP29	381	--	1.8	--	--	--	--	--	--
D	9U	WLCSLH01GP30	564	--	1.3	--	--	--	ND	--	--
D	9U	WLCSLH01GP31	381	--	13.9	--	--	--	--	--	--
D	9U	WLCSLH01GP32	198	--	43.6	--	--	--	--	--	--
D	9U	WR-WSI98SD072	90	--	2.2	--	0.0	--	0.1	0.3	--
E	11	LW2-C206	137	--	0.7	0.7	0.5	0.3	0.3	3.5	--
E	11	LW2-C207	159	0.13	0.7	0.3	0.1	0.0	0.5	--	2.9
E	11	LWM-TCLP7	275	--	1.5	--	--	--	--	--	--
E	12	LW2-C244	270	--	0.5	0.3	0.1	0.1	0.1	1.2	--
E	13	LW2-C254	74	--	0.2	0.2	0.1	0.0	0.1	1.2	--
E	13	LW2-C277	341	--	1.1	1.1	0.4	0.2	0.1	--	1.0
E	13	LW2-C280	137	--	1.1	ND	ND	ND	0.1	ND	--
E	13	LW2-C291	289	0.04	0.3	0.0	0.1	0.1	0.0	--	3.7
E	13	LW2-C293	272	--	2.2	1.6	0.5	0.2	0.1	--	1.5
E	13	LW2-C293-2	152	0.13	2.7	0.4	0.4	0.1	0.2	--	2.0
E	13	LW2-C295	256	--	2.9	17.0	1.1	1.1	0.6	0.8	--
E	13	LW3-C665	366	--	1.4	0.3	ND	0.1	0.2	--	0.1
E	14	LW2-C300-2	152	--	0.2	0.1	0.2	0.1	--	1.1	--
E	14	LW2-C316	339	1.69	8.8	60.9	3.8	2.5	9.0	0.4	--
E	14	LW2-C327	174	0.03	0.2	0.1	0.1	0.0	0.0	1.1	--
E	14	LW2-C329	359	0.04	9.3	0.1	ND	0.1	0.9	ND	--
E	14	LW2-C332	170	1.2	0.7	13.1	1.6	6.5	0.0	ND	--
E	14	LW2-C334	110	4.42	0.3	4.0	1.4	1.7	0.1	ND	--
E	14	LW2-C335	70	1.01	0.4	3.1	1.0	6.8	0.1	ND	--
E	14	LW2-C348	240	--	28.4	711.0	26.0	153.3	0.2	ND	--
E	14	LW2-C351	80	5.73	2.2	51.0	2.8	21.5	0.3	0.3	--
E	14	LW2-C356	336	--	0.2	2.8	0.2	0.3	0.0	--	--
E	14	LW2-C359	378	--	3.4	73.9	4.9	80.7	0.1	0.6	--
E	14	LW2-C360	213	--	0.3	1.7	0.4	2.5	0.0	ND	--
E	14	LW2-C360-2	299	--	1.9	15.0	3.8	19.3	--	ND	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
E	14	LW2-C366	464	--	0.1	ND	ND	ND	ND	4.2	--
E	14	LW2-C366-2	288	--	0.2	2.3	0.3	1.0	0.1	0.4	--
E	14	LW2-C368	136	--	0.1	1.3	0.9	1.5	ND	ND	--
E	14	LW2-C371	162	--	0.2	0.9	0.3	0.4	0.0	--	2.2
E	14	LW2-C377	482	0.23	0.6	2.4	0.3	0.0	0.1	--	0.3
E	14	LW3-C664	115	--	0.3	0.4	0.3	0.2	--	--	1.4
E	14	LW3-C679	317	3.38	0.2	0.5	0.4	2.4	--	--	1.4
E	14	LW3-C688	281	0.1	0.3	2.0	9.0	4.5	0.0	--	1.2
E	14	LWM-C14	376	418.5	8.7	250.0	ND	220.0	0.3	--	5.0
E	14	WLCDRD05VC070	274	--	0.3	0.4	1.2	0.8	--	0.3	--
E	14	WLCEAF02WB08	497	--	0.2	1.0	ND	2.2	--	--	--
E	14	WLCEAF02WB09	1036	--	0.1	0.2	ND	1.6	--	--	--
E	14	WLCEAF02WB10	518	--	1443.7	6400.0	ND	230.0	--	--	--
E	14	WLCEAF02WB11	442	--	1562.9	6900.0	ND	733.3	--	--	--
E	14	WLCEAF02WB13	518	--	1.1	4.6	ND	4.1	--	--	--
E	14	WLCEAF02WB14	61	--	1.4	8.1	3.0	9.3	--	--	--
E	14	WLCEAF02WB15	61	--	0.2	0.8	0.5	1.9	--	--	--
E	14	WLCEAF02WB17	61	--	1.3	3.2	ND	40.7	--	--	--
E	14	WLCEAF02WB18	610	--	0.5	2.2	ND	1.0	--	--	--
E	14	WLCEAF02WB19	43	--	0.6	3.1	2.0	4.1	--	--	--
E	14	WLCEAF02WB23	201	--	0.6	2.3	ND	3.0	--	--	--
E	14	WLCEAF02WB24	567	--	2.6	0.9	ND	180.0	--	--	--
E	14	WLCEAF02WB25	52	--	18.7	3.5	ND	--	--	--	--
E	14	WLRELF99OSS001	70	--	1.3	17.7	4.5	7.1	0.2	--	--
E	14	WLRELF99OSS002	90	--	3.9	52.0	7.1	113.3	0.2	--	--
E	14	WLRELF99OSS003	30	--	0.7	7.4	ND	18.7	0.1	--	--
E	14	WLRELF99OSS004	50	--	13.8	160.0	36.8	ND	3.8	--	--
E	14	WLRELF99OSS005	90	--	0.2	1.5	ND	1.4	0.0	--	--
E	14	WLRELF99OSS006	30	--	3.2	41.0	23.6	73.3	0.1	--	--
E	14	WLRELF99RB2	23	--	0.4	3.6	6.2	8.7	0.0	--	--
E	14	WLRELF99RB6	58	--	0.1	0.4	2.0	2.6	0.1	--	--
E	14	WR-WSI98SD081C	90	2.85	0.4	0.8	ND	0.3	0.2	--	--
E	14	WR-WSI98SD084	90	--	2.6	45.5	ND	12.0	0.4	ND	--
E	14	WR-WSI98SD090	90	--	0.6	1.7	ND	7.3	0.2	ND	--
E	14	WR-WSI98SD092	90	550	12.8	290.0	ND	146.7	0.6	ND	--
E	16	WLCCWI08DMMU3ABDE	91	--	0.6	2.2	0.4	0.3	0.0	--	--
E	16	WLCCWI08DMMU3B	91	--	0.6	6.6	0.8	ND	0.1	1.3	--
E	17D	WR-WSI98SD096	90	--	0.4	0.1	ND	ND	0.1	1.5	--
E	17S	LW2-C364	75	--	0.2	0.5	0.2	0.0	0.1	2.0	--
E	17S	LW2-C379	196	--	0.3	0.1	0.1	0.1	0.0	2.2	--
E	17S	LW2-C382	153	0.01	0.3	2.8	0.5	0.0	0.0	--	1.5
E	17S	LW2-C383	63	--	0.1	0.0	0.0	ND	0.0	1.2	--
E	17S	LW2-C384	128	--	2.4	0.2	0.2	0.2	0.7	--	55.0
E	17S	LW2-C392	76	--	0.4	0.0	0.1	0.0	0.2	4.5	--
E	17S	LW2-C393	152	--	0.2	0.0	0.0	0.0	0.1	--	1.6
E	17S	LW2-C397	341	ND	0.4	0.1	0.1	0.0	0.0	2.1	--
E	17S	LW2-C402	65	--	0.4	--	--	--	0.0	2.1	--
E	17S	LW2-C421	123	--	0.3	--	--	--	0.0	1.7	--
E	17S	LW3-C708	236	--	7.5	2.3	ND	7.3	1.3	--	34.5
E	17S	PSYD&M97DM20	137	--	0.5	--	--	--	0.1	1.1	--
E	17S	PSYSEA98PSY07C	222	--	0.3	--	--	--	0.0	1.9	--
E	17S	PSYSEA98PSY16C	121	--	0.4	--	--	--	0.1	4.1	--
E	17S	PSYSEA98PSY18C	121	--	0.4	--	--	--	0.1	3.3	--
E	17S	PSYSEA98PSY20C	121	--	0.7	--	--	--	0.1	11.5	--
E	17S	PSYSEA98PSY23C	121	--	0.6	--	--	--	0.1	8.5	--
E	17S	PSYSEA98PSY27C	121	--	1.2	--	--	--	0.0	ND	--
E	17S	PSYSEA98PSY30C	152	--	1.0	--	--	--	--	--	--
E	17S	WLCPSK09DMMU1	328	--	0.2	0.1	ND	0.3	0.3	1.4	--
E	17S	WR-WSI98SD133	90	--	1.1	--	--	--	0.5	12.0	--
E	18	LW2-C431	175	--	0.3	1.3	0.3	0.1	0.1	ND	--
E	19	LW2-C440	254	--	0.2	0.1	0.1	0.0	0.0	1.4	--
E	19	LW2-C441-2	147	--	0.2	0.1	0.2	0.0	0.0	2.3	--
E	19	LW2-C444	206	--	0.2	0.1	0.4	ND	0.0	1.4	--
E	19	LW2-C447	112	--	0.3	--	--	--	0.0	4.0	--
E	19	LW2-C448	365	--	0.3	--	--	--	--	2.0	--
E	19	LW2-C450	245	0.02	0.5	0.3	1.4	0.1	0.1	11.2	--
E	19	LW2-C453	270	--	0.7	1.0	4.8	0.0	0.0	1.7	--
E	19	LW2-C455	274	0.1	0.7	1.5	7.7	0.0	0.1	--	3.0
E	19	LW2-C456	222	--	0.3	0.1	0.2	0.0	0.2	1.4	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
E	19	LW2-C461	279	--	0.2	0.0	0.1	ND	0.0	1.2	--
E	19	LW2-C477	123	--	0.2	0.1	0.1	0.0	0.0	--	2.6
E	19	LWM-TCLP19	374	--	2.1	--	--	--	--	--	--
E	19	WLCGNG03HA42	61	--	6.5	--	--	--	0.3	--	--
E	19	WLCGNG03HA43	76	--	22.4	--	--	--	4.2	--	--
E	19	WR-WSI98SD143	90	--	1.9	--	--	--	ND	--	--
E	1A	LW2-C009	153	--	0.1	0.0	0.0	ND	0.0	3.8	--
E	1A	LW2-C011	341	--	0.3	0.1	0.1	ND	0.1	1.2	--
E	1A	LW2-C011-2	256	--	0.2	0.1	0.1	0.0	0.0	3.0	--
E	1A	LW2-C015	107	0.01	0.3	0.1	0.1	ND	0.0	--	5.5
E	1A	LW2-C019	264	--	0.2	0.0	0.0	0.0	0.0	--	5.5
E	1A	LW2-C019-2	153	0.02	1.1	--	--	--	--	--	5.5
E	1A	LW2-C020	232	--	0.3	0.1	0.1	0.1	0.1	8.5	--
E	1A	LW3-C600	276	--	0.3	0.3	0.4	0.1	0.1	--	2.5
E	1A	LW3-DC01-2	170	0.01	0.3	0.1	0.1	0.1	0.0	2.8	--
E	1A	WLCOSJ00RB13	60	--	1.0	--	--	--	0.0	9.5	--
E	20	LW3-C738	115	--	0.2	0.1	0.1	0.1	0.1	--	3.2
E	20	LWM-C24	370	--	0.4	0.9	3.6	ND	0.1	--	4.3
E	24	LW3-C747	158	--	0.2	0.1	0.1	0.1	--	--	1.5
E	24	LW3-C752	344	--	1.8	0.2	0.3	0.1	--	--	1.3
E	24	LW3-C757	214	--	0.1	0.1	0.1	0.1	--	1.1	--
E	24	WLCDRD05VC049	244	--	0.4	0.1	0.1	0.1	--	2.2	--
E	24	WLCDRD05VC051	122	--	0.2	0.1	0.1	0.1	--	1.1	--
E	24	WLCDRD05VC106	229	--	0.7	0.1	ND	0.2	--	4.5	--
E	24	WLCDRD05VC108	235	--	0.7	0.2	ND	1.9	--	12.5	--
E	24	WLCDRD05VC110	195	--	0.8	0.3	ND	0.3	--	5.0	--
E	25	LW3-UC01	93	--	0.4	0.2	0.1	0.8	0.0	2.4	--
E	25	LW3-UC03	120	--	0.6	0.3	ND	0.6	--	12.0	--
E	25	RM11E-C003	172	1	1.2	0.6	ND	ND	0.1	4.9	--
E	25	RM11E-C019	213	0.04	1.3	2.3	ND	ND	0.0	45.0	--
E	25	RM11E-C020	91	--	0.1	0.0	ND	ND	--	1.2	--
E	25	RM11E-C022	140	0.06	3.6	0.8	0.0	ND	0.1	14.0	--
E	25	RM11E-C023	301	0.05	0.2	0.3	0.1	ND	0.0	3.4	--
E	25	RM11E-C047	91	ND	0.1	0.1	ND	ND	0.0	1.1	--
E	25	RM11E-C048-R1	134	0.82	1.3	0.1	0.1	0.0	0.1	0.2	--
E	25	RM11E-C048-R2	82	--	0.2	--	--	--	--	1.1	--
E	25	WLCGWF03GNVC01	85	--	0.9	--	--	--	--	4.5	--
E	25	WLCGWF03GNVC0103	88	--	0.9	--	--	--	--	4.3	--
E	3	LW2-C083	188	--	0.1	0.0	0.0	0.1	0.0	1.2	--
E	3	LW2-C084	65	0.01	0.2	0.0	0.0	0.1	0.0	1.5	--
E	3	LW2-C087	110	--	0.1	0.0	0.0	0.0	0.0	1.5	--
E	3	LW2-C089	98	--	0.5	0.2	ND	1.7	0.1	16.5	--
E	3	LW2-C090	112	--	0.2	0.0	0.0	0.1	0.1	2.2	--
E	3	LW2-C091	211	--	0.2	0.0	0.1	0.1	0.1	--	2.5
E	3	LW2-C092	212	0.23	3.0	ND	ND	5.5	0.8	75.0	--
E	3	LW2-C094	72	0.06	0.4	0.2	0.3	0.8	0.2	10.5	--
E	3	LW2-C096	153	--	0.4	0.1	ND	0.2	1.0	8.0	--
E	3	LW2-C099	305	--	0.6	0.9	0.4	2.6	0.4	1.2	--
E	3	LW2-C106	461	--	0.5	0.2	0.3	0.1	0.2	1.1	--
E	3	LW2-C109	373	--	0.4	0.4	0.5	3.7	0.4	0.5	--
E	3	LW2-C111	153	0.01	0.1	0.1	0.1	0.0	0.0	1.5	--
E	3	LW2-C111-2	420	0.08	0.3	0.3	0.3	0.0	0.2	1.1	--
E	3	LW2-C112	274	--	0.3	0.3	0.2	0.1	1.4	1.4	--
E	3	LWM-C3	382	--	1.1	ND	ND	ND	0.2	--	25.0
E	3	WLCITG08SED01	198	--	0.8	--	--	--	0.1	2.9	--
E	3	WLCITG08SED02	259	--	7.4	--	--	--	0.6	6.0	--
E	3	WLCITG08SED11	76	--	3.0	--	--	--	0.6	10.0	--
E	3	WLCITG08SED14	107	--	1.3	--	--	--	0.5	5.5	--
E	3	WLCT0I98B401C1	91	--	0.3	0.1	0.1	3.1	--	0.4	--
E	5	LW2-C121	242	--	0.6	0.1	0.0	ND	1.2	0.2	--
E	5	LW2-C122	192	--	0.4	1.5	0.5	0.0	0.6	0.3	--
E	5	WR-WSI98SD017	90	--	1.6	--	--	--	1.2	--	--
E	6	WLCT4C04VC09	152	--	0.2	0.1	0.1	0.2	0.1	1.6	--
E	6	WLCT4C04VC15	91	--	0.5	0.2	0.2	0.1	0.2	1.7	--
E	6	WLCT4C04VC19	91	--	0.6	0.1	0.1	0.0	4.5	0.4	--
E	6	WLCT4C04VC22	335	--	1.6	ND	ND	ND	ND	ND	--
E	6	WLCT4C04VC29	152	--	0.2	0.0	0.0	0.0	1.3	0.3	--
E	6	WLCT4C04VC32	152	--	0.4	0.1	0.1	0.0	2.8	0.4	--
E	6	WLCT4G06T4B41106	305	--	1.5	ND	ND	ND	7.5	0.7	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
E	6	WLCT4G06T4S301	274	--	2.4	--	--	--	4.0	--	--
E	6	WLCT4G06T4S302	183	--	1.3	--	--	--	2.5	--	--
E	6	WLCT4G06T4S303	61	--	1.2	--	--	--	2.2	--	--
E	6	WLCT4G06T4S305	244	--	2.1	--	--	--	4.5	--	--
E	6	WLCT4G06T4S307	122	--	0.6	--	--	--	1.2	--	--
E	6	WLCT4G06T4S308	61	--	0.7	--	--	--	1.5	--	--
E	6	WLCT4J98HCS07	128	--	3.6	--	--	--	4.0	--	--
E	6	WLCT4J98HCS11	121	--	2.0	--	--	--	6.3	--	--
E	6	WLCT4J98HCS27	106	--	0.6	--	--	--	1.7	--	--
E	6	WLCT4J98HCS42	121	--	1.5	--	--	--	8.3	--	--
E	6	WR-WSI98SD031	90	--	1.3	--	--	--	6.3	--	--
E	8	WLCBPE06SGP14	122	--	1.5	--	--	--	1.0	--	--
E	9D	LW2-C179	346	--	1.2	ND	ND	ND	1.7	ND	--
E	9D	LW2-C182	337	--	0.7	2.7	1.2	0.4	0.4	0.8	--
E	9D	LW2-C184	275	--	1.9	2.3	0.5	0.2	2.8	0.8	--
E	9D	LW2-C185	246	ND	1.1	--	--	--	1.7	--	--
E	9D	LW2-C187	197	--	1.2	0.8	ND	0.2	2.8	0.3	--
E	9D	LW2-C221	150	--	1.6	0.1	0.0	0.0	--	0.1	--
E	9D	LW2-C240	312	--	0.8	ND	ND	0.0	1.8	ND	--
E	9D	LW2-C263	376	--	8.1	2.5	0.2	0.2	9.8	ND	--
E	9D	LW2-C527	482	--	1.5	8.3	2.2	1.2	1.3	1.8	--
E	9D	LW2-C528	386	--	2.0	5.4	3.4	1.3	1.2	1.1	--
E	9D	LW2-C530	544	--	0.8	2.1	1.1	0.2	0.6	ND	--
E	9D	LW2-C531	371	--	5.5	0.6	0.8	0.0	4.3	0.3	--
E	9D	WLCMFH00SD05	54	--	8.4	--	--	--	9.8	0.8	--
E	9D	WLCMRD08SDDA17SB	213	--	4.4	0.5	ND	0.1	6.5	ND	--
E	9D	WLCMRD08SDDB22SB	335	--	0.5	0.6	0.4	0.1	1.1	1.0	--
E	9D	WLCMRD08SDDC23SB	518	--	1.3	3.5	0.9	1.3	1.0	ND	--
E	9D	WLCMRD08SDDC24SB	457	--	11.9	2.2	ND	ND	6.8	1.4	--
E	9D	WLCMRD08SDDC25SB	366	--	2.4	0.8	ND	ND	7.0	1.2	--
E	9D	WLCMRD08SDUD1SB	610	--	1.1	ND	ND	ND	ND	ND	--
E	9D	WLCMRD08SDUD27SB	183	--	3.9	0.4	ND	ND	6.0	ND	--
E	9D	WLCMRI02CS001	91	--	4.3	0.6	0.2	0.2	4.0	ND	--
E	9D	WLCMRI02CS003	91	--	1.0	0.7	0.2	0.4	1.6	ND	--
E	9U	LW2-C258	304	--	1.6	--	--	--	--	--	--
E	9U	LW2-C263	376	--	8.1	2.5	0.2	0.2	9.8	ND	--
E	9U	LW2-C264	220	--	3.2	0.3	0.1	0.0	18.3	0.3	--
E	9U	LW2-C269	541	--	3.5	0.1	0.1	0.1	5.3	ND	--
E	9U	LW2-C270	182	--	3.4	2.1	0.8	1.1	6.0	ND	--
E	9U	LW2-C273	355	--	2.5	0.0	ND	ND	2.8	--	--
E	9U	LW2-C283	258	--	9.1	1.5	0.1	0.2	8.3	ND	--
E	9U	LW2-C289	206	--	10.8	--	--	--	--	--	--
E	9U	LW2-C299	230	--	106.1	0.6	ND	0.4	--	ND	--
E	9U	LW2-C301	516	--	28.2	0.4	0.3	0.4	22.8	ND	--
E	9U	LW2-C302	348	--	1379.9	3.6	ND	ND	120.0	ND	--
E	9U	LW2-C305	220	--	0.4	0.8	0.3	12.5	--	ND	--
E	9U	LW2-C305-2	240	--	9.0	2.0	0.9	0.4	--	0.6	--
E	9U	LW2-C311	153	--	2.9	2.0	0.2	0.2	4.0	0.2	--
E	9U	LW2-C312	152	--	0.2	0.2	0.0	1.9	--	ND	--
E	9U	LW2-C521	280	--	40.3	ND	ND	ND	--	ND	--
E	9U	LW2-C525	341	--	11.6	ND	ND	ND	14.3	ND	--
E	9U	LW3-C662	327	--	14.2	0.2	0.1	0.1	8.8	ND	--
E	9U	LWM-C11	386	--	249.0	ND	ND	ND	62.5	--	0.5
E	9U	WLCDRD05VC052	88	--	15.6	0.5	ND	ND	--	1.9	--
E	9U	WLCDRD05VC054	201	--	2.4	0.5	ND	ND	--	1.0	--
E	9U	WLCGSD01AN0101	40	--	11.9	--	--	--	3.3	--	--
E	9U	WLCGSD01AN0102	40	--	31.6	--	--	--	6.3	--	--
E	9U	WLCGSD01AN0103	40	--	642.6	--	--	--	42.5	--	--
E	9U	WLCGSG04RAA17	610	--	39.3	--	--	--	40.0	--	--
E	9U	WLCGSG07GSB2	213	--	3.5	--	--	--	5.5	--	--
E	9U	WLCGSG07GSB5	213	--	4.3	--	--	--	6.3	--	--
E	9U	WLCGSG07GSB7	457	--	88.9	--	--	--	50.0	--	--
E	9U	WLCGSG07GSC2	213	--	1.8	--	--	--	--	--	--
E	9U	WLCGSG07GSC7	213	--	61.0	--	--	--	--	--	--
E	9U	WLCGSJ06GS05	335	--	5.8	--	--	--	2.0	--	--
E	9U	WLCGSJ06GS06	335	--	1.7	--	--	--	1.4	--	--
E	9U	WLCGSJ06GS07	823	--	117.1	--	--	--	32.5	--	--
E	9U	WLCGSJ06GS09	823	--	12.1	--	--	--	3.5	--	--
E	9U	WLCMRD08SDDA17SB	213	--	4.4	0.5	ND	0.1	6.5	ND	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor: 2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
E	9U	WLCMRD08SDUD1SB	610	--	1.1	ND	ND	ND	ND	ND	--
E	9U	WLCMRD08SDUD27SB	183	--	3.9	0.4	ND	ND	6.0	ND	--
E	9U	WLCSLH01GP25	960	--	4.5	--	--	--	4.3	--	--
E	9U	WLCSLH01GP26	716	--	1.1	--	--	--	0.3	--	--
E	9U	WLCSLH01GP27	472	--	1.1	--	--	--	--	--	--
E	9U	WLCSLH01GP28	930	--	1.9	--	--	--	3.5	--	--
E	9U	WLCSLH01GP29	381	--	1.8	--	--	--	--	--	--
E	9U	WLCSLH01GP30	564	--	1.3	--	--	--	ND	--	--
E	9U	WLCSLH01GP31	381	--	13.9	--	--	--	--	--	--
E	9U	WLCSLH01GP32	198	--	43.6	--	--	--	--	--	--
E	9U	WR-WSI98SD072	90	1.9	2.2	0.2	0.1	0.1	0.2	0.7	--
F	10	LW2-C192	249	0.12	1.0	1.7	0.6	0.2	3.3	2.9	--
F	10	WR-WSI98SD049	90	--	0.3	0.1	0.1	ND	0.4	1.5	--
F	11	LW2-C192	249	0.12	1.0	1.7	0.6	0.2	3.3	2.9	--
F	11	LW2-C197	203	--	0.9	4.9	1.2	1.1	1.4	3.9	--
F	11	LW2-C199	172	--	9.3	0.2	0.1	0.0	0.6	2.7	--
F	11	LW2-C202	188	--	1.2	3.1	0.5	1.2	2.1	5.0	--
F	11	LW2-C203	214	0.13	1.1	2.5	0.5	0.2	1.6	--	37.3
F	11	LW2-C206	137	--	0.7	1.5	1.2	0.7	0.9	9.4	--
F	11	LW2-C207	159	0.25	0.7	0.7	0.2	0.1	1.4	--	7.7
F	11	LW2-C207-2	143	0.03	0.9	0.3	0.1	0.3	2.1	3.2	--
F	11	LW3-C651	128	--	0.9	0.9	ND	1.8	0.7	0.8	--
F	11	LWM-TCLP7	275	--	1.5	--	--	--	--	--	--
F	12	LW2-C244	270	--	0.5	0.6	0.3	0.3	0.3	3.1	--
F	12	LW3-C651	128	--	0.9	0.9	ND	1.8	0.7	0.8	--
F	13	LW2-C254	74	--	0.2	0.4	0.2	0.0	0.3	3.1	--
F	13	LW2-C277	341	--	1.1	2.1	1.1	0.6	0.2	--	2.7
F	13	LW2-C280	137	--	1.1	ND	ND	ND	0.1	ND	--
F	13	LW2-C291	289	0.09	0.3	0.0	0.2	0.2	0.1	--	9.9
F	13	LW2-C293	272	--	2.2	3.2	1.2	0.4	0.4	--	3.9
F	13	LW2-C293-2	152	0.26	2.7	0.8	1.1	0.2	0.4	--	5.3
F	13	LW2-C295	256	--	2.9	34.0	2.7	2.8	1.5	2.0	--
F	13	LW2-C296	152	--	0.5	0.3	0.4	0.2	0.2	1.7	--
F	13	LW2-C303	86	--	0.4	0.6	0.3	1.8	0.6	--	1.0
F	13	LW3-C665	366	--	1.4	0.6	ND	0.2	0.5	--	0.4
F	13	LWM-C13	388	1.86	0.5	0.2	ND	0.1	0.2	--	1.2
F	14	LW2-C290	92	ND	0.1	0.4	0.2	1.2	0.0	--	0.2
F	14	LW2-C293-2	152	0.26	2.7	0.8	1.1	0.2	0.4	--	5.3
F	14	LW2-C300-2	152	--	0.2	0.2	0.4	0.2	--	2.8	--
F	14	LW2-C312	152	--	0.2	0.4	0.1	4.7	--	ND	--
F	14	LW2-C314	336	0.27	0.2	5.8	ND	1.2	--	ND	--
F	14	LW2-C316	339	3.38	8.8	121.8	9.5	6.3	24.0	1.1	--
F	14	LW2-C321-2	138	0.04	0.2	0.1	0.2	0.0	0.1	1.5	--
F	14	LW2-C323	119	0.53	0.2	0.7	0.3	0.1	0.2	3.4	--
F	14	LW2-C324	328	0.14	0.6	0.6	0.4	0.0	1.1	2.1	--
F	14	LW2-C326	61	0.07	0.2	0.2	0.2	0.0	--	3.2	--
F	14	LW2-C327	301	0.34	0.1	2.0	0.2	0.2	0.2	--	0.5
F	14	LW2-C329	359	0.08	9.3	0.2	ND	0.3	2.4	ND	--
F	14	LW2-C332	170	2.41	0.7	26.2	4.1	16.3	0.1	ND	--
F	14	LW2-C333	103	0.33	0.1	1.1	0.3	0.0	0.2	ND	--
F	14	LW2-C334	110	8.84	0.3	8.0	3.5	4.3	0.3	ND	--
F	14	LW2-C335	70	2.02	0.4	6.2	2.4	17.0	0.1	ND	--
F	14	LW2-C348	240	--	28.4	1422.0	65.0	383.3	0.5	ND	--
F	14	LW2-C351	80	11.47	2.2	102.0	7.0	53.7	0.8	0.8	--
F	14	LW2-C356	336	--	0.2	5.6	0.4	0.7	0.0	--	--
F	14	LW2-C358	303	--	0.3	0.4	0.4	1.7	--	ND	--
F	14	LW2-C359	378	--	3.4	147.8	12.2	201.7	0.1	1.5	--
F	14	LW2-C360	213	--	0.3	3.4	1.0	6.2	0.1	ND	--
F	14	LW2-C360-2	572	--	0.2	0.2	0.2	0.2	--	2.3	--
F	14	LW2-C361	155	--	0.2	0.2	0.2	0.0	--	1.6	--
F	14	LW2-C362	152	--	0.2	1.9	0.9	0.5	0.0	ND	--
F	14	LW2-C366	464	--	0.1	0.0	0.0	ND	ND	11.2	--
F	14	LW2-C366-2	288	--	0.2	4.5	0.6	2.5	0.1	1.0	--
F	14	LW2-C368	241	--	0.2	1.0	0.3	0.7	0.1	2.1	--
F	14	LW2-C371	162	--	0.2	1.8	0.8	0.9	0.0	--	5.7
F	14	LW2-C377	482	0.46	0.6	4.8	0.7	0.1	0.3	--	0.9
F	14	LW2-C523	118	0.13	0.4	2.2	0.9	0.4	--	1.0	--
F	14	LW3-C664	115	--	0.3	0.7	0.9	0.6	--	--	3.6
F	14	LW3-C679	317	6.75	0.2	1.1	1.0	6.0	--	--	3.6

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
F	14	LW3-C688	281	0.21	0.3	4.0	22.5	11.2	0.0	--	3.1
F	14	LW3-C690	471	1.28	0.4	1.3	0.9	0.2	0.2	--	6.0
F	14	LWM-C14	376	837	8.7	500.0	ND	550.0	0.8	--	13.3
F	14	LWM-TCLP14A	207	--	1.3	--	--	--	--	--	--
F	14	WLCDRD05VC056	265	--	1.2	22.0	ND	8.5	--	ND	--
F	14	WLCDRD05VC062	165	--	0.2	0.9	0.7	0.2	--	2.0	--
F	14	WLCDRD05VC068	238	--	0.2	0.4	0.4	1.2	--	1.1	--
F	14	WLCDRD05VC070	274	--	0.3	0.7	3.0	2.0	--	0.8	--
F	14	WLCDRD05VC072	274	--	0.3	0.5	0.5	0.3	--	1.3	--
F	14	WLCEAF02WB08	497	--	0.2	1.9	ND	5.5	--	--	--
F	14	WLCEAF02WB09	1036	--	0.1	0.4	ND	4.0	--	--	--
F	14	WLCEAF02WB10	518	--	1443.7	12800.0	ND	575.0	--	--	--
F	14	WLCEAF02WB11	442	--	1562.9	13800.0	ND	1833.3	--	--	--
F	14	WLCEAF02WB12	46	--	0.1	0.8	1.3	1.7	--	--	--
F	14	WLCEAF02WB13	518	--	1.1	9.2	ND	10.2	--	--	--
F	14	WLCEAF02WB14	61	--	1.4	16.2	7.5	23.3	--	--	--
F	14	WLCEAF02WB15	61	--	0.2	1.6	1.3	4.8	--	--	--
F	14	WLCEAF02WB16	58	--	0.1	0.8	ND	2.2	--	--	--
F	14	WLCEAF02WB17	61	--	1.3	6.4	ND	101.7	--	--	--
F	14	WLCEAF02WB18	610	--	0.5	4.4	ND	2.5	--	--	--
F	14	WLCEAF02WB19	43	--	0.6	6.2	5.0	10.3	--	--	--
F	14	WLCEAF02WB20	61	--	0.1	0.5	ND	1.1	--	--	--
F	14	WLCEAF02WB23	201	--	0.6	4.6	ND	7.5	--	--	--
F	14	WLCEAF02WB24	567	--	2.6	1.8	ND	450.0	--	--	--
F	14	WLCEAF02WB25	52	--	18.7	7.0	ND	--	--	--	--
F	14	WLR0797WRGC24	182	--	0.2	2.0	0.2	1.6	--	0.7	--
F	14	WLR0797WRGC25	61	--	0.2	0.1	0.2	ND	--	1.3	--
F	14	WLRELF99OSS001	70	--	1.3	35.4	11.3	17.7	0.5	--	--
F	14	WLRELF99OSS002	90	--	3.9	104.0	17.8	283.3	0.4	--	--
F	14	WLRELF99OSS003	30	--	0.7	14.7	ND	46.7	0.2	--	--
F	14	WLRELF99OSS004	50	--	13.8	320.0	92.0	ND	10.0	--	--
F	14	WLRELF99OSS005	90	--	0.2	2.9	ND	3.6	0.1	--	--
F	14	WLRELF99OSS006	30	--	3.2	82.0	59.0	183.3	0.2	--	--
F	14	WLRELF99RB2	23	--	0.4	7.2	15.5	21.7	0.1	--	--
F	14	WLRELF99RB6	58	--	0.1	0.7	5.0	6.5	0.2	--	--
F	14	WR-WSI98SD072	90	3.8	2.2	0.3	0.3	0.3	0.6	1.9	--
F	14	WR-WSI98SD081C	90	5.7	0.4	1.6	ND	0.8	0.6	--	--
F	14	WR-WSI98SD084	90	--	2.6	91.0	ND	30.0	1.0	ND	--
F	14	WR-WSI98SD090	90	--	0.6	3.4	ND	18.3	0.6	ND	--
F	14	WR-WSI98SD092	90	1100	12.8	580.0	ND	366.7	1.6	ND	--
F	15	LW3-C676	62	--	0.4	0.3	0.4	0.2	0.8	--	1.5
F	15	LW3-C678	245	0.58	1.3	1.1	2.2	0.2	0.2	--	2.9
F	16	LW2-C358	303	--	0.3	0.4	0.4	1.7	--	ND	--
F	16	LW2-C361	155	--	0.2	0.2	0.2	0.0	--	1.6	--
F	16	LW2-C377	482	0.46	0.6	4.8	0.7	0.1	0.3	--	0.9
F	16	LW2-C401	367	--	0.2	0.4	0.7	0.0	0.1	--	11.9
F	16	LW2-C532	293	--	0.4	--	--	--	--	--	5.1
F	16	LW3-C688	281	0.21	0.3	4.0	22.5	11.2	0.0	--	3.1
F	16	LW3-C690	471	1.28	0.4	1.3	0.9	0.2	0.2	--	6.0
F	16	PSYSEA98PSY39C	121	--	0.1	--	--	--	--	1.2	--
F	16	TOSCO99DMMU1	304	--	0.4	0.2	0.4	0.2	0.2	4.7	--
F	16	WLCCWI08DMMU3ABDE	91	--	0.6	4.4	1.1	0.8	0.1	--	--
F	16	WLCCWI08DMMU3B	91	--	0.6	13.1	2.0	ND	0.2	3.5	--
F	16	WLCDRD05VC072	274	--	0.3	0.5	0.5	0.3	--	1.3	--
F	16	WLCPWL09APS-3	122	--	0.3	0.1	0.4	0.0	0.1	1.5	--
F	16	WLCPWL09URB-1	326	--	0.4	0.1	0.3	0.0	0.1	1.7	--
F	16	WLCPWL09URB-2	149	--	0.6	1.3	2.2	0.3	0.3	2.7	--
F	16	WLCPWL09URB-D	194	--	0.2	0.1	0.2	0.1	0.1	1.1	--
F	16	WR-WSI98SD117	90	--	0.5	0.4	0.3	0.4	0.1	2.1	--
F	17D	LW2-C342	210	0.02	0.2	0.5	0.4	0.0	0.1	--	2.3
F	17D	WR-WSI98SD096	90	--	0.4	0.2	ND	ND	0.2	3.9	--
F	17D	WR-WSI98SD106	90	--	0.2	0.0	0.1	ND	0.1	1.1	--
F	17S	LW2-C364	75	--	0.2	1.0	0.6	0.0	0.2	5.3	--
F	17S	LW2-C372	94	0.02	0.3	0.0	0.1	ND	0.1	2.4	--
F	17S	LW2-C379	196	--	0.3	0.2	0.3	0.3	0.0	5.9	--
F	17S	LW2-C382	153	0.02	0.3	5.5	1.2	0.1	0.1	--	3.9
F	17S	LW2-C383	63	--	0.1	0.0	0.0	0.0	0.0	3.1	--
F	17S	LW2-C384	207	--	0.1	0.0	0.0	0.0	0.1	--	1.3
F	17S	LW2-C392	76	--	0.4	0.1	0.3	0.0	0.5	11.9	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
F	17S	LW2-C393	152	--	0.2	0.1	0.1	0.0	0.2	--	4.1
F	17S	LW2-C397	341	ND	0.4	0.2	0.3	0.0	0.0	5.5	--
F	17S	LW2-C402	65	--	0.4	--	--	--	0.1	5.7	--
F	17S	LW2-C405	134	0.02	0.2	0.2	0.2	0.1	0.1	6.5	--
F	17S	LW2-C417	353	--	0.1	0.1	0.1	0.0	0.2	2.3	--
F	17S	LW2-C421	123	--	0.3	--	--	--	0.1	4.5	--
F	17S	LW2-C425-2	300	--	0.1	0.1	0.0	0.0	0.2	1.5	--
F	17S	LW2-C426	132	ND	0.2	0.1	0.1	0.0	0.0	2.7	--
F	17S	LW2-C430	520	--	0.4	0.3	0.5	0.0	0.1	--	4.5
F	17S	LW2-NA4B	94	--	0.3	0.1	0.3	0.0	0.0	1.7	--
F	17S	LW3-C702	275	--	0.2	0.2	0.7	0.4	0.1	--	3.3
F	17S	LW3-C703	152	--	0.3	0.3	0.6	0.1	0.1	--	1.6
F	17S	LW3-C708	305	--	0.4	0.2	ND	0.3	0.1	--	2.7
F	17S	LWM-C21/LWM-C23	351	--	0.2	ND	ND	ND	0.1	--	1.5
F	17S	PSYD&M97DM20	137	--	0.5	--	--	--	0.2	2.9	--
F	17S	PSYSEA98PSY01C	219	--	0.5	--	--	--	0.2	5.7	--
F	17S	PSYSEA98PSY07C	222	--	0.3	--	--	--	0.1	5.1	--
F	17S	PSYSEA98PSY11C	121	--	0.3	--	--	--	0.1	1.3	--
F	17S	PSYSEA98PSY16C	243	--	0.3	--	--	--	0.1	1.7	--
F	17S	PSYSEA98PSY18C	121	--	0.4	--	--	--	0.3	8.8	--
F	17S	PSYSEA98PSY20C	121	--	0.7	--	--	--	0.3	30.7	--
F	17S	PSYSEA98PSY23C	121	--	0.6	--	--	--	0.4	22.7	--
F	17S	PSYSEA98PSY27C	121	--	1.2	--	--	--	0.0	ND	--
F	17S	PSYSEA98PSY30C	152	--	1.0	--	--	--	--	--	--
F	17S	WLCPSK09DMMU1	328	--	0.2	0.2	ND	0.7	0.7	3.6	--
F	17S	WR-WSI98SD133	90	--	1.1	--	--	--	1.2	32.0	--
F	17S	WR-WSI98SD141	90	--	0.5	0.1	ND	ND	0.2	2.7	--
F	18	LW2-C413	299	--	0.2	0.4	0.5	0.0	0.0	1.3	--
F	18	LW2-C413-2	349	--	0.3	2.2	0.6	2.3	0.0	1.0	--
F	18	LW2-C431	175	--	0.3	2.6	0.7	0.2	0.2	ND	--
F	18	LW2-C434	144	--	0.4	0.5	0.6	0.0	0.1	1.3	--
F	18	LW3-C701	375	--	0.1	0.2	0.6	0.1	0.0	1.9	--
F	18	LW3-C704	247	--	0.2	0.2	0.6	0.1	0.1	1.3	--
F	19	LW2-C440	354	--	0.2	--	--	--	0.1	2.3	--
F	19	LW2-C441	156	--	0.2	0.1	0.2	0.0	0.0	2.1	--
F	19	LW2-C441-2	147	--	0.2	0.2	0.6	0.0	0.1	6.1	--
F	19	LW2-C444	206	--	0.2	0.3	1.1	ND	0.1	3.6	--
F	19	LW2-C445	530	--	0.4	0.4	1.2	0.0	0.1	1.6	--
F	19	LW2-C447	112	--	0.3	--	--	--	0.1	10.6	--
F	19	LW2-C448	365	--	0.3	--	--	--	--	5.3	--
F	19	LW2-C450	245	0.05	0.5	0.6	3.6	0.3	0.1	29.7	--
F	19	LW2-C453	270	--	0.7	2.0	12.1	0.1	0.1	4.4	--
F	19	LW2-C455	274	0.2	0.7	3.0	19.2	0.0	0.2	--	7.9
F	19	LW2-C456	222	--	0.3	0.2	0.5	0.0	0.6	3.7	--
F	19	LW2-C457	173	--	0.4	0.1	0.3	0.0	0.8	1.9	--
F	19	LW2-C458-2	274	--	0.2	0.1	0.2	ND	--	1.1	--
F	19	LW2-C461	361	--	0.2	--	--	--	--	2.5	--
F	19	LW2-C468	272	--	0.2	0.1	0.2	0.0	0.0	1.6	--
F	19	LW2-C477	208	--	0.2	0.1	0.2	0.0	0.3	2.0	--
F	19	LW3-C721	362	0.08	0.2	0.5	1.3	0.2	0.1	--	1.7
F	19	LW3-C724	110	--	0.1	0.2	0.7	0.1	0.1	--	2.0
F	19	LWM-TCLP19	374	--	2.1	--	--	--	--	--	--
F	19	WLCGNG03HA42	61	--	6.5	--	--	--	0.7	--	--
F	19	WLCGNG03HA43	76	--	22.4	--	--	--	11.2	--	--
F	19	WR-WSI98SD143	90	--	1.9	--	--	--	ND	--	--
F	19	WR-WSI98SD151	90	--	0.3	ND	ND	ND	0.0	2.1	--
F	1A	LW2-C009	153	--	0.1	0.1	0.0	ND	0.1	10.1	--
F	1A	LW2-C011	341	--	0.3	0.2	0.1	ND	0.2	3.2	--
F	1A	LW2-C011-2	256	--	0.2	0.1	0.1	0.0	0.1	7.9	--
F	1A	LW2-C015	107	0.02	0.3	0.1	0.2	0.0	0.1	--	14.7
F	1A	LW2-C019	264	--	0.2	0.1	0.1	0.1	0.0	--	14.7
F	1A	LW2-C019-2	153	0.04	1.1	--	--	--	--	--	14.7
F	1A	LW2-C020	232	--	0.3	0.2	0.4	0.2	0.2	22.7	--
F	1A	LW2-C022	327	--	0.2	--	--	--	--	1.2	--
F	1A	LW2-C025-2	152	0.02	0.2	--	--	--	--	--	2.1
F	1A	LW2-C027	150	--	0.1	0.0	0.0	ND	0.0	1.5	--
F	1A	LW3-C600	276	--	0.3	0.6	0.9	0.2	0.3	--	6.7
F	1A	LW3-C602	318	--	0.2	0.1	0.5	0.2	0.1	--	2.1
F	1A	LW3-C604	343	--	0.2	0.2	0.5	0.2	0.1	--	2.4

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
F	1A	LW3-C605	341	--	0.1	0.1	0.4	0.1	0.0	--	1.9
F	1A	LW3-C609	273	--	0.3	0.4	0.5	1.4	0.7	--	1.6
F	1A	LW3-DC01-1	219	0.27	0.5	0.4	0.5	0.1	0.6	1.1	--
F	1A	LW3-DC01-2	250	0.06	0.3	0.5	0.8	ND	0.2	2.1	--
F	1A	LWM-C1	358	--	0.2	ND	ND	ND	0.1	--	2.5
F	1A	WLCOSJ00RB13	60	--	1.0	--	--	--	0.0	25.3	--
F	20	LW2-C477	208	--	0.2	0.1	0.2	0.0	0.3	2.0	--
F	20	LW3-C735	166	--	0.2	0.3	0.4	ND	0.0	1.6	--
F	20	LW3-C738	507	--	0.2	0.3	0.6	0.2	0.0	--	1.7
F	20	LW3-C739	515	0.11	0.2	0.4	0.6	1.2	--	--	7.7
F	20	LWM-C24	370	--	0.4	1.9	9.0	ND	0.2	--	11.3
F	21	PSYSEA98PSY50C	237	--	0.2	--	--	--	--	1.6	--
F	21	WR-WSI98SD150	90	--	0.3	ND	ND	0.1	--	1.3	--
F	22	LW3-C742	277	--	0.1	0.1	0.3	0.1	0.0	1.3	--
F	23	LW3-C749	134	--	0.3	0.1	0.2	0.1	0.1	1.2	--
F	24	LW3-C747	251	--	0.1	ND	ND	0.0	--	--	1.9
F	24	LW3-C749	134	--	0.3	0.1	0.2	0.1	0.1	1.2	--
F	24	LW3-C752	344	--	1.8	0.4	0.8	0.2	--	--	3.3
F	24	LW3-C757	214	--	0.1	0.3	0.3	0.2	--	2.8	--
F	24	LW3-C773-2	348	--	0.3	0.1	0.3	0.2	0.1	1.5	--
F	24	WLCDRD05VC049	244	--	0.4	0.2	0.3	0.2	--	5.9	--
F	24	WLCDRD05VC051	122	--	0.2	0.1	0.1	0.1	--	2.8	--
F	24	WLCDRD05VC055	259	--	0.2	0.1	0.1	0.1	--	2.1	--
F	24	WLCDRD05VC106	229	--	0.7	0.2	ND	0.6	--	11.9	--
F	24	WLCDRD05VC108	235	--	0.7	0.4	ND	4.7	--	33.3	--
F	24	WLCDRD05VC110	195	--	0.8	0.6	ND	0.7	--	13.3	--
F	25	LW3-C779	97	--	0.1	0.0	ND	ND	--	--	1.1
F	25	LW3-UC01	93	--	0.4	0.3	0.2	2.0	0.1	6.4	--
F	25	LW3-UC03	242	--	0.3	0.2	0.3	0.1	--	2.5	--
F	25	RM11E-C002	91	--	0.2	--	--	--	--	2.3	--
F	25	RM11E-C003	172	1.99	1.2	1.3	ND	ND	0.2	12.9	--
F	25	RM11E-C009	91	0.07	0.1	0.0	ND	0.1	0.1	1.3	--
F	25	RM11E-C012	91	0.2	0.2	0.4	0.1	0.2	0.1	2.1	--
F	25	RM11E-C015	152	--	0.2	--	--	--	--	2.4	--
F	25	RM11E-C019	213	0.09	1.3	4.6	ND	ND	0.1	120.0	--
F	25	RM11E-C020	91	--	0.1	0.1	ND	ND	--	3.2	--
F	25	RM11E-C022	140	0.12	3.6	1.6	0.1	ND	0.2	37.3	--
F	25	RM11E-C023	301	0.1	0.2	0.6	0.2	ND	0.1	8.9	--
F	25	RM11E-C047	152	--	0.1	--	--	--	--	1.1	--
F	25	RM11E-C048-R1	134	1.63	1.3	0.2	0.2	0.0	0.2	0.5	--
F	25	RM11E-C048-R2	82	--	0.2	--	--	--	--	2.9	--
F	25	WLCGWF03GNVC01	85	--	0.9	--	--	--	--	12.0	--
F	25	WLCGWF03GNVC0103	88	--	0.9	--	--	--	--	11.5	--
F	25	WLCGWF03GNVC03	88	--	0.1	--	--	--	--	1.2	--
F	25	WLR0797WRCD40	61	--	0.2	0.4	0.2	ND	--	1.7	--
F	3	LW2-C067	400	--	0.6	0.8	0.8	0.0	0.9	2.3	--
F	3	LW2-C073	296	--	0.2	0.3	0.1	0.0	1.2	0.5	--
F	3	LW2-C083	188	--	0.1	0.0	0.1	0.2	0.1	3.2	--
F	3	LW2-C084	65	0.02	0.2	0.1	0.1	0.2	0.1	4.0	--
F	3	LW2-C087	110	--	0.1	0.1	0.1	0.1	0.1	3.9	--
F	3	LW2-C088	165	--	0.2	0.1	0.2	0.1	0.2	4.0	--
F	3	LW2-C089	98	--	0.5	0.4	ND	4.2	0.2	44.0	--
F	3	LW2-C090	112	--	0.2	0.1	0.1	0.4	0.1	5.9	--
F	3	LW2-C091	211	--	0.2	0.1	0.3	0.1	0.2	--	6.7
F	3	LW2-C092	276	ND	0.3	0.0	ND	0.1	0.3	2.3	--
F	3	LW2-C094	72	0.12	0.4	0.5	0.9	2.0	0.5	28.0	--
F	3	LW2-C096	153	--	0.4	0.1	ND	0.4	2.5	21.3	--
F	3	LW2-C099	305	--	0.6	1.7	1.0	6.5	0.9	3.1	--
F	3	LW2-C103	363	--	0.3	1.0	0.7	2.8	0.5	2.0	--
F	3	LW2-C106	461	--	0.5	0.4	0.7	0.2	0.6	2.9	--
F	3	LW2-C109	373	--	0.4	0.8	1.3	9.2	1.1	1.3	--
F	3	LW2-C111	250	0.1	0.2	0.2	0.4	0.0	0.1	2.5	--
F	3	LW2-C111-2	420	0.16	0.3	0.6	0.7	0.0	0.6	3.0	--
F	3	LW2-C112	425	--	0.6	0.5	0.8	0.1	0.9	2.3	--
F	3	LW3-C614	343	--	0.6	0.2	0.4	0.3	--	1.6	--
F	3	LWM-C3	382	--	1.1	ND	ND	ND	0.4	--	66.7
F	3	WLCDRD05VC007	207	--	0.2	0.1	0.2	0.1	--	1.1	--
F	3	WLCITG08SED01	198	--	0.8	--	--	--	0.3	7.7	--
F	3	WLCITG08SED02	259	--	7.4	--	--	--	1.6	16.0	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
F	3	WLCITG08SED10	76	--	0.1	--	--	--	0.1	1.2	--
F	3	WLCITG08SED11	76	--	3.0	--	--	--	1.6	26.7	--
F	3	WLCITG08SED14	107	--	1.3	--	--	--	1.4	14.7	--
F	3	WLCT0I98B401C1	91	--	0.3	0.3	0.3	7.7	--	0.9	--
F	3	WLCT4C04VC01	91	--	0.2	0.1	ND	0.1	0.4	2.3	--
F	3	WLCT4C04VC02	91	--	0.3	0.1	ND	0.3	0.2	3.3	--
F	4	LW2-C121	242	--	0.6	0.2	0.1	0.0	3.1	0.6	--
F	5	LW2-C121	242	--	0.6	0.2	0.1	0.0	3.1	0.6	--
F	5	LW2-C122	192	--	0.4	2.9	1.2	0.1	1.5	0.7	--
F	5	LW2-C127	184	0.05	0.7	1.6	0.8	0.1	3.1	1.0	--
F	5	LW2-C130	76	--	1.0	0.2	0.3	0.1	5.7	0.9	--
F	5	LW2-C522	86	--	0.2	0.2	0.2	0.1	--	1.5	--
F	5	LW3-C626	526	--	0.6	ND	ND	ND	1.8	ND	--
F	5	WLCDRD05VC010	238	--	0.3	0.3	0.4	0.3	--	1.3	--
F	5	WLCDRD05VC012	183	--	0.3	0.3	0.5	0.1	--	1.9	--
F	5	WLCDRD05VC014	201	--	0.2	0.2	0.4	0.1	--	1.3	--
F	5	WLCGXV99S3	40	--	0.7	0.6	ND	ND	ND	4.3	--
F	5	WR-WSI98SD017	90	--	1.6	--	--	--	3.3	--	--
F	6	WLCT4C04PS20	518	--	0.4	0.2	0.6	0.1	0.5	2.1	--
F	6	WLCT4C04VC05	91	--	0.1	0.1	0.1	0.1	0.3	1.3	--
F	6	WLCT4C04VC07	152	--	0.1	0.1	0.1	0.1	0.1	1.5	--
F	6	WLCT4C04VC09	152	--	0.2	0.1	0.3	0.4	0.3	4.3	--
F	6	WLCT4C04VC11	152	--	0.0	0.1	0.1	0.1	0.0	1.3	--
F	6	WLCT4C04VC12	152	--	0.2	0.3	0.9	0.2	0.2	1.9	--
F	6	WLCT4C04VC14	213	--	0.1	0.1	0.2	0.1	0.3	1.2	--
F	6	WLCT4C04VC15	91	--	0.5	0.3	0.6	0.3	0.4	4.5	--
F	6	WLCT4C04VC18	152	--	0.2	0.2	0.5	ND	0.1	1.5	--
F	6	WLCT4C04VC19	152	--	0.2	0.1	0.4	0.1	0.8	1.5	--
F	6	WLCT4C04VC20	396	--	0.3	0.3	0.4	0.1	0.6	2.0	--
F	6	WLCT4C04VC21	396	--	0.4	ND	ND	0.0	0.3	1.3	--
F	6	WLCT4C04VC22	335	--	1.6	ND	ND	ND	ND	ND	--
F	6	WLCT4C04VC26	213	--	0.0	0.1	0.1	0.0	0.0	1.1	--
F	6	WLCT4C04VC29	152	--	0.2	0.1	0.1	0.0	3.3	0.7	--
F	6	WLCT4C04VC31	274	--	0.5	ND	ND	0.0	0.4	1.1	--
F	6	WLCT4C04VC32	152	--	0.4	0.1	0.2	0.1	7.3	1.1	--
F	6	WLCT4G06T4B41106	305	--	1.5	ND	ND	ND	20.0	1.9	--
F	6	WLCT4G06T4B41403	61	--	0.4	--	--	--	1.4	--	--
F	6	WLCT4G06T4PI09	61	--	0.3	3.6	2.0	3.5	0.4	ND	--
F	6	WLCT4G06T4S301	274	--	2.4	--	--	--	10.7	--	--
F	6	WLCT4G06T4S302	183	--	1.3	--	--	--	6.6	--	--
F	6	WLCT4G06T4S303	61	--	1.2	--	--	--	5.8	--	--
F	6	WLCT4G06T4S305	244	--	2.1	--	--	--	12.0	--	--
F	6	WLCT4G06T4S307	122	--	0.6	--	--	--	3.3	--	--
F	6	WLCT4G06T4S308	61	--	0.7	--	--	--	4.1	--	--
F	6	WLCT4J98HCS07	128	--	3.6	--	--	--	10.7	--	--
F	6	WLCT4J98HCS11	121	--	2.0	--	--	--	16.7	--	--
F	6	WLCT4J98HCS27	106	--	0.6	--	--	--	4.5	--	--
F	6	WLCT4J98HCS42	121	--	1.5	--	--	--	22.0	--	--
F	6	WR-WSI98SD031	90	--	1.3	--	--	--	16.7	--	--
F	7	LW2-C142	261	--	2.4	3.9	1.2	0.2	12.0	1.3	--
F	7	LW2-NA1B	94	--	0.4	0.7	0.6	0.2	1.3	0.9	--
F	7	WR-WSI98SD035	90	--	2.7	0.5	ND	0.3	12.0	ND	--
F	8	LW2-C148	238	--	0.1	0.3	0.3	0.1	--	2.1	--
F	8	LW2-C157	152	--	0.4	0.0	ND	0.0	1.3	ND	--
F	8	LW2-C158	308	--	0.1	0.2	0.2	0.1	0.5	1.3	--
F	8	WLCBPE06SGP14	122	--	1.5	--	--	--	2.6	--	--
F	8	WLCBPE06SGP15	122	--	1.1	--	--	--	1.1	--	--
F	8	WLCBPE06SGP16	122	--	2.1	--	--	--	3.7	--	--
F	9D	LW2-C179	346	--	1.2	ND	ND	ND	4.6	ND	--
F	9D	LW2-C182	337	--	0.7	5.4	3.0	0.9	0.9	2.1	--
F	9D	LW2-C184	275	--	1.9	4.6	1.2	0.5	7.3	2.1	--
F	9D	LW2-C185	246	ND	1.1	--	--	--	4.4	--	--
F	9D	LW2-C187	197	--	1.2	1.6	ND	0.4	7.3	0.9	--
F	9D	LW2-C221	150	--	1.6	0.3	0.0	0.1	--	0.2	--
F	9D	LW2-C227	192	--	0.3	0.3	0.2	0.1	0.5	1.3	--
F	9D	LW2-C228	154	--	0.7	1.1	0.2	0.1	3.8	0.6	--
F	9D	LW2-C231	162	--	0.2	0.1	0.1	ND	1.1	0.6	--
F	9D	LW2-C240	312	--	0.8	ND	ND	0.1	4.9	ND	--
F	9D	LW2-C245	173	ND	0.2	2.3	0.7	0.8	0.2	ND	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
F	9D	LW2-C252	252	--	0.2	1.5	0.3	0.5	--	0.4	--
F	9D	LW2-C263	376	--	8.1	5.0	0.5	0.4	26.0	ND	--
F	9D	LW2-C527	482	--	1.5	16.6	5.5	3.0	3.4	4.8	--
F	9D	LW2-C528	386	--	2.0	10.8	8.5	3.2	3.1	2.9	--
F	9D	LW2-C529	541	--	0.9	6.4	1.2	0.2	1.7	1.2	--
F	9D	LW2-C530	544	--	0.8	4.2	2.8	0.6	1.5	ND	--
F	9D	LW2-C531	371	--	5.5	1.2	1.9	0.1	11.3	0.9	--
F	9D	WLCMFH00SD04	54	--	0.2	--	--	--	1.4	0.7	--
F	9D	WLCMFH00SD05	54	--	8.4	--	--	--	26.0	2.1	--
F	9D	WLCMRD08SDDA17SB	213	--	4.4	0.9	ND	0.2	17.3	ND	--
F	9D	WLCMRD08SDDA18SB	335	--	1.6	3.8	ND	0.9	4.5	1.2	--
F	9D	WLCMRD08SDDA19SB	427	--	0.3	ND	ND	ND	1.3	ND	--
F	9D	WLCMRD08SDDB22SB	335	--	0.5	1.3	0.9	0.2	2.8	2.7	--
F	9D	WLCMRD08SDDC23SB	518	--	1.3	7.0	2.2	3.2	2.5	ND	--
F	9D	WLCMRD08SDDC24SB	457	--	11.9	4.4	ND	ND	18.0	3.6	--
F	9D	WLCMRD08SDDC25SB	366	--	2.4	1.5	ND	ND	18.7	3.2	--
F	9D	WLCMRD08SDUD1SB	610	--	1.1	ND	ND	ND	ND	ND	--
F	9D	WLCMRD08SDUD26SB	183	--	0.3	0.2	0.3	0.1	1.1	ND	--
F	9D	WLCMRD08SDUD27SB	183	--	3.9	0.9	ND	ND	16.0	ND	--
F	9D	WLCMRI02CS001	91	--	4.3	1.1	0.4	0.5	10.7	ND	--
F	9D	WLCMRI02CS002	91	--	0.6	0.3	0.2	0.1	1.9	ND	--
F	9D	WLCMRI02CS003	91	--	1.0	1.5	0.6	1.0	4.1	ND	--
F	9D	WR-WSI98SD048	90	--	0.8	0.2	0.2	0.2	0.8	2.3	--
F	9D	WR-WSI98SD055C	90	--	3.4	1.2	ND	0.6	10.0	ND	--
F	9D	WR-WSI98SD057	90	--	0.4	ND	ND	0.1	1.2	ND	--
F	9U	LW2-C252	252	--	0.2	1.5	0.3	0.5	--	0.4	--
F	9U	LW2-C258	304	--	1.6	--	--	--	--	--	--
F	9U	LW2-C263	376	--	8.1	5.0	0.5	0.4	26.0	ND	--
F	9U	LW2-C264	220	--	3.2	0.5	0.2	0.0	48.7	0.8	--
F	9U	LW2-C269	541	--	3.5	0.1	0.2	0.2	14.0	ND	--
F	9U	LW2-C270	182	--	3.4	4.2	1.9	2.8	16.0	ND	--
F	9U	LW2-C273	355	--	2.5	0.0	ND	ND	7.3	--	--
F	9U	LW2-C283	258	--	9.1	2.9	0.2	0.4	22.0	ND	--
F	9U	LW2-C289	206	--	10.8	--	--	--	--	--	--
F	9U	LW2-C299	230	--	106.1	1.1	ND	1.0	--	ND	--
F	9U	LW2-C301	516	--	28.2	0.9	0.8	1.0	60.7	ND	--
F	9U	LW2-C302	348	--	1379.9	7.2	ND	ND	320.0	ND	--
F	9U	LW2-C305	220	--	0.4	1.7	0.7	31.2	--	ND	--
F	9U	LW2-C305-2	240	--	9.0	4.0	2.2	0.9	--	1.6	--
F	9U	LW2-C311	533	--	0.3	ND	ND	ND	1.1	ND	--
F	9U	LW2-C312	152	--	0.2	0.4	0.1	4.7	--	ND	--
F	9U	LW2-C521	280	--	40.3	ND	ND	ND	--	ND	--
F	9U	LW2-C525	341	--	11.6	ND	ND	ND	38.0	ND	--
F	9U	LW3-C662	327	--	14.2	0.4	0.2	0.2	23.3	ND	--
F	9U	LWM-C11	386	--	249.0	ND	ND	ND	166.7	--	1.3
F	9U	WLCDRD05VC052	88	--	15.6	1.0	ND	ND	--	5.1	--
F	9U	WLCDRD05VC054	201	--	2.4	0.9	ND	ND	--	2.7	--
F	9U	WLCDRD05VC056	265	--	1.2	22.0	ND	8.5	--	ND	--
F	9U	WLCGSD01AN0101	40	--	11.9	--	--	--	8.7	--	--
F	9U	WLCGSD01AN0102	40	--	31.6	--	--	--	16.7	--	--
F	9U	WLCGSD01AN0103	40	--	642.6	--	--	--	113.3	--	--
F	9U	WLCGSG04RAA17	610	--	39.3	--	--	--	106.7	--	--
F	9U	WLCGSG07GSB2	457	--	0.4	--	--	--	1.7	--	--
F	9U	WLCGSG07GSB5	213	--	4.3	--	--	--	16.7	--	--
F	9U	WLCGSG07GSB7	457	--	88.9	--	--	--	133.3	--	--
F	9U	WLCGSG07GSC2	213	--	1.8	--	--	--	--	--	--
F	9U	WLCGSG07GSC7	213	--	61.0	--	--	--	--	--	--
F	9U	WLCGSJ06GS05	335	--	5.8	--	--	--	5.4	--	--
F	9U	WLCGSJ06GS06	701	--	0.6	--	--	--	1.9	--	--
F	9U	WLCGSJ06GS07	823	--	117.1	--	--	--	86.7	--	--
F	9U	WLCGSJ06GS09	823	--	12.1	--	--	--	9.3	--	--
F	9U	WLCMRD08SDDA17SB	213	--	4.4	0.9	ND	0.2	17.3	ND	--
F	9U	WLCMRD08SDUD1SB	610	--	1.1	ND	ND	ND	ND	ND	--
F	9U	WLCMRD08SDUD27SB	183	--	3.9	0.9	ND	ND	16.0	ND	--
F	9U	WLCSLH01GP25	960	--	4.5	--	--	--	11.3	--	--
F	9U	WLCSLH01GP26	716	--	1.1	--	--	--	0.9	--	--
F	9U	WLCSLH01GP27	472	--	1.1	--	--	--	--	--	--
F	9U	WLCSLH01GP28	930	--	1.9	--	--	--	9.3	--	--
F	9U	WLCSLH01GP29	381	--	1.8	--	--	--	--	--	--

Table 5.10-3. RAL Exceedance Factors at DOI in Impacted Cores

Alt	SMA	Core ID	DoI (cm)	RAL Exceedance Factor							
				2,3,4,7,8-Pentachlorodibenzofuran	Benthic MQ	Sum DDD	Sum DDE	Sum DDT	Total cPAH	Total PCB Aroclors	Total PCB Congener
F	9U	WLCSLH01GP30	564	--	1.3	--	--	--	ND	--	--
F	9U	WLCSLH01GP31	381	--	13.9	--	--	--	--	--	--
F	9U	WLCSLH01GP32	198	--	43.6	--	--	--	--	--	--
F	9U	WR-WSI98SD072	90	3.8	2.2	0.3	0.3	0.3	0.6	1.9	--

Notes:

Only cores with at least one RAL exceedance are shown on this table

-- = no data available for this chemical

Exceedance factors are calculated by dividing the detected concentration of the chemical by its RAL.

ND = Chemical not detected about the laboratory detection limit, exceedance factor not calculated.

Table 5.10-4. Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Aldrin								Arsenic							
Unit	µg/kg								mg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	21	1.41E-02	8.62E-02	2.15E-02	4.85E-01	3.39E-01	0	6.34E-02	5	3.10E+00	3.95E+00	4.04E+00	4.67E+00	3.97E+00	3	1.02E+00
3	17	2.17E-02	1.41E-01	7.50E-02	7.39E-01	3.39E-01	2	2.21E-01	3	3.56E+00	3.70E+00	3.76E+00	3.78E+00	3.97E+00	0	9.47E-01
6	0	--	--	--	--	3.39E-01	--	--	0	--	--	--	--	3.97E+00	--	--
9D	12	1.77E-02	1.50E-01	1.00E-01	4.85E-01	3.39E-01	0	2.95E-01	2	2.71E+00	2.74E+00	2.74E+00	2.76E+00	3.97E+00	0	6.89E-01
9U	14	1.69E-02	6.81E-01	1.65E-01	5.04E+00	3.39E-01	2	4.87E-01	8	1.26E+00	3.55E+00	3.33E+00	9.00E+00	3.97E+00	1	8.38E-01
13	17	1.42E-02	1.05E-01	8.45E-02	4.90E-01	3.39E-01	1	2.49E-01	3	2.36E+00	2.59E+00	2.50E+00	2.91E+00	3.97E+00	0	6.30E-01
14	49	1.58E-02	1.14E+01	3.10E+00	1.46E+02	3.39E-01	13	9.14E+00	21	2.50E+00	5.22E+00	4.04E+00	1.65E+01	3.97E+00	11	1.02E+00
17S	14	1.50E-02	1.00E-01	4.70E-02	5.91E-01	3.39E-01	1	1.39E-01	9	1.90E+00	4.42E+00	2.30E+00	1.61E+01	3.97E+00	3	5.79E-01
19	24	1.65E-02	2.80E-01	7.25E-02	2.19E+00	3.39E-01	3	2.14E-01	13	2.50E+00	4.82E+00	4.07E+00	1.22E+01	3.97E+00	7	1.03E+00
25	17	2.30E-02	8.90E-01	9.00E-02	6.50E+00	3.39E-01	0	2.65E-01	7	1.60E+00	5.10E+00	2.60E+00	2.17E+01	3.97E+00	1	6.55E-01
Alternative C																
1A	22	1.64E-02	9.99E-02	6.00E-02	4.85E-01	3.39E-01	0	1.77E-01	4	3.50E+00	4.17E+00	4.25E+00	4.67E+00	3.97E+00	3	1.07E+00
3	19	2.17E-02	1.35E-01	7.50E-02	7.39E-01	3.39E-01	2	2.21E-01	3	3.56E+00	3.70E+00	3.76E+00	3.78E+00	3.97E+00	0	9.47E-01
5	8	6.50E-02	5.20E-01	1.04E-01	3.35E+00	3.39E-01	0	3.06E-01	0	--	--	--	--	3.97E+00	--	--
6	0	--	--	--	--	3.39E-01	--	--	0	--	--	--	--	3.97E+00	--	--
9D	21	1.65E-02	1.07E-01	1.00E-01	4.85E-01	3.39E-01	0	2.95E-01	3	2.71E+00	4.71E+00	2.76E+00	8.66E+00	3.97E+00	1	6.95E-01
9U	17	1.57E-02	5.67E-01	1.00E-01	5.04E+00	3.39E-01	2	2.95E-01	11	1.06E+00	3.02E+00	2.46E+00	9.00E+00	3.97E+00	1	6.20E-01
13	20	1.42E-02	1.33E-01	8.73E-02	4.90E-01	3.39E-01	1	2.57E-01	5	2.36E+00	3.14E+00	2.50E+00	5.45E+00	3.97E+00	1	6.30E-01
14	64	1.57E-02	5.65E+00	7.40E-01	9.27E+01	3.39E-01	11	2.18E+00	23	2.10E+00	4.63E+00	3.82E+00	1.65E+01	3.97E+00	9	9.62E-01
17S	26	1.50E-02	8.57E-02	4.20E-02	5.91E-01	3.39E-01	1	1.24E-01	18	1.00E+00	2.88E+00	1.98E+00	1.61E+01	3.97E+00	2	4.97E-01
19	27	1.65E-02	2.82E-01	6.00E-02	2.19E+00	3.39E-01	3	1.77E-01	13	2.50E+00	4.82E+00	4.07E+00	1.22E+01	3.97E+00	7	1.03E+00
25	19	2.30E-02	7.99E-01	6.00E-02	6.50E+00	3.39E-01	0	1.77E-01	9	1.60E+00	4.60E+00	2.60E+00	2.17E+01	3.97E+00	1	6.55E-01
Alternative D																
1A	29	1.64E-02	9.71E-02	6.00E-02	4.85E-01	3.39E-01	0	1.77E-01	6	3.12E+00	3.85E+00	3.77E+00	4.67E+00	3.97E+00	3	9.50E-01
3	25	2.13E-02	1.46E-01	8.50E-02	7.39E-01	3.39E-01	3	2.51E-01	3	3.56E+00	3.70E+00	3.76E+00	3.78E+00	3.97E+00	0	9.47E-01
5	8	6.50E-02	5.20E-01	1.04E-01	3.35E+00	3.39E-01	0	3.06E-01	0	--	--	--	--	3.97E+00	--	--
6	0	--	--	--	--	3.39E-01	--	--	4	2.00E+00	2.00E+00	2.00E+00	2.00E+00	3.97E+00	0	5.04E-01
9D	24	1.65E-02	1.01E-01	7.50E-02	4.85E-01	3.39E-01	0	2.21E-01	3	2.71E+00	4.71E+00	2.76E+00	8.66E+00	3.97E+00	1	6.95E-01
9U	17	1.57E-02	5.67E-01	1.00E-01	5.04E+00	3.39E-01	2	2.95E-01	11	1.06E+00	3.02E+00	2.46E+00	9.00E+00	3.97E+00	1	6.20E-01
13	20	1.35E-02	1.31E-01	8.23E-02	4.90E-01	3.39E-01	1	2.43E-01	6	2.36E+00	3.31E+00	2.71E+00	5.45E+00	3.97E+00	2	6.81E-01
14	67	1.40E-02	5.72E+00	4.79E-01	9.27E+01	3.39E-01	12	1.41E+00	24	2.10E+00	4.56E+00	3.82E+00	1.65E+01	3.97E+00	9	9.61E-01
17S	31	1.50E-02	1.01E-01	6.00E-02	4.80E-01	3.39E-01	0	1.77E-01	18	1.00E+00	2.72E+00	1.98E+00	1.61E+01	3.97E+00	1	4.97E-01
19	27	1.65E-02	1.97E-01	6.00E-02	1.01E+00	3.39E-01	2	1.77E-01	11	2.50E+00	4.73E+00	4.07E+00	1.22E+01	3.97E+00	6	1.03E+00
20	3	6.00E-02	7.50E-02	6.00E-02	1.05E-01	3.39E-01	0	1.77E-01	0	--	--	--	--	3.97E+00	--	--
23	0	--	--	--	--	3.39E-01	--	--	0	--	--	--	--	3.97E+00	--	--
25	19	2.30E-02	5.87E-01	6.00E-02	6.50E+00	3.39E-01	0	1.77E-01	9	1.60E+00	4.64E+00	2.60E+00	2.17E+01	3.97E+00	1	6.55E-01

Table 5.10-4. Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Aldrin								Arsenic							
Unit	µg/kg								mg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	35	1.57E-02	1.12E-01	6.00E-02	8.80E-01	3.39E-01	1	1.77E-01	10	8.60E-01	3.95E+00	3.77E+00	7.88E+00	3.97E+00	5	9.48E-01
3	31	2.31E-02	1.04E-01	6.50E-02	6.50E-01	3.39E-01	2	1.92E-01	6	1.65E+00	2.37E+00	2.15E+00	3.78E+00	3.97E+00	0	5.42E-01
4	2	1.95E-02	1.99E-02	1.99E-02	2.03E-02	3.39E-01	0	5.86E-02	0	--	--	--	--	3.97E+00	--	--
5	4	6.50E-02	9.14E-01	1.20E-01	3.35E+00	3.39E-01	0	3.54E-01	0	--	--	--	--	3.97E+00	--	--
6	0	--	--	--	--	3.39E-01	--	--	14	1.40E+00	2.50E+00	2.45E+00	4.00E+00	3.97E+00	1	6.17E-01
8	2	1.03E-01	1.05E-01	1.05E-01	1.07E-01	3.39E-01	0	3.09E-01	0	--	--	--	--	3.97E+00	--	--
9D	27	1.65E-02	3.34E-01	8.50E-02	5.04E+00	3.39E-01	2	2.51E-01	5	2.71E+00	4.18E+00	3.15E+00	8.66E+00	3.97E+00	1	7.93E-01
9U	19	1.57E-02	5.17E-01	1.00E-01	5.04E+00	3.39E-01	2	2.95E-01	10	1.06E+00	3.12E+00	2.81E+00	9.00E+00	3.97E+00	1	7.07E-01
11	6	6.00E-02	1.86E-01	6.00E-02	4.85E-01	3.39E-01	1	1.77E-01	5	2.00E+00	3.34E+00	3.59E+00	4.00E+00	3.97E+00	0	9.04E-01
12	2	1.48E-02	1.55E-02	1.55E-02	1.63E-02	3.39E-01	0	4.58E-02	0	--	--	--	--	3.97E+00	--	--
13	19	1.35E-02	1.31E-01	8.00E-02	4.90E-01	3.39E-01	1	2.36E-01	5	2.36E+00	3.14E+00	2.50E+00	5.45E+00	3.97E+00	1	6.30E-01
14	63	1.40E-02	1.32E+00	3.00E-01	8.87E+00	3.39E-01	8	8.85E-01	19	2.10E+00	4.55E+00	3.59E+00	1.65E+01	3.97E+00	7	9.04E-01
15	0	--	--	--	--	3.39E-01	--	--	1	4.00E+00	4.00E+00	4.00E+00	4.00E+00	3.97E+00	0	1.01E+00
16	9	4.85E-01	9.62E-01	1.01E+00	1.27E+00	3.39E-01	0	2.96E+00	3	4.96E+00	5.34E+00	5.29E+00	5.76E+00	3.97E+00	3	1.33E+00
17S	32	1.50E-02	8.24E-02	6.00E-02	4.80E-01	3.39E-01	0	1.77E-01	27	1.00E+00	2.56E+00	2.30E+00	4.50E+00	3.97E+00	7	5.79E-01
18	2	1.68E-02	4.09E-02	4.09E-02	6.50E-02	3.39E-01	0	1.21E-01	2	2.97E+00	3.49E+00	3.49E+00	4.00E+00	3.97E+00	0	8.78E-01
19	31	1.65E-02	1.49E-01	6.00E-02	9.00E-01	3.39E-01	0	1.77E-01	8	2.50E+00	3.83E+00	3.94E+00	4.71E+00	3.97E+00	3	9.91E-01
20	7	6.00E-02	1.29E-01	9.00E-02	3.90E-01	3.39E-01	0	2.65E-01	0	--	--	--	--	3.97E+00	--	--
23	0	--	--	--	--	3.39E-01	--	--	0	--	--	--	--	3.97E+00	--	--
24	8	6.00E-02	1.29E-01	6.00E-02	6.00E-01	3.39E-01	0	1.77E-01	3	--	3.73E+00	3.95E+00	3.96E+00	3.97E+00	0	9.95E-01
25	20	2.30E-02	1.64E-01	6.00E-02	1.85E+00	3.39E-01	0	1.77E-01	11	1.38E+00	4.41E+00	2.60E+00	2.17E+01	3.97E+00	2	6.55E-01
Alternative F																
1A	21	1.57E-02	5.97E-02	2.02E-02	2.30E-01	3.39E-01	0	5.96E-02	1	3.50E+00	3.50E+00	3.50E+00	3.50E+00	3.97E+00	0	8.82E-01
3	30	6.00E-02	9.27E-02	7.00E-02	6.50E-01	3.39E-01	1	2.06E-01	7	1.65E+00	2.42E+00	2.30E+00	3.78E+00	3.97E+00	0	5.79E-01
4	3	1.95E-02	3.49E-02	2.03E-02	6.50E-02	3.39E-01	0	5.97E-02	0	--	--	--	--	3.97E+00	--	--
5	6	1.48E-02	5.96E-01	6.50E-02	3.35E+00	3.39E-01	0	1.92E-01	0	--	--	--	--	3.97E+00	--	--
6	3	6.00E-02	2.68E-01	9.50E-02	6.50E-01	3.39E-01	0	2.80E-01	16	1.40E+00	2.70E+00	2.75E+00	4.20E+00	3.97E+00	2	6.93E-01
7	4	6.00E-02	7.88E-02	7.50E-02	1.05E-01	3.39E-01	0	2.21E-01	10	2.26E+00	2.95E+00	2.86E+00	3.99E+00	3.97E+00	1	7.20E-01
8	8	1.45E-02	1.19E-01	9.80E-02	4.95E-01	3.39E-01	0	2.89E-01	4	2.28E+00	4.00E+00	3.69E+00	6.34E+00	3.97E+00	2	9.28E-01
9D	32	1.65E-02	1.10E-01	1.00E-01	8.50E-01	3.39E-01	0	2.95E-01	5	2.71E+00	4.31E+00	3.07E+00	8.66E+00	3.97E+00	2	7.73E-01
9U	15	1.57E-02	1.90E-01	1.00E-01	8.50E-01	3.39E-01	0	2.95E-01	8	1.06E+00	3.05E+00	2.09E+00	9.00E+00	3.97E+00	1	5.26E-01
10	0	--	--	--	--	3.39E-01	--	--	0	--	--	--	--	3.97E+00	--	--
11	14	1.48E-02	1.29E-01	6.00E-02	4.85E-01	3.39E-01	1	1.77E-01	13	1.51E+00	2.87E+00	3.16E+00	4.00E+00	3.97E+00	0	7.96E-01
12	6	1.48E-02	2.38E-02	1.72E-02	6.00E-02	3.39E-01	0	5.07E-02	3	6.43E+00	7.74E+00	7.62E+00	9.18E+00	3.97E+00	3	1.92E+00
13	18	1.35E-02	9.71E-02	7.50E-02	4.90E-01	3.39E-01	1	2.21E-01	4	2.36E+00	2.57E+00	2.50E+00	2.91E+00	3.97E+00	0	6.30E-01
14	55	1.40E-02	1.10E+00	8.05E-02	8.87E+00	3.39E-01	5	2.37E-01	15	2.36E+00	3.64E+00	2.96E+00	1.06E+01	3.97E+00	4	7.46E-01
15	3	6.00E-02	1.20E-01	6.00E-02	2.40E-01	3.39E-01	0	1.77E-01	1	4.00E+00	4.00E+00	4.00E+00	4.00E+00	3.97E+00	0	1.01E+00
16	32	1.72E-02	5.14E-01	4.45E-01	1.27E+00	3.39E-01	1	1.31E+00	15	1.00E+00	4.01E+00	4.35E+00	5.76E+00	3.97E+00	10	1.10E+00
17D	5	6.00E-02	2.43E-01	8.65E-02	5.10E-01	3.39E-01	1	2.55E-01	0	--	--	--	--	3.97E+00	--	--
17S	31	1.50E-02	8.03E-02	6.00E-02	2.51E-01	3.39E-01	0	1.77E-01	31	1.00E+00	2.63E+00	2.30E+00	4.50E+00	3.97E+00	7	5.79E-01
18	13	1.60E-02	9.22E-02	6.00E-02	5.00E-01	3.39E-01	1	1.77E-01	9	2.50E+00	3.78E+00	3.50E+00	5.41E+00	3.97E+00	3	8.82E-01

Table 5.10-4. Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Aldrin								Arsenic							
Unit	µg/kg								mg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	26	1.68E-02	2.24E-01	6.00E-02	1.00E+00	3.39E-01	0	1.77E-01	6	3.40E+00	4.01E+00	4.03E+00	4.71E+00	3.97E+00	3	1.02E+00
20	3	6.00E-02	2.22E-01	2.15E-01	3.90E-01	3.39E-01	0	6.34E-01	1	2.40E+00	2.40E+00	2.40E+00	2.40E+00	3.97E+00	0	6.05E-01
21	3	6.00E-02	1.78E-01	2.35E-01	2.40E-01	3.39E-01	0	6.93E-01	1	3.10E+00	3.10E+00	3.10E+00	3.10E+00	3.97E+00	0	7.81E-01
22	6	1.53E-02	4.07E-02	2.13E-02	9.00E-02	3.39E-01	0	6.28E-02	4	1.84E+00	2.54E+00	2.22E+00	3.89E+00	3.97E+00	0	5.59E-01
23	5	6.00E-02	2.89E-01	9.50E-02	1.00E+00	3.39E-01	0	2.80E-01	1	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.97E+00	0	8.31E-01
24	5	6.00E-02	2.67E-01	7.50E-02	8.40E-01	3.39E-01	1	2.21E-01	0	--	--	--	--	3.97E+00	--	--
25	29	2.30E-02	1.60E-01	9.00E-02	1.85E+00	3.39E-01	0	2.65E-01	9	1.38E+00	4.36E+00	2.50E+00	2.17E+01	3.97E+00	1	6.30E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Benzo(a)anthracene								Benzo(a)anthracene							
Unit	mg/kg-OC								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[1]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	20	7.00E-03	7.21E+00	3.35E+00	2.90E+01	1.96E+00	13	1.71E+00	6	1.30E-01	6.27E+01	2.50E+01	2.60E+02	4.23E+03	0	5.91E-03
3	19	1.50E-02	1.09E+01	6.90E+00	5.10E+01	1.96E+00	15	3.52E+00	4	1.20E-01	4.25E-01	4.25E-01	7.30E-01	4.23E+03	0	1.00E-04
6	14	3.75E-01	6.08E+01	1.60E+01	3.00E+02	1.96E+00	10	8.16E+00	6	2.45E+00	6.67E+01	3.25E+00	3.60E+02	4.23E+03	0	7.68E-04
9D	14	1.75E-01	1.59E+02	1.03E+01	9.00E+02	1.96E+00	9	5.23E+00	3	7.40E-01	1.25E+00	1.20E+00	1.80E+00	4.23E+03	0	2.84E-04
9U	69	3.05E-02	2.77E+01	1.50E+00	5.50E+02	1.96E+00	31	7.65E-01	35	2.10E-01	6.90E+01	2.50E+00	1.40E+03	4.23E+03	0	5.91E-04
13	18	5.50E-02	7.25E+00	2.50E+00	3.10E+01	1.96E+00	10	1.28E+00	3	1.05E-01	6.98E+00	8.40E-01	2.00E+01	4.23E+03	0	1.98E-04
14	37	2.00E-01	1.01E+01	4.20E+00	6.50E+01	1.96E+00	25	2.14E+00	8	4.00E-01	5.76E+01	3.18E+01	2.45E+02	4.23E+03	0	7.50E-03
17S	22	1.20E-02	4.70E+00	7.50E-01	3.20E+01	1.96E+00	7	3.83E-01	13	1.10E-01	6.75E+00	7.40E-01	4.20E+01	4.23E+03	0	1.75E-04
19	29	2.70E-02	4.60E+00	1.20E+00	4.00E+01	1.96E+00	10	6.12E-01	3	2.40E-01	3.47E-01	2.40E-01	5.60E-01	4.23E+03	0	5.67E-05
25	16	2.85E-02	4.03E+00	4.50E+00	1.20E+01	1.96E+00	9	2.30E+00	5	2.40E-01	4.62E-01	2.40E-01	9.90E-01	4.23E+03	0	5.67E-05
Alternative C																
1A	21	7.00E-03	6.97E+00	3.60E+00	2.90E+01	1.96E+00	14	1.84E+00	6	1.30E-01	5.57E+01	3.86E+00	2.60E+02	4.23E+03	0	9.11E-04
3	21	1.50E-02	1.04E+01	6.90E+00	5.10E+01	1.96E+00	16	3.52E+00	5	1.20E-01	4.04E-01	3.20E-01	7.30E-01	4.23E+03	0	7.56E-05
5	8	9.50E-01	4.36E+01	3.35E+01	1.20E+02	1.96E+00	6	1.71E+01	1	1.65E+02	1.65E+02	1.65E+02	1.65E+02	4.23E+03	0	3.90E-02
6	33	6.00E-02	4.43E+01	1.10E+01	3.30E+02	1.96E+00	21	5.61E+00	15	8.90E-01	7.06E+01	2.50E+00	6.40E+02	4.23E+03	0	5.91E-04
9D	23	5.50E-02	1.02E+02	5.50E+00	9.00E+02	1.96E+00	14	2.81E+00	5	1.10E-01	7.93E-01	7.40E-01	1.80E+00	4.23E+03	0	1.75E-04
9U	96	3.05E-02	2.62E+01	1.50E+00	5.50E+02	1.96E+00	36	7.65E-01	54	2.10E-01	5.09E+01	4.18E+00	1.40E+03	4.23E+03	0	9.88E-04
13	21	5.50E-02	6.99E+00	3.30E+00	3.10E+01	1.96E+00	13	1.68E+00	3	1.05E-01	6.98E+00	8.40E-01	2.00E+01	4.23E+03	0	1.98E-04
14	50	2.05E-02	8.77E+00	4.20E+00	6.50E+01	1.96E+00	31	2.14E+00	11	1.20E-01	3.78E+01	2.70E+01	1.66E+02	4.23E+03	0	6.38E-03
17S	42	1.20E-02	4.95E+00	1.20E+00	3.20E+01	1.96E+00	15	6.12E-01	20	1.10E-01	5.45E+00	9.70E-01	4.20E+01	4.23E+03	0	2.29E-04
19	34	2.70E-02	4.02E+00	1.05E+00	4.00E+01	1.96E+00	10	5.36E-01	3	2.40E-01	3.47E-01	2.40E-01	5.60E-01	4.23E+03	0	5.67E-05
25	18	2.85E-02	4.14E+00	4.50E+00	1.20E+01	1.96E+00	10	2.30E+00	6	2.40E-01	4.25E-01	2.40E-01	9.90E-01	4.23E+03	0	5.67E-05
Alternative D																
1A	28	7.00E-03	7.16E+00	2.95E+00	2.90E+01	1.96E+00	19	1.51E+00	6	1.30E-01	5.57E+01	3.86E+00	2.60E+02	4.23E+03	0	9.11E-04
3	29	1.50E-02	1.35E+01	6.90E+00	7.00E+01	1.96E+00	24	3.52E+00	5	1.20E-01	4.04E-01	3.20E-01	7.30E-01	4.23E+03	0	7.56E-05
5	8	9.50E-01	4.36E+01	3.35E+01	1.20E+02	1.96E+00	6	1.71E+01	1	1.65E+02	1.65E+02	1.65E+02	1.65E+02	4.23E+03	0	3.90E-02
6	54	6.00E-02	2.70E+01	6.25E+00	3.00E+02	1.96E+00	30	3.19E+00	29	7.00E-01	6.89E+01	2.50E+00	6.40E+02	4.23E+03	0	5.91E-04
9D	29	5.50E-02	8.21E+01	5.50E+00	9.00E+02	1.96E+00	19	2.81E+00	5	1.10E-01	7.93E-01	7.40E-01	1.80E+00	4.23E+03	0	1.75E-04
9U	96	3.05E-02	2.62E+01	1.50E+00	5.50E+02	1.96E+00	36	7.65E-01	54	2.10E-01	5.09E+01	4.18E+00	1.40E+03	4.23E+03	0	9.88E-04
13	21	5.50E-02	7.07E+00	3.30E+00	3.10E+01	1.96E+00	14	1.68E+00	3	1.05E-01	6.98E+00	8.40E-01	2.00E+01	4.23E+03	0	1.98E-04
14	53	2.05E-02	9.52E+00	4.50E+00	6.50E+01	1.96E+00	35	2.30E+00	12	1.20E-01	3.47E+01	1.48E+01	1.66E+02	4.23E+03	0	3.48E-03
17S	50	1.20E-02	2.12E+01	1.20E+00	4.10E+02	1.96E+00	21	6.12E-01	21	1.10E-01	3.51E+00	1.20E+00	2.70E+01	4.23E+03	0	2.84E-04
19	35	2.70E-02	4.66E+00	1.00E+00	4.00E+01	1.96E+00	10	5.10E-01	3	2.40E-01	3.47E-01	2.40E-01	5.60E-01	4.23E+03	0	5.67E-05
20	3	8.40E-01	2.75E+00	1.40E+00	6.00E+00	1.96E+00	1	7.14E-01	0	--	--	--	--	4.23E+03	--	--
23	1	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.96E+00	0	7.65E-01	0	--	--	--	--	4.23E+03	--	--
25	18	2.85E-02	4.16E+00	4.50E+00	1.20E+01	1.96E+00	10	2.30E+00	6	2.40E-01	4.25E-01	2.40E-01	9.90E-01	4.23E+03	0	5.67E-05

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Benzo(a)anthracene								Benzo(a)anthracene							
Unit	mg/kg-OC								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[1]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	35	7.00E-03	7.15E+00	2.90E+00	3.80E+01	1.96E+00	22	1.48E+00	5	1.30E-01	2.18E+00	5.10E-01	7.20E+00	4.23E+03	0	1.20E-04
3	35	1.50E-02	1.14E+01	6.00E+00	7.00E+01	1.96E+00	24	3.06E+00	12	9.50E-02	7.96E+00	4.30E-01	7.30E+01	4.23E+03	0	1.02E-04
4	2	2.00E-02	1.81E+00	1.81E+00	3.60E+00	1.96E+00	1	9.23E-01	1	3.00E-01	3.00E-01	3.00E-01	3.00E-01	4.23E+03	0	7.09E-05
5	4	9.50E-01	2.47E+01	1.65E+01	6.50E+01	1.96E+00	2	8.42E+00	1	1.65E+02	1.65E+02	1.65E+02	1.65E+02	4.23E+03	0	3.90E-02
6	95	1.80E-02	1.59E+01	4.70E+00	1.80E+02	1.96E+00	51	2.40E+00	53	2.30E-01	7.29E+01	2.50E+00	7.90E+02	4.23E+03	0	5.91E-04
8	3	6.49E+00	1.75E+01	1.50E+01	3.10E+01	1.96E+00	3	7.65E+00	0	--	--	--	--	4.23E+03	--	--
9D	32	5.50E-02	9.63E+01	1.05E+01	9.00E+02	1.96E+00	23	5.36E+00	5	1.10E-01	7.93E-01	7.40E-01	1.80E+00	4.23E+03	0	1.75E-04
9U	98	3.05E-02	2.43E+01	1.40E+00	5.50E+02	1.96E+00	36	7.14E-01	56	2.10E-01	4.91E+01	3.74E+00	1.40E+03	4.23E+03	0	8.84E-04
11	9	1.20E-01	9.02E+00	2.80E+00	5.40E+01	1.96E+00	5	1.43E+00	3	2.40E-01	5.33E-01	2.60E-01	1.10E+00	4.23E+03	0	6.14E-05
12	2	2.00E+00	4.25E+00	4.25E+00	6.50E+00	1.96E+00	2	2.17E+00	2	4.00E+00	8.50E+00	8.50E+00	1.30E+01	4.23E+03	0	2.01E-03
13	20	5.50E-02	7.18E+00	3.05E+00	3.10E+01	1.96E+00	13	1.56E+00	3	1.05E-01	6.98E+00	8.40E-01	2.00E+01	4.23E+03	0	1.98E-04
14	53	2.05E-02	1.65E+01	4.20E+00	1.70E+02	1.96E+00	31	2.14E+00	13	1.20E-01	2.69E+01	1.20E+00	1.66E+02	4.23E+03	0	2.84E-04
15	0	--	--	--	--	1.96E+00	--	--	0	--	--	--	--	4.23E+03	--	--
16	9	2.90E+00	5.63E+00	3.40E+00	1.40E+01	1.96E+00	8	1.73E+00	6	6.00E+01	8.69E+01	7.83E+01	1.47E+02	4.23E+03	0	1.85E-02
17S	54	1.20E-02	3.81E+00	9.50E-01	2.90E+01	1.96E+00	18	4.85E-01	27	1.10E-01	2.53E+00	1.20E+00	5.00E+00	4.23E+03	0	2.84E-04
18	1	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.96E+00	1	1.02E+01	0	--	--	--	--	4.23E+03	--	--
19	39	2.70E-02	6.02E+00	1.30E+00	4.90E+01	1.96E+00	15	6.63E-01	6	2.40E-01	3.80E+01	5.40E-01	1.80E+02	4.23E+03	0	1.28E-04
20	7	1.90E-01	2.54E+00	1.40E+00	7.00E+00	1.96E+00	2	7.14E-01	1	3.75E-01	3.75E-01	3.75E-01	3.75E-01	4.23E+03	0	8.86E-05
23	1	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.96E+00	0	7.65E-01	0	--	--	--	--	4.23E+03	--	--
24	9	1.20E-01	2.32E+00	2.40E+00	6.90E+00	1.96E+00	6	1.22E+00	5	7.60E-01	2.51E+01	3.00E+01	4.70E+01	4.23E+03	0	7.09E-03
25	20	1.70E-02	3.52E+00	1.14E+00	1.20E+01	1.96E+00	9	5.82E-01	9	2.40E-01	3.63E-01	2.40E-01	9.90E-01	4.23E+03	0	5.67E-05
Alternative F																
1A	20	7.00E-03	1.07E+01	4.80E+00	6.00E+01	1.96E+00	14	2.45E+00	4	1.30E-01	2.05E+00	4.25E-01	7.20E+00	4.23E+03	0	1.00E-04
3	35	1.50E-02	9.16E+00	2.00E+00	7.00E+01	1.96E+00	18	1.02E+00	17	9.50E-02	6.12E+00	5.40E-01	7.30E+01	4.23E+03	0	1.28E-04
4	3	2.00E-02	1.52E+00	9.50E-01	3.60E+00	1.96E+00	1	4.85E-01	1	3.00E-01	3.00E-01	3.00E-01	3.00E-01	4.23E+03	0	7.09E-05
5	6	1.90E-01	1.58E+01	4.45E+00	6.50E+01	1.96E+00	3	2.27E+00	2	6.80E-01	8.28E+01	8.28E+01	1.65E+02	4.23E+03	0	1.96E-02
6	123	1.80E-02	1.49E+01	3.80E+00	1.80E+02	1.96E+00	63	1.94E+00	68	2.20E-01	5.89E+01	2.50E+00	7.90E+02	4.23E+03	0	5.91E-04
7	5	5.50E-01	1.43E+00	7.00E-01	3.00E+00	1.96E+00	2	3.57E-01	2	1.10E+00	1.25E+00	1.25E+00	1.40E+00	4.23E+03	0	2.95E-04
8	15	5.50E-01	1.88E+01	1.80E+01	3.90E+01	1.96E+00	14	9.18E+00	5	1.10E+00	2.15E+02	5.87E+01	5.74E+02	4.23E+03	0	1.39E-02
9D	41	5.50E-02	5.79E+01	5.60E+00	9.00E+02	1.96E+00	29	2.86E+00	7	1.10E-01	7.11E-01	7.40E-01	1.80E+00	4.23E+03	0	1.75E-04
9U	93	3.05E-02	1.44E+01	1.13E+00	2.70E+02	1.96E+00	30	5.77E-01	55	2.10E-01	1.11E+01	3.34E+00	2.50E+02	4.23E+03	0	7.88E-04
10	1	6.40E+01	6.40E+01	6.40E+01	6.40E+01	1.96E+00	1	3.27E+01	0	--	--	--	--	4.23E+03	--	--
11	20	1.20E-01	1.38E+01	2.70E+00	1.00E+02	1.96E+00	11	1.38E+00	6	2.40E-01	2.12E+01	3.80E-01	1.25E+02	4.23E+03	0	8.98E-05
12	6	6.00E-02	1.82E+00	1.05E+00	6.50E+00	1.96E+00	2	5.36E-01	5	1.15E-01	3.71E+00	1.00E+00	1.30E+01	4.23E+03	0	2.36E-04
13	19	5.50E-02	7.92E+00	2.80E+00	3.10E+01	1.96E+00	12	1.43E+00	3	1.05E-01	6.98E+00	8.40E-01	2.00E+01	4.23E+03	0	1.98E-04
14	51	2.05E-02	1.61E+01	2.80E+00	1.70E+02	1.96E+00	29	1.43E+00	15	1.20E-01	4.53E+00	9.20E-01	2.90E+01	4.23E+03	0	2.17E-04
15	4	1.20E-01	3.50E+00	2.40E+00	9.07E+00	1.96E+00	2	1.22E+00	2	2.40E-01	4.55E+01	4.55E+01	9.07E+01	4.23E+03	0	1.07E-02
16	32	1.25E-02	3.97E+00	2.85E+00	2.69E+01	1.96E+00	21	1.45E+00	19	1.40E-01	5.54E+01	6.00E+01	1.47E+02	4.23E+03	0	1.42E-02
17D	6	1.20E-01	3.91E+00	1.70E+00	1.20E+01	1.96E+00	3	8.67E-01	1	2.40E-01	2.40E-01	2.40E-01	2.40E-01	4.23E+03	0	5.67E-05
17S	54	1.20E-02	4.91E+00	9.50E-01	7.87E+01	1.96E+00	19	4.85E-01	32	1.10E-01	1.70E+01	2.28E+00	4.11E+02	4.23E+03	0	5.38E-04
18	13	5.50E-02	3.46E+00	2.00E+00	2.00E+01	1.96E+00	7	1.02E+00	3	1.10E-01	6.10E-01	8.10E-01	9.10E-01	4.23E+03	0	1.91E-04

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Benzo(a)anthracene								Benzo(a)anthracene							
Unit	mg/kg-OC								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[1]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	34	2.70E-02	4.16E+00	8.85E-01	4.90E+01	1.96E+00	8	4.52E-01	7	2.40E-01	3.28E+01	5.60E-01	1.80E+02	4.23E+03	0	1.32E-04
20	3	1.90E-01	2.73E+00	1.00E+00	7.00E+00	1.96E+00	1	5.10E-01	1	3.75E-01	3.75E-01	3.75E-01	3.75E-01	4.23E+03	0	8.86E-05
21	3	5.30E-01	3.00E+00	8.80E-01	7.60E+00	1.96E+00	1	4.49E-01	1	9.10E+00	9.10E+00	9.10E+00	9.10E+00	4.23E+03	0	2.15E-03
22	6	9.90E-01	3.13E+00	2.70E+00	7.00E+00	1.96E+00	3	1.38E+00	0	--	--	--	--	4.23E+03	--	--
23	6	9.00E-02	2.79E+00	8.25E-01	1.20E+01	1.96E+00	2	4.21E-01	3	6.60E-01	1.31E+00	7.60E-01	2.50E+00	4.23E+03	0	1.80E-04
24	6	1.20E-01	1.02E+00	7.75E-01	2.80E+00	1.96E+00	1	3.95E-01	3	2.40E-01	8.67E-01	7.60E-01	1.60E+00	4.23E+03	0	1.80E-04
25	31	1.70E-02	1.78E+00	5.70E-01	1.20E+01	1.96E+00	7	2.91E-01	12	2.40E-01	4.79E-01	2.40E-01	2.00E+00	4.23E+03	0	5.67E-05

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Benzo(b)fluoranthene								Benzo(k)fluoranthene							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[2]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC3	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	6	3.10E-01	5.87E+01	4.32E+01	1.70E+02	4.23E+03	0	1.02E-02	20	1.35E-02	4.58E+00	2.00E+00	2.40E+01	1.5E+02	0	1.33E-02
3	4	3.50E-01	4.81E-01	3.63E-01	8.50E-01	4.23E+03	0	8.56E-05	19	9.00E-03	6.16E+00	3.50E+00	2.40E+01	1.5E+02	0	2.33E-02
6	6	2.30E-01	9.69E+01	3.25E+00	5.40E+02	4.23E+03	0	7.68E-04	14	3.75E-01	7.00E+01	1.80E+01	3.40E+02	1.5E+02	3	1.20E-01
9D	2	3.70E-01	7.85E-01	7.85E-01	1.20E+00	4.23E+03	0	1.85E-04	14	6.80E-02	1.03E+02	4.55E+00	6.00E+02	1.5E+02	3	3.03E-02
9U	36	1.60E-01	8.84E+01	2.50E+00	1.90E+03	4.23E+03	0	5.91E-04	69	9.50E-03	1.83E+01	1.50E+00	4.60E+02	1.5E+02	5	1.00E-02
13	4	3.10E-01	6.35E+01	1.69E+01	2.20E+02	4.23E+03	0	4.00E-03	18	1.05E-01	3.91E+00	1.60E+00	2.00E+01	1.5E+02	0	1.07E-02
14	9	3.25E-01	5.58E+01	4.00E+01	1.80E+02	4.23E+03	0	9.45E-03	37	1.15E-01	4.77E+00	2.00E+00	3.00E+01	1.5E+02	0	1.33E-02
17S	13	3.20E-01	7.46E+00	7.20E-01	4.70E+01	4.23E+03	0	1.70E-04	22	2.35E-02	2.91E+00	6.85E-01	2.20E+01	1.5E+02	0	4.57E-03
19	4	3.10E-01	1.29E+01	5.75E-01	5.00E+01	4.23E+03	0	1.36E-04	29	8.50E-03	2.26E+00	8.90E-01	2.30E+01	1.5E+02	0	5.93E-03
25	5	1.25E-01	3.41E-01	1.25E-01	8.40E-01	4.23E+03	0	2.95E-05	16	9.00E-03	2.12E+00	1.55E+00	8.00E+00	1.5E+02	0	1.03E-02
Alternative C																
1A	6	3.10E-01	4.60E+01	5.19E+00	1.70E+02	4.23E+03	0	1.23E-03	21	1.35E-02	3.71E+00	2.00E+00	1.90E+01	1.5E+02	0	1.33E-02
3	5	2.95E-01	4.44E-01	3.55E-01	8.50E-01	4.23E+03	0	8.39E-05	21	9.00E-03	6.05E+00	3.50E+00	2.40E+01	1.5E+02	0	2.33E-02
5	2	1.30E+00	8.32E+01	8.32E+01	1.65E+02	4.23E+03	0	1.96E-02	8	8.50E-01	3.04E+01	1.90E+01	8.60E+01	1.5E+02	0	1.27E-01
6	15	2.30E-01	9.37E+01	2.50E+00	8.10E+02	4.23E+03	0	5.91E-04	33	6.00E-02	4.95E+01	1.10E+01	3.70E+02	1.5E+02	5	7.33E-02
9D	4	3.20E-01	5.56E-01	3.53E-01	1.20E+00	4.23E+03	0	8.33E-05	23	6.80E-02	6.48E+01	2.80E+00	6.00E+02	1.5E+02	3	1.87E-02
9U	56	1.60E-01	9.14E+01	4.18E+00	1.90E+03	4.23E+03	0	9.88E-04	96	9.50E-03	1.52E+01	1.00E+00	4.60E+02	1.5E+02	7	6.67E-03
13	4	3.10E-01	6.35E+01	1.69E+01	2.20E+02	4.23E+03	0	4.00E-03	21	1.05E-01	3.93E+00	1.90E+00	2.00E+01	1.5E+02	0	1.27E-02
14	12	3.25E-01	4.69E+01	2.30E+01	1.57E+02	4.23E+03	0	5.43E-03	50	4.20E-02	4.49E+00	1.90E+00	3.00E+01	1.5E+02	0	1.27E-02
17S	20	3.20E-01	5.90E+00	9.10E-01	4.70E+01	4.23E+03	0	2.15E-04	42	2.35E-02	3.04E+00	9.35E-01	2.20E+01	1.5E+02	0	6.23E-03
19	4	3.10E-01	1.29E+01	5.75E-01	5.00E+01	4.23E+03	0	1.36E-04	34	8.50E-03	2.00E+00	7.00E-01	2.30E+01	1.5E+02	0	4.67E-03
25	6	1.25E-01	3.05E-01	1.25E-01	8.40E-01	4.23E+03	0	2.95E-05	18	9.00E-03	2.07E+00	1.55E+00	8.00E+00	1.5E+02	0	1.03E-02
Alternative D																
1A	6	3.10E-01	4.60E+01	5.19E+00	1.70E+02	4.23E+03	0	1.23E-03	28	1.35E-02	3.49E+00	1.85E+00	1.90E+01	1.5E+02	0	1.23E-02
3	5	2.95E-01	4.44E-01	3.55E-01	8.50E-01	4.23E+03	0	8.39E-05	29	9.00E-03	7.59E+00	6.00E+00	3.10E+01	1.5E+02	0	4.00E-02
5	2	1.30E+00	8.32E+01	8.32E+01	1.65E+02	4.23E+03	0	1.96E-02	8	8.50E-01	3.04E+01	1.90E+01	8.60E+01	1.5E+02	0	1.27E-01
6	29	2.30E-01	8.54E+01	2.50E+00	8.40E+02	4.23E+03	0	5.91E-04	54	6.00E-02	2.87E+01	6.50E+00	3.40E+02	1.5E+02	3	4.33E-02
9D	4	3.20E-01	5.56E-01	3.53E-01	1.20E+00	4.23E+03	0	8.33E-05	29	6.80E-02	5.22E+01	2.80E+00	6.00E+02	1.5E+02	3	1.87E-02
9U	56	1.60E-01	9.14E+01	4.18E+00	1.90E+03	4.23E+03	0	9.88E-04	96	9.50E-03	1.52E+01	1.00E+00	4.60E+02	1.5E+02	7	6.67E-03
13	4	3.10E-01	6.35E+01	1.69E+01	2.20E+02	4.23E+03	0	4.00E-03	21	1.05E-01	4.07E+00	2.00E+00	2.00E+01	1.5E+02	0	1.33E-02
14	13	3.25E-01	4.34E+01	2.30E+01	1.57E+02	4.23E+03	0	5.43E-03	53	4.20E-02	5.22E+00	2.20E+00	3.00E+01	1.5E+02	0	1.47E-02
17S	21	3.20E-01	3.70E+00	1.10E+00	3.10E+01	4.23E+03	0	2.60E-04	50	2.35E-02	8.44E+00	9.35E-01	1.50E+02	1.5E+02	2	6.23E-03
19	4	3.10E-01	1.29E+01	5.75E-01	5.00E+01	4.23E+03	0	1.36E-04	35	8.50E-03	2.58E+00	7.30E-01	2.30E+01	1.5E+02	0	4.87E-03
20	0	--	--	--	--	4.23E+03	--	--	3	4.60E-01	1.15E+00	5.00E-01	2.50E+00	1.5E+02	0	3.33E-03
23	1	4.10E+01	4.10E+01	4.10E+01	4.10E+01	4.23E+03	0	9.69E-03	1	4.00E-01	4.00E-01	4.00E-01	4.00E-01	1.5E+02	0	2.67E-03
25	6	1.25E-01	3.05E-01	1.25E-01	8.40E-01	4.23E+03	0	2.95E-05	18	9.00E-03	2.02E+00	1.10E+00	8.00E+00	1.5E+02	0	7.33E-03

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Benzo(b)fluoranthene								Benzo(k)fluoranthene							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[2]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC3	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	6	3.10E-01	2.59E+00	1.29E+00	1.00E+01	4.23E+03	0	3.05E-04	35	1.35E-02	3.68E+00	1.40E+00	1.90E+01	1.5E+02	0	9.33E-03
3	12	2.75E-01	7.43E+00	3.53E-01	7.00E+01	4.23E+03	0	8.33E-05	35	9.00E-03	6.69E+00	3.40E+00	3.10E+01	1.5E+02	0	2.27E-02
4	1	3.65E-01	3.65E-01	3.65E-01	3.65E-01	4.23E+03	0	8.62E-05	2	1.75E-02	8.09E-01	8.09E-01	1.60E+00	1.5E+02	0	5.39E-03
5	2	1.30E+00	8.32E+01	8.32E+01	1.65E+02	4.23E+03	0	1.96E-02	4	8.50E-01	2.40E+01	1.50E+01	6.50E+01	1.5E+02	0	1.00E-01
6	53	2.10E-01	8.58E+01	2.50E+00	9.60E+02	4.23E+03	0	5.91E-04	95	2.40E-02	1.57E+01	4.80E+00	2.00E+02	1.5E+02	1	3.20E-02
8	0	--	--	--	--	4.23E+03	--	--	3	5.63E+00	1.52E+01	1.50E+01	2.50E+01	1.5E+02	0	1.00E-01
9D	4	3.20E-01	5.56E-01	3.53E-01	1.20E+00	4.23E+03	0	8.33E-05	32	6.80E-02	6.32E+01	4.85E+00	6.00E+02	1.5E+02	5	3.23E-02
9U	56	1.60E-01	7.63E+01	3.74E+00	1.90E+03	4.23E+03	0	8.84E-04	98	9.50E-03	1.45E+01	1.00E+00	4.60E+02	1.5E+02	6	6.67E-03
11	3	1.25E-01	4.42E-01	3.10E-01	8.90E-01	4.23E+03	0	7.32E-05	9	3.75E-02	7.26E+00	2.50E+00	4.30E+01	1.5E+02	0	1.67E-02
12	2	6.00E+00	1.45E+01	1.45E+01	2.30E+01	4.23E+03	0	3.43E-03	2	1.05E-01	1.08E-01	1.08E-01	1.10E-01	1.5E+02	0	7.17E-04
13	4	3.10E-01	6.35E+01	1.69E+01	2.20E+02	4.23E+03	0	4.00E-03	20	1.05E-01	4.09E+00	1.95E+00	2.00E+01	1.5E+02	0	1.30E-02
14	13	3.05E-01	2.15E+01	1.30E+00	1.30E+02	4.23E+03	0	3.07E-04	53	4.20E-02	8.63E+00	1.80E+00	1.00E+02	1.5E+02	0	1.20E-02
15	0	--	--	--	--	4.23E+03	--	--	0	--	--	--	--	1.5E+02	--	--
16	6	7.44E+01	1.23E+02	1.06E+02	1.94E+02	4.23E+03	0	2.50E-02	9	1.60E+00	6.72E+00	3.70E+00	2.80E+01	1.5E+02	0	2.47E-02
17S	27	3.20E-01	2.54E+00	1.20E+00	5.00E+00	4.23E+03	0	2.84E-04	54	2.35E-02	2.36E+00	6.70E-01	2.20E+01	1.5E+02	0	4.47E-03
18	0	--	--	--	--	4.23E+03	--	--	1	8.00E+00	8.00E+00	8.00E+00	8.00E+00	1.5E+02	0	5.33E-02
19	7	3.10E-01	2.93E+01	6.90E-01	1.30E+02	4.23E+03	0	1.63E-04	39	8.50E-03	3.67E+00	1.00E+00	3.50E+01	1.5E+02	0	6.67E-03
20	1	3.20E-01	3.20E-01	3.20E-01	3.20E-01	4.23E+03	0	7.56E-05	7	1.55E-01	1.69E+00	5.00E-01	7.20E+00	1.5E+02	0	3.33E-03
23	1	4.10E+01	4.10E+01	4.10E+01	4.10E+01	4.23E+03	0	9.69E-03	1	4.00E-01	4.00E-01	4.00E-01	4.00E-01	1.5E+02	0	2.67E-03
24	6	7.60E-01	4.00E+01	5.45E+01	6.50E+01	4.23E+03	0	1.29E-02	9	5.60E-02	9.82E-01	8.80E-01	3.10E+00	1.5E+02	0	5.87E-03
25	9	1.25E-01	2.84E-01	1.25E-01	8.40E-01	4.23E+03	0	2.95E-05	20	5.00E-03	1.62E+00	5.05E-01	8.00E+00	1.5E+02	0	3.37E-03
Alternative F																
1A	4	3.10E-01	2.76E+00	3.68E-01	1.00E+01	4.23E+03	0	8.68E-05	20	1.35E-02	5.57E+00	2.20E+00	3.00E+01	1.5E+02	0	1.47E-02
3	17	2.75E-01	5.87E+00	3.55E-01	7.00E+01	4.23E+03	0	8.39E-05	35	9.00E-03	5.37E+00	2.40E+00	3.10E+01	1.5E+02	0	1.60E-02
4	2	3.65E-01	8.33E-01	8.33E-01	1.30E+00	4.23E+03	0	1.97E-04	3	1.75E-02	8.23E-01	8.50E-01	1.60E+00	1.5E+02	0	5.67E-03
5	3	3.40E-01	5.55E+01	1.30E+00	1.65E+02	4.23E+03	0	3.07E-04	6	6.50E-02	1.37E+01	4.20E+00	6.50E+01	1.5E+02	0	2.80E-02
6	68	1.90E-01	6.90E+01	2.48E+00	9.60E+02	4.23E+03	0	5.85E-04	123	2.40E-02	1.42E+01	4.00E+00	2.00E+02	1.5E+02	1	2.67E-02
7	2	8.20E-01	8.65E-01	8.65E-01	9.10E-01	4.23E+03	0	2.04E-04	5	2.90E-01	1.30E+00	4.80E-01	3.00E+00	1.5E+02	0	3.20E-03
8	5	8.70E-01	2.65E+02	6.02E+01	7.91E+02	4.23E+03	0	1.42E-02	15	3.90E-01	1.56E+01	1.50E+01	3.80E+01	1.5E+02	0	1.00E-01
9D	7	3.20E-01	1.47E+01	3.70E-01	1.00E+02	4.23E+03	0	8.74E-05	41	6.80E-02	3.81E+01	4.00E+00	6.00E+02	1.5E+02	3	2.67E-02
9U	55	1.60E-01	2.49E+01	3.34E+00	7.80E+02	4.23E+03	0	7.88E-04	93	9.50E-03	7.54E+00	8.00E-01	1.80E+02	1.5E+02	3	5.33E-03
10	0	--	--	--	--	4.23E+03	--	--	1	1.05E-01	1.05E-01	1.05E-01	1.05E-01	1.5E+02	0	7.00E-04
11	6	1.25E-01	2.03E+01	2.18E-01	1.20E+02	4.23E+03	0	5.14E-05	20	3.75E-02	7.17E+00	1.30E+00	5.80E+01	1.5E+02	0	8.67E-03
12	5	3.40E-01	6.01E+00	3.45E-01	2.30E+01	4.23E+03	0	8.15E-05	6	1.05E-01	2.24E-01	1.20E-01	7.70E-01	1.5E+02	0	8.00E-04
13	3	3.10E-01	1.14E+01	8.80E-01	3.30E+01	4.23E+03	0	2.08E-04	19	1.05E-01	4.40E+00	1.90E+00	2.00E+01	1.5E+02	0	1.27E-02
14	15	3.05E-01	5.98E+00	7.30E-01	5.10E+01	4.23E+03	0	1.72E-04	51	2.35E-02	8.05E+00	1.60E+00	1.00E+02	1.5E+02	0	1.07E-02
15	2	1.25E-01	5.00E+01	5.00E+01	9.99E+01	4.23E+03	0	1.18E-02	4	3.75E-02	2.25E+00	1.02E+00	6.93E+00	1.5E+02	0	6.77E-03
16	19	3.20E-01	7.41E+01	7.44E+01	1.94E+02	4.23E+03	0	1.76E-02	32	2.40E-02	3.47E+00	1.60E+00	2.80E+01	1.5E+02	0	1.07E-02
17D	1	1.25E-01	1.25E-01	1.25E-01	1.25E-01	4.23E+03	0	2.95E-05	6	3.75E-02	2.29E+00	1.02E+00	7.00E+00	1.5E+02	0	6.77E-03
17S	32	1.25E-01	2.16E+01	2.28E+00	5.26E+02	4.23E+03	0	5.38E-04	54	2.35E-02	2.51E+00	6.90E-01	3.81E+01	1.5E+02	0	4.60E-03
18	3	3.30E-01	5.15E-01	3.35E-01	8.80E-01	4.23E+03	0	7.91E-05	13	1.15E-01	1.66E+00	1.10E+00	8.00E+00	1.5E+02	0	7.33E-03

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Benzo(b)fluoranthene								Benzo(k)fluoranthene							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[2]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC3	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	8	3.10E-01	2.58E+01	1.15E+00	1.30E+02	4.23E+03	0	2.71E-04	34	8.50E-03	2.53E+00	6.70E-01	3.50E+01	1.5E+02	0	4.47E-03
20	1	3.20E-01	3.20E-01	3.20E-01	3.20E-01	4.23E+03	0	7.56E-05	3	1.55E-01	2.82E+00	1.10E+00	7.20E+00	1.5E+02	0	7.33E-03
21	1	9.70E+00	9.70E+00	9.70E+00	9.70E+00	4.23E+03	0	2.29E-03	3	3.80E-01	1.08E+00	7.70E-01	2.10E+00	1.5E+02	0	5.13E-03
22	0	--	--	--	--	4.23E+03	--	--	6	4.80E-01	1.90E+00	1.45E+00	5.00E+00	1.5E+02	0	9.67E-03
23	4	8.40E-01	1.70E+01	1.31E+01	4.10E+01	4.23E+03	0	3.08E-03	6	4.00E-02	1.92E+00	8.50E-01	6.90E+00	1.5E+02	0	5.67E-03
24	4	1.25E-01	1.62E+01	9.30E-01	6.30E+01	4.23E+03	0	2.20E-04	6	3.75E-02	4.84E-01	3.05E-01	1.20E+00	1.5E+02	0	2.03E-03
25	13	1.25E-01	5.19E+00	1.25E-01	6.30E+01	4.23E+03	0	2.95E-05	31	5.00E-03	1.08E+00	5.50E-01	8.00E+00	1.5E+02	0	3.67E-03

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Dibenzo(a,h)anthracene								Dieldrin							
Unit	µg/kg								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[4]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[5]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	9	1.70E-01	8.37E+00	9.20E-01	4.15E+01	4.2E+02	0	2.17E-03	20	1.50E-02	1.75E-01	3.37E-02	1.10E+00	7.7E-01	1	4.35E-02
3	6	1.75E-01	4.25E-01	1.98E-01	1.20E+00	4.2E+02	0	4.67E-04	17	3.55E-02	2.00E-01	1.00E-01	7.00E-01	7.7E-01	0	1.29E-01
6	6	1.05E+00	1.83E+01	2.50E+00	9.50E+01	4.2E+02	0	5.91E-03	0	--	--	--	--	7.7E-01	--	--
9D	6	2.90E-01	9.40E-01	1.04E+00	1.70E+00	4.2E+02	0	2.45E-03	14	2.90E-02	1.50E-01	1.00E-01	5.50E-01	7.7E-01	0	1.29E-01
9U	51	1.80E-01	1.13E+01	2.50E+00	1.80E+02	4.2E+02	0	5.91E-03	14	2.77E-02	3.71E-01	1.17E-01	3.00E+00	7.7E-01	1	1.51E-01
13	7	1.65E-01	4.12E+00	9.80E-01	2.00E+01	4.2E+02	0	2.32E-03	17	2.32E-02	1.26E-01	6.50E-02	1.00E+00	7.7E-01	0	8.41E-02
14	17	1.70E-01	9.07E+00	7.65E+00	2.20E+01	4.2E+02	0	1.81E-02	50	2.58E-02	4.14E+00	1.77E-01	8.00E+01	7.7E-01	1	2.29E-01
17S	15	1.75E-01	2.50E+00	2.20E-01	8.60E+00	4.2E+02	0	5.20E-04	14	2.46E-02	7.48E-02	3.89E-02	2.03E-01	7.7E-01	0	5.03E-02
19	16	1.40E-01	1.63E+01	1.25E+00	9.80E+01	4.2E+02	0	2.95E-03	24	1.50E-02	2.36E-01	8.00E-02	1.75E+00	7.7E-01	1	1.03E-01
25	7	1.40E-01	4.59E-01	1.40E-01	1.30E+00	4.2E+02	0	3.31E-04	17	1.50E-02	2.70E-01	4.95E-02	1.80E+00	7.7E-01	0	6.40E-02
Alternative C																
1A	9	1.70E-01	7.08E+00	9.20E-01	4.15E+01	4.2E+02	0	2.17E-03	21	1.50E-02	2.00E-01	6.00E-02	1.10E+00	7.7E-01	1	7.76E-02
3	7	1.60E-01	3.87E-01	1.95E-01	1.20E+00	4.2E+02	0	4.61E-04	19	3.55E-02	2.15E-01	1.00E-01	7.00E-01	7.7E-01	0	1.29E-01
5	2	1.75E-01	8.26E+01	8.26E+01	1.65E+02	4.2E+02	0	1.95E-01	8	4.35E-02	5.39E-01	1.65E-01	3.35E+00	7.7E-01	0	2.14E-01
6	17	7.40E-01	1.72E+01	2.50E+00	1.60E+02	4.2E+02	0	5.91E-03	0	--	--	--	--	7.7E-01	--	--
9D	11	1.85E-01	1.01E+00	1.20E+00	2.00E+00	4.2E+02	0	2.84E-03	23	2.69E-02	1.25E-01	1.00E-01	5.50E-01	7.7E-01	0	1.29E-01
9U	76	1.80E-01	1.17E+01	4.01E+00	1.80E+02	4.2E+02	0	9.47E-03	17	2.57E-02	3.17E-01	1.00E-01	3.00E+00	7.7E-01	1	1.29E-01
13	7	1.65E-01	4.12E+00	9.80E-01	2.00E+01	4.2E+02	0	2.32E-03	20	2.32E-02	1.64E-01	6.75E-02	1.00E+00	7.7E-01	0	8.73E-02
14	25	1.70E-01	7.33E+00	2.50E+00	2.20E+01	4.2E+02	0	5.91E-03	65	2.57E-02	4.23E+00	1.99E-01	8.00E+01	7.7E-01	1	2.57E-01
17S	26	1.75E-01	2.96E+00	2.25E+00	9.50E+00	4.2E+02	0	5.32E-03	26	1.50E-02	6.15E-02	3.28E-02	1.78E-01	7.7E-01	0	4.23E-02
19	20	1.40E-01	1.34E+01	1.35E+00	9.80E+01	4.2E+02	0	3.19E-03	27	1.50E-02	2.76E-01	8.00E-02	1.75E+00	7.7E-01	1	1.03E-01
25	8	1.40E-01	4.19E-01	1.40E-01	1.30E+00	4.2E+02	0	3.31E-04	19	1.50E-02	3.01E-01	4.95E-02	1.80E+00	7.7E-01	0	6.40E-02
Alternative D																
1A	9	1.70E-01	7.08E+00	9.20E-01	4.15E+01	4.2E+02	0	2.17E-03	28	1.50E-02	2.11E-01	1.25E-01	1.10E+00	7.7E-01	1	1.62E-01
3	8	1.60E-01	4.89E-01	1.98E-01	1.20E+00	4.2E+02	0	4.67E-04	25	3.48E-02	1.85E-01	6.00E-02	7.00E-01	7.7E-01	0	7.76E-02
5	2	1.75E-01	8.26E+01	8.26E+01	1.65E+02	4.2E+02	0	1.95E-01	8	4.35E-02	5.39E-01	1.65E-01	3.35E+00	7.7E-01	0	2.14E-01
6	32	3.40E-01	1.60E+01	2.50E+00	1.60E+02	4.2E+02	0	5.91E-03	0	--	--	--	--	7.7E-01	--	--
9D	14	1.85E-01	9.85E-01	1.08E+00	2.00E+00	4.2E+02	0	2.55E-03	29	2.57E-02	1.11E-01	9.50E-02	5.50E-01	7.7E-01	0	1.23E-01
9U	76	1.80E-01	1.17E+01	4.01E+00	1.80E+02	4.2E+02	0	9.47E-03	17	2.57E-02	3.17E-01	1.00E-01	3.00E+00	7.7E-01	1	1.29E-01
13	8	1.65E-01	3.73E+00	9.75E-01	2.00E+01	4.2E+02	0	2.30E-03	20	2.20E-02	1.69E-01	6.50E-02	1.00E+00	7.7E-01	0	8.41E-02
14	26	1.70E-01	7.05E+00	2.48E+00	2.20E+01	4.2E+02	0	5.85E-03	68	2.29E-02	4.05E+00	1.80E-01	8.00E+01	7.7E-01	1	2.32E-01
17S	30	1.40E-01	2.70E+00	2.25E+00	9.50E+00	4.2E+02	0	5.32E-03	31	1.50E-02	1.07E-01	3.18E-02	9.50E-01	7.7E-01	0	4.11E-02
19	20	1.40E-01	1.34E+01	1.35E+00	9.80E+01	4.2E+02	0	3.19E-03	27	1.50E-02	2.34E-01	4.09E-02	1.75E+00	7.7E-01	0	5.29E-02
20	1	3.90E-01	3.90E-01	3.90E-01	3.90E-01	4.2E+02	0	9.21E-04	3	1.50E-02	1.50E-02	1.50E-02	1.50E-02	7.7E-01	0	1.94E-02
23	1	5.00E+00	5.00E+00	5.00E+00	5.00E+00	4.2E+02	0	1.18E-02	0	--	--	--	--	7.7E-01	--	--
25	8	1.40E-01	4.19E-01	1.40E-01	1.30E+00	4.2E+02	0	3.31E-04	19	1.50E-02	2.87E-01	4.95E-02	1.80E+00	7.7E-01	0	6.40E-02

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Dibenzo(a,h)anthracene								Dieldrin							
Unit	µg/kg								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[4]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[5]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	11	1.55E-01	8.13E-01	4.80E-01	2.40E+00	4.2E+02	0	1.13E-03	35	1.50E-02	2.05E-01	1.30E-01	1.10E+00	7.7E-01	1	1.68E-01
3	18	1.50E-01	1.16E+00	2.85E-01	1.12E+01	4.2E+02	0	6.73E-04	30	3.77E-02	1.34E-01	5.75E-02	1.20E+00	7.7E-01	1	7.44E-02
4	1	2.00E-01	2.00E-01	2.00E-01	2.00E-01	4.2E+02	0	4.73E-04	2	3.18E-02	3.25E-02	3.25E-02	3.31E-02	7.7E-01	0	4.20E-02
5	2	1.75E-01	8.26E+01	8.26E+01	1.65E+02	4.2E+02	0	1.95E-01	4	4.35E-02	8.73E-01	4.93E-02	3.35E+00	7.7E-01	0	6.37E-02
6	60	2.20E-01	1.25E+01	2.50E+00	1.60E+02	4.2E+02	0	5.91E-03	0	--	--	--	--	7.7E-01	--	--
8	0	--	--	--	--	4.2E+02	--	--	2	1.68E-01	1.72E-01	1.72E-01	1.76E-01	7.7E-01	0	2.22E-01
9D	12	1.85E-01	1.03E+00	1.23E+00	2.00E+00	4.2E+02	0	2.89E-03	29	2.69E-02	1.96E-01	1.00E-01	3.00E+00	7.7E-01	1	1.29E-01
9U	77	1.65E-01	1.00E+01	3.50E+00	1.80E+02	4.2E+02	0	8.27E-03	19	2.57E-02	2.89E-01	1.00E-01	3.00E+00	7.7E-01	1	1.29E-01
11	5	1.40E-01	2.02E+01	1.70E-01	1.00E+02	4.2E+02	0	4.02E-04	8	1.50E-02	1.62E-01	3.95E-02	9.50E-01	7.7E-01	0	5.11E-02
12	2	1.65E-01	7.33E-01	7.33E-01	1.30E+00	4.2E+02	0	1.73E-03	2	2.42E-02	2.54E-02	2.54E-02	2.67E-02	7.7E-01	0	3.28E-02
13	8	1.65E-01	3.73E+00	9.75E-01	2.00E+01	4.2E+02	0	2.30E-03	19	2.20E-02	1.66E-01	6.50E-02	1.00E+00	7.7E-01	0	8.41E-02
14	26	1.65E-01	4.41E+00	1.70E+00	2.10E+01	4.2E+02	0	4.02E-03	63	2.29E-02	9.96E-01	1.60E-01	5.50E+00	7.7E-01	0	2.06E-01
15	0	--	--	--	--	4.2E+02	--	--	0	--	--	--	--	7.7E-01	--	--
16	8	1.17E+01	2.28E+01	1.25E+01	7.85E+01	4.2E+02	0	2.95E-02	9	4.85E-01	9.62E-01	1.01E+00	1.27E+00	7.7E-01	0	1.30E+00
17S	36	1.40E-01	2.68E+00	2.25E+00	9.50E+00	4.2E+02	0	5.32E-03	33	1.50E-02	8.19E-02	3.18E-02	9.50E-01	7.7E-01	0	4.11E-02
18	0	--	--	--	--	4.2E+02	--	--	2	2.74E-02	4.12E-02	4.12E-02	5.50E-02	7.7E-01	0	5.33E-02
19	22	1.40E-01	9.26E+00	1.48E+00	5.00E+01	4.2E+02	0	3.48E-03	31	1.50E-02	2.26E-01	6.50E-02	1.75E+00	7.7E-01	0	8.41E-02
20	3	2.00E-01	9.63E-01	3.90E-01	2.30E+00	4.2E+02	0	9.21E-04	7	1.50E-02	1.61E-01	4.90E-02	3.95E-01	7.7E-01	0	6.34E-02
23	1	5.00E+00	5.00E+00	5.00E+00	5.00E+00	4.2E+02	0	1.18E-02	0	--	--	--	--	7.7E-01	--	--
24	8	1.40E-01	3.81E+00	3.55E+00	8.00E+00	4.2E+02	0	8.39E-03	8	1.50E-02	1.44E-01	1.18E-01	4.80E-01	7.7E-01	0	1.52E-01
25	11	1.40E-01	3.43E-01	1.40E-01	1.30E+00	4.2E+02	0	3.31E-04	20	1.50E-02	1.27E-01	2.55E-02	1.10E+00	7.7E-01	0	3.30E-02
Alternative F																
1A	9	1.70E-01	7.79E-01	6.40E-01	2.20E+00	4.2E+02	0	1.51E-03	21	1.50E-02	1.49E-01	3.22E-02	1.10E+00	7.7E-01	1	4.16E-02
3	25	1.50E-01	1.18E+00	4.80E-01	1.12E+01	4.2E+02	0	1.13E-03	30	4.55E-02	7.27E-02	5.50E-02	1.85E-01	7.7E-01	0	7.11E-02
4	2	1.75E-01	1.88E-01	1.88E-01	2.00E-01	4.2E+02	0	4.43E-04	3	3.18E-02	4.00E-02	3.31E-02	5.50E-02	7.7E-01	0	4.28E-02
5	5	1.75E-01	3.37E+01	1.30E+00	1.65E+02	4.2E+02	0	3.07E-03	6	2.43E-02	5.95E-01	5.50E-02	3.35E+00	7.7E-01	0	7.11E-02
6	84	2.20E-01	1.27E+01	2.50E+00	1.90E+02	4.2E+02	0	5.91E-03	3	8.00E-02	3.47E-01	4.10E-01	5.50E-01	7.7E-01	0	5.30E-01
7	2	1.65E-01	1.68E-01	1.68E-01	1.70E-01	4.2E+02	0	3.96E-04	6	4.95E-02	8.23E-02	5.78E-02	1.99E-01	7.7E-01	0	7.47E-02
8	7	1.85E-01	2.91E+01	2.55E+00	1.26E+02	4.2E+02	0	6.02E-03	8	2.37E-02	2.19E-01	1.60E-01	1.00E+00	7.7E-01	0	2.07E-01
9D	18	1.80E-01	9.26E+00	1.23E+00	1.50E+02	4.2E+02	0	2.89E-03	37	2.57E-02	1.72E-01	9.50E-02	3.00E+00	7.7E-01	1	1.23E-01
9U	76	1.65E-01	6.50E+00	3.37E+00	1.70E+02	4.2E+02	0	7.96E-03	15	2.57E-02	2.90E-01	1.00E-01	3.00E+00	7.7E-01	1	1.29E-01
10	0	--	--	--	--	4.2E+02	--	--	1	1.32E-01	1.32E-01	1.32E-01	1.32E-01	7.7E-01	0	1.70E-01
11	10	1.40E-01	1.19E+01	2.33E-01	1.00E+02	4.2E+02	0	5.49E-04	19	1.50E-02	9.56E-02	3.05E-02	9.50E-01	7.7E-01	0	3.94E-02
12	5	1.65E-01	4.05E-01	1.85E-01	1.30E+00	4.2E+02	0	4.37E-04	6	2.42E-02	3.55E-02	2.81E-02	7.70E-02	7.7E-01	0	3.63E-02
13	7	1.65E-01	1.40E+00	9.70E-01	4.80E+00	4.2E+02	0	2.29E-03	18	2.20E-02	1.18E-01	5.50E-02	1.00E+00	7.7E-01	0	7.11E-02
14	28	1.65E-01	3.01E+00	1.03E+00	1.50E+01	4.2E+02	0	2.43E-03	55	2.29E-02	7.77E-01	7.00E-02	4.55E+00	7.7E-01	0	9.05E-02
15	2	1.40E-01	8.87E+00	8.87E+00	1.76E+01	4.2E+02	0	2.10E-02	3	1.50E-02	1.12E-01	9.50E-02	2.25E-01	7.7E-01	0	1.23E-01
16	25	1.75E-01	1.14E+01	1.10E+01	7.85E+01	4.2E+02	0	2.60E-02	32	2.81E-02	4.85E-01	3.15E-01	1.27E+00	7.7E-01	0	4.07E-01
17D	2	1.40E-01	1.40E-01	1.40E-01	1.40E-01	4.2E+02	0	3.31E-04	4	1.50E-02	1.68E-01	7.85E-02	5.00E-01	7.7E-01	0	1.02E-01
17S	39	1.40E-01	4.11E+00	1.90E+00	6.29E+01	4.2E+02	0	4.49E-03	34	1.50E-02	5.03E-02	2.92E-02	1.60E-01	7.7E-01	0	3.78E-02
18	7	1.80E-01	2.31E+00	1.20E+00	1.00E+01	4.2E+02	0	2.84E-03	13	2.62E-02	1.01E-01	8.00E-02	3.30E-01	7.7E-01	0	1.03E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Dibenzo(a,h)anthracene								Dieldrin							
Unit	µg/kg								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[4]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[5]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	24	1.40E-01	6.45E+00	1.35E+00	5.00E+01	4.2E+02	0	3.19E-03	26	1.50E-02	3.98E-01	6.25E-02	1.95E+00	7.7E-01	0	8.08E-02
20	2	2.00E-01	3.50E+00	3.50E+00	6.80E+00	4.2E+02	0	8.27E-03	3	4.90E-02	1.85E-01	1.70E-01	3.35E-01	7.7E-01	0	2.20E-01
21	2	2.05E+00	2.08E+00	2.08E+00	2.10E+00	4.2E+02	0	4.90E-03	3	7.00E-02	7.67E-02	8.00E-02	8.00E-02	7.7E-01	0	1.03E-01
22	0	--	--	--	--	4.2E+02	--	--	6	2.51E-02	1.11E-01	3.48E-02	5.00E-01	7.7E-01	0	4.50E-02
23	4	1.40E-01	2.00E+00	1.42E+00	5.00E+00	4.2E+02	0	3.35E-03	5	4.40E-02	2.99E-01	1.40E-01	1.00E+00	7.7E-01	0	1.81E-01
24	4	1.40E-01	2.16E+00	2.40E-01	8.00E+00	4.2E+02	0	5.67E-04	5	1.50E-02	2.01E-01	1.40E-01	3.90E-01	7.7E-01	0	1.81E-01
25	21	1.40E-01	1.64E+00	1.50E-01	1.50E+01	4.2E+02	0	3.54E-04	29	1.50E-02	1.24E-01	4.05E-02	3.85E-01	7.7E-01	0	5.24E-02

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Heptachlor epoxide								Hexachlorobenzene							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 Percentile DW[10]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	22	1.79E-02	1.34E-01	3.71E-02	8.00E-01	6.30E-01	0	5.89E-02	23	6.95E-04	2.73E-01	6.50E-02	3.15E+00	1.25E-01	0	5.22E-01
3	17	2.75E-02	7.74E-02	4.90E-02	1.55E-01	6.30E-01	0	7.78E-02	17	1.30E-03	9.74E-02	1.10E-02	6.50E-01	1.25E-01	0	8.84E-02
6	0	--	--	--	--	6.30E-01	--	--	0	--	--	--	--	1.25E-01	--	--
9D	14	2.24E-02	1.48E-01	1.00E-01	5.50E-01	6.30E-01	0	1.59E-01	14	9.00E-03	1.25E-01	2.53E-02	6.05E-01	1.25E-01	3	2.03E-01
9U	17	2.15E-02	1.00E+01	2.25E-01	8.00E+01	6.30E-01	0	3.57E-01	36	3.38E-03	1.70E+01	3.95E+00	3.55E+02	1.25E-01	2	3.17E+01
13	17	1.80E-02	1.08E-01	6.50E-02	4.90E-01	6.30E-01	0	1.03E-01	18	8.00E-04	1.21E-01	1.00E-02	7.00E-01	1.25E-01	0	8.03E-02
14	51	2.00E-02	3.42E+00	1.70E-01	6.50E+01	6.30E-01	3	2.70E-01	38	4.50E-03	8.30E-01	1.89E-01	6.70E+00	1.25E-01	10	1.51E+00
17S	13	1.91E-02	5.99E-02	2.99E-02	1.57E-01	6.30E-01	0	4.75E-02	18	5.50E-03	3.96E-01	2.10E-01	1.75E+00	1.25E-01	0	1.69E+00
19	24	2.09E-02	3.21E-01	9.78E-02	2.18E+00	6.30E-01	3	1.55E-01	29	5.10E-04	1.88E-01	9.00E-02	1.25E+00	1.25E-01	0	7.23E-01
25	17	2.40E-02	1.83E-01	3.40E-02	8.60E-01	6.30E-01	1	5.40E-02	17	3.45E-03	1.34E-02	9.00E-03	3.00E-02	1.25E-01	0	7.23E-02
Alternative C																
1A	23	2.07E-02	3.26E-01	1.00E-01	3.50E+00	6.30E-01	2	1.59E-01	24	6.95E-04	2.19E-01	1.93E-02	3.15E+00	1.25E-01	0	1.55E-01
3	19	2.75E-02	7.43E-02	4.90E-02	1.55E-01	6.30E-01	0	7.78E-02	19	1.30E-03	8.85E-02	1.10E-02	6.50E-01	1.25E-01	0	8.84E-02
5	8	4.40E-02	6.14E-01	1.90E-01	3.35E+00	6.30E-01	0	3.01E-01	8	2.75E-03	8.20E+00	3.04E-02	6.50E+01	1.25E-01	0	2.44E-01
6	0	--	--	--	--	6.30E-01	--	--	--	--	--	--	--	1.25E-01	--	--
9D	23	2.09E-02	1.16E-01	1.00E-01	5.50E-01	6.30E-01	0	1.59E-01	23	9.00E-03	1.86E-01	3.25E-02	1.00E+00	1.25E-01	3	2.61E-01
9U	20	1.99E-02	8.52E+00	1.06E-01	8.00E+01	6.30E-01	0	1.69E-01	63	3.38E-03	1.19E+01	4.40E+00	3.55E+02	1.25E-01	2	3.53E+01
13	20	1.80E-02	1.63E-01	9.25E-02	8.00E-01	6.30E-01	1	1.47E-01	21	8.00E-04	1.21E-01	7.00E-03	7.00E-01	1.25E-01	0	5.62E-02
14	65	1.99E-02	3.74E+00	3.00E-01	6.50E+01	6.30E-01	4	4.76E-01	50	4.50E-03	5.27E-01	1.08E-01	6.70E+00	1.25E-01	8	8.63E-01
17S	22	1.90E-02	7.50E-02	2.54E-02	5.40E-01	6.30E-01	0	4.03E-02	31	4.53E-04	3.33E-01	1.60E-01	1.75E+00	1.25E-01	3	1.29E+00
19	27	2.09E-02	3.19E-01	8.00E-02	2.18E+00	6.30E-01	3	1.27E-01	35	5.10E-04	1.83E-01	8.50E-02	1.25E+00	1.25E-01	0	6.83E-01
25	19	2.40E-02	1.84E-01	3.40E-02	8.60E-01	6.30E-01	1	5.40E-02	19	2.50E-03	1.33E-02	9.00E-03	3.00E-02	1.25E-01	0	7.23E-02
Alternative D																
1A	30	2.08E-02	3.89E-01	2.08E-01	3.50E+00	6.30E-01	4	3.30E-01	31	1.40E-03	1.73E-01	1.95E-02	3.15E+00	1.25E-01	0	1.57E-01
3	25	2.70E-02	1.03E-01	5.50E-02	5.60E-01	6.30E-01	0	8.73E-02	25	1.30E-03	1.16E-01	1.50E-02	6.50E-01	1.25E-01	0	1.20E-01
5	8	4.40E-02	6.14E-01	1.90E-01	3.35E+00	6.30E-01	0	3.01E-01	8	2.75E-03	8.20E+00	3.04E-02	6.50E+01	1.25E-01	0	2.44E-01
6	0	--	--	--	--	6.30E-01	--	--	4	1.50E+00	4.13E+00	5.00E+00	5.00E+00	1.25E-01	0	4.02E+01
9D	29	2.00E-02	9.78E-02	8.50E-02	5.50E-01	6.30E-01	0	1.35E-01	29	1.55E-03	2.07E-01	3.30E-02	1.00E+00	1.25E-01	3	2.65E-01
9U	20	1.99E-02	8.52E+00	1.06E-01	8.00E+01	6.30E-01	0	1.69E-01	63	3.38E-03	1.19E+01	4.40E+00	3.55E+02	1.25E-01	2	3.53E+01
13	20	1.71E-02	1.48E-01	7.25E-02	8.00E-01	6.30E-01	1	1.15E-01	21	8.00E-04	1.52E-01	1.30E-02	7.00E-01	1.25E-01	0	1.04E-01
14	67	1.78E-02	3.60E+00	1.70E-01	6.50E+01	6.30E-01	3	2.70E-01	53	1.00E-02	5.28E-01	1.77E-01	6.70E+00	1.25E-01	10	1.42E+00
17S	26	1.90E-02	1.00E-01	3.20E-02	5.40E-01	6.30E-01	0	5.07E-02	37	4.53E-04	3.03E-01	1.60E-01	1.75E+00	1.25E-01	3	1.29E+00
19	27	2.09E-02	3.10E-01	3.40E-02	2.18E+00	6.30E-01	3	5.40E-02	36	5.10E-04	1.78E-01	9.00E-02	7.50E-01	1.25E-01	0	7.23E-01
20	3	3.40E-02	2.01E-01	1.10E-01	4.60E-01	6.30E-01	0	1.75E-01	3	8.00E-03	1.97E-02	1.70E-02	3.40E-02	1.25E-01	0	1.37E-01
23	0	--	--	--	--	6.30E-01	--	--	1	3.10E-01	3.10E-01	3.10E-01	3.10E-01	1.25E-01	0	2.49E+00
25	19	2.40E-02	1.84E-01	3.40E-02	8.60E-01	6.30E-01	1	5.40E-02	19	2.50E-03	1.37E-02	9.90E-03	3.00E-02	1.25E-01	0	7.95E-02

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Heptachlor epoxide								Hexachlorobenzene							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 Percentile DW[10]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	36	1.99E-02	2.98E-01	1.08E-01	2.10E+00	6.30E-01	4	1.71E-01	38	1.40E-03	2.70E-01	1.95E-02	3.15E+00	1.25E-01	1	1.57E-01
3	31	2.92E-02	1.62E-01	4.85E-02	2.30E+00	6.30E-01	1	7.70E-02	32	1.30E-03	6.67E-02	1.53E-02	6.50E-01	1.25E-01	0	1.22E-01
4	2	2.47E-02	2.52E-02	2.52E-02	2.57E-02	6.30E-01	0	3.99E-02	2	9.00E-02	1.00E-01	1.00E-01	1.10E-01	1.25E-01	0	8.03E-01
5	4	4.40E-02	1.07E+00	4.40E-01	3.35E+00	6.30E-01	0	6.98E-01	4	1.10E-02	1.63E+01	2.60E-02	6.50E+01	1.25E-01	0	2.09E-01
6	0	--	--	--	--	6.30E-01	--	--	9	5.50E-01	3.23E+00	2.50E+00	5.00E+00	1.25E-01	0	2.01E+01
8	2	1.30E-01	1.33E-01	1.33E-01	1.36E-01	6.30E-01	0	2.11E-01	2	2.86E-03	3.16E-03	3.16E-03	3.45E-03	1.25E-01	0	2.53E-02
9D	29	2.09E-02	8.48E-02	1.00E-01	2.75E-01	6.30E-01	0	1.59E-01	32	8.25E-04	2.45E-01	3.90E-02	1.20E+00	1.25E-01	4	3.13E-01
9U	22	1.99E-02	7.75E+00	1.00E-01	8.00E+01	6.30E-01	0	1.59E-01	65	3.38E-03	1.15E+01	4.39E+00	3.55E+02	1.25E-01	2	3.53E+01
11	8	1.84E-02	1.00E-01	3.73E-02	4.85E-01	6.30E-01	0	5.91E-02	9	4.15E-03	1.08E-01	1.70E-02	5.00E-01	1.25E-01	0	1.37E-01
12	2	1.88E-02	1.97E-02	1.97E-02	2.07E-02	6.30E-01	0	3.13E-02	2	1.40E-01	4.15E-01	4.15E-01	6.90E-01	1.25E-01	2	3.33E+00
13	19	1.71E-02	1.47E-01	6.50E-02	8.00E-01	6.30E-01	1	1.03E-01	20	8.00E-04	1.59E-01	1.50E-02	7.00E-01	1.25E-01	0	1.20E-01
14	62	1.78E-02	1.16E+00	1.85E-01	8.50E+00	6.30E-01	2	2.94E-01	53	5.00E-03	3.38E-01	8.00E-02	6.70E+00	1.25E-01	8	6.43E-01
15	1	8.00E-01	8.00E-01	8.00E-01	8.00E-01	6.30E-01	0	1.27E+00	1	3.25E+00	3.25E+00	3.25E+00	3.25E+00	1.25E-01	0	2.61E+01
16	7	7.85E-01	1.25E+00	1.23E+00	2.05E+00	6.30E-01	0	1.94E+00	9	2.00E-01	2.05E+01	1.42E+01	7.00E+01	1.25E-01	0	1.14E+02
17S	30	1.91E-02	9.02E-02	3.13E-02	5.40E-01	6.30E-01	0	4.96E-02	39	1.75E-03	2.20E-01	1.50E-01	1.07E+00	1.25E-01	3	1.20E+00
18	3	2.13E-02	2.89E-01	4.50E-02	8.00E-01	6.30E-01	0	7.14E-02	3	1.65E-02	1.30E+00	6.90E-01	3.20E+00	1.25E-01	1	5.54E+00
19	31	2.09E-02	3.33E-01	8.00E-02	2.18E+00	6.30E-01	5	1.27E-01	41	5.10E-04	2.16E-01	7.00E-02	1.00E+00	1.25E-01	0	5.62E-01
20	7	3.40E-02	1.62E-01	1.10E-01	4.60E-01	6.30E-01	0	1.75E-01	7	2.90E-03	1.75E-02	1.50E-02	3.50E-02	1.25E-01	0	1.20E-01
23	0	--	--	--	--	6.30E-01	--	--	1	3.10E-01	3.10E-01	3.10E-01	3.10E-01	1.25E-01	0	2.49E+00
24	8	3.40E-02	2.43E-01	1.43E-01	7.50E-01	6.30E-01	0	2.26E-01	9	3.90E-03	7.18E-02	8.00E-03	4.10E-01	1.25E-01	0	6.43E-02
25	20	2.40E-02	1.33E-01	5.20E-02	8.60E-01	6.30E-01	1	8.25E-02	20	2.40E-03	1.39E-02	1.28E-02	3.00E-02	1.25E-01	0	1.02E-01
Alternative F																
1A	21	1.99E-02	1.29E-01	2.56E-02	8.00E-01	6.30E-01	0	4.06E-02	23	4.10E-03	4.99E-01	1.25E-01	3.15E+00	1.25E-01	1	1.00E+00
3	30	3.75E-02	8.06E-02	4.70E-02	5.60E-01	6.30E-01	0	7.46E-02	31	1.30E-03	3.95E-02	1.45E-02	4.00E-01	1.25E-01	0	1.16E-01
4	3	2.47E-02	3.14E-02	2.57E-02	4.40E-02	6.30E-01	0	4.07E-02	3	1.60E-02	7.20E-02	9.00E-02	1.10E-01	1.25E-01	0	7.23E-01
5	6	1.88E-02	5.87E-01	4.45E-02	3.35E+00	6.30E-01	0	7.06E-02	6	2.80E-03	1.10E+01	2.20E-02	6.50E+01	1.25E-01	0	1.77E-01
6	3	7.50E-02	3.65E-01	2.70E-01	7.50E-01	6.30E-01	0	4.29E-01	12	9.00E-03	2.43E+00	2.25E+00	5.00E+00	1.25E-01	0	1.81E+01
7	6	4.20E-02	1.17E-01	8.10E-02	3.00E-01	6.30E-01	0	1.29E-01	7	1.43E-04	1.19E-01	1.55E-02	7.00E-01	1.25E-01	0	1.24E-01
8	8	1.83E-02	1.94E-01	1.29E-01	4.95E-01	6.30E-01	0	2.04E-01	10	2.74E-03	4.20E-01	4.10E-01	1.00E+00	1.25E-01	0	3.29E+00
9D	37	2.00E-02	1.11E-01	1.00E-01	7.22E-01	6.30E-01	1	1.59E-01	40	8.25E-04	2.08E-01	2.82E-02	1.20E+00	1.25E-01	3	2.27E-01
9U	18	1.99E-02	9.43E+00	1.00E-01	8.00E+01	6.30E-01	0	1.59E-01	61	1.00E-02	1.22E+01	4.40E+00	3.55E+02	1.25E-01	1	3.53E+01
10	1	1.02E-01	1.02E-01	1.02E-01	1.02E-01	6.30E-01	0	1.62E-01	1	4.35E-03	4.35E-03	4.35E-03	4.35E-03	1.25E-01	0	3.49E-02
11	19	1.84E-02	1.14E-01	4.05E-02	6.05E-01	6.30E-01	0	6.43E-02	20	3.45E-03	1.07E-01	2.55E-02	7.00E-01	1.25E-01	2	2.05E-01
12	6	1.88E-02	4.59E-02	2.18E-02	1.70E-01	6.30E-01	0	3.46E-02	6	3.45E-03	4.40E-01	4.15E-01	1.00E+00	1.25E-01	2	3.33E+00
13	18	1.71E-02	8.58E-02	5.13E-02	4.90E-01	6.30E-01	0	8.13E-02	19	8.00E-04	1.67E-01	1.40E-02	7.00E-01	1.25E-01	0	1.12E-01
14	56	1.78E-02	8.99E-01	1.02E-01	8.50E+00	6.30E-01	0	1.62E-01	51	2.45E-03	3.91E-01	1.05E-01	6.70E+00	1.25E-01	8	8.43E-01
15	4	4.00E-02	2.55E-01	9.00E-02	8.00E-01	6.30E-01	0	1.43E-01	4	1.45E-03	9.37E-01	2.49E-01	3.25E+00	1.25E-01	0	2.00E+00
16	26	2.18E-02	5.86E-01	2.10E-01	2.05E+00	6.30E-01	1	3.33E-01	32	1.80E-03	8.19E+00	1.63E-01	7.00E+01	1.25E-01	1	1.31E+00
17D	5	3.40E-02	1.34E-01	9.50E-02	3.95E-01	6.30E-01	0	1.51E-01	5	3.18E-03	8.88E-03	9.50E-03	1.70E-02	1.25E-01	0	7.63E-02
17S	32	1.91E-02	8.95E-02	3.01E-02	7.50E-01	6.30E-01	0	4.77E-02	43	1.75E-03	2.67E-01	1.50E-01	3.20E+00	1.25E-01	3	1.20E+00
18	13	2.03E-02	1.59E-01	5.50E-02	8.00E-01	6.30E-01	0	8.73E-02	15	3.20E-03	3.91E-01	3.05E-02	3.20E+00	1.25E-01	2	2.45E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Heptachlor epoxide								Hexachlorobenzene							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 Percentile DW[10]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW-OC	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	26	2.13E-02	3.09E-01	5.33E-02	1.00E+00	6.30E-01	2	8.45E-02	36	5.10E-04	2.50E-01	8.25E-02	1.00E+00	1.25E-01	0	6.63E-01
20	2	4.05E-02	1.58E-01	1.58E-01	2.75E-01	6.30E-01	0	2.50E-01	3	1.50E-02	3.33E-02	3.50E-02	5.00E-02	1.25E-01	0	2.81E-01
21	1	7.00E-02	7.00E-02	7.00E-02	7.00E-02	6.30E-01	0	1.11E-01	3	9.00E-03	7.13E-02	1.00E-01	1.05E-01	1.25E-01	0	8.03E-01
22	6	1.94E-02	1.09E-01	2.70E-02	3.30E-01	6.30E-01	0	4.28E-02	7	3.63E-04	1.20E-01	1.45E-02	5.00E-01	1.25E-01	0	1.16E-01
23	5	3.40E-02	3.17E-01	1.20E-01	1.00E+00	6.30E-01	0	1.90E-01	5	4.65E-03	6.70E-02	5.50E-03	3.10E-01	1.25E-01	0	4.42E-02
24	5	3.40E-02	3.46E-01	1.70E-01	1.20E+00	6.30E-01	1	2.70E-01	6	5.50E-03	8.98E-02	1.53E-02	4.10E-01	1.25E-01	0	1.22E-01
25	27	2.40E-02	3.16E-01	7.50E-02	1.90E+00	6.30E-01	4	1.19E-01	31	2.40E-03	3.92E-02	1.70E-02	4.10E-01	1.25E-01	0	1.37E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Indeno(1,2,3-c,d)pyrene								Lead							
Unit	µg/kg								mg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[6]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[7]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	6	1.55E-01	4.85E+01	4.24E+01	1.17E+02	4.2E+03	0	1.00E-02	8	9.33E+00	1.70E+01	1.71E+01	2.75E+01	3.63E+01	0	4.70E-01
3	4	1.75E-01	3.28E-01	1.83E-01	7.70E-01	4.2E+03	0	4.31E-05	3	5.61E+00	2.72E+01	3.38E+01	4.21E+01	3.63E+01	1	9.31E-01
6	6	2.45E+00	5.10E+01	2.50E+00	2.80E+02	4.2E+03	0	5.91E-04	6	1.75E+01	3.10E+02	8.88E+01	9.01E+02	3.63E+01	5	2.44E+00
9D	4	2.95E-01	9.49E-01	1.13E+00	1.25E+00	4.2E+03	0	2.66E-04	5	5.00E+00	3.38E+01	7.12E+00	8.78E+01	3.63E+01	2	1.96E-01
9U	38	1.05E-01	7.80E+01	2.50E+00	1.70E+03	4.2E+03	0	5.91E-04	5	3.48E+00	1.30E+01	1.00E+01	3.00E+01	3.63E+01	0	2.75E-01
13	4	1.55E-01	2.22E+01	1.13E+01	6.60E+01	4.2E+03	0	2.67E-03	4	2.02E+01	4.74E+01	4.19E+01	8.57E+01	3.63E+01	3	1.15E+00
14	11	1.65E-01	3.10E+01	3.70E+01	6.60E+01	4.2E+03	0	8.74E-03	22	8.00E+00	4.60E+01	2.47E+01	3.24E+02	3.63E+01	6	6.79E-01
17S	13	1.60E-01	7.32E+00	1.95E-01	4.30E+01	4.2E+03	0	4.61E-05	13	3.34E+00	3.27E+01	5.97E+00	1.16E+02	3.63E+01	5	1.64E-01
19	6	8.00E-02	1.27E+01	1.02E+00	5.00E+01	4.2E+03	0	2.41E-04	2	1.30E+01	1.36E+01	1.36E+01	1.42E+01	3.63E+01	0	3.75E-01
25	5	8.00E-02	2.40E-01	8.00E-02	5.00E-01	4.2E+03	0	1.89E-05	9	1.81E+00	2.98E+01	2.36E+01	7.69E+01	3.63E+01	3	6.50E-01
Alternative C																
1A	6	1.55E-01	3.61E+01	4.98E+00	1.17E+02	4.2E+03	0	1.18E-03	7	9.33E+00	1.55E+01	1.66E+01	2.06E+01	3.63E+01	0	4.57E-01
3	5	1.50E-01	2.92E-01	1.80E-01	7.70E-01	4.2E+03	0	4.25E-05	3	5.61E+00	2.72E+01	3.38E+01	4.21E+01	3.63E+01	1	9.31E-01
5	1	1.65E+02	1.65E+02	1.65E+02	1.65E+02	4.2E+03	0	3.90E-02	0	--	--	--	--	3.63E+01	--	--
6	15	3.60E-01	5.60E+01	2.50E+00	5.20E+02	4.2E+03	0	5.91E-04	10	1.75E+01	2.70E+02	1.29E+02	9.01E+02	3.63E+01	9	3.55E+00
9D	7	1.60E-01	7.98E-01	1.05E+00	1.25E+00	4.2E+03	0	2.48E-04	6	5.00E+00	3.11E+01	1.23E+01	8.78E+01	3.63E+01	2	3.38E-01
9U	61	1.05E-01	8.17E+01	4.36E+00	1.70E+03	4.2E+03	0	1.03E-03	5	3.48E+00	1.30E+01	1.00E+01	3.00E+01	3.63E+01	0	2.75E-01
13	4	1.55E-01	2.22E+01	1.13E+01	6.60E+01	4.2E+03	0	2.67E-03	5	2.02E+01	4.89E+01	4.66E+01	8.57E+01	3.63E+01	4	1.28E+00
14	15	1.65E-01	5.15E+01	3.60E+01	2.05E+02	4.2E+03	0	8.51E-03	21	8.00E+00	4.50E+01	2.56E+01	3.24E+02	3.63E+01	4	7.05E-01
17S	20	1.60E-01	5.80E+00	6.85E-01	4.30E+01	4.2E+03	0	1.62E-04	19	3.34E+00	3.16E+01	5.97E+00	1.23E+02	3.63E+01	7	1.64E-01
19	7	8.00E-02	1.11E+01	1.40E+00	5.00E+01	4.2E+03	0	3.31E-04	2	1.30E+01	1.36E+01	1.36E+01	1.42E+01	3.63E+01	0	3.75E-01
25	6	8.00E-02	2.13E-01	8.00E-02	5.00E-01	4.2E+03	0	1.89E-05	11	1.81E+00	2.90E+01	2.36E+01	7.69E+01	3.63E+01	4	6.50E-01
Alternative D																
1A	6	1.55E-01	3.61E+01	4.98E+00	1.17E+02	4.2E+03	0	1.18E-03	8	9.33E+00	1.65E+01	1.69E+01	2.37E+01	3.63E+01	0	4.64E-01
3	5	1.50E-01	2.92E-01	1.80E-01	7.70E-01	4.2E+03	0	4.25E-05	3	5.61E+00	2.72E+01	3.38E+01	4.21E+01	3.63E+01	1	9.31E-01
5	1	1.65E+02	1.65E+02	1.65E+02	1.65E+02	4.2E+03	0	3.90E-02	0	--	--	--	--	3.63E+01	--	--
6	30	3.60E-01	6.24E+01	2.50E+00	7.80E+02	4.2E+03	0	5.91E-04	13	5.35E+00	2.09E+02	6.60E+01	9.01E+02	3.63E+01	9	1.82E+00
9D	7	1.60E-01	7.98E-01	1.05E+00	1.25E+00	4.2E+03	0	2.48E-04	10	4.08E+00	2.09E+01	6.41E+00	8.78E+01	3.63E+01	2	1.77E-01
9U	61	1.05E-01	8.17E+01	4.36E+00	1.70E+03	4.2E+03	0	1.03E-03	5	3.48E+00	1.30E+01	1.00E+01	3.00E+01	3.63E+01	0	2.75E-01
13	4	1.55E-01	2.22E+01	1.13E+01	6.60E+01	4.2E+03	0	2.67E-03	5	2.74E+00	4.31E+01	4.66E+01	8.57E+01	3.63E+01	3	1.28E+00
14	16	1.65E-01	4.83E+01	2.40E+01	2.05E+02	4.2E+03	0	5.67E-03	24	3.45E+00	4.04E+01	2.00E+01	3.24E+02	3.63E+01	4	5.51E-01
17S	23	1.60E-01	3.59E+00	1.20E+00	3.50E+01	4.2E+03	0	2.84E-04	21	3.34E+00	3.04E+01	5.97E+00	1.23E+02	3.63E+01	8	1.64E-01
19	7	8.00E-02	1.11E+01	1.40E+00	5.00E+01	4.2E+03	0	3.31E-04	2	1.30E+01	1.36E+01	1.36E+01	1.42E+01	3.63E+01	0	3.75E-01
20	0	--	--	--	--	4.2E+03	--	--	0	--	--	--	--	3.63E+01	--	--
23	1	2.00E+01	2.00E+01	2.00E+01	2.00E+01	4.2E+03	0	4.73E-03	0	--	--	--	--	3.63E+01	--	--
25	6	8.00E-02	2.13E-01	8.00E-02	5.00E-01	4.2E+03	0	1.89E-05	11	1.81E+00	3.27E+01	2.36E+01	1.17E+02	3.63E+01	4	6.50E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Indeno(1,2,3-c,d)pyrene								Lead							
Unit	µg/kg								mg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[6]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[7]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	6	1.55E-01	2.32E+00	9.78E-01	9.70E+00	4.2E+03	0	2.31E-04	7	4.24E+00	1.40E+01	1.35E+01	2.37E+01	3.63E+01	0	3.72E-01
3	12	1.50E-01	8.60E+00	3.68E-01	8.25E+01	4.2E+03	0	8.68E-05	8	2.40E+00	7.28E+00	4.71E+00	2.54E+01	3.63E+01	0	1.30E-01
4	1	5.00E-01	5.00E-01	5.00E-01	5.00E-01	4.2E+03	0	1.18E-04	0	--	--	--	--	3.63E+01	--	--
5	1	1.65E+02	1.65E+02	1.65E+02	1.65E+02	4.2E+03	0	3.90E-02	0	--	--	--	--	3.63E+01	--	--
6	56	2.40E-01	8.30E+01	2.50E+00	1.10E+03	4.2E+03	0	5.91E-04	20	2.19E+00	1.39E+02	2.30E+01	9.01E+02	3.63E+01	9	6.32E-01
8	0	--	--	--	--	4.2E+03	--	--	0	--	--	--	--	3.63E+01	--	--
9D	7	1.60E-01	7.98E-01	1.05E+00	1.25E+00	4.2E+03	0	2.48E-04	6	5.00E+00	7.68E+00	5.79E+00	1.74E+01	3.63E+01	0	1.59E-01
9U	62	1.05E-01	6.64E+01	4.28E+00	1.70E+03	4.2E+03	0	1.01E-03	5	3.48E+00	1.30E+01	1.00E+01	3.00E+01	3.63E+01	0	2.75E-01
11	3	8.00E-02	2.75E-01	1.55E-01	5.90E-01	4.2E+03	0	3.66E-05	5	2.26E+00	2.56E+01	6.84E+00	7.48E+01	3.63E+01	2	1.88E-01
12	2	1.80E+00	5.90E+00	5.90E+00	1.00E+01	4.2E+03	0	1.39E-03	0	--	--	--	--	3.63E+01	--	--
13	4	1.55E-01	2.22E+01	1.13E+01	6.60E+01	4.2E+03	0	2.67E-03	4	2.74E+00	4.74E+01	5.07E+01	8.57E+01	3.63E+01	3	1.40E+00
14	15	1.55E-01	2.74E+01	9.40E-01	1.79E+02	4.2E+03	0	2.22E-04	19	3.25E+00	3.61E+01	1.72E+01	3.24E+02	3.63E+01	2	4.74E-01
15	0	--	--	--	--	4.2E+03	--	--	1	3.90E+01	3.90E+01	3.90E+01	3.90E+01	3.63E+01	1	1.07E+00
16	6	4.17E+01	6.66E+01	6.35E+01	9.83E+01	4.2E+03	0	1.50E-02	3	1.59E+01	2.20E+01	1.99E+01	3.03E+01	3.63E+01	0	5.48E-01
17S	29	1.60E-01	2.38E+00	1.20E+00	5.00E+00	4.2E+03	0	2.84E-04	23	2.75E+00	2.20E+01	5.86E+00	1.23E+02	3.63E+01	5	1.61E-01
18	0	--	--	--	--	4.2E+03	--	--	1	4.40E+01	4.40E+01	4.40E+01	4.40E+01	3.63E+01	1	1.21E+00
19	10	8.00E-02	2.10E+01	1.48E+00	1.10E+02	4.2E+03	0	3.48E-04	3	8.94E+00	1.20E+01	1.30E+01	1.42E+01	3.63E+01	0	3.58E-01
20	1	3.80E-01	3.80E-01	3.80E-01	3.80E-01	4.2E+03	0	8.98E-05	0	--	--	--	--	3.63E+01	--	--
23	1	2.00E+01	2.00E+01	2.00E+01	2.00E+01	4.2E+03	0	4.73E-03	0	--	--	--	--	3.63E+01	--	--
24	5	1.95E-01	2.15E+01	3.10E+01	4.20E+01	4.2E+03	0	7.32E-03	3	1.77E+01	6.76E+01	5.30E+01	1.32E+02	3.63E+01	2	1.46E+00
25	9	8.00E-02	1.73E-01	8.00E-02	5.00E-01	4.2E+03	0	1.89E-05	13	1.81E+00	3.13E+01	2.36E+01	1.17E+02	3.63E+01	5	6.50E-01
Alternative F																
1A	4	1.55E-01	2.58E+00	2.23E-01	9.70E+00	4.2E+03	0	5.26E-05	3	9.33E+00	1.21E+01	1.34E+01	1.35E+01	3.63E+01	0	3.69E-01
3	17	1.50E-01	6.70E+00	6.30E-01	8.25E+01	4.2E+03	0	1.49E-04	9	2.40E+00	6.91E+00	3.97E+00	2.54E+01	3.63E+01	0	1.09E-01
4	1	5.00E-01	5.00E-01	5.00E-01	5.00E-01	4.2E+03	0	1.18E-04	0	--	--	--	--	3.63E+01	--	--
5	2	4.10E-01	8.27E+01	8.27E+01	1.65E+02	4.2E+03	0	1.95E-02	1	4.88E+00	4.88E+00	4.88E+00	4.88E+00	3.63E+01	0	1.34E-01
6	78	1.80E-01	8.08E+01	2.50E+00	1.10E+03	4.2E+03	0	5.91E-04	27	2.19E+00	2.20E+02	9.71E+00	3.13E+03	3.63E+01	10	2.67E-01
7	2	9.40E-01	9.65E-01	9.65E-01	9.90E-01	4.2E+03	0	2.28E-04	3	1.70E+01	2.01E+01	2.08E+01	2.26E+01	3.63E+01	0	5.73E-01
8	5	1.10E+00	2.80E+02	4.23E+01	7.48E+02	4.2E+03	0	9.99E-03	7	5.34E+00	2.16E+01	1.49E+01	5.18E+01	3.63E+01	1	4.10E-01
9D	10	1.60E-01	1.06E+01	8.05E-01	1.00E+02	4.2E+03	0	1.90E-04	14	3.42E+00	9.33E+00	6.07E+00	2.74E+01	3.63E+01	0	1.67E-01
9U	61	1.05E-01	2.33E+01	4.15E+00	8.10E+02	4.2E+03	0	9.81E-04	5	3.48E+00	1.30E+01	1.00E+01	3.00E+01	3.63E+01	0	2.75E-01
10	0	--	--	--	--	4.2E+03	--	--	1	1.76E+01	1.76E+01	1.76E+01	1.76E+01	3.63E+01	0	4.85E-01
11	6	8.00E-02	2.43E+01	1.18E-01	1.45E+02	4.2E+03	0	2.78E-05	12	2.25E+00	1.82E+01	5.83E+00	7.48E+01	3.63E+01	3	1.61E-01
12	5	1.70E-01	2.54E+00	5.60E-01	1.00E+01	4.2E+03	0	1.32E-04	1	1.17E+01	1.17E+01	1.17E+01	1.17E+01	3.63E+01	0	3.22E-01
13	3	1.55E-01	7.59E+00	6.20E-01	2.20E+01	4.2E+03	0	1.46E-04	3	2.74E+00	4.50E+01	4.66E+01	8.57E+01	3.63E+01	2	1.28E+00
14	18	1.55E-01	1.04E+01	8.40E-01	8.80E+01	4.2E+03	0	1.98E-04	18	2.78E+00	1.96E+02	8.90E+00	3.33E+03	3.63E+01	2	2.45E-01
15	2	1.70E-01	1.90E+01	1.90E+01	3.79E+01	4.2E+03	0	4.50E-03	1	3.90E+01	3.90E+01	3.90E+01	3.90E+01	3.63E+01	1	1.07E+00
16	19	1.75E-01	4.48E+01	4.90E+01	9.83E+01	4.2E+03	0	1.16E-02	7	2.30E+00	1.57E+01	1.58E+01	3.03E+01	3.63E+01	0	4.35E-01
17D	1	8.00E-02	8.00E-02	8.00E-02	8.00E-02	4.2E+03	0	1.89E-05	1	6.49E+00	6.49E+00	6.49E+00	6.49E+00	3.63E+01	0	1.79E-01
17S	34	8.00E-02	1.14E+01	1.45E+00	2.52E+02	4.2E+03	0	3.43E-04	26	1.50E+00	1.67E+01	5.88E+00	1.23E+02	3.63E+01	3	1.62E-01
18	3	1.65E-01	2.85E-01	1.70E-01	5.20E-01	4.2E+03	0	4.02E-05	2	2.08E+01	3.24E+01	3.24E+01	4.40E+01	3.63E+01	1	8.93E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	Indeno(1,2,3-c,d)pyrene								Lead							
Unit	µg/kg								mg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[6]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[7]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	10	8.00E-02	1.87E+01	1.48E+00	1.10E+02	4.2E+03	0	3.48E-04	3	8.94E+00	1.15E+01	1.26E+01	1.30E+01	3.63E+01	0	3.47E-01
20	1	3.80E-01	3.80E-01	3.80E-01	3.80E-01	4.2E+03	0	8.98E-05	0	--	--	--	--	3.63E+01	--	--
21	2	1.80E+00	6.40E+00	6.40E+00	1.10E+01	4.2E+03	0	1.51E-03	1	7.57E+00	7.57E+00	7.57E+00	7.57E+00	3.63E+01	0	2.09E-01
22	0	--	--	--	--	4.2E+03	--	--	1	3.95E+01	3.95E+01	3.95E+01	3.95E+01	3.63E+01	1	1.09E+00
23	4	2.35E-01	5.77E+00	1.41E+00	2.00E+01	4.2E+03	0	3.34E-04	0	--	--	--	--	3.63E+01	--	--
24	3	8.00E-02	2.00E-01	1.95E-01	3.25E-01	4.2E+03	0	4.61E-05	0	--	--	--	--	3.63E+01	--	--
25	12	8.00E-02	2.23E-01	8.00E-02	1.00E+00	4.2E+03	0	1.89E-05	10	1.81E+00	1.53E+01	1.07E+01	5.79E+01	3.63E+01	1	2.95E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	LWG RA Total Chlordane (Calculated U = 1/2)								PCB-077							
Unit	µg/kg								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[8]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	22	2.18E-02	7.36E-01	2.39E-01	3.00E+00	6.98E-01	7	3.42E-01	1	2.90E-03	2.90E-03	2.90E-03	2.90E-03	2.72E+00	0	1.07E-03
3	17	4.40E-02	1.96E+00	1.19E+00	7.24E+00	6.98E-01	9	1.70E+00	0	--	--	--	--	2.72E+00	--	--
6	0	--	--	--	--	6.98E-01	--	--	0	--	--	--	--	2.72E+00	--	--
9D	14	2.35E-02	5.19E-01	2.95E-01	1.95E+00	6.98E-01	1	4.23E-01	0	--	--	--	--	2.72E+00	--	--
9U	17	2.25E-02	2.74E+01	4.50E-01	3.05E+02	6.98E-01	3	6.45E-01	0	--	--	--	--	2.72E+00	--	--
13	17	1.89E-02	5.89E-01	2.13E-01	1.83E+00	6.98E-01	4	3.05E-01	3	6.63E-02	1.90E-01	1.16E-01	3.88E-01	2.72E+00	0	4.26E-02
14	52	2.10E-02	7.69E+00	3.28E+00	9.40E+01	6.98E-01	24	4.69E+00	3	1.25E-02	3.18E-02	2.33E-02	5.96E-02	2.72E+00	0	8.57E-03
17S	14	2.00E-02	1.95E+00	1.33E-01	1.40E+01	6.98E-01	5	1.91E-01	3	2.53E-03	1.25E-01	6.07E-02	3.13E-01	2.72E+00	0	2.23E-02
19	23	2.70E-02	1.03E+01	1.10E+00	1.10E+02	6.98E-01	15	1.58E+00	3	8.60E-04	1.20E-03	1.26E-03	1.48E-03	2.72E+00	0	4.61E-04
25	17	3.20E-02	3.57E+00	3.30E-01	1.70E+01	6.98E-01	7	4.73E-01	2	4.89E-04	6.37E-04	6.37E-04	7.85E-04	2.72E+00	0	2.34E-04
Alternative C																
1A	23	2.18E-02	1.05E+00	2.50E-01	7.40E+00	6.98E-01	8	3.58E-01	1	2.90E-03	2.90E-03	2.90E-03	2.90E-03	2.72E+00	0	1.07E-03
3	19	4.40E-02	2.01E+00	1.19E+00	7.24E+00	6.98E-01	10	1.70E+00	0	--	--	--	--	2.72E+00	--	--
5	8	4.50E-02	2.24E+00	1.75E+00	7.18E+00	6.98E-01	5	2.51E+00	0	--	--	--	--	2.72E+00	--	--
6	0	--	--	--	--	6.98E-01	--	--	0	--	--	--	--	2.72E+00	--	--
9D	23	2.20E-02	6.32E-01	3.20E-01	2.16E+00	6.98E-01	4	4.58E-01	0	--	--	--	--	2.72E+00	--	--
9U	20	2.25E-02	2.34E+01	3.65E-01	3.05E+02	6.98E-01	4	5.23E-01	0	--	--	--	--	2.72E+00	--	--
13	20	1.89E-02	6.08E-01	3.02E-01	1.83E+00	6.98E-01	5	4.32E-01	3	6.63E-02	1.90E-01	1.16E-01	3.88E-01	2.72E+00	0	4.26E-02
14	65	2.10E-02	5.62E+00	3.20E+00	6.50E+01	6.98E-01	26	4.58E+00	3	1.25E-02	3.18E-02	2.33E-02	5.96E-02	2.72E+00	0	8.57E-03
17S	26	2.00E-02	1.12E+00	1.21E-01	1.40E+01	6.98E-01	8	1.73E-01	3	2.53E-03	1.25E-01	6.07E-02	3.13E-01	2.72E+00	0	2.23E-02
19	25	2.70E-02	9.55E+00	9.80E-01	1.10E+02	6.98E-01	16	1.40E+00	3	8.60E-04	1.20E-03	1.26E-03	1.48E-03	2.72E+00	0	4.61E-04
25	19	3.20E-02	3.47E+00	3.30E-01	1.70E+01	6.98E-01	8	4.73E-01	2	4.89E-04	6.37E-04	6.37E-04	7.85E-04	2.72E+00	0	2.34E-04
Alternative D																
1A	30	2.20E-02	1.52E+00	9.69E-01	7.40E+00	6.98E-01	13	1.39E+00	2	8.90E-04	1.90E-03	1.90E-03	2.90E-03	2.72E+00	0	6.97E-04
3	25	4.40E-02	2.47E+00	1.80E+00	1.30E+01	6.98E-01	14	2.58E+00	1	7.36E-01	7.36E-01	7.36E-01	7.36E-01	2.72E+00	0	2.71E-01
5	8	4.50E-02	2.24E+00	1.75E+00	7.18E+00	6.98E-01	5	2.51E+00	0	--	--	--	--	2.72E+00	--	--
6	0	--	--	--	--	6.98E-01	--	--	0	--	--	--	--	2.72E+00	--	--
9D	29	2.10E-02	5.33E-01	2.70E-01	2.16E+00	6.98E-01	4	3.87E-01	0	--	--	--	--	2.72E+00	--	--
9U	20	2.25E-02	2.34E+01	3.65E-01	3.05E+02	6.98E-01	4	5.23E-01	0	--	--	--	--	2.72E+00	--	--
13	20	1.80E-02	5.73E-01	2.02E-01	1.83E+00	6.98E-01	5	2.89E-01	1	1.16E-01	1.16E-01	1.16E-01	1.16E-01	2.72E+00	0	4.26E-02
14	67	1.87E-02	5.36E+00	2.90E+00	6.50E+01	6.98E-01	24	4.15E+00	3	1.25E-02	3.18E-02	2.33E-02	5.96E-02	2.72E+00	0	8.57E-03
17S	31	2.00E-02	1.13E+00	1.22E-01	1.40E+01	6.98E-01	7	1.74E-01	5	1.85E-03	7.61E-02	2.53E-03	3.13E-01	2.72E+00	0	9.30E-04
19	25	2.70E-02	2.02E+00	9.70E-01	1.01E+01	6.98E-01	15	1.39E+00	3	8.60E-04	1.20E-03	1.26E-03	1.48E-03	2.72E+00	0	4.61E-04
20	3	6.50E-02	2.84E+00	2.65E+00	5.80E+00	6.98E-01	1	3.80E+00	1	1.25E-03	1.25E-03	1.25E-03	1.25E-03	2.72E+00	0	4.60E-04
23	0	--	--	--	--	6.98E-01	--	--	0	--	--	--	--	2.72E+00	--	--
25	19	3.20E-02	2.86E+00	3.30E-01	1.60E+01	6.98E-01	8	4.73E-01	2	4.89E-04	6.37E-04	6.37E-04	7.85E-04	2.72E+00	0	2.34E-04

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	LWG RA Total Chlordane (Calculated U = 1/2)								PCB-077							
Unit	µg/kg								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[8]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	37	2.09E-02	1.37E+00	8.00E-01	7.40E+00	6.98E-01	15	1.15E+00	3	8.90E-04	6.53E-02	2.90E-03	1.92E-01	2.72E+00	0	1.07E-03
3	31	4.15E-02	7.67E-01	2.60E-01	7.24E+00	6.98E-01	8	3.72E-01	0	--	--	--	--	2.72E+00	--	--
4	2	2.59E-02	1.83E-01	1.83E-01	3.40E-01	6.98E-01	0	2.62E-01	0	--	--	--	--	2.72E+00	--	--
5	4	4.50E-02	1.55E+00	1.40E+00	3.35E+00	6.98E-01	1	2.01E+00	0	--	--	--	--	2.72E+00	--	--
6	0	--	--	--	--	6.98E-01	--	--	0	--	--	--	--	2.72E+00	--	--
8	2	1.37E-01	1.40E-01	1.40E-01	1.43E-01	6.98E-01	0	2.00E-01	0	--	--	--	--	2.72E+00	--	--
9D	29	2.20E-02	5.00E-01	2.70E-01	2.40E+00	6.98E-01	5	3.87E-01	0	--	--	--	--	2.72E+00	--	--
9U	22	2.25E-02	2.13E+01	2.80E-01	3.05E+02	6.98E-01	3	4.01E-01	0	--	--	--	--	2.72E+00	--	--
11	8	1.93E-02	1.62E-01	4.30E-02	9.50E-01	6.98E-01	0	6.16E-02	2	5.40E-04	6.55E-04	6.55E-04	7.70E-04	2.72E+00	0	2.41E-04
12	2	1.95E-02	1.54E-01	1.54E-01	2.88E-01	6.98E-01	0	2.20E-01	0	--	--	--	--	2.72E+00	--	--
13	19	1.80E-02	5.42E-01	1.90E-01	1.83E+00	6.98E-01	4	2.72E-01	1	1.16E-01	1.16E-01	1.16E-01	1.16E-01	2.72E+00	0	4.26E-02
14	62	1.87E-02	2.31E+00	1.75E+00	1.60E+01	6.98E-01	22	2.51E+00	2	2.33E-02	4.15E-02	4.15E-02	5.96E-02	2.72E+00	0	1.52E-02
15	1	8.00E-01	8.00E-01	8.00E-01	8.00E-01	6.98E-01	0	1.15E+00	0	--	--	--	--	2.72E+00	--	--
16	9	7.85E-01	1.06E+00	1.01E+00	1.27E+00	6.98E-01	2	1.44E+00	0	--	--	--	--	2.72E+00	--	--
17S	33	2.00E-02	7.05E-01	1.17E-01	7.70E+00	6.98E-01	6	1.68E-01	4	1.85E-03	1.68E-02	2.38E-03	6.07E-02	2.72E+00	0	8.73E-04
18	3	4.60E-02	4.79E-01	5.91E-01	8.00E-01	6.98E-01	0	8.47E-01	0	--	--	--	--	2.72E+00	--	--
19	29	2.25E-02	1.50E+00	6.80E-01	8.00E+00	6.98E-01	14	9.74E-01	4	8.60E-04	1.87E-03	1.37E-03	3.88E-03	2.72E+00	0	5.03E-04
20	7	4.10E-02	2.72E+00	2.65E+00	5.80E+00	6.98E-01	4	3.80E+00	1	1.25E-03	1.25E-03	1.25E-03	1.25E-03	2.72E+00	0	4.60E-04
23	0	--	--	--	--	6.98E-01	--	--	0	--	--	--	--	2.72E+00	--	--
24	8	4.35E-02	1.80E+00	1.60E+00	3.90E+00	6.98E-01	6	2.29E+00	0	--	--	--	--	2.72E+00	--	--
25	20	3.20E-02	1.53E+00	2.25E-01	5.60E+00	6.98E-01	7	3.22E-01	5	4.20E-04	7.86E-04	4.89E-04	1.76E-03	2.72E+00	0	1.80E-04
Alternative F																
1A	22	2.09E-02	2.46E-01	8.50E-02	1.40E+00	6.98E-01	2	1.22E-01	4	8.90E-04	6.81E-02	3.98E-02	1.92E-01	2.72E+00	0	1.46E-02
3	30	4.15E-02	2.71E-01	1.03E-01	1.60E+00	6.98E-01	3	1.47E-01	0	--	--	--	--	2.72E+00	--	--
4	3	2.59E-02	1.37E-01	4.50E-02	3.40E-01	6.98E-01	0	6.45E-02	0	--	--	--	--	2.72E+00	--	--
5	6	1.98E-02	6.33E-01	4.55E-02	3.35E+00	6.98E-01	0	6.52E-02	0	--	--	--	--	2.72E+00	--	--
6	3	2.75E-01	1.19E+00	1.60E+00	1.70E+00	6.98E-01	2	2.29E+00	0	--	--	--	--	2.72E+00	--	--
7	6	4.60E-02	6.88E-01	5.40E-01	1.50E+00	6.98E-01	3	7.74E-01	0	--	--	--	--	2.72E+00	--	--
8	8	1.93E-02	2.01E-01	1.31E-01	1.00E+00	6.98E-01	0	1.87E-01	1	4.43E-03	4.43E-03	4.43E-03	4.43E-03	2.72E+00	0	1.63E-03
9D	37	2.10E-02	5.83E-01	2.70E-01	4.40E+00	6.98E-01	9	3.87E-01	0	--	--	--	--	2.72E+00	--	--
9U	18	2.25E-02	2.57E+01	2.75E-01	3.05E+02	6.98E-01	1	3.94E-01	0	--	--	--	--	2.72E+00	--	--
10	1	1.07E-01	1.07E-01	1.07E-01	1.07E-01	6.98E-01	0	1.53E-01	0	--	--	--	--	2.72E+00	--	--
11	19	1.93E-02	1.69E-01	4.35E-02	1.40E+00	6.98E-01	1	6.23E-02	4	5.40E-04	9.78E-04	9.90E-04	1.39E-03	2.72E+00	0	3.64E-04
12	6	1.95E-02	8.77E-02	2.32E-02	2.88E-01	6.98E-01	0	3.32E-02	0	--	--	--	--	2.72E+00	--	--
13	18	1.80E-02	4.75E-01	1.70E-01	1.83E+00	6.98E-01	3	2.44E-01	0	--	--	--	--	2.72E+00	--	--
14	55	1.87E-02	1.83E+00	8.51E-01	1.60E+01	6.98E-01	15	1.22E+00	1	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.72E+00	0	8.57E-03
15	4	8.50E-02	6.19E-01	5.45E-01	1.30E+00	6.98E-01	1	7.81E-01	2	5.70E-04	7.88E-04	7.88E-04	1.01E-03	2.72E+00	0	2.90E-04
16	32	4.50E-02	1.15E+00	1.00E+00	5.00E+00	6.98E-01	11	1.44E+00	1	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.72E+00	0	8.57E-03
17D	5	4.35E-02	8.23E-01	1.16E-01	2.40E+00	6.98E-01	2	1.65E-01	1	1.38E-03	1.38E-03	1.38E-03	1.38E-03	2.72E+00	0	5.07E-04
17S	35	2.00E-02	9.12E-01	1.17E-01	1.10E+01	6.98E-01	8	1.68E-01	8	4.71E-04	4.07E-02	2.38E-03	1.28E-01	2.72E+00	0	8.73E-04
18	14	2.25E-02	4.84E-01	3.83E-01	1.70E+00	6.98E-01	2	5.48E-01	1	4.02E-03	4.02E-03	4.02E-03	4.02E-03	2.72E+00	0	1.48E-03

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	LWG RA Total Chlordane (Calculated U = 1/2)								PCB-077							
Unit	µg/kg								µg/kg							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[8]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	21	2.25E-02	4.79E-01	3.42E-01	1.50E+00	6.98E-01	6	4.90E-01	4	8.60E-04	1.87E-03	1.37E-03	3.88E-03	2.72E+00	0	5.03E-04
20	3	4.10E-02	1.71E+00	7.80E-01	4.30E+00	6.98E-01	2	1.12E+00	0	--	--	--	--	2.72E+00	--	--
21	3	3.45E-01	4.18E-01	4.40E-01	4.70E-01	6.98E-01	0	6.30E-01	0	--	--	--	--	2.72E+00	--	--
22	6	2.20E-02	3.68E-01	4.08E-01	6.20E-01	6.98E-01	0	5.84E-01	0	--	--	--	--	2.72E+00	--	--
23	4	4.35E-02	8.26E-01	7.80E-01	1.70E+00	6.98E-01	2	1.12E+00	0	--	--	--	--	2.72E+00	--	--
24	5	4.35E-02	1.28E+00	2.20E-01	3.70E+00	6.98E-01	2	3.15E-01	0	--	--	--	--	2.72E+00	--	--
25	29	3.20E-02	6.81E-01	2.70E-01	2.70E+00	6.98E-01	11	3.87E-01	7	4.20E-04	5.25E-04	4.89E-04	7.85E-04	2.72E+00	0	1.80E-04

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	PCB-126								Tributyltin ion							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[9]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 Percentile DW-OC[10]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative B																
1A	1	5.25E-04	5.25E-04	5.25E-04	5.25E-04	4.50E-02	0	1.17E-02	0	--	--	--	--	0.153	--	--
3	0	--	--	--	--	4.50E-02	--	--	17	1.55E-03	1.34E+00	5.10E-02	6.40E+00	0.153	5	3.33E-01
6	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
9D	0	--	--	--	--	4.50E-02	--	--	9	8.00E-02	2.59E-01	2.80E-01	6.10E-01	0.153	2	1.83E+00
9U	0	--	--	--	--	4.50E-02	--	--	6	6.00E-02	1.79E-01	1.08E-01	3.50E-01	0.153	0	7.03E-01
13	3	9.01E-03	7.07E-02	1.20E-02	1.91E-01	4.50E-02	1	2.67E-01	6	5.50E-03	1.10E+00	7.75E-03	3.70E+00	0.153	2	5.07E-02
14	5	3.02E-03	7.63E-03	7.94E-03	1.51E-02	4.50E-02	0	1.76E-01	0	--	--	--	--	0.153	--	--
17S	3	7.40E-04	3.74E-02	1.96E-02	9.18E-02	4.50E-02	1	4.36E-01	17	5.50E-03	2.05E+01	2.50E-01	2.30E+02	0.153	8	1.63E+00
19	3	6.25E-04	6.70E-04	6.90E-04	6.95E-04	4.50E-02	0	1.53E-02	18	3.65E-03	1.18E+00	4.95E-01	5.40E+00	0.153	13	3.24E+00
25	2	7.10E-04	8.10E-04	8.10E-04	9.10E-04	4.50E-02	0	1.80E-02	9	2.55E-02	1.83E+00	3.80E-02	1.60E+01	0.153	1	2.48E-01
Alternative C																
1A	2	5.25E-04	1.94E-03	1.94E-03	3.35E-03	4.50E-02	0	4.31E-02	0	--	--	--	--	0.153	--	--
3	0	--	--	--	--	4.50E-02	--	--	19	1.55E-03	1.83E+00	5.10E-02	1.20E+01	0.153	6	3.33E-01
5	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
6	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
9D	0	--	--	--	--	4.50E-02	--	--	15	7.00E-02	3.20E-01	1.10E-01	1.80E+00	0.153	3	7.19E-01
9U	0	--	--	--	--	4.50E-02	--	--	6	6.00E-02	1.79E-01	1.08E-01	3.50E-01	0.153	0	7.03E-01
13	3	9.01E-03	7.07E-02	1.20E-02	1.91E-01	4.50E-02	1	2.67E-01	7	5.50E-03	1.23E+00	8.00E-03	3.70E+00	0.153	3	5.23E-02
14	5	3.02E-03	7.63E-03	7.94E-03	1.51E-02	4.50E-02	0	1.76E-01	0	--	--	--	--	0.153	--	--
17S	3	7.40E-04	3.74E-02	1.96E-02	9.18E-02	4.50E-02	1	4.36E-01	33	5.50E-03	5.55E+01	3.00E-01	8.50E+02	0.153	17	1.96E+00
19	3	6.25E-04	6.70E-04	6.90E-04	6.95E-04	4.50E-02	0	1.53E-02	22	3.65E-03	9.99E-01	4.00E-01	5.40E+00	0.153	14	2.61E+00
25	2	7.10E-04	8.10E-04	8.10E-04	9.10E-04	4.50E-02	0	1.80E-02	11	2.55E-02	1.51E+00	5.00E-02	1.60E+01	0.153	1	3.27E-01
Alternative D																
1A	3	5.25E-04	1.48E-03	5.55E-04	3.35E-03	4.50E-02	0	1.23E-02	0	--	--	--	--	0.153	--	--
3	1	3.93E-02	3.93E-02	3.93E-02	3.93E-02	4.50E-02	0	8.73E-01	24	1.55E-03	1.63E+00	6.30E-02	1.20E+01	0.153	7	4.12E-01
5	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
6	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
9D	0	--	--	--	--	4.50E-02	--	--	18	5.00E-02	2.77E-01	1.05E-01	1.80E+00	0.153	3	6.86E-01
9U	0	--	--	--	--	4.50E-02	--	--	6	6.00E-02	1.79E-01	1.08E-01	3.50E-01	0.153	0	7.03E-01
13	1	1.20E-02	1.20E-02	1.20E-02	1.20E-02	4.50E-02	0	2.67E-01	5	5.50E-03	4.05E-01	7.50E-03	2.00E+00	0.153	1	4.90E-02
14	3	3.02E-03	6.32E-03	7.94E-03	7.99E-03	4.50E-02	0	1.76E-01	0	--	--	--	--	0.153	--	--
17S	5	7.40E-04	2.29E-02	1.34E-03	9.18E-02	4.50E-02	1	2.97E-02	35	5.50E-03	6.47E+01	3.00E-01	8.50E+02	0.153	18	1.96E+00
19	3	6.25E-04	6.70E-04	6.90E-04	6.95E-04	4.50E-02	0	1.53E-02	24	5.00E-03	2.09E+00	4.00E-01	2.80E+01	0.153	15	2.61E+00
20	1	9.45E-04	9.45E-04	9.45E-04	9.45E-04	4.50E-02	0	2.10E-02	0	--	--	--	--	0.153	--	--
23	0	--	--	--	--	4.50E-02	--	--	1	5.40E-01	5.40E-01	5.40E-01	5.40E-01	0.153	1	3.53E+00
25	2	7.10E-04	8.10E-04	8.10E-04	9.10E-04	4.50E-02	0	1.80E-02	11	1.75E-02	1.51E+00	5.00E-02	1.60E+01	0.153	1	3.27E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

Contaminant	PCB-126								Tributyltin ion							
Unit	µg/kg								mg/kg-OC							
SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[9]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 Percentile DW-OC[10]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
Alternative E																
1A	4	5.25E-04	5.11E-03	1.95E-03	1.60E-02	4.50E-02	0	4.34E-02	0	--	--	--	--	0.153	--	--
3	0	--	--	--	--	4.50E-02	--	--	26	1.55E-03	1.32E+00	2.53E-02	3.00E+01	0.153	3	1.65E-01
4	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
5	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
6	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
8	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
9D	0	--	--	--	--	4.50E-02	--	--	15	2.50E-02	2.95E-01	1.05E-01	1.80E+00	0.153	2	6.86E-01
9U	0	--	--	--	--	4.50E-02	--	--	8	6.00E-02	1.88E-01	1.08E-01	3.50E-01	0.153	0	7.03E-01
11	3	6.50E-04	2.31E-03	7.50E-04	5.54E-03	4.50E-02	0	1.67E-02	6	6.00E-03	1.02E+01	5.25E-02	6.00E+01	0.153	2	3.43E-01
12	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
13	1	1.20E-02	1.20E-02	1.20E-02	1.20E-02	4.50E-02	0	2.67E-01	5	5.50E-03	4.05E-01	7.50E-03	2.00E+00	0.153	1	4.90E-02
14	3	1.00E-03	4.00E-03	3.02E-03	7.99E-03	4.50E-02	0	6.71E-02	0	--	--	--	--	0.153	--	--
15	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
16	0	--	--	--	--	4.50E-02	--	--	9	4.05E-02	4.42E-01	1.25E-01	2.40E+00	0.153	2	8.17E-01
17S	4	7.40E-04	5.68E-03	1.18E-03	1.96E-02	4.50E-02	0	2.62E-02	34	4.00E-03	4.70E+01	1.00E-01	8.50E+02	0.153	14	6.54E-01
18	0	--	--	--	--	4.50E-02	--	--	1	4.40E-02	4.40E-02	4.40E-02	4.40E-02	0.153	0	2.88E-01
19	4	6.25E-04	8.29E-04	6.93E-04	1.31E-03	4.50E-02	0	1.54E-02	23	5.00E-03	1.77E+00	1.00E-01	2.80E+01	0.153	10	6.54E-01
20	1	9.45E-04	9.45E-04	9.45E-04	9.45E-04	4.50E-02	0	2.10E-02	0	--	--	--	--	0.153	--	--
23	0	--	--	--	--	4.50E-02	--	--	1	5.40E-01	5.40E-01	5.40E-01	5.40E-01	0.153	1	3.53E+00
24	0	--	--	--	--	4.50E-02	--	--	1	2.00E-01	2.00E-01	2.00E-01	2.00E-01	0.153	1	1.31E+00
25	5	7.10E-04	1.02E-03	9.10E-04	1.63E-03	4.50E-02	0	2.02E-02	11	1.75E-02	1.53E+00	5.50E-02	1.60E+01	0.153	2	3.59E-01
Alternative F																
1A	5	5.25E-04	4.98E-03	3.35E-03	1.60E-02	4.50E-02	0	7.44E-02	0	--	--	--	--	0.153	--	--
3	0	--	--	--	--	4.50E-02	--	--	27	1.55E-03	1.31E+00	3.20E-02	3.00E+01	0.153	4	2.09E-01
4	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
5	0	--	--	--	--	4.50E-02	--	--	1	8.00E-02	8.00E-02	8.00E-02	8.00E-02	0.153	0	5.23E-01
6	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
7	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
8	1	4.92E-03	4.92E-03	4.92E-03	4.92E-03	4.50E-02	0	1.09E-01	0	--	--	--	--	0.153	--	--
9D	0	--	--	--	--	4.50E-02	--	--	24	0.00E+00	3.49E-01	9.75E-02	4.20E+00	0.153	3	6.37E-01
9U	0	--	--	--	--	4.50E-02	--	--	8	6.00E-02	1.88E-01	1.08E-01	3.50E-01	0.153	0	7.03E-01
10	0	--	--	--	--	4.50E-02	--	--	1	3.40E-02	3.40E-02	3.40E-02	3.40E-02	0.153	0	2.22E-01
11	5	5.15E-04	1.61E-03	6.50E-04	5.54E-03	4.50E-02	0	1.44E-02	12	6.00E-03	5.13E+00	4.70E-02	6.00E+01	0.153	4	3.07E-01
12	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
13	0	--	--	--	--	4.50E-02	--	--	5	5.50E-03	4.05E-01	7.50E-03	2.00E+00	0.153	1	4.90E-02
14	2	1.00E-03	4.50E-03	4.50E-03	7.99E-03	4.50E-02	0	9.99E-02	2	5.50E-03	3.28E-02	3.28E-02	6.00E-02	0.153	0	2.14E-01
15	3	5.00E-04	1.93E-03	1.28E-03	4.00E-03	4.50E-02	0	2.84E-02	0	--	--	--	--	0.153	--	--
16	1	7.99E-03	7.99E-03	7.99E-03	7.99E-03	4.50E-02	0	1.78E-01	16	3.25E-02	3.80E-01	1.28E-01	2.40E+00	0.153	4	8.33E-01
17D	2	1.43E-03	1.63E-03	1.63E-03	1.82E-03	4.50E-02	0	3.61E-02	1	2.10E-02	2.10E-02	2.10E-02	2.10E-02	0.153	0	1.37E-01
17S	8	3.21E-04	8.36E-03	1.18E-03	2.76E-02	4.50E-02	0	2.62E-02	30	4.00E-03	4.96E+01	1.00E-01	8.50E+02	0.153	11	6.54E-01
18	1	8.60E-04	8.60E-04	8.60E-04	8.60E-04	4.50E-02	0	1.91E-02	6	4.40E-02	1.88E+00	5.50E-02	1.10E+01	0.153	1	3.59E-01

Table. 5.10-4 - Additional Contaminants Below the DOI with PRGs Above Background and Consistent with the Risk Assessment

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SMA	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 UPL DW[9]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background	Count of Samples	Minimum Result	Average Result	Median Result	Maximum Result	Background 95 Percentile DW-OC[10]	Count of Detected Samples Greater than Background	Ratio of Median Value to Background
19	4	6.25E-04	8.29E-04	6.93E-04	1.31E-03	4.50E-02	0	1.54E-02	20	5.00E-03	1.50E-01	6.00E-02	1.00E+00	0.153	4	3.92E-01
20	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
21	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
22	0	--	--	--	--	4.50E-02	--	--	0	--	--	--	--	0.153	--	--
23	0	--	--	--	--	4.50E-02	--	--	1	5.40E-01	5.40E-01	5.40E-01	5.40E-01	0.153	1	3.53E+00
24	0	--	--	--	--	4.50E-02	--	--	1	2.00E-01	2.00E-01	2.00E-01	2.00E-01	0.153	1	1.31E+00
25	7	5.50E-04	7.97E-04	7.90E-04	9.55E-04	4.50E-02	0	1.76E-02	10	2.00E-02	1.67E+00	7.00E-02	1.60E+01	0.153	2	4.58E-01

Footnotes:

1 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is In-Water Sediment (Direct Contact) Tribal Fisher

2 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is In-Water Sediment (Direct Contact) Tribal Fisher

3 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is Adult Shellfish Clam Consumption (18 g/day High IR)

4 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is In-Water Sediment (Direct Contact) Tribal Fisher

5 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is Adult Shellfish Clam Consumption (18 g/day High IR)

6 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is In-Water Sediment (Direct Contact) Tribal Fisher

7 -Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is Eco-Tissue Residue Assessment Invertivore Peamouth

8 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is Eco-Wildlife Dietary Assessment, Bird Dietary Assessment, Sediment Probing Invertivore, Spotted Sandpiper, Worms

9 - Background is less than all PRGs, so the background value is replaced with the lowest PRG value which is Wildlife Dietary Assessment, Mannals Dietary Assessment, Aquatic-Dependent Carnivore, Mink, crayfish, scuplin, smallmouth bass, carp, Refined multi sp, diet

10 - Background levels are from Tables 7.3-5b and 7.3-6b of the Portland Harbor RI/FS, Draft Final Remedial Investigation Report (Integral et al. 2011). The 95 UPL was used as background when available. The 95 percentile was used when the UPL was not available.

General Notes:

Results detected below the associated MDL were considered to not exceed the assocated background level.

Dataset used for statistical calculations and background screen consist of subsurface sediment sample results collected from cores located in areas of active remediation below the depth of impact assigned to the core.

SMAs not listed do not have data below the depth of impact.

-- = indicates that the statistic was not calculated because no data was avaliable.

Table 5.11-1. Comparison of Total Estimated Dredge Volume by EPA Method to LWG Method

Alternative	Average Alternative Wide DOI (Ft)	Total Dredge Volume For Disposal - EPA Method (cy)		Total Dredge Volume For Disposal - LWG Method (cy)		EPA Method Volume as Percentage of LWG Method Volume	
		Low	High	Low	High	Low	High
B-i	3.7	198,000	293,000	234,000	369,000	85%	79%
B-r	5.6	541,000	783,000	581,000	859,000	93%	91%
C-i	4.0	314,000	459,000	362,000	564,000	87%	81%
C-r	5.4	776,000	1,127,000	842,000	1,255,000	92%	90%
D-i	3.9	387,000	564,000	448,000	699,000	86%	81%
D-r	5.1	914,000	1,321,000	1,000,000	1,496,000	91%	88%
E-i	4.6	936,000	1,362,000	1,054,000	1,610,000	89%	85%
E-r	5.3	1,775,000	2,596,000	1,926,000	2,887,000	92%	90%
F-i	5.3	2,129,000	3,151,000	2,314,000	3,498,000	92%	90%
F-r	6.0	4,195,000	6,182,000	4,446,000	6,600,000	94%	94%

This section identifies and reviews a wide array of well established and innovative technologies that have or can be used to remediate contaminated sediments. Information from the previous sections on the characteristics of the Site and Site sediments is used to evaluate and screen this wide array of technologies using EPA guidance methods and identify the subset of technologies that are most appropriate for use in sediment remediation at this Site. It was found that most of the commonly applied (EPA 2005a) technologies of MNR, enhanced monitored natural recovery (EMNR), capping, environmental dredging, and disposal are widely appropriate for this Site as well as some more innovative technologies such as in-situ treatment using carbon amendments, which is described more below. In many cases, there are a wide array of "process options" for each major technology, so certain representative options were selected to facilitate later draft FS evaluations. Both the technology screening and process option selections are for draft FS purposes, and technologies or options screened out in this draft FS may still be appropriate for consideration in remedial design as indicated by SMA-specific conditions and design-level data. The screened through technologies and process options identified in this section are used in Section 7 as the components for use in assembling Site-wide comprehensive remedial alternatives.

6.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

A key early step in the development of remedial alternatives that address Site RAOs is the selection of general response actions (GRAs) and remedial technologies that comprise alternatives. GRAs represent categories of remedial technologies, which are applied to the Site and assembled into comprehensive Site-wide alternatives aimed at achieving RAOs. This process starts with the identification and screening of remedial technologies to identify those technologies and process options (specific forms or variations on technologies) potentially applicable to Site conditions. Following this initial screening, a range of comprehensive alternatives can be developed using this focused list of Site-specific technologies. EPA's general RI/FS guidance (EPA 1988) and specific Contaminated Sediment Remediation Guidance (EPA 2005a) were used for the identification and screening process performed in the following subsections.

6.1 IDENTIFICATION OF TECHNOLOGIES

As described in EPA's general RI/FS guidance (1988), remedial alternatives have the following three components:

- **GRAs –** major categories of cleanup activities such as source control/natural recovery, institutional controls, containment, removal, or treatment.
- **Remedial technologies –** types of technologies within each GRA, such as different containment options (e.g., thin-layer capping, engineered caps, active caps).
- **Process options –** specific variations in the way technologies are implemented such as variations in excavation (e.g., mechanical and hydraulic dredging) and capping specifications (e.g., specific cap armor and chemical isolation layer components).

Following EPA's guidance (1988, 2005a), a wide range of contaminated sediment GRAs and technologies were initially evaluated for possible consideration at the Site in the Programmatic Work Plan (Integral et al. 2004). The GRAs that have been carried into this draft FS evaluation include:

- **Institutional Controls –** Institutional controls generally refer to non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to CERCLA material often by limiting land or resource use.
- **Monitored Natural Recovery (MNR) –** MNR is a remedy for contaminated sediment that typically uses ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. As described in Magar et al. (2009), natural processes that are fundamental to the recovery of contaminated sediments include chemical transformation, reduction in contaminant mobility/bioavailability, physical isolation, and dispersion. The MNR remedy relies on these processes to reduce potentially unacceptable ecological and human health risks to acceptable levels, while monitoring recovery over time to verify remedy success.
- **Enhanced Monitored Natural Recovery (EMNR) –** Deposition of clean sediment plays a role in the natural recovery of contaminated sediments, and recovery can be enhanced by actively providing a layer of clean sediment to the target area. EMNR refers to the application of a thin layer of clean sediment, typically sand, to a sediment area targeted for remediation. Application thicknesses of approximately 6 inches are common, producing an immediate reduction in surface chemical concentrations. EMNR typically reduces the time to achieve RAOs over what is possible by relying solely on natural sediment deposition where burial is the principal recovery mechanism (EPA 2005a). Surface sediment contaminant concentrations in areas of EMNR can be affected by bioturbation if the sand layer is less than about 12 inches (Appendix Ha). These processes result in the mixing of underlying contaminated sediment with the cleaner near-surface material.
- **Capping –** As described in EPA (2005a), capping refers to the placement of clean material over contaminated sediment. Caps are generally constructed of granular material, such as suitable fine-grained sediment, sand, or gravel, but can have more complex designs. Caps are designed to reduce potentially unacceptable risk through: 1) physical isolation of the contaminated sediment to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the surface; 2) stabilization of contaminated sediment and erosion protection of sediment and cap to reduce resuspension and transport to other sites; and/or 3) chemical isolation of contaminated sediment to reduce exposure from contaminants transported into the water column. Caps may be designed with different layers (including innovative "active" capping layers that provide treatment) to serve these primary functions or in some cases a single layer may serve multiple functions.

- **In Situ Treatment –** In general, in situ treatment technologies are based on methods that have been successfully implemented as full-scale ex situ technologies (e.g., biological, stabilization, chemical, etc.). As discussed in EPA (2005a), in situ treatment (via stabilization or immobilization) is an innovative sediment remediation approach that can involve introducing sorbent amendments such as activated carbon (AC) into contaminated sediments to alter sediment geochemistry and increase contaminant binding, reducing sediment porewater concentrations and bioavailability for uptake by benthic organisms, and resulting in reduced potential contaminant exposure risks to people and the environment. Motivated by encouraging bench-scale results, similarly promising in situ treatment pilot-scale field trials have recently been completed at a wide range of sites in the United States and Europe, demonstrating the efficacy of full-scale in situ sediment immobilization treatment technologies (Ghosh et al 2011). In situ treatment, particularly via direct amendment of the surface sediments with AC, has proven effective in reducing the bioavailability of a range of sediment contaminants, including PCBs, PAHs, dioxins/furans, DDx, and mercury. Based on these data, application of in situ treatment technologies is currently being planned at other similar Superfund sediment sites (e.g., Lower Duwamish River), and these technologies may also be potentially applicable to this Site.

- **Removal –** As discussed in EPA (2005a), removal of sediments can be accomplished either while it is submerged (dredging) or after water has been diverted or drained (excavation). Removal or dredging for environmental purposes should be distinguished from maintenance or navigation dredging as described more in Section 6.2.7. For this Site, both environmental dredging and excavation methods necessitate transporting the sediment to another location within the Site or off-Site for treatment and/or disposal (see below). Environmental dredging can also be combined with in situ technologies whereby a portion of the contaminated sediment is removed and a remainder is remediated via EMNR, in situ treatment, capping, or similar. Environmental dredging is intended to remove sediment contaminated above action levels while minimizing the spread of contaminants to the surrounding environment during dredging (NRC 1997a). However, as discussed in Bridges et al. (2010), a number of Site operational conditions influence the effect of environmental dredging on aquatic systems. Specifically, a wide range of experience at other sites has demonstrated that resuspension of contaminated sediment and release of contaminants occurs during dredging, and that contaminated sediment residuals will remain after operations. These processes affect the magnitude, distribution, and bioavailability of contaminants, and the resultant potential exposure and risk to receptors of concern.

- **Ex Situ Treatment –** Ex situ treatment is a component of a sediment remediation process train that requires removal before treatment occurs, followed by disposal or beneficial use of the treated materials. Treatment can be defined as any process, manufactured or naturally occurring, which causes the destruction or reduction in toxicity, mobility, or volume of contamination in a given media.

- **Disposal –** Disposal is the final component of a sediment remediation process train that starts with removal and ends with placement (disposal) in a facility where potential environmental impacts are monitored, controlled, and limited. This process train can also include ex situ treatment between removal and disposal. Disposal can either be within an in-water disposal facility specifically engineered for the sediment remediation, (i.e., in a CAD or a nearshore CDF) or within an upland landfill disposal facility such as operating commercial landfills.

Figure 6.1-1 lists the different GRAs and technologies and shows their inter-relationships. Table 6.1-1 summarizes the different GRAs, technologies, and process options considered for the draft FS. This table was reviewed by EPA during development of the draft FS (Appendix O; EPA 2011d) and includes all the technologies and process options that EPA requested for inclusion in the draft FS. Figure 6.1-2 shows generalized schematics for each of the technologies including CAD, nearshore CDF, and upland disposal options.

6.2 SCREENING OF REMEDIAL TECHNOLOGIES

Table 6.1-1 was used as the basis for the technology screening process. Following EPA's general RI/FS guidance (1988), technologies are typically screened based on simplified evaluations of effectiveness, implementability, and cost. However, EPA's comments on the December 2009 Example Alternatives Screening (EPA 2009e; Appendix O) requested that remedial technologies should not be eliminated based on cost alone. Also, given the wide array of SMA conditions within the Site and how different technologies could potentially be applied, it is difficult to evaluate the costs of technologies consistently across the Site. For example, for large SMAs without many structural constraints and a nearby disposal location, hydraulic environmental dredging may be more cost-effective than mechanical dredging. Conversely, for a smaller SMA with extensive structures and a distant disposal site, mechanical dredging may be more cost-effective than hydraulic dredging. Consequently, cost was generally not used in the technology screening step for this draft FS. In a few cases noted below, cost was evaluated at a general level in conjunction with effectiveness and implementability for some specific technologies, particularly where cost differentials were large and easily extrapolated across the general conditions of the Site. However, in no case was any technology screened out based on cost alone.

Screening rules were developed for each technology based on general implementability and effectiveness criteria consistent with EPA's RI/FS guidance (1988):

- **Effectiveness**. The screening level effectiveness criterion evaluated the technology relative to its ability to achieve RAOs. Both short-term and long-term effectiveness were evaluated at a screening level of detail. Short-term effectiveness addressed protection during the construction and implementation periods, while long-term effectiveness evaluated the protectiveness of the technology after construction.

- **Implementability**. The screening level implementability criterion evaluated the technology for technical and administrative feasibility. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Administrative feasibility refers to the ability to obtain permits for off-Site actions (on-Site actions would be performed under CERCLA authorities) and the availability of specific equipment and technical specialists.

The spatial scale of the technology screening determinations varied across technologies. For example, institutional controls are generally applicable to all or most of the Site and did not need to be evaluated at relatively small spatial scales. In contrast, capping, environmental dredging, EMNR, in situ treatment, and ex situ treatment are highly specific to variations in small scale Site conditions (e.g., presence of structures, site navigation uses, contaminants present, contaminant levels, etc.), and these technologies were evaluated on a subSMA basis using the subSMAs presented in Section 5. As noted in Section 5, subSMAs were developed based on Site uses and implementability characteristics that are most relevant to technology screening based on implementability and effectiveness criteria. MNR is evaluated in Section 6.2.2 on a multi-scale basis, with empirical/physical information relevant to MNR screening evaluated at a subSMA basis and compared to overall modeling and other estimates on a river mile spatial scale, which is most relevant to the RGs described in Section 3.5.

It should be noted that the screening of technologies was conducted expressly and solely for the purposes of developing detailed alternatives for this draft FS. Any particular technology that was screened out in this draft FS may still be potentially useful under appropriate SMA-specific conditions, subject to more detailed evaluations as may be performed by individual parties working with EPA during remedial design. Consequently, screening of technologies conducted for this draft FS does not apply any restrictions to further consideration or more detailed evaluations of these technologies, as appropriate, either by EPA during Proposed Plan development or by EPA or individual parties during remedial design.

Screening of technologies conducted for this draft FS does not apply any restrictions to further consideration or more detailed evaluations of these technologies, as appropriate, either by EPA during Proposed Plan development or by EPA or individual parties during remedial design.

Also, the screening of technologies is based on the current Site uses and conditions and/or reasonable likely future conditions and uses for navigation and maintenance dredging issues, as currently understood for the Site. It is not possible to predict or evaluate all potential future conditions and Site uses across a large and complex Site such as this including potential changes in shoreline property uses, shoreline features, or changes in docks or dock usage. Consequently, for the screening and evaluation of remedial technologies existing conditions and Site uses are the general default assumption, and information on likely potential future uses is only used where available (see Site Use Survey in Section 2.4).

An additional implementability issue that needs consideration for any technology that adds material to the river bottom (i.e., EMNR, capping, and disposal) is potential flood rise impacts. Although such impacts are possible, they can only be fully evaluated in context of an overall alternative so that the balance of EMNR, capping, removal, and disposal site effects on potential flood rise can be evaluated. Further, the balance of capping versus removal/disposal can be changed and refined within an overall alternative to avoid or mitigate some or all potential flood rise impacts. Thus, this implementability issue is evaluated in Sections 8 and 9, rather than here at a screening level for each technology.

The following subsections discuss the effectiveness and implementability screening for each technology. The overall results of the screening across all technologies and areas is summarized and discussed in Section 6.3.

6.2.1 Institutional Controls Screening

The term "institutional controls" generally refers to non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to CERCLA materials, often by limiting land or resource use (EPA 2005a). Per the NCP, institutional controls are generally expected to supplement active remediation and MNR to manage short- and long-term potentially unacceptable risks, even if they may not be acceptable as a stand-alone remedy. Institutional controls may be used both in the short term during active remedy implementation to minimize potential for human exposures during construction and in the long term after active remedy implementation to minimize potential exposures while the system recovers over time to acceptable levels. Institutional controls may also be used to help ensure active remedies remain effective in the long term, such as government or proprietary controls designed to limit the potential for disturbance to cap areas. EPA's RI/FS guidance for sediment remediation (2005a) notes four broad categories of institutional controls, which can generally be classified as types of institutional control technologies (Table 6.1-1). Within those institutional control technologies, process options have been identified for this draft FS as follows:

- Government Controls
  - Commercial Fishing Bans
  - Waterway Use Restrictions or Regulated Navigation Areas (RNA)
- Proprietary Controls
  - Land use and access restrictions (such as deed restrictions, easements, and covenants, placed in property related documents or physical barriers, such as fences)
  - Structure Maintenance Agreements
- Enforcement and Permit Tools
  - Permit Processes or Provisions of Administrative Orders or Consent Decrees

- Informational Devices
  - Fish Consumption Advisories

The institutional control process options are summarized in Table 6.1-1.

It is common for these institutional control technology categories to overlap and for multiple institutional controls to perform augmenting functions. For example, informational devices may include information on a variety of other institutional controls and methods for informing the public on their applicability and restrictions. Similarly, RNAs may be applied to cap areas in combination with proprietary controls such as deed restrictions and structure maintenance agreements, all of which may be subject to enforcement tools under permits, orders, and decrees.

All of these institutional controls can be effective and implementable under a wide range of conditions and generally apply to the entire Site. Consequently, all institutional control technology categories listed above were retained in this draft FS.

It is important to note that the development of detailed institutional controls that are effectively integrated into the overall remedy can be a relatively complex process. For example, Site-wide efforts such as governmental controls and informational devices may need to be developed as comprehensive plans spanning the range of Site conditions, requiring close coordination among EPA, other federal agencies, and the State (e.g., the U.S. Coast Guard for RNAs and Oregon Department of Health for fish advisories). In addition, SMA-specific efforts may need to be tailored and integrated with the specific combinations of other remedial technologies selected by EPA, and in some cases these will be highly dependent on the type of Site uses and ownership involved now and in the future (e.g., for land use and access restrictions). For all these reasons, it is not necessary or prudent to develop a detailed institutional control plan for the Site and specific SMAs at the draft FS stage of analysis; these types of detailed plans are more appropriately and typically developed during remedial design. Consequently, for the draft FS all the retained institutional controls were included in the comprehensive alternatives to recognize their general function and necessity within the overall remedy. The application of the retained institutional controls to remedial alternative development is discussed more in Section 7.

6.2.2 Monitored Natural Recovery (MNR) Screening

As stated above, MNR is a remedy for contaminated sediment that typically uses ongoing naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment (EPA 2005a; Magar et al. 2009). There are multiple physical, biological, and chemical processes that can act together to contribute to natural recovery. Figure 6.1-2 shows an overall summary of typical MNR processes.

As a remedial technology, important parts of MNR include: 1) a monitoring plan to assess whether natural recovery is occurring as expected (i.e., the rate and level of potentially unacceptable risk reduction estimated is occurring); and 2) a contingency plan to implement additional study or technologies should natural recovery not progress as expected (see Appendix T, Section 4). As discussed in EPA (2005a) and Magar et al. (2009), MNR is most often included as one component of an overall remedy that includes active remediation (e.g., dredging and capping) of areas of higher contamination in combination with MNR in areas of lower contamination, although MNR can sometimes be selected as a sole remedy. Such an approach is consistent with the development of the RALs and the SMAs described in Sections 4 and 5, where RALs define active remediation areas that are expected in combination with MNR of the entire Site to achieve a range of RGs over time.

As outlined in EPA's Contaminated Sediment Remediation Guidance (EPA 2005a) and technical support documents (e.g., Magar et al. 2009), evaluation of the effectiveness of MNR should be based on Site-specific data, including multiple LOEs, as well as through the use of a predictive tool such as a model to estimate future effects of the physical, biological, and chemical processes contributing to natural recovery. Such was the case for this draft FS.

6.2.2.1 Effectiveness

Consistent with the EPA (2005a) guidance and more detailed recommendations provided in Magar et al. (2009), the effectiveness of MNR at the Site was assessed using a combination of empirical data and predictive modeling. Together this information was used to develop an overall weight-of-evidence assessment of the effectiveness of MNR across the Site as whole, as well as within different sub-areas of the Site. The next two subsections discuss specific elements of this effectiveness evaluation, including: 1) the empirical LOEs (i.e., multiple independent datasets that were used to evaluate natural recovery processes and/or assess trends in reduced chemical exposures over time at the Site); and 2) a summary of the predictive modeling tools developed for the Site, which integrate many of the Site-specific datasets within a quantitative framework that simulates sediment transport and contaminant fate and transport processes (described in detail in Appendices La and Ha, respectively). Following those discussions, an overall weight-of-evidence assessment (Section 6.2.2.1.3) is presented to develop an integrated and robust evaluation of MNR effectiveness at the Site. Because each individual dataset, as well as the modeling, contains uncertainty and limitations, this integrated analysis combines that information using a weight-of-evidence approach, in which the relative degree of certainty (or uncertainty) regarding effectiveness of MNR within different areas of the Site is determined, including considerations of the consistency (or inconsistency) among the individual LOEs.

6.2.2.1.1 Empirical Lines of Evidence

As described in EPA (2005a) and Magar et al. (2009), there are numerous types of site-specific information that can be used to evaluate natural recovery at contaminated sediment sites. Most of these types of data have been collected as part of the Portland Harbor RI/FS process and are thus suitable for use in this MNR effectiveness evaluation. Table 6.2-1 contains a summary of the site-specific information listed in the EPA (2005a) guidance, and the corresponding empirical dataset(s) that are available for this Site.

The numerous and robust datasets for the draft FS provide a strong empirical basis to evaluate the occurrence of natural recovery at the Site.

The numerous and robust datasets for the draft FS provide a strong empirical basis to evaluate the occurrence of natural recovery at the Site, as described below. Each independent dataset has unique uncertainty and variability, as described in more detail below. For each dataset, example graphics are used to illustrate evidence (or lack thereof) of the occurrence of natural recovery processes and/or trends in reduced chemical exposures over time at various locations within the Site (more complete descriptions of the individual datasets used in this MNR effectiveness evaluation were provided in the draft final RI report). As discussed above, Section 6.2.2.1.3 integrates several of these datasets, along with results from predictive modeling of recovery rates, to develop an overall assessment of MNR effectiveness at the Site.

Source Control

As described in EPA (2005a) and Magar et al. (2009), the success of any sediment remedy, including MNR, depends upon effective source control. MNR is likely to be a particularly effective remedy in depositional sediment environments once source control actions have been completed. Source control is not limited to primary known sources but considers potential secondary sources (e.g., ongoing contaminant releases from higher concentration sediment deposits) that can also affect recovery rates. Further, background contamination by ubiquitous urban contaminants (e.g., metals, PAHs, and PCBs) has the potential to limit recovery or recontaminate the sediment surface following any cleanup remedy. While background contamination is beyond the control of CERCLA, it was taken into account in projecting future reductions of potentially unacceptable risk in this draft FS.

As summarized in the draft final RI report, numerous upland known sources of contaminants, both historical and ongoing, have been identified at the Site. The majority of the observed contaminant distributions in Site sediments are attributable to historical known sources that have been controlled over time; however there are a number of ongoing known sources that have been documented (see Section 2.5.1 and Appendix Q), and it is possible that additional unidentified sources exist. In addition to relatively diffuse, non-point known sources that can be difficult to control (e.g., watershed loadings and atmospheric deposition), specific point sources under evaluation by the agencies include direct discharges from stormwater (including both industrial stormwater and urban runoff) and NPDES permitted industrial discharges, localized groundwater discharges and localized overland runoff/ riverbank erosion known sources. DEQ is the lead agency responsible for controlling discrete upland known sources and is currently investigating or directing source control work at more than 80 individual upland sites in the Portland Harbor watershed. The resulting loading reduction achieved by these upland source control programs will contribute to future recovery at the Site.

Data generated from known sources allows these sources to be quantified and represented in the predictive model (see Appendix Ha). For potential sources that are not well characterized, there is potential uncertainty in estimation of ongoing contaminant inputs to the Site.

Currently known ongoing contaminant inputs associated with permitted stormwater and NPDES discharges, localized groundwater discharges, and upstream watershed inputs have been characterized at the Site through data collection programs as summarized in the draft final RI report. Data generated from such sampling allow for these currently known sources to be quantified and represented in the predictive model (see Appendix Ha), although some potential sources may not be well characterized, potentially leading to uncertainty in estimation of ongoing contaminant inputs to the Site. Contaminant fate and transport modeling in Portland Harbor indicates that MNR and recontamination are not significantly influenced by ubiquitous external known sources (see Section 6 of Appendix Ha).

Sedimentation

Three separate types of datasets were evaluated to estimate the extent of sedimentation at the Site: 1) a series of multi-beam bathymetric surveys collected over a 7-year period; 2) sediment trap data; and 3) radioisotope coring data.

As noted above, there are multiple physical, biological, and chemical processes that act together to reduce sediment exposures and potentially unacceptable risks over time; however burial by clean sediment inputs is often the primary process relied upon in sediment MNR remedies (EPA 2005a; Magar et al. 2009). Three separate types of datasets were evaluated to estimate the extent of sedimentation at the Site: 1) a series of multi-beam bathymetric surveys collected over a 7-year period; 2) sediment trap data; and 3) radioisotope coring data. Each is described below.

Multi-beam Bathymetric Survey Data

As described in the draft final RI report, five multi-beam bathymetric surveys were conducted at the Site between January 2002 and January 2009. Compared to other CERCLA sediment sites, this is a particularly accurate and detailed time series of bathymetry data that provides invaluable information to directly assess the potential for MNR. Analysis of these data was conducted to assess bed elevation changes (and corresponding net sedimentation rates) over various time periods. Table 6.2-2 contains a summary of the time periods evaluated, and the estimated Site-wide net sedimentation rate calculated for each time period. Over the 7-year monitoring period, the average Site-wide net sedimentation rate was approximately 2.6 cm/yr, equating to net accretion of

Compared to other CERCLA sediment sites, this draft FS has a particularly accurate and detailed time series of bathymetry data that provides invaluable information to directly assess the potential for MNR. Over the 7-year monitoring period, the average Site-wide net sedimentation rate was approximately 2.6 cm/yr, equating to net accretion of roughly 18 cm (7.2 inches) of sediment over the time period—a thickness that can be reliably measured using differential bathymetric surveys.

roughly 18 cm (7.2 inches) of sediment over the time period—a thickness that can be reliably measured using differential bathymetric surveys (see below).

As described in the HST report (see Section 2.3.6 of Appendix La), these multi-beam bathymetric survey data (and specifically the data on sedimentation rates within the Site collected from May 2003 to January 2009) were used to calibrate the long-term sediment transport model. As shown in Table 6.2-2, over longer time periods (greater than 2 years), the overall Site is net depositional.

While the analysis presented above indicates that the Site as a whole is net depositional, sedimentation rates do vary spatially across the Site, both laterally and longitudinally. Figure 6.2-1 presents a map showing net sediment bed elevation change between 2003 and 2009 (i.e., the primary data collection period used to calibrate the sediment transport model, as discussed above). Areas shown in blue on this figure—which encompass most of the Study Area—represent net deposition over this time period, while the localized areas shown in red represent net erosion. Areas shown in gray, which indicate a net bathymetric change over the 6-year monitoring period of ± 7.5 cm (± 3 inches), represent no discernible change in bed elevation, which is based on the vertical accuracy of the sequential multi-beam surveys (DEA 2003).[1] Figure 6.2-1 also depicts the spatial variation of net sedimentation rates at the Site. As noted above, most of the Site is net depositional. Of the localized areas of net erosion identified on the figure, several are known to be attributable to anthropogenic operations (e.g., propwash and maintenance dredging). For example, there are several areas in slips and/or nearshore areas that are indicated as net erosion on Figure 6.2-1; while it is possible that erosion in these areas may have been caused by natural influences, it is more likely that the observed decreases in bed elevation may have been caused by anthropogenic factors given the relative quiescent setting of such areas. As a specific example, the areas of negative net bed elevation change in Terminal 4 Slip 3, Berth 410 (see Figure 6.2-1) are known to be due to maintenance dredging and removal action dredging that occurred in this area. A complete listing of recent dredging activities in the Study Area is provided in Table 2.4-2. The fact that maintenance dredging was needed and performed in an area typically indicates that specific area is depositional (hence the need to occasionally remove that newly incoming sedimentation).

To further illustrate spatial differences in sedimentation, Figure 6.2-2a-c shows cross sections that present the same information shown on Figure 6.2-1 (note that bed elevation change shown on Figure 6.2-1 has been converted to sedimentation rate on Figure 6.2-2a-

[1] Nearshore areas where shallow water depths did not allow for the survey equipment to take measurements are also indicated on Figure 6.2-1 in cross hatching.

c) for every half mile of the Site. These cross sections further illustrate how sedimentation rates vary laterally and longitudinally across the Site, although at most locations positive (i.e., net sedimentation) rates were observed over most of the cross section, consistent with Figure 6.2-1. To summarize the sedimentation rate data on a larger scale, this same information was averaged over half mile segments divided laterally into the east nearshore, navigation channel, and west nearshore, as shown on Figure 6.2-3. Also shown on that figure are sedimentation rates averaged within only the AOPCs. When averaged over such segmentation, the sedimentation rate data again show that most of the Site experienced net accumulation of sediment over the 7-year survey period. For example, within the navigation channel and west nearshore area, nearly every half mile averaging segment and AOPC had net sedimentation, with rates ranging from 1 to 10 cm/yr. The same trend is observed along parts of the east nearshore area, although there are also some half mile averaging segments and AOPCs where net erosion was observed over the survey period (e.g., RMs 11 to 9). Finally, this same information was averaged laterally over the entire Site area and plotted every half mile on Figure 6.2-4. This figure again shows that the Site is net depositional, with sedimentation occurring in every half mile averaging segment; it also illustrates how rates of deposition vary longitudinally (i.e., up and down the river). Net sedimentation rates are generally higher towards the upstream end of the Site (i.e., upstream of RM 7) and downstream of RM 3, while the middle portion of the Site generally experiences somewhat lower net sedimentation (particularly between RMs 5 and 7, where there are several zones of no discernible change in bed elevation shown on Figure 6.2-1).

Sediment Trap Data

As part of the RI, numerous sediment traps were deployed in nearshore areas throughout the Site; samples were collected from the traps following four quarterly deployments during 2007. Figure 5.2-2 in the draft final RI Report shows observed gross sediment accumulation (in grams of sediment per square centimeter per day [$g/cm^2/d$]) in the traps for each of the four quarterly monitoring events. These data demonstrate a relatively large range in gross accumulation of trapped sediments; rates of gross deposition flux observed during the first quarter (approximately 0.04 to 0.12 $g/cm^2/d$) were considerably higher than rates observed during the remaining three quarters (approximately 0.01 to 0.04 $g/cm^2/d$), likely due to the considerably higher flows (and associated transport of solids from upstream) during the first quarter. The areal deposition fluxes stated above correspond to gross sedimentation rates ranging from approximately 20 to 60 cm/yr during the first quarter, and 5 to 20 cm/yr during the remaining three quarters (assuming a sediment bulk density of 0.7 g/cm^3).[2]

[2] The average bulk density in cohesive sediment areas is 0.7 g/cm^3 (see Appendix La).

The sediment trap data are consistent with the bathymetric data in that they both indicate relatively high sedimentation rates within the Site and a large source of potentially settleable material that is available to contribute to natural recovery processes over time.

The range of gross sedimentation rates calculated based on the sediment trap data is between approximately 2 and 20 times higher than the net sedimentation rates (2.6 cm/yr average) measured using the 7-year period of multi-beam bathymetry data described above. Differences between gross and net sedimentation rates are expected, given that all sediment intercepted by a sediment trap is not expected to permanently settle and be buried over time. Nonetheless, the sediment trap data are consistent with the bathymetric data in that they both indicate relatively high sedimentation rates within the Site and a large source of potentially settleable material that is available to contribute to natural recovery processes over time.

Radioisotope Data

In 2004, four finely segmented sediment cores were collected from relatively quiescent, and expected depositional, areas of the Site; samples from these cores were analyzed for radionuclides (^{7}Be, ^{137}Cs, and ^{210}Pb) down to a depth of 90 cm to provide an independent evaluation of net long-term (decadal) sedimentation rates at the Site (Anchor Environmental 2005a). While the relatively low radioisotope levels observed in these cores confounded detailed interpretation of the radioisotope markers for dating, the two cores with interpretable profiles exhibited sedimentation rates in the range of 1 to 2 cm/yr (based on ^{210}Pb data), which is similar to the net sedimentation rates observed in these areas over the 7-year multi-beam monitoring record (see above). Thus, the radioisotope data corroborate the net sedimentation rates estimated from the multi-beam bathymetric survey data in the limited cases where the available data permit such comparisons.

Contaminant Concentration of Depositing Particles

Incoming Upstream Sediments

Suspended sediment loads entering from upstream in the Willamette River are by far the largest source of solids loading to the Site (see Appendix La). As described above, because the overall Site area is depositional (recognizing the spatial variability in deposition that occurs across the Site), the potential effectiveness of MNR is controlled in part by the relative magnitude of particulate-phase contaminant concentrations that enter from upstream. That is, if contaminant concentrations of incoming sediment particles are considerably lower than the current bedded sediment concentrations, natural recovery can be effective, particularly in depositional environments. Further, even in areas that are in dynamic equilibrium (i.e., areas that are less depositional or periodically erosional, resulting in a dynamic interchange between sedimentation and erosion), surface sediment concentrations will also decrease over time when contaminant levels on incoming sediment particles are lower than those in bedded sediments. To evaluate this element of MNR effectiveness, four sources of information regarding contaminant concentrations on particles entering the Site from upstream were evaluated:

- LWG sediment trap data located upstream of the Site at RM 16.

- Water column samples collected at RM 11 and 16, for which contaminant concentrations were measured in both particulate and dissolved phases. These data were separated into two groups based on flow conditions in the river (low flow and high flow), as the majority of sediment loading to the Site occurs during high flow conditions.

- Two deep sediment cores collected in 2007 from highly depositional areas at the upstream end of Study Area (near RMs 10 to 11). While these cores were collected within the Study Area (and not upstream of it), they were collected in two former dredge “pits” excavated in approximately 1988 that functioned as effective sediment traps (i.e., 15 to 25 feet of deposition occurred over the 19 years following dredging; Anchor Environmental 2007). Because of the high sediment trapping efficiency of this area, the 2007 sediment core results provide a good representation of contaminant levels on incoming sediment particles that settled in the pits during this period.

- Nearshore sediment traps deployed by the City of Portland in 2010 near RM 11 on the east side of the river (GSI 2010). Samples included in this evaluation were only those located upstream of AOPC 25 so as not to be impacted by a known localized contaminant source believed to exist in that area.

Figures 6.2-5, 6.2-6, and 6.2-7 show the average contaminant concentrations on incoming sediment particles from the four data sources listed above, compared to the average contaminant concentrations in bedded surface sediments within the Site area (averaged by AOPC) for total PCB, BaP, and DDE, respectively.[3] These figures demonstrate that contaminant concentrations of incoming sediment particles are generally lower than those of the bedded surface sediments in the AOPCs.[4] Therefore, future bedded surface sediment concentrations in most AOPCs would be expected to decline over time, particularly in net deposition areas.[5]

Contaminant concentrations of incoming sediment particles are generally lower than those of the bedded surface sediments in the AOPCs (Figures 6.2-5,6.2-6, and 6.2-7). Therefore, future bedded surface sediment concentrations in most AOPCs would be expected to decline over time, particularly in net deposition areas.

[3] PCBs, BaP (representative of PAHs) and DDE (representative of DDx) were used in this and several other empirical evaluations of contaminant data described in this section, as these three classes of compounds represent the bounding COCs for the Site (see Section 4).

[4] One exception would be for DDE; for which sediments in most areas of the Site are already similar to the levels on incoming sediment particles except in a few localized areas that have elevated levels of DDE in sediments.

[5] An area of the Site that demonstrates this point is a previously remediated and capped area adjacent to the Gasco site. Samples collected from sediments that accumulated on the surface of the cap (which represent recently deposited sediments, not impacted by historical sources) had an average total PCB concentration of approximately 15 ppb (ranging from 5 to 50 ppb; Anchor QEA 2010a). As shown on Figure 6.2-5, total PCB concentrations on incoming sediment particles from the various data sources evaluated are generally in the range of 5 to 20 ppb. As such, the samples collected from the sediments that deposited on the surface of the Gasco cap provide an

Sediment Trap Samples

A similar evaluation was conducted using contaminant concentrations measured on sediment trap particulate matter sampled from within the Site in 2007. Figure 6.2-8 compares total PCB concentrations in Site sediment trap particulate matter with concentrations in the surrounding bedded surface sediments (surface [top 30 cm] samples located within 500 feet of each sediment trap were selected for this analysis). This analysis further demonstrates that PCB concentrations on settling particles are generally lower than those in the surrounding bedded sediments, particularly within the AOPCs. For example, in areas of the river where the sediment concentrations are not already similar to those of the upstream particulate matter, PCB concentrations in the sediment traps were on average five times lower than the nearby surface sediments (Figure 6.2-8). One exception to this observed trend of contaminant concentrations in sediment traps being lower than those in the local sediments is the LWG sediment trap located near RM 11, which showed locally higher concentrations as compared to the bedded sediment. This area is also unique in that surface sediment concentrations generally are higher than subsurface sediment concentrations (discussed more below). As discussed in Section 10 of the draft final RI report, these and other data suggest a local, recent source input or redistribution of PCBs historically released into this area and present in the sediments. Potential suspected sources in the area include disturbance of PCBs in the sediment bed from ship traffic and maintenance dredging (e.g., Glacier NW dock at RM 11.3E and the CDL Pacific Grain dock at RM 11.4E).

Supplemental sediment trap data collected by the City of Portland have confirmed that current sediment trap concentrations are now much lower, and below those in the surrounding bedded surface sediments in that area, consistent with conditions in other areas of the Site (see Figure 6.2-8). Similar comparisons of sediment trap data for BaP and DDE, which for brevity were not plotted in this section, indicate that concentrations on particulate matter for these contaminants are also lower than those of the surrounding sediments (for the areas where concentrations of these contaminants are generally elevated above background; i.e., RMs 4 to 7 for BaP and RMs 7 to 8 along the west shore for DDE). Again, these data further confirm that future bedded surface sediment concentrations in most AOPCs would be expected to decline over time, particularly in net deposition areas.

Surface Sediment Grain Size

The strong correspondence of sediment grain size patterns and multi-beam bathymetry provides additional support for the MNR analysis, and also helps delineate footprints of relatively stable depositional environments at the Site where MNR may be particularly effective.

Another independent LOE that can be used to assess depositional and dynamic equilibrium environments at the Site and the potential effectiveness of MNR is surface sediment grain size patterns. Typically, fine-grained sediments such as silts and clays accumulate in relatively low-energy (depositional) environments, since

independent validation that PCB levels in recently deposited sediments in the Site are generally in the range of concentrations on incoming sediment particles from the datasets evaluated here.

low current velocities allow finer particles to settle and remain in place. Conversely, lower percentages of fines and the predominance of coarser sediments such as sands and gravels are often indicative of higher energy, dynamic equilibrium environments. Figure 6.2-9 shows a contour map of surface sediment grain size (i.e., percent fines) throughout the Site. Spatial averages of these data were also calculated over 1-mile segments divided into east nearshore, navigation channel, and west nearshore zones and by AOPC, as shown on Figure 6.2-10. These two figures indicate that surface sediments in the majority of the Site are comprised of relatively fine-grained depositional sediments (e.g., areas having 40 to 50 percent or more fines). Furthermore, the locations of these fine sediment deposits correlate well with areas of relatively higher net deposition rates observed in the multi-beam bathymetric survey data (compare Figure 6.2-9 with Figure 6.2-1 showing net sedimentation rates).[6] Conversely, the areas having relatively coarser sediment deposits tend to have experienced less recent net sedimentation (e.g., RMs 5 to 7 and upstream of RM 11). The strong correspondence of these two LOEs provides additional support for the MNR analysis, and also helps delineate footprints of relatively stable depositional environments at the Site where MNR may be particularly effective.

Sediment Contaminant Temporal Trends

As discussed in EPA (2005a) and Magar et al. (2009), if source controls have been in place long enough, analysis of temporal declines in surface sediment concentrations, particularly in net depositional environments, can provide a further LOE to assess the potential effectiveness of natural recovery.[7] Analysis of the surface sediment contaminant data collected during the RI/FS was performed to identify any discernible declining temporal trends (or lack thereof) in concentrations over time. These analyses were conducted in two ways: 1) vertical patterns in sediment concentrations were evaluated through use of ratios of surface to subsurface sediment concentrations for various contaminants to qualitatively assess recent recovery; and 2) trend analyses of surface sediment chemical concentrations collected over the past 10 to 20 years to evaluate the rates of decline. Both of these datasets can provide further independent LOEs for evaluating MNR effectiveness, consistent with EPA (2005a) guidance and more detailed recommendations provided in Magar et al. (2009).

Surface versus Deep Sediment Concentrations

As noted above, the Site is a generally depositional system (recognizing the spatial variability in sedimentation rates described above). In a system that is depositional and in which known sources have been controlled over time, differences between surface and

[6] It should also be noted that the immediate sub-surface sediment texture is usually consistent with the surface (see draft final RI report Section 3.1.4.1); this suggests that energy regimes in the system have likely been stable over time.

[7] EPA (2005a) guidance also cites evaluation of temporal trends in biota data as another means of assessing natural recovery processes in the system. However, biota data collection during the RI focused on characterization of contaminant concentrations spatially, for various species and trophic levels (i.e., several species were collected, but no one species was collected consistently during each year of sampling [2002, 2003, 2005, 2006, and 2007]). Further, samples sizes in any given year were generally small. For these reasons, it is not possible to accurately assess temporal trends in Portland Harbor biota data, and thus, such an evaluation is not presented here.

deep sediment concentrations can provide evidence of recovery, as newly depositing sediments with lower concentrations of contaminants deposit above the historical deposits with higher concentrations. Under such circumstances, sediment cores collected in these areas would exhibit lower concentrations in the surface intervals, and relatively higher concentrations at depth. The RI/FS sediment core dataset was therefore used to evaluate such patterns across the Site. For this analysis, surface sediment was taken to be the top 30 cm of sediment, which corresponds to the upper segment analyzed from sediment cores collected at the Site. At an overall average sedimentation rate of 2.6 cm/yr (see Table 6.2-2), the top 30 cm represents roughly the most recent 12 years of sediment deposition, although this deposition timeframe is spatially variable across the Site. To evaluate vertical concentration gradients with the Site sediment core data, ratios of surface to subsurface concentration were computed, consistent with the evaluations presented in Section 5.1 of the draft final RI report. These ratios are presented for different selections of the data and at a few different spatial scales, as described below:

- Figures 6.2-11, 6.2-12, and 6.2-13 show the ratio of average surface to subsurface sediment concentrations across the Site (by river mile, separated laterally by east nearshore, navigation channel, and west nearshore) for total PCB, total DDx, and BaP, respectively.[8] These figures indicate that the more recently deposited sediments (i.e., surface 0 to 30 cm) in the majority of the Site have lower concentrations than the underlying deeper sediments. Specifically, for total PCB and total DDx, surface concentrations are approximately 2 to 5 times lower than subsurface in most areas of the Site, as shown on Figures 6.2-11 and 6.2-12, respectively. The results for BaP are consistent with this analysis, as average surface concentrations in the nearshore areas of RMs 4 to 7 (i.e., the areas where BaP is elevated above background) are lower than the subsurface concentrations by a similar factor (Figure 6.2-13).
- Variations of the analysis described above were also conducted to focus on the areas of relatively higher concentration (because the ratios are not as relevant in areas where concentrations of a contaminant are at or below background levels in both the surface and subsurface):
  - First, the ratios within the same 1-mile averaging segments presented on Figures 6.2-11 through 6.2-13 were recalculated by excluding cores with low concentrations (i.e., less than or equal to the upstream background levels shown on Table 2.2-4) in both the surface and subsurface sections. The results from that analysis were nearly identical to those shown on Figures 6.2-11 through 6.2-13.

[8] It should be noted that these graphics are similar to those presented in Section 5.1 of the draft final RI Report for total PCBs, total PCDD/F, total DDx, and total PAH; however, they have been updated to use the draft FS sediment dataset. The only figures shown here are for the contaminants from that subset that are also simulated by the fate and transport model (i.e., total PCB, DDx, and BaP as a representative of PAHs). The uncertainty bounds of the ratios of means shown on these figures were approximated based on the Taylor series expansion method described in Mood et al. (1974).

- Second, the ratios were recalculated based only on the subset of sediment cores collected from within the footprints of the AOPCs (see Figures 5.1-1 through 5.1-3 of Appendix U). The results of the surface to subsurface ratios, when averaged by AOPC, were also similar to those shown on Figures 6.2-11 through 6.2-13.
- As another means of evaluating vertical concentration patterns in the areas of highest concentration, the ratios were recalculated excluding cores that are within the footprint of the smallest overall SMA footprint evaluated in this draft FS (Alternative B; see Section 7). The top panel of Figure 6.2-14 shows average surface to subsurface total PCB concentration ratios revised to exclude those cores within the Alternative B footprint. The results shown on the top panel of this figure are not considerably different from the results shown on Figure 6.2-11, except for RM 11 to 12 east and central (which includes cores from the entire Site), both of which indicate that more recently deposited surface sediments have lower concentrations than the underlying deep sediments. By contrast, the bottom panel of Figure 6.2-14 shows average core ratios for only those cores located *within* the active remediation footprint of Alternative B;[9] this plot shows that natural recovery (based on this metric) is generally occurring to a lesser extent in the areas already identified for active remediation. This figure thus confirms that the development of SMA footprints is properly focusing active remediation on areas where MNR may be less likely, as indicated by this one LOE. In the case of RM 11 to 12, the elevated surface sediment concentrations outside of SMA B as compared to subsurface sediment may be due to resuspension and redistribution of more highly contaminated sediments near the Glacier NW dock (RM 11.3E) and the CDL Pacific Grain dock (RM 11.4E) as a result of ship traffic and historical maintenance dredging (see Section 6.2.2.1.1, Sediment Trap Samples).

Together, these alternate evaluations of surface to subsurface concentration ratios demonstrate that more recently deposited surface sediments in the areas of highest contaminant concentrations within the Site have lower concentrations than the underlying deep sediments, which provides further corroborating evidence of natural recovery.

[9] The bottom panel of this figure showing cores within the active remediation footprint of Alternative B is only presented to illustrate the observed differences in surface to subsurface concentration ratios between these areas and possible MNR areas (shown on the top panel).

Comparing surface to subsurface contaminant levels provides strong corroborating evidence of recent reductions in sediment concentrations at the Site and support for natural recovery through deposition processes.

- Finally, because the averages presented above were over relatively coarse 1-mile segments, the ratio analysis was also conducted on a finer spatial scale. In this analysis, the Thiessen polygon-based method used to map contaminant concentrations onto the fate and transport model grid was used to map surface to subsurface ratios. As described in Section 3.2.2.2 of Appendix Ha, modified Thiessen polygons were generated for the sediment core data, for both surface (0 to 1 foot) and subsurface (defined by core segments spanning depths of 1 to 4 feet), and mapped onto the model grid; having both surface and subsurface data mapped at this finer scale allowed for mapping of concentration ratios at the same scale. The polygon-based mapping of surface to subsurface concentration ratio for total PCBs is shown on Figure 6.2-15. This figure shows that in most areas of the Site, surface PCB concentrations are lower than subsurface concentration (shown in shades of blue), consistent with ongoing natural recovery.[10] There are some areas in which the surface concentrations are elevated relative to the subsurface (e.g., a large portion of RM 11.8 to 11 and portions of RM 5 to 7), which is consistent with other LOEs (e.g., lower net sedimentation, coarser sediments) that suggest there may be less effective natural recovery in these portions of the Site.

Overall, these data comparing surface to subsurface contaminant levels provide strong corroborating evidence of recent reductions in sediment concentrations at the Site and support for natural recovery through deposition processes.

Surface Sediment Temporal Trends

As stated above, trend analyses of surface sediment contaminant concentrations in samples collected over the past 10 to 20 years were performed to further evaluate recent rates of sediment recovery, and to provide another independent LOE for evaluating MNR effectiveness. While assessment of contaminant temporal trends in surface sediment was not an objective of the RI/FS or earlier sampling designs, and though the RI/FS intentionally used the 0 to 30 cm surface sediment depth interval to avoid high frequency temporal changes in the dataset, the RI/FS data nonetheless can be assessed to evaluate trends. Figure 6.2-16 shows representative examples of the spatial and temporal coverage of surface sediment data in the Study Area in three areas: 1) near Swan Island Lagoon (RMs 9 to 8 east nearshore); 2) the west nearshore area of RMs 8 to 7; and 3) the east nearshore areas of RMs 2 to 3. Clearly, the different RI/FS sampling programs had different objectives that led to variable spatial coverage over the 10-year sampling period. However, while the different sampling designs confound the temporal trend analysis, the

[10] Similar to that shown for PCBs, mapping of concentration ratios for BaP and DDE indicated surface concentrations that were lower than the subsurface for the areas where concentrations of these two contaminants are generally elevated above background.

data are nevertheless useful as another LOE in the MNR effectiveness evaluation, as described below.

Figures 6.2-16 and 6.2-17 show that while there is considerable variability in individual data points, there was nevertheless an observed decline in surface sediment concentrations between the late 1990s and 2005 to 2006 in these areas.

Figure 6.2-17 shows three example time series plots of surface sediment data from the RI/FS dataset (which span an approximate 10-year period) averaged over 1-mile reaches (total PCB from RMs 2 to 3 in the east nearshore area and DDE and BaP in the west nearshore area of RMs 8 to 7; the sample locations corresponding to these areas are shown on Figure 6.2-16). These figures show that while there is considerable variability in individual data points, there was nevertheless an observed decline in surface sediment concentrations between the late 1990s and 2005 to 2006 in these areas. The declines evident in these examples are more prominent for PCBs and DDE than for BaP, although in the latter case the example shown does not correspond to the highest concentration area for that contaminant. Note that similar figures for all 1-mile reaches over the Study Area have been provided for all contaminants simulated by the fate model in Appendix Ha (Section 3.3 and Attachment 1).

The trend analysis near RM 7 indicated a statistically significant ($p \leq 0.001$) decline in sediment concentrations, with observed half-lives (time to reduce surface concentrations by 50 percent) ranging between approximately 3 and 6 years (which is similar to MNR modeling predictions for these two contaminants in this area of the Site; see Appendix Ha). These data provide further confirmation of MNR effectiveness and corroborate the CSM of natural recovery at the Site.

A second surface sediment temporal evaluation was conducted for a smaller portion of the Study Area near RM 7, for which a larger historical data record was available to support a more robust trend analysis. For this analysis, the RI/FS dataset (1997 to 2010) was supplemented with an earlier, site-specific dataset collected adjacent to the McCormick & Baxter site in 1990-91 to support an initial site characterization.[11] Collectively, the surface sediment time series data available near RM 7 provide a more comprehensive basis to evaluate temporal trends, as they cover a longer (18-year) timeframe than the data available for other areas of the Site. The area included in this more comprehensive temporal trend analysis is shown on Figure 6.2-18. This temporal trend analysis area excluded shoreline areas that were capped in 2005. The mid-channel area targeted in this trend analysis contains a representative mixture of depositional and dynamic equilibrium sediment environments, as indicated by Figure 6.2-1, with an overall average net sedimentation rate in this area of approximately 2 cm/yr (which is similar to the Site-wide average of 2.6 cm/yr). Time series plots of surface sediment concentrations for those contaminants with locally elevated surface sediment

[11] These earlier data were used as a basis for EPA's (1996) Record of Decision addressing elevated PAH concentrations in that area.

concentrations and without potential analytical issues due to the age of the dataset (i.e., limited to BaP and naphthalene) are shown on Figure 6.2-19. Similar to temporal trends observed in other areas of the Site (e.g., see Figure 6.2-17), the historical RM 7 time series data document a decline in surface sediment concentrations over the 18-year period of record. The trend analysis in this area indicated a statistically significant ($p \leq 0.001$) decline, with observed half-lives (time to reduce surface concentrations by 50 percent) ranging between approximately 3 and 6 years (which is similar to MNR modeling predictions for these two contaminants in this area of the Site; see Appendix Ha). These data provide further confirmation of MNR effectiveness and corroborate the CSM of natural recovery at the Site.

Empirical Lines of Evidence Summary

The overall weight of evidence from the evaluation of independent empirical datasets described above confirms that MNR is effective on a Site-wide basis, although the rates of natural recovery will vary depending on the specific location within the Site. In summary:

The overall weight of evidence from the evaluation of independent empirical datasets confirms that MNR is effective on a Site-wide basis, although the rates of natural recovery will vary depending on the specific location within the Site.

- DEQ is currently investigating or directing source control work at more than 80 upland sites; this ongoing source control work has likely contributed to, and should continue to contribute to, natural recovery at the Site. Moreover, the specific spatial and time scales for MNR at the Site can be evaluated in the predictive modeling using the characterization of known ongoing contaminant inputs that has been performed at the Site.
- Multiple datasets and independent LOEs consistently reveal that the Site is predominantly depositional, although deposition rates vary spatially across the Site (both laterally and longitudinally) and there are localized areas of the Site where sediments are in dynamic equilibrium (alternating deposition and erosion). Again, this spatial variability can be addressed explicitly through modeling of sediment transport processes (see Section 6.2.2.1.2 below).
- Concentrations on sediment particles entering the Site from upstream, and depositing within the Site, are generally lower than bedded surface sediments in the AOPCs. These conditions accelerate temporal declines in surface sediment concentrations, even in areas that are in dynamic equilibrium.
- Large areas of the sediment bed are fine-grained and reveal a depositional history of more permanent deposition; such sediment deposits appear to have been stable over decades.
- More recently deposited sediments (i.e., surface 0 to 30 cm) in the majority of the Site areas have lower concentrations than the underlying deeper sediments; specifically, for total PCB, total DDx, and BaP surface concentrations are approximately 2 to 5 times lower than subsurface in most areas of the river.

These data provide corroborating evidence of the trend of sediment recovery at the Site.

- Time series plots of surface sediment concentrations are available for much of the Site, and a particularly detailed time series is available for a representative area near RM 7. The RM 7 data show a statistically significant ($p<0.05$) decline in surface sediment PAH concentrations over the 18-year period of record, with observed half-lives ranging between approximately 3 and 6 years, similar to MNR modeling predictions for this area (see Figure 3.3-32 and Attachment 1 of Appendix Ha). These data further corroborate the effectiveness of MNR at the Site.

6.2.2.1.2 Predictive Modeling Tools

All of the empirical datasets, as well as other more focused fate and transport datasets, were used in the development and calibration of quantitative HST and contaminant fate and transport (QEAFATE) models of Portland Harbor (see Appendices La and Ha, respectively). These models are EPA approved and peer reviewed and integrate the empirical datasets into an objective quantitative framework built on the principles of mass and energy balances.

As stated in the EPA (2005a) guidance and discussed in more detail in Magar et al. (2009), in addition to evaluating independent empirical LOEs as presented above, a predictive tool such as a model is useful to evaluate future reductions in surface sediment concentrations as a result of physical, biological, and chemical processes that contribute to MNR effectiveness. A well-developed and supported predictive model can also more specifically address the spatial variability of key MNR processes (e.g., deposition versus dynamic equilibrium sediment environments) and can estimate the timeframes for potentially unacceptable risk reduction resulting from MNR. Such models are also useful in evaluating the potential impacts of extreme hydrologic events (floods, hurricanes, etc.) on future sediment concentrations and rates of natural recovery. All of the empirical datasets described above, as well as other more focused fate and transport datasets, were used in the development and calibration of quantitative HST and contaminant fate and transport (QEAFATE) models of Portland Harbor (see Appendices La and Ha, respectively). These models have been EPA approved and peer reviewed and integrate the empirical datasets into an objective quantitative framework built on the principles of mass and energy balances. Table 6.2-3 lists the various empirical datasets discussed above and their corresponding application in the models.

6.2.2.1.3 Weight-of-Evidence Assessment of MNR Effectiveness

This section presents an overall assessment of MNR effectiveness for the Site. This evaluation combines several of the empirical datasets described above in Section 6.2.2.1.1 (specifically, net sedimentation rate, surface sediment grain size, and sediment contaminant surface to subsurface concentration ratios) with two additional location-specific conditions that could also affect the effectiveness of MNR: 1) maintenance dredging and propwash that occur in FMD and/or berthing areas; and 2) relatively shallow nearshore areas that are subject to wave and wake forces. Also integrated in this overall weight-of-evidence assessment are results from a sediment transport model simulation that provides predictions of long-term recovery rates throughout the Site, including how those rates would be potentially impacted by an extreme flow event. As discussed above, each of the individual LOEs included in this evaluation were combined in the weight-of-evidence approach to assess the degree of certainty (or uncertainty) regarding the effectiveness of MNR within different areas of the Site.

The methods used for relating each individual LOE included in this assessment to the degree of MNR effectiveness are described in the following subsection; this subsection also discusses how these LOEs were combined to develop an overall assessment of MNR effectiveness for a given area of the Site. A detailed discussion of the results from this combined analysis for each river mile of the Site is then provided in the subsequent subsection.

Methodology

The approach used for this weight-of-evidence evaluation of MNR effectiveness was based on categorizing the Site into one of three "recovery categories" for each type of information noted above (i.e., net sedimentation rate, surface sediment grain size, sediment contaminant surface to subsurface concentration ratios, maintenance dredging/propwash activity, shoreline wave action, and model-predicted long-term recovery rates). The three categories used for each LOE were as follows:

1. Category 3 was assigned to areas where a given LOE indicates MNR would be effective
2. Category 2 was assigned to areas where a given LOE suggests that natural recovery will likely occur, but the degree of effectiveness is less certain
3. Category 1 was assigned to areas where a given LOE suggests that effective natural recovery is uncertain

Below is a description of how these three recovery categories were assigned for each LOE; this is also summarized in Table 6.2-4.

FMD/Berthing (Propeller Wash) Areas: Deep FMD areas were assigned to Category 1 because maintenance dredging in these areas would remove recent sediment accumulations in these areas and likely retard recovery rates, depending on the specifics of how the dredging was performed and the nature of the sediment deposit dredged (e.g., potential to expose more deeply buried deposits and increase exposure). Note that navigation channel areas are also subject to maintenance dredging, but subsurface sediment concentrations in these areas are relatively low, particularly compared with nearshore and FMD areas (e.g., see Section 5.1.10 of the draft final RI report and Table 6.2-5). Thus, future maintenance dredging of the navigation channel is expected to have little impact on overall recovery trends, particularly on a river mile SWAC basis, which is typical of the relevant spatial scale for evaluating potentially unacceptable risk. As discussed in Appendix Fb, propwash can disturb approximately the top 1 foot of sediments, and in some localized areas could be a factor retarding natural recovery. However, because biological mixing processes measured at the Site (and incorporated into the predictive model) are also taken to extend to a depth of 1 foot,[12] surface mixing associated with propwash would have no net effect on the effectiveness of MNR in this setting. Areas designated as shallow-use FMD/berthing areas were assigned to Category 2 because some relatively shallow maintenance dredging could occur periodically in these areas, which could slow the rate of recovery if such areas have sediments with elevated contaminant concentrations. Portions of the Site located outside of these areas were assigned to Category 3 because they have the greatest potential for recovery[13] (i.e., areas outside of FMD areas are not routinely dredged and are likely not subject to the heaviest disturbance from vessel traffic as discussed in Section 5).

Wave/Wake Areas: As described in Appendix Hc (Section 4), for the purpose of this draft FS analysis, the wave zone has been defined as areas with surface sediment elevations ranging from 0 to13 feet NAVD88. The frequency of wave and wake forces in shallow water environments is also dependent on river stage fluctuations. Based on an evaluation of such fluctuations, the lowest elevation subject to wave forces when the river is at its 50th percentile stage height is approximately 6 feet NAVD88 (see Section 5.1.6 in Appendix Hc). Therefore, it follows that the majority of wave forces occur between elevations 6 and 13 feet NAVD88, and that wave forces occur to a lesser extent between elevations 0 and 6 feet NAVD88 (since the sediments at those elevations are fully submerged most of the time). As such, areas of the harbor between elevations 6 and 13 feet NAVD88 were assigned to Category 1 for this LOE. In these areas, wave/wake disturbance could potentially cause a regular reworking of the shoreline sediments that would impede recovery via sedimentation and long-term burial in portions of the areas with elevated contaminant concentrations. Likewise, areas between elevations 0 and 6 feet NAVD88 were assigned to Category 2. Areas outside these wave zones were assigned Category 3 for this LOE.

Net Sedimentation Rate: As discussed in Section 6.2.2.1.1, net sedimentation rates across the Site have been accurately characterized by performing sequential multi-beam bathymetric surveys from 2002 to 2009. Recent long-term (i.e., multi-year) net sedimentation rates calculated from these data are mapped in Figure 6.2-1; areas shown in blue represent areas of recent net deposition (greater than approximately 1 cm/yr), while areas shown in red represent net erosion (less than approximately -1 cm/yr). Areas shown in gray indicate bathymetric changes within the precision of the survey equipment (in this case, approximately ± 1 cm/yr). For this combined MNR effectiveness analysis,

[12] The 1-foot depth of biological mixing used at the Site is greater than mixing depths used at most other sediment sites, which are typically in the range of 5 to 15 cm. Based on discussions with EPA, physical mixing processes, including those associated with river currents and propwash, were considered when this larger mixing depth was established for this Site.

[13] Note, as discussed above, each LOE was first evaluated independently; areas outside FMD/berthing areas were assumed to have a greater potential for recovery as compared to areas within FMD/berthing (based on this information alone). However, there may be other LOEs that suggest areas assigned to Category 3 for one LOE have less recovery potential. Such differences were taken into account when the individual criteria were combined into an overall assessment based on the weight of evidence, as described at the end of this subsection.

areas experiencing recent net erosion in excess of approximately 1 cm/yr were assigned to Category 1, because such areas would likely have less propensity to recover via deposition processes or would recover at slower rates. Conversely, areas experiencing net deposition in excess of 1 cm/yr were assigned to Category 3 because such areas would have the greatest potential for natural recovery (due to the propensity for depositing sediment to have lower contaminant concentrations, particularly within AOPCs; see Section 6.2.2.1.1). Areas within the uncertainty range of the surveys were assigned to Category 2 for this LOE.

Surface Sediment Grain Size: Fine-grained sediments such as silts and clays tend to dominate in relatively low-energy (depositional) environments. This occurs because the lower current velocity regime allows fine particles to settle and remain in place. Conversely, the presence of relatively coarser sediments such as sands and gravels is typically indicative of higher energy environments. As such, the rate of natural recovery is likely greater in sediment deposits comprised of finer grained sediments. For this evaluation, areas of the harbor with percent fines less than 20 percent were assigned to Category 1 for this LOE, areas having between 20 percent and 40 percent fines were assigned to Category 2, and areas with greater than 40 percent fines were assigned to Category 3 (see Figure 6.2-9).

Sediment Surface to Subsurface Concentration Ratios: As discussed in Section 6.2.2.1.1 above, differences between surface and deep sediment concentrations provide an additional LOE to evaluate and corroborate natural recovery. In a system that is largely depositional and in which contaminant loadings from known sources have been reduced, new sediments with lower concentrations deposit above the historical deposits—this natural recovery process is reflected by sediment cores that exhibit lower concentrations in the surface intervals and relatively higher concentrations at depth. Surface to subsurface sediment concentration ratios for total PCBs were mapped across the Study Area based on the Thiessen polygon method used in the contaminant fate and transport model, as presented on Figure 6.2-15. For this weight-of-evidence categorization, fate model grid cells with average surface sediment total PCB concentrations more than 1.5 times greater than the average subsurface concentration (based on Figure 6.2-15) were assigned to Category 1, because such areas are likely experiencing relatively lower rates of natural recovery.[14] Conversely, areas where the average surface total PCB concentration is more than 1.5 times lower than the average subsurface concentration were assigned to Category 3, because such areas show a significant decrease in concentration going from deep to surface, consistent with effective natural recovery. Areas where the average ratio is between these ranges (i.e., subsurface concentrations are within a factor of 1.5 of the subsurface concentrations) were assigned to Category 2.

[14] It should be noted that the surface to subsurface concentration ratios presented in this section focused on total PCBs because this contaminant is a bounding COC that is a primary contributor to potentially unacceptable risk (see Section 4). Furthermore, as discussed in Section 6.2.2.1.1, vertical concentration ratios for total DDx and BaP were shown to exhibit patterns similar to PCBs in the areas where these two contaminants are elevated above background levels (i.e., the western nearshore areas of RMs 7 to 8 and RMs 4 to 7, respectively).

Sediment Transport Model Predictions of Long-term Recovery Rates: As discussed in Section 6.2.2.1.2, a properly developed and calibrated model can be a useful tool for evaluating natural recovery effectiveness, especially on smaller spatial scales and over longer timeframes than the Site data permit. To evaluate long-term rates of natural recovery at the Site, a simulation was conducted using the calibrated HST model over the same 45-year period used to evaluate remedy effectiveness in this draft FS (see Appendices La and Ha for details). This simulation period allows for quantification of long-term average recovery rates, and takes into account the potential impacts of numerous high-flow events. In particular, the 45-year hydrologic record used for these simulations includes an extreme flow event corresponding to the January 1996 flood (see Appendix La). This approach allows for a robust evaluation of recovery rates, and in particular allows for an evaluation of the extent to which such an extreme event may disrupt natural recovery. This sediment transport modeling was conducted as a “bed tracer” simulation, in which a unit concentration (of 100) was specified throughout the sediment bed (i.e., laterally and vertically uniform) at the beginning of the simulation, and incoming particles from upstream were assigned a concentration of zero. As incoming particles deposited on the bed in this model simulation, predicted concentrations within the surface (0 to 30 cm) of the bed were tracked over time to evaluate rates of decline. Figure 6.2-20 presents the results from this sediment transport model simulation; in this figure, the predicted time series of surface sediment (0 to 30 cm) tracer concentration was plotted in terms of 1-mile averages, separated laterally into three zones (east and west nearshore areas and the navigational channel). These plots demonstrate that over long timeframes, natural recovery processes are predicted to reduce surface concentrations throughout the Site. In most locations, these reductions are caused by sedimentation, which acts to bury the higher concentration sediments with lower concentration depositing particles. In certain cases, alternating periods of deposition and erosion (i.e., dynamic equilibrium) also act to reduce surface concentrations, as the higher concentration material in the bed surface is replaced by newly depositing lower concentration material. The results from these simulations show that recovery rates vary over time (e.g., faster rates of decline are predicted within the first few years of the simulation in certain areas because those years contain higher flows and incoming sediment loads, resulting in more deposition) and spatially across the Site. Furthermore, these results show that the simulated extreme flow event (in year 17 of the simulation) results in increases in bed tracer concentration (due to erosion processes) in many areas, but that in most cases, the surface concentrations recover from that temporary disruption, returning to the pre-event trajectory relatively quickly. Therefore, these model results further corroborate the effectiveness of natural recovery at the Site over long timescales.

To incorporate these model results into this MNR effectiveness evaluation, a half-life over the 45-year model simulation period was calculated. This is a reasonable calculation, as the model-predicted bed tracer concentrations generally follow an exponential decline, with the exception of interruptions in the trends in many places caused by the extreme flow event, which has the effect of temporarily slowing long-term average recovery rates (see Figure 6.2-20a-d). For this evaluation of MNR effectiveness, the half-life calculation method illustrated by Figure 6.2-20a-d was applied to each model grid cell within the Site, and the grid cells were assigned to one of the three recovery categories based on the calculated half-life.[15] Areas having a calculated half-life of more than 20 years were assigned to Category 1, since this timeframe suggests slow or little recovery over timeframes typically considered for MNR at sediment sites (Magar et al. 2009). Areas exhibiting a half-life between 10 and 20 years were assigned to Category 2, and areas having a calculated half-life of less than 10 years were assigned to Category 3, which would be indicative of areas where recovery is expected to be particularly effective.

Combined Analysis: Recovery category assignments were made throughout the Site for each of the five individual physical/empirical datasets and for the long-term bed recovery rate predictions from the sediment transport model, as described above. The results of this categorization for the six LOEs are shown on Figures 6.2-21a through 6.2-21j (see Panels 1 through 6 on each figure; note that each page of these figures shows a 1-mile portion of the Site, moving from upstream to downstream). Determination of the overall weight of evidence for the effectiveness of natural recovery was conducted by combining the recovery scores for each LOE at a given location within the Site into an average. This combination was accomplished by overlaying the individual recovery category assignments for each of the six LOEs in GIS on a 100-foot square grid (so that all LOEs were evaluated on the same spatial scale), and calculating an average recovery category within each grid cell, resulting in a mapping of average recovery score. The calculated average recovery scores are shown on Panel 7 of Figures 6.2-21a -j.[16] On these panels, Category 1 areas (shown in red) correspond to calculated average recovery category values that are predominantly a combination of Categories 1 and 2. Category 2 areas (shown in yellow) correspond to calculated average recovery category values that are predominantly a combination of Categories 2 and 3, and combined Category 3 areas (shown in green) contain a majority of Category 3 scores from the six individual LOEs. Areas from within the footprint of Alternative B (shaded in black on these figures) were omitted from this MNR effectiveness evaluation because it only considers the portion of the Site outside of areas already identified for active remediation using removal or in-place technologies (which were identified based on methods described in Section 5).

In the following subsection, the results from the overall weight of evidence assessment of MNR effectiveness are discussed, at the spatial scale that is most relevant to exposure

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[15]Other methods for evaluating MNR effectiveness were also reviewed, including half-life calculations over other timeframes (i.e., less than 45 years), and by calculating percent reduction in the bed tracer concentrations shortly after the extreme flow event relative to the initial concentration; each method produced similar results.

[16] The number of LOEs that went into the calculated average for each 100-ft grid cell is displayed in Panel 8 of Figures 6.2-21a through 6.2-21j. These panels show that the vast majority of the Site contains information for all six LOEs. The limited areas having fewer than six available LOEs are typically right along the shoreline, and often are a result of locations where the multi-beam bathymetry surveys did not extent all the way to shore. However, in most cases such areas are generally missing only one or two LOEs. Although lack of one or more LOEs area adds uncertainty to the evaluation of a given area, these areas are generally small relative to the larger scale focus of this analysis and, as described below, it is often the case that multiple LOEs are consistent with one another, such that the effectiveness of MNR can still be reliably evaluated.

scales for many of the RGs used in the draft FS (i.e., river miles). A summary of these results is provided at the end of this subsection.

Results

This subsection contains a discussion of overall MNR effectiveness for each river mile of the Site based on the methodology described above and presented on Figures 6.2-21a-j. The results across all LOEs were combined to assess the overall weight of evidence for the effectiveness of natural recovery (or lack thereof) and the consistency (or inconsistency) among these various LOEs. Discussion of these findings is presented in the detailed narratives below.

- ***RMs 11.8 to 11***: Overall, the combined physical/empirical/modeling LOEs suggest that natural recovery may occur at rates that would not reduce potentially unacceptable risks within an acceptable timeframe in this river mile. Thus, the effectiveness of MNR in this river mile is uncertain, which is consistent with the majority of the grid cells that are characterized as average recovery Categories 1 and 2; see Figure 6.2-21a. The combined assessment does indicate a likelihood of effective natural recovery along a limited portion of the west side of the river; however, the relatively widespread areas of Category 1 and 2 in the navigation channel and east nearshore areas (Figure 6.2-21a) suggest that the effectiveness of natural recovery for this river mile as a whole is uncertain. This assessment is based on: 1) sediment concentration ratios over much of the navigation channel and east nearshore regions (including much of AOPC 25) that indicate surface concentrations are higher than those in the subsurface; 2) the presence of relatively coarser sediments in this area; 3) a significant proportion of the area that is either net erosional or experiences relatively low deposition; and 4) prediction of relatively slow recovery rates by the sediment transport model. Based on large fractions of Category 1 and 2 areas and the consistency among multiple LOEs, this river mile is classified as Category 1 overall.
- ***RMs 11 to 10***: The combined LOEs indicate that natural recovery is expected to be effective over the majority of this river mile. Most of this river mile is characterized as average recovery Category 3, which is based mainly on: 1) lack of FMD areas; 2) surface concentrations that are lower than the subsurface over most of the river mile; 3) presence of primarily fine sediments; and 4) relatively short bed half-lives predicted by the long-term sediment transport simulation (Figure 6.2-21b). There is a relatively small portion along the east shore of this river mile (outside of the AOPCs) where the effectiveness of natural recovery is more uncertain (due to areas of variable sedimentation rate, intermittent coarse sediment deposits, and small areas with a lack of significant vertical concentration gradient). However, although this limited region may contribute less to recovery, the overall weight of evidence indicates that on a whole, this river mile is expected to recover over time and is therefore classified as Category 3.
- ***RMs 10 to 9***: The combined LOEs indicate that natural recovery is expected to be effective over the majority of this river mile, more than half of which is

characterized as average recovery Category 3 (Figure 6.2-21c). This assessment is based on: 1) presence of few FMD areas and limited wave-wake zones: 2) presence of primarily fine sediments; and 3) relatively short bed half-lives predicted by the long-term sediment transport simulation. Along the east nearshore area of this river mile in AOPCs 21, 22, and 23 and in a portion of AOPC 20 on the western side of the river, some of the LOEs (e.g., sedimentation rate, surface to subsurface concentration ratio, a shallow FMD area and relatively long predicted bed half-life in AOPC 20) suggest that the effectiveness of natural recovery is less certain in these localized areas and would need to be confirmed through future sampling. Despite the presence of these two zones that may contribute less to recovery, the majority of the LOEs indicate a likelihood of effective natural recovery for the remainder of this river mile, and as such this mile on a whole is classified as Category 3.

- ***Swan Island Lagoon***: The average physical/empirical LOEs indicate that natural recovery will likely occur relatively slowly in Swan Island Lagoon. Most of this area is characterized as average recovery Categories 1 and 2, with only a limited area mapped as Category 3; thus, the effectiveness of MNR is uncertain in Swan Island Lagoon as a whole. The large portions of Category 1 and 2 areas within Swan Island Lagoon are due to: 1) variable and generally lower sedimentation rates; 2) presence of large scale FMD areas; 3) presence of coarse sediments and wave/wake zones along the eastern edge of the lagoon; 4) model predictions of relatively long half-lives over much of the lagoon, and areas having sediment concentrations that are elevated at the surface relative to the subsurface (Figure 6.2-21d). Swan Island Lagoon is a quiescent area that receives relatively little sediment input from upstream; therefore, although the bathymetry data indicated Swan Island Lagoon is net depositional (recognizing that there are some areas with no data coverage), it receives lower sediment input than other areas of the Site. Furthermore, Swan Island Lagoon has the highest total PCB sediment concentrations on a 1 mile SWAC basis of any area in the Site (e.g., see Table 4.3-1). Thus, the presence of high concentrations and slow deposition rate together, along with the other LOEs, suggest that natural recovery would not occur rapidly enough to reduce potentially unacceptable risks within an acceptable timeframe within Swan Island Lagoon. Swan Island Lagoon was therefore classified as Category 1.

- ***RMs 9 to 8 (Excluding Swan Island Lagoon)***: The combined LOEs indicate that natural recovery is expected to be effective over the majority of this river mile, most of which is characterized as average recovery Category 3 (Figure 6.2-21d). This assessment is based on: 1) limited presence of FMD areas: 2) presence of lower contaminant concentrations in the surface sediments relative to those at depth over portions of this river mile: 3) prevalence of fine sediment: and 4) relatively short half-lives predicted by the sediment transport model. There are two small, localized regions of less certain recovery in this area: 1) the west nearshore area within part of AOPC 18, which is due to shallow FMD areas, variable sedimentation rate, and lack of vertical gradients in sediment concentration; and 2) the zone right along the eastern shore adjacent to Swan Island (generally outside of the AOPCs), which has low sedimentation rates (including areas with missing data coverage) and wave/wake zones. However, these areas are limited in extent, such that when the weight of evidence is considered over this river mile as a whole, it is classified as Category 3.

- ***RMs 8 to 7***: Overall, the combined LOEs suggest that natural recovery is expected to be effective in this river mile, as most of this river mile is characterized as average recovery Category 3 (Figure 6.2-21e). This assessment is based on: 1) relatively high sedimentation rates; 2) surface sediment concentrations being lower than those at depth in many parts of this river mile; 3) prevalence of fine sediment; and 4) relatively short half-lives predicted by the long-term sediment transport simulation. One exception is the Willbridge Terminal area within AOPC 16, where the effectiveness of natural recovery is more uncertain given the presence of an FMD area that is co-located with areas of observed net erosion (or elevation change due to maintenance dredging) near the terminal docks and sediment cores with higher concentrations at the surface relative to the subsurface. Observed bed elevation decreases in this area during the 2002 to 2009 period was likely due to a combination of maintenance dredging and/or propwash disturbances associated with vessel traffic. However, despite these limited areas that may contribute less to natural recovery, the weight of evidence for this river mile as a whole (i.e., on a 1-mile average basis) indicates that natural recovery would be expected to be effective, and it was therefore characterized as Category 3.
- ***RMs 7 to 6***: Multiple LOEs indicate that the effectiveness of natural recovery is less certain over a large fraction of this river mile. More than half of this river mile is characterized as average recovery Category 2, with the remainder being a mixture of Category 1 and Category 3 (Figure 6.2-21f). This assessment is largely based on: 1) the presence of relatively coarser sediments over much of this area; 2) a significant portion of the area that is either net erosional or experiences relatively low deposition (more so in the east nearshore area and less so in the west nearshore area); 3) predictions of relatively long bed half-lives over much of the area from the long-term sediment transport model simulation; and 4) sediment concentration ratios that indicate surface levels are higher than those of the subsurface in portions of this river mile. Although these LOEs are often consistent (e.g., multiple Category 1 LOEs in the lower portion of AOPC 9U and the upper portion of AOPC 12), there are also areas where the LOEs are inconsistent, or those that result in a Category 3 mapping. Thus, the weight of evidence, which is somewhat inconsistent in places, suggests that although natural recovery processes are occurring in this river mile as a whole, it is uncertain as to whether it would occur at a sufficient rate such that it would require confirmatory sampling prior to or during remedial design. Based on this assessment and given that the majority of the river mile is mapped as Category 2 (along with the presence of Category 1 and 3 areas), on balance it is classified as Category 2.

- ***RMs 6 to 5***: The combined LOEs indicate that the effectiveness of natural recovery is less certain over this river mile, particularly in the navigation channel and portions of the east nearshore area of the upper half of this river mile. Approximately half of this river mile is characterized as average recovery Category 2, with the remainder being mostly Category 3, with the exception of a few areas mapped as Category 1 (Figure 6.2-21g). The greater uncertainty in MNR effectiveness over the upper half of this river mile is largely based on: 1) the presence of relatively coarser sediments in this area; 2) a significant portion of the area that is either net erosional or experiences relatively low deposition (and recognizing the lack of bathymetry data at the eastern shore); 3) areas having surface concentrations higher than the subsurface (e.g., portions of AOPCs 11 and 12 and a small section of AOPC 9D); and 4) the prediction of relatively long bed half-lives by the sediment transport model in this area. However, the remaining areas within this river mile, including the lower half of AOPC 9D, are mapped as mostly Category 3 (with some Category 2) based on presence of finer sediment, higher deposition rates, lower concentrations at the surface relative to the subsurface, and sediment transport model predictions of more rapid recovery. Overall, the various LOEs are generally consistent with one another at a given location within this river mile, indicating that the upper portion contains mostly Category 2, with some Category 3 and Category 1 areas, while the lower portion is mostly Category 3, with some Category 2 areas. Therefore, on balance, the river mile was classified as Category 2, indicating that the rate of recovery, and hence the effectiveness of MNR, is somewhat less certain and would require confirmatory sampling.

- ***RMs 5 to 4***: The combined LOEs indicate that natural recovery is expected to be effective over a large portion of this river mile, most of which is characterized as average recovery Category 3 (Figure 6.2-21h). This assessment is supported by: 1) generally high deposition rates; 2) prevalence of fine sediments; 3) surface contaminant concentrations that are lower than the subsurface over most of the river mile; and 4) relatively short half-lives predicted by the sediment transport model. However, there are some smaller scale areas mapped as Category 1 or 2, which would indicate a higher uncertainty in the effectiveness of natural recovery in these portions of the river mile. Such areas include: 1) the Terminal 4 slips located in the east nearshore area (within AOPC 6), for which several LOEs are Category 1 or 2 including surface to subsurface concentration ratio, presence of FMD areas, net erosion (due primarily to maintenance dredging that occurred in this area in 2005 and 2008; see Figure 2.4-5), zones of coarser sediment, and long half-lives predicted by the model; and 2) portions of the west nearshore area (within parts of AOPCs 8, 7, and 5), based primarily on presence of wave/wake zones and coarser sediments (and recognizing that the bathymetry data did not extend all the way to the shore in this region). Nonetheless, these areas represent a relatively small portion of the overall river mile, for which the weight of evidence suggests a high likelihood of effective natural recovery. Therefore, overall natural recovery is expected to be effective in this river mile, and thus, it is classified as Category 3.

- ***RMs 4 to 3***: The combined LOEs indicate that natural recovery is expected to be effective over a large portion of this river mile, most of which is characterized as average recovery Category 3 (Figure 6.2-21i). This assessment is supported by: 1) prevalence of fine sediments; 2) surface contaminant concentrations that are lower than the subsurface throughout most of the river mile; and 3) relatively short half-lives predicted by the sediment transport model over most of this area. However, within the east nearshore area, particularly in International Slip, and a relatively small portion of the west nearshore area and near the Multnomah Channel, there is an increased uncertainty in natural recovery effectiveness that is due to: 1) low net sedimentation that occurs within International Slip (and net erosion that likely occurs due to anthropogenic factors) and near Multnomah Channel (outside the AOPCs); 2) the presence of relatively coarse sediments; 3) the presence of FMD areas along the east shore and within International Slip; 4) predictions of relatively long half-lives by the sediment transport model; and 5) a small area within AOPC 4 having surface concentrations that are elevated relative to the subsurface. Nonetheless, these areas represent a relatively small portion of the overall river mile, which the weight of evidence suggests has a high likelihood of effective natural recovery. Therefore, on a whole natural recovery is expected to be effective in this river mile, and thus, overall it is classified as Category 3.

- ***RMs 3 to 1.9***: The combined LOEs indicate that effective natural recovery is expected over the majority of this river mile, most of which is characterized as average recovery Category 3 (Figure 6.2-21j). Over most of this river mile, all six LOEs (where data are available) are characterized as Category 3. There are some localized exceptions, such as:1) the west nearshore area (in the vicinity of Multnomah Channel), where an increased uncertainty of natural recovery is due to some small areas of relatively low net sedimentation (including lack of data coverage along the shore), presence of relatively coarse sediments, wave/wake areas, and a small area of slower recovery predicted by the sediment transport model; and 2) a small zone along the eastern shore, including a portion of AOPC 1A, due to an FMD area, areas of lower net sedimentation, wave/wake zones, and areas where sediment core ratios indicate higher concentrations at the surface. Despite these relatively small portions of the river mile that may contribute less to natural recovery, the weight of evidence indicates that overall MNR is expected to be effective in this river mile, and thus it is classified as Category 3.

6.2.2.1.4 Summary of MNR Effectiveness

The overall weight-of-evidence analysis presented above uses a combination of six independent LOEs based on empirical data, physical information, and sediment transport modeling to evaluate the effectiveness of MNR throughout the Site. The combined average recovery score from these LOEs was mapped over the Site, with resulting scores ranging from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this mapping, the relative amounts of each category were used to develop an overall assessment of MNR effectiveness for each river mile, although discussions of smaller scale features of the mapping were provided. A summary of the MNR effectiveness evaluation for each river mile of the Site presented above is contained in Table 6.2-6. The results from the combined LOE analysis indicate the following:

- When evaluated on a 1-mile average basis, which is the smallest relevant spatial scale consistent with the risk assessment, natural recovery would be effective over most of the Site. Specifically:
  - In most river miles (i.e., those classified as Category 3), MNR is anticipated to provide reductions in potentially unacceptable risk within an acceptable timeframe, even considering the uncertainty in the evaluation.
  - As noted in Table 6.2-6, several of the river miles where natural recovery is expected to be effective overall contain limited regions where the effectiveness is less certain due to local conditions (e.g., future navigation/propwash areas, wake/wave areas, etc.). Such areas may not contribute substantially to the rate of recovery that the river mile as a whole is expected to experience. Uncertainty analyses presented in Appendix U (Section 5) evaluate the extent to which these smaller-scale regions mapped as Category 1 or 2 affect the detailed evaluations of alternatives by assessing how the results change if no natural recovery were to occur in such portions of the Site.
  - Areas where MNR would be part of the selected remedy would still require confirmatory sampling to verify effectiveness (during remedial design and after active remedy implementation), consistent with the EPA (2005b) guidance. Furthermore, they would also require that contingency plans be implemented should natural recovery not progress as expected (see Appendix T, Section 4).
- There are two river miles where multiple LOEs suggest that the effectiveness of natural recovery is expected to be somewhat less certain and were thus classified as Category 2 (i.e., RM 7 to 6 and RM 6 to 5). Supplemental data collection during remedial design and after active remedy implementation would be needed to verify MNR effectiveness throughout these areas.
- Finally, the effectiveness of MNR is uncertain and may occur at rates that would not reduce potentially unacceptable risks within an acceptable timeframe in two river miles; these areas, RM 11.8 to 11 and Swan Island Lagoon, were thus classified as Category 1. In both these cases, there is enough uncertainty in the overall evaluation that augmentation of active remedy elements in these areas is indicated (as discussed in Section 7.4.1.2 for Swan Island Lagoon and in Section 10.4 for RM 11.8 to 11).

One consideration from the screening assessment presented above is that it did not take into account the sediment contaminant levels in each area (with the exception of the evaluation for Swan Island Lagoon). In some cases, contaminant levels may already be at or below risk-based goals, in which case the MNR categorization presented above is less relevant. Assessments that take into account contaminant levels are included in the development and detailed evaluation of alternatives presented in Sections 8 and 9, and the uncertainty analyses presented in Section 5 of Appendix U assess the extent to which uncertainty in natural recovery affects these evaluations.

6.2.2.2 Implementability

The above effectiveness discussion addresses all of the natural and anthropogenic processes that are relevant to the determination of whether MNR is likely to be implementable. Monitoring and contingency planning is generally highly implementable, although it requires planning and coordination, which is described more in Appendix T.

6.2.3 Enhanced Monitored Natural Recovery (EMNR) Screening

EMNR involves active measures, such as the placement of a thin layer of suitable sand or sediment, to accelerate the natural recovery process (Figure 6.1-2). EMNR is often applied in areas where natural recovery may appear to be an appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce potentially unacceptable risks within an acceptable timeframe (EPA 2005a). The acceleration of natural recovery most often occurs due to burial and/or incorporation and mixing of the clean material into the contaminated surface sediments through bioturbation and physical mixing processes. Other recovery processes can also occur such as binding of contaminants to organic carbon in the clean material, particularly if the material is from a clean sediment source with naturally occurring organic carbon. Placement of such EMNR materials is typically different than capping (discussed in Sections 6.2.5 and 6.2.6), because it is not designed to provide long-term isolation of contaminants. Clean sand or sediment can be placed in a relatively uniform thin layer over a contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the clean material over wider areas. As with MNR, EMNR includes both monitoring and contingency plan components to verify that recovery is occurring as expected, and to respond accordingly.

6.2.3.1 Effectiveness

The effectiveness screening for EMNR is linked to the results of the MNR screening discussed above. Per EPA's (2005a) sediment remediation guidance, EMNR is generally applied in areas where natural recovery is an appropriate remedy, but for which the rate of sedimentation or other natural processes is insufficient to reduce potentially unacceptable risks within an acceptable timeframe. Only two river miles of the Site were found to be uncertain (Category 1) for MNR in Section 6.2.2. Of those, Swan Island Lagoon is a quiescent area where the main limitation for potential natural recovery is lack of sedimentation. Thus, augmentation of sedimentation rates via EMNR would likely be highly effective here.

RM 11 to 11.8, although found to be in the uncertain category for MNR, has significant areas of historical deposition as indicated by measured bathymetry changes measured, and thus EMNR may be effective in specific areas in this river mile as well. Therefore, EMNR was determined to be potentially effective for the entire Site. As discussed for MNR, this determination was made with the understanding that both MNR and EMNR may not be effective for certain smaller scale areas. However, the net impact of a potential lack of recovery in these areas (e.g., on river mile SWACs) is evaluated further in Sections 8 and 9.

6.2.3.2 Implementability

The primary implementability challenge with EMNR is that a reasonable level of stability is needed for the EMNR material to stay in place and either bury or be incorporated into surface sediments over time. Site conditions where the stability of EMNR material is uncertain are similar to uncertain areas identified for MNR above and include:

- EMNR material placed in areas subject maintenance dredging (i.e., NC and FMD areas) could be removed over time, thus removing the benefit of the clean material. (It is important to note that this issue differs from maintenance dredging that might reveal new contaminated subsurface sediments, an issue which is addressed in SMA development in detail in Section 5.6.)
- EMNR material in these FMD and NC areas could be subject to propwash forces that may redistribute the materials elsewhere.
- EMNR material placed in WZ areas would be subject to wave forces that could move or erode the materials downslope and/or downstream.

EPA provided comments on May 18, 2011 on the "LWG 4/21/2009 presentation of 'Remedial Technologies' for the Feasibility Study" (EPA 2011d; Appendix O) regarding EMNR. EPA commented that the movement of EMNR material from areas of lower stability to more stable depositional areas of the Site could be used as an overall mechanism to augment MNR on a larger Site scale. Specifically, EPA stated that:

> "*Wave zones, for example, may be the logical placement location of material that is then allowed to erode to integrate with more contaminated downstream sediments. Higher areas of sediment conveyance in the river also may be the logical deposition points for materials that would then erode and be dispersed to enhance downstream beaches or shoals that are lightly to moderately contaminated.*"

This innovative broader concept for EMNR would increase the overall Site sedimentation rate, taking advantage of Site-wide sediment transport dynamics. Such an approach would likely need to be implemented on a Site-wide scale, rather than through SMA-specific remedial designs, consistent with Site-wide MNR and EMNR monitoring programs. To fully understand the potential efficacy of such an approach, modeling or similar techniques would be needed to estimate where and how much this approach would augment MNR and as well as the best locations to place EMNR material over time. However, such an approach also has wider implications in terms of navigation maintenance dredging, both in the channel and in FMD areas. Modeling runs to further evaluate this approach were not conducted for this draft FS, but could be considered as part of follow-on remedial design. As discussed above, key elements of EMNR are the monitoring and contingency plan components to verify the long-term protectiveness of this remedy, including in WZ and FMD areas.

For maintenance dredging issues in FMD areas, EMNR may not be implementable if it would adversely affect Site uses, including navigation. However, within specific SMAs, parties may determine that continued use of a dock or berthing area is not warranted given the additional expense it causes for remediation. Consequently, if appropriate institutional controls can be implemented to remove the potential for maintenance dredging of placed EMNR material, then EMNR may implementable within some areas currently assumed to be FMD areas.

EMNR in the NC areas was judged to be generally incompatible with existing navigation maintenance programs and thus may be infeasible in these areas for the purposes of the draft FS. However, as noted above, wider application of EMNR material such that some material is applied to and/or transported into or through the navigation channel may still be a valid Site-wide EMNR approach, subject to further evaluation as appropriate. But again, this application of EMNR is generally incompatible for NC and FMD areas.

6.2.4 In Situ Treatment Screening

The process to identify and screen in situ treatment technologies began with the preparation of the *Treatability Study Literature Survey Technical Memorandum* (Anchor 2007; Treatability Study Technical Memorandum) and was followed by an additional screening step presented to EPA in the *Draft Treatment Technology Screening Tables* in June 2009 (Anchor QEA 2009a). Since that time, field-scale pilot studies have been conducted at other sites to demonstrate the implementability and effectiveness of several amendments such as AC to reduce the bioavailability of organic contaminants and certain metals. As discussed in more detail below, results to date from these pilot studies, which continue to demonstrate the capabilities of in situ sediment immobilization treatment, have recently been made available through peer-reviewed scientific papers (Ghosh et al. 2011; Cornelissen et al. 2011 are examples) and EPA presentations.

> *In situ sediment treatment, particularly through direct placement of amendments such as activated carbon to reduce the bioavailability of certain organic and metal contaminants, is now a proven and likely cost-effective innovative treatment technology that is evaluated in more detail in this draft FS.*

Consequently, the identification and screening of in situ treatment technologies from the Treatability Study Technical Memorandum and *Treatment Technology Screening Tables* has been updated to reflect these technological innovations. This update also factors in EPA's comments and LWG responses regarding treatment technologies that took place between 2007 and 2011 (see Appendix O; EPA 2011d). Based on this updated screening analysis, in situ sediment treatment, particularly through direct placement of amendments such as AC to reduce the bioavailability of certain organic and metal contaminants, is now a proven and likely cost-effective innovative treatment technology that is evaluated in more detail in this draft FS.

This section provides a discussion and screening of the direct application or placement of amendments to reduce the bioavailability of certain contaminants as an in situ treatment technology, including an evaluation of representative process options to determine which amendments and distribution methods are likely to be most applicable to Site sediment. The basic technology involves the placement of AC or other types of reagents that bind certain organic and/or metal contaminants. These materials have been applied at other similar sites using one of five process options at the field pilot scale, including:

- Mechanical mixing of amendments into shallow sediment using injection tines or rotary tilling equipment
- Slurry placement of the amendments onto the sediment surface (e.g., in a clay mixture), potentially including injection or mixing into near-surface sediments
- Mixing amendments with sand, and placing the blended materials using methods similar to the EMNR technology discussed above (see Section 6.2.3)
- Sequentially placing amendments under a thin sand cover
- Broadcast application of amendments in a pelletized form to improve settling characteristics (e.g., SediMite™; the pellet matrix subsequently degrades, allowing the AC to slowly mix into surface sediments through bioturbation)

Representative amendments and process options are discussed in more detail below.

6.2.4.1 Effectiveness

In situ treatment techniques are less energy-intensive, less expensive, and less disruptive to the environment than conventional remedial technologies, and they can reduce ecosystem exposure by binding contaminants to organic or inorganic sediment matrices. The contaminant sorption capacity of natural sediments may be modified and enhanced by adding such amendments as AC for adsorption of non-polar organics and certain metals (various AC products are available as powder, granules, or pellets, each with different sediment application characteristics); natural minerals such as apatite, zeolites, or bauxite and refined minerals such as alumina/activated alumina for sequestration of metals/metalloids; ion exchange resins (organoclays) for replacement of metals/inorganic contaminants with amines or other functional groups; zero-valent iron for dechlorination of PCBs; and lime for pH control or degradation of nitroaromatic compounds (Ghosh 2008; O'Day and Vlassopoulos 2010). Multifunctional amendment blends may also be used to address complex contaminant mixtures in sediments, and subsequently may enhance overall sorption capacity.

The two most common material classes for amendment are AC and organoclays. The transfer of organic contaminants such as PCBs from the sediment to the strongly binding AC particles not only reduces contaminant concentration and the bioavailability to benthic organisms, but also reduces contaminant flux into the water column, and thus accumulation of contaminants in the aquatic food-chain (Ghosh et al. 2011). Of the two amendments, AC has received more testing and evaluation than organoclays, particularly with respect to sediment remediation, because the sorption capacities for PCBs, PAHs, dioxin/furans, DDx compounds, and other chemicals in AC are at least an order of magnitude higher than in the other sorbents. Organoclays have received attention largely in the context of addressing localized deposits of dense non-aqueous phase liquids (DNAPLs; Bullock 2007; Lampert and Reible 2009).

Usually AC serves as the backbone (for hydrophobic partitioning) and either is impregnated with the target amendment or blended in a briquette-like composite using an appropriate and non-toxic binder (e.g., clays or other binder materials; Ghosh et al. 2011). This treatment has the effect of adsorbing hydrophobic contaminants, reducing porewater contaminant concentrations, and reducing their bioavailability for uptake by benthic organisms. As discussed in more detail below, direct placement of AC to sediments has now been demonstrated in a wide range of bench-scale and pilot studies, and successfully deployed in large field efforts with promising documented monitoring results. AC has proven effective in reducing the bioavailability of a range of sediment contaminants for a variety of pathways and receptors including the benthic community.

Ghosh et al. (2011) provides a comprehensive summary of the results of the most recent studies. The studies cover a range of contaminants and evaluate different amendment delivery methods. The studies also assess the potential for environmental impacts (e.g., to benthic organisms) that can occur at relatively high AC doses (greater than approximately 5 percent by weight).

Encouraged by the preliminary bench-scale data suggesting that porewater concentrations and bio-uptake of hydrophobic contaminants can be reduced between 70 and 100 percent at AC doses of between 2 and 4 percent, eight field-scale demonstration projects have either been completed or are currently underway in the United States and Norway, spanning a range of environmental conditions including a freshwater river (i.e., the Grasse River in New York). The field demonstration sites are summarized in Table 6.2-7. The remainder of this section highlights a few of the case study results pertinent to this Site.

6.2.4.1.1 Hunters Point Shipyard, California

One of the first field-scale demonstrations of AC-induced in situ PCB stabilization in sediment was initiated in Hunters Point Shipyard in San Francisco Bay, California. The purpose of the project was to demonstrate the ability of AC to reduce PCB bioaccumulation in field tests and to evaluate two methods of large-scale mixing equipment (Luthy et al. 2009). AC was delivered and mixed into the sediment using two techniques: one via rotary tilling and the other via injection. Control plots with mixing only and no action were also tested for comparison.

The bioavailability of PCBs from the sediment was tested before and after the AC application via PCB congener testing of sediment, surface water, porewater, resident clam tissue, tissue of biota exposed to test sediment in situ and in the laboratory for 28 days, and semi-permeable membrane devices (SPMDs). Post-treatment sampling indicated that both AC mixing methods were effective in delivering the amendment throughout the test area. However, post-treatment porewater measurements indicate that the tilling method was potentially more effective in reducing PCB concentrations. The difference in effectiveness was attributed to the heterogeneous distribution of AC observed in the ‘injection’ test plot (Cho et al. 2009).

The results of the study indicated significant reductions in PCB tissue concentrations as measured by the 28-day laboratory bioaccumulation analyses; however, incomplete source control in the pilot study area coupled with a relatively high rate of sedimentation in the test plots confounded the test results. Nevertheless, the authors concluded that, under conditions where sources were controlled, reductions in PCB bioaccumulation between 80 to 90 percent can likely be achieved with AC amendment. The authors also concluded that AC treatment did not adversely impact macroinvertebrate benthic community composition, richness, or diversity (Janssen et al. 2009, 2011).

6.2.4.1.2 Grasse River, New York

The most comprehensive pilot study of AC amendments performed to date is the Activated Carbon Pilot Study (ACPS) performed in the Lower Grasse River (Massena, New York). The ACPS was initiated in September 2006 to evaluate the effectiveness of AC as a means to sequester sediment PCBs and reduce PCB flux from sediments and uptake by biota. Initial laboratory and field studies conducted by Stanford University, the University of Maryland at Baltimore County, and others demonstrated that mixing AC into surface sediments successfully sequestered PCBs and is effective at reducing PCB bioaccumulation in benthic organisms and reducing release of bioavailable PCBs into the water column.

The overall objective of the ACPS was to evaluate if the bioavailability of PCBs within Lower Grasse River sediments can be reduced at the field scale through the placement and mixing (by mechanical or natural processes) of AC into native sediments. Other ACPS objectives included the following:

- Evaluate the ability to deliver AC into in-place sediments and determine the extent to which PCBs and sediments are released to the river during application
- Measure the change in PCB bioavailability to deposit-feeding benthic organisms that results from AC amendment
- Evaluate changes in PCB desorption kinetics and equilibrium partitioning from sediments that result from AC amendment
- Evaluate potential impacts to the benthic community structure associated with the addition of AC to the sediments
- Evaluate whether the erosion potential of the sediments is altered by AC amendment.

In support of these objectives, Alcoa Inc. (Alcoa), with oversight from the EPA and other agencies, implemented the pilot demonstration project. The project began with further laboratory studies and land-based equipment testing, continued with field-scale testing of alternative placement methods, and culminated in a field demonstration of the most promising AC application and mixing methods to a 0.5-acre pilot area within the Lower Grasse River. Additional information can be found in Alcoa (2010).

After pilot study construction, an annual physical, chemical, and biological monitoring program was initiated to evaluate the longer term effectiveness of the AC treatment. Monitoring included measurements of PCBs and black carbon within aqueous and sediment matrices, as well as bioaccumulation testing, benthic habitat evaluations, and erosion potential studies; results from the 2007, 2008, and 2009 events have recently been published (Ghosh 2010; Alcoa 2010).

A summary of results from the 2009 ACPS is provided below. Additional information can be found in Alcoa (2010).

- AC was successfully applied to surface sediments using all application methods, including broadcasting, mixing with a rototiller-type unit, and a “tine sled” device that directly injected AC into near-surface sediment. Both the tiller mixing and tine sled applications successfully mixed AC into the 0- to 3-inch sediment layer, with some AC also applied to the 3- to 6-inch sediment layer. Compared with the tine sled, application of AC using the tiller resulted in greater small-scale spatial variability in delivered AC levels.
- Water quality monitoring demonstrated that construction activities did not impact water quality in the river, and also suggested that the use of silt curtains is not necessary for future applications using the tine sled or tiller equipment.
- All of the delivered AC remained in place throughout the post-placement monitoring period. AC levels measured in the sediments were consistent with expected levels considering mass balance calculations based on application rates. Small-scale variability of AC levels declined over time as a result of bioturbation processes.
- PCB accumulation in the test organisms (wet weight basis) exposed to the mixed (tiller) treatment area was reduced in excess of 80 percent for the in situ tests and in excess of 90 percent for the ex situ tests. Bioavailability of sediment PCBs to deposit-feeding benthic organisms was dependent on the dose of AC, particularly over the range of 0 to 5 percent AC (Figure 6.2-22a).
- Batch equilibrium testing to evaluate the effect of AC on PCB partitioning between the sediment and water phases showed reductions in the range of 93 to 99 percent for treated areas. By 2009 (3 years after application), porewater PCB concentrations in areas treated with at least 2 percent AC were reduced by greater than 99 percent when compared to the pre-treatment concentration (Figure 6.2-22b).

- Results of ecological monitoring activities revealed a benthic community adapted to fine-grained sediments pre- and post-AC application. Benthic habitat measures were similar comparing the treatment areas and upstream background locations, suggesting that AC amendment did not adversely affect the macroinvertebrate community.
- The erosion potential of AC-treated sediments was slightly higher than pre-treatment sediments, but was within the range of historical data for native sediments.

Additional studies on the potential effects of AC on plant growth are ongoing.

6.2.4.1.3 Norwegian Geotechnical Institute Studies

The Norwegian Geotechnical Institute (NGI) has undertaken three field demonstration projects to evaluate the effectiveness of AC placement methods to control bioaccumulation of PAHs, TBT, and dioxins/furans (Oen et al. 2010, 2011). The first project, conducted in Tronheim Harbor, Norway, focused on evaluating the effect bioturbation has on the natural mixing of AC into surface sediments with different covers. Accordingly, five test plots were established: a reference, a thin layer of powdered AC with no cover, a thin layer of powdered with a 5-mm sand cover, an AC-bentonite (AC-clay) slurry mixture, and a sand-only cover. Except for the AC-clay slurry test plot, no mixing of AC into natural aggregate was performed prior to material placement. In addition, all four amendments were broadcast onto the sediment surface without subsequent in situ mechanical mixing.

The AC-clay slurry performed better than the unmixed AC applications with respect to reductions of PAH flux into porewater within the biologically active zone and in surface water just above the sediment interface, and also did not impact the benthic community. Based on these observations, the researchers concluded that pre-mixing AC with another medium prior to placement accelerates the natural bioturbation process, resulting in a more homogeneous long-term application of AC.

The second field study conducted by NGI is located in Grenlandfjord, Norway and focused on sediment with dioxin/furan TEQ (TEQ) concentrations of approximately 9 ppb TEQ, and porewater TEQ concentrations 5 to 25 times those in overlying surface water (indicating that these sediments could be a source of bioaccumulation exposure). Treatments and controls included crushed limestone, clay only, and AC-clay mixtures. Sediment profile imaging (SPI) was used to evaluate the effectiveness of the AC amendment placement. Figures 6.2-23a and 6.2-23b present the SPIs for the two AC-clay test plots after placement of the mixture and demonstrate successful placement using conventional construction equipment. Long-term monitoring data are pending (Oen et al 2010, 2011).

The third field study is located in Fiskerstrand, Norway and focused on sediments with elevated concentrations of TBT. The pilot study used a limestone application control and a mixed AC-limestone treatment. Preliminary results indicate a reduction in contaminant flux greater than 95 percent for both the limestone and mixed AC-limestone applications (Oen et al 2010, 2011).

6.2.4.1.4 SediMite^{TM} Field Studies

SediMite^{TM} is a manufactured product developed as an alternative distribution method for direct placement of treatment agents in comparison to mechanical mixing methods. The product is an agglomerate composed of a treatment agent (e.g., AC, organoclay), an inert binder, and a weighting agent to facilitate delivery of the treatment agent to surface sediments. SediMite^{TM} is typically broadcast directly over the area of interest and no subsequent mechanical in situ mixing is performed. With funding from the National Institute of Environmental Health Science's Superfund Research Program and the U.S. Department of Defense's Environmental Security Technology Certification Program, two field demonstration projects were conducted at two federal Superfund sites: one in Bailey Creek at the Fort Eustis facility in Virginia and one in Canal Creek at the Aberdeen Proving Ground in Maryland (Menzie 2011a).

Two test plots were established at Bailey Creek to evaluate the effectiveness of the SediMite^{TM} application in channel and marsh/wetland conditions. Post-treatment monitoring at Bailey Creek indicated that PCB concentrations in sediment porewater were reduced by 60 percent with an application of 1 percent AC and by 96 percent when 3 percent AC was applied. Bioaccumulation tests were performed on estuarine amphipods (*L. Plumulosus*) adults and second generation animals. The adults were exposed to treated sediment for 14 days, while the second generation was exposed for 60 days. With a 5 percent AC dose, average decreases in tissue concentrations of approximately 72 percent and 82 percent, respectively, were observed for the 14- and 60-day tests (Figure 6.2-24a-d; Menzie 2011a). In addition, sediment samples collected 18 months after the AC/SediMite^{TM} application indicate successful recolonization of the biologically active zone by both worms and two species of clams (Menzie 2011b). The results of the Bailey Creek pilot project are similar to those observed in the Grasse River ACPS (see above).

Laboratory treatability studies were performed prior to the field project at Canal Creek to determine the optimal AC dose to reduce PCB and DDx uptake. Worms (*L. variegatus*) were exposed to sediment treated with AC at doses equal to 0.5 and 1.0 times the total organic carbon (TOC) measured in the control sediment collected from Canal Creek. After 14 days of exposure, PCB and DDx concentrations in the worms were reduced by 81 percent and 87 percent, respectively, for the 0.5 times TOC dose and by 95 percent and 92 percent, respectively, for the 1.0 times TOC dose. Laboratory studies were also performed to evaluate the effectiveness of AC on reducing methyl-mercury concentrations in porewater and worm tissue. SediMite^{TM} with AC doses equal to 0.5, 1.0, and 1.5 times the TOC measured in the Canal Creek control sediment achieved 86 to 92 percent and 57 to 74 percent reductions of methyl-mercury concentrations in porewater and worm tissue, respectively (Menzie 2011b).

6.2.4.2 Implementability

Similar to the EMNR, in situ treatment requires a stable sediment deposit in order for the placed material (e.g., AC) to remain within the sediment treatment zone. Site conditions where the stability of in situ treatment material is uncertain (similar to uncertain areas identified for EMNR above) include:

- NC and FMD areas where maintenance dredging could remove placed materials
- FMD areas that could be subject to propwash forces that could redistribute the materials elsewhere
- WZ areas where wave forces could move or erode the materials downslope and/or downstream

Accordingly, in situ treatment was not generally considered implementable for NC, FMD, and WZ subSMAs for the purposes of the draft FS. However, for FMD areas, this determination is only valid to the extent that the Site uses and navigation depths assumed for the draft FS are actually determined necessary in SMA-specific remedial designs. As discussed above for EMNR, if appropriate institutional controls can be implemented to remove the potential for maintenance dredging of placed in situ treatment materials, then in situ treatment may be implementable within some currently assumed FMD areas.

If in situ treatment is selected in the ROD as a component of the sediment remedy, further design-level evaluations of this technology should be performed at the location-specific level and will likely influence implementation decisions on the type (e.g., source and type of carbon) and amount of amendment used (i.e., design safety factor). Physical stability and chemical activity (e.g., adsorption capacity) over the long term are the most important design life factors. AC and other charcoals created under high-temperature conditions are known to persist for thousands of years in soils and sediments, and both laboratory studies and modeling evaluations indicate promising long-term physical stability of the amendment material and chemical permanence of the remedy (Ghosh et al. 2011). The results of pilot studies and modeling simulations have demonstrated that in situ treatment can reduce bioavailability over the long term where contaminant loading (mass transfer) from groundwater or surface water is low and ongoing accumulations of newly deposited material contain low contaminant concentrations. Because net sediment deposition occurs throughout most of the Site, natural deposition should reduce and likely eliminate the functional need for replenishing the amendment over time.

6.2.4.3 Conclusions

As discussed above, innovative studies that commenced in the mid-2000s are producing promising data demonstrating effective and implementable methods for distributing and mixing immobilization amendments into sediment in the biologically active zone. While the field studies have generally focused on the use of AC, these delivery methods can be used to distribute a wide range of amendments that could address various organic and inorganic Site contaminants.

Based on recent case studies at contaminated sediment sites, in situ immobilization treatment is considered a potentially effective innovative technology for the entire Site. Based on the bounding COCs, direct broadcasting AC was selected as the main process option to generally represent this technology and was used to develop alternatives for the draft FS. This is a draft FS-level assumption only, and other process options and reagents could be retained for further evaluation and use in remedial design of specific SMAs, particularly because this technology is rapidly evolving. Another potential process option is to mix AC or other materials with sand or similar material before placement. To assist EPA in evaluation of the potential cost impacts of other potential placement process options that may be selected in remedial design, Appendix K (Table 10) contains unit cost factors for other placement techniques that can be applied to each localized SMA.

Based on recent case studies at contaminated sediment sites, in situ immobilization treatment is considered a potentially effective innovative technology for the entire Site.

Also, in areas where metals may contribute to potentially unacceptable risk, additional analysis in remedial design could be conducted to determine if the AC application will sufficiently address these contaminants and the extent to which other amendments such as apatite might be necessary.

6.2.5 Engineered Capping Screening

Engineered capping (or capping) is a remedial technology for containing contaminants in sediments and preventing or reducing the potential exposure and mobility of those contaminants from the sediment. It involves the placement of a subaqueous covering or cap of suitable material over contaminated sediment that remains in place and is one of the most commonly evaluated and implemented remedial technologies for contaminated sediments (EPA 2005a; Palermo et al. 1998). Its effectiveness as a remedial option has been demonstrated by numerous successful projects. The results of a detailed evaluation of capping as a remedial technology for the Site are presented in Appendix Hc.

Capping is defined as a designed system that is intended to isolate the contaminants underlying the cap. Typically, isolation caps are mostly composed of suitable sand and/or sediment and can range from approximately 1 foot to several feet thick, depending on the particular site. This primary isolation layer may be augmented by layers of other materials for various purposes, such as providing habitat and/or erosion controls on the cap surface (e.g., spawning gravels, cobble, or even riprap). The sources of capping materials can vary depending on the project and are usually determined in remedial design. Likely sources of various cap materials include upland quarries for sand, gravel, and riprap and suitable maintenance dredge material for contaminant isolation layers (e.g., from Columbia River maintenance dredging). Figure 6.2-25 shows a typical example of a two-layer capping system with a sand isolation layer overlain with a coarser erosion protection layer. Depending on the contaminants and sediment environment, a cap is designed to reduce potentially unacceptable risk through the following functions (EPA 2005a):

- Physical isolation of the contaminated sediment sufficient to reduce potential exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the surface
- Stabilization of the contaminated sediment and erosion protection of the sediment and cap, sufficient to reduce potential resuspension and transport to other sites
- Contaminant isolation of the contaminated sediment sufficient to reduce potential exposure from dissolved and colloidally bound contaminants transported into the water column.

The feasibility of isolation capping as a remedial technology is related to several factors, including underlying sediment strength, contaminant characteristics, physical and hydrological conditions at a site, and current and potential future uses of the waterbody. Important fate and transport properties of the contaminants in question include partitioning rates to solid materials, solubility, and biodegradation rates (in the case of organic compounds). Important physical characteristics of the Site include groundwater upwelling rates (which affect the rate of contaminant advection through the cap) and surface water velocities due to currents, propwash, and wind- and vessel-generated wave action (which potentially affects the stability of the cap). Localized vessel effects such as the potential for vessel anchoring, inadvertent vessel grounding, or small scour holes due to bow thruster operations near docks are considered during design but do not typically prohibit the selection of a capping remedy. Isolation capping may not be feasible in some areas if it negatively affects future hydraulic conditions (e.g., increases flooding) or limits habitat or potential uses of the waterway, such as navigation and recreation. However, combinations of removal followed by capping are common remedies, and such approaches can offset the effects related to hydraulic requirements.

The engineering basis for sediment isolation cap design is unique for each application and depends on site-specific conditions and project objectives. Several factors are considered in a cap design:

- Amount of erosion protection required to keep the cap in place
- Cap thickness required to prevent the activities of benthic organisms from mixing contaminated layers with cap material layers
- Cap thickness and permeability required to effectively reduce the migration of contaminants (flux) to the water column via advection and diffusion.

Other issues related to cap construction that are also relevant to screening effectiveness and implementability determinations include the availability of cap materials, stability of the underlying material, potential placement techniques, construction tolerances, short-term effects of cap placement on the aquatic environment, long-term monitoring and maintenance, any habitat enhancements provided by the cap, and any CWA habitat mitigation that may be required due to cap changes in elevations and substrate (discussed more in Appendix M, Attachment 1).

A one-dimensional (i.e., vertical) contaminant transport model is typically used to evaluate the long-term performance of an isolation sediment cap and its ability to reduce contaminant flux to the overlying water column. Contaminant transport through a cap is driven by advective and/or diffusive forces. While the amount of advection varies according to the presence (or lack) of groundwater upwelling, diffusion is an ever-present condition driven by concentration gradients. Where sufficient information is available, these models can be used to conservatively estimate the thickness and type of material (e.g., permeability and organic carbon content) that would effectively reduce the flux of contaminants from the underlying sediments (Palermo et al., 1998).

Another important consideration for isolation capping is the overall habitat provided by the cap. Caps can provide a means to create additional or more desirable habitats in a waterbody. In deeper areas, additional thickness can be added to the cap (beyond what is needed for the functional purposes described above) so that the cap surface is at a more biologically productive water depth. In addition, the substrate at the surface of the cap can also be selected to provide some desired type of habitat (e.g., spawning sands or gravels). However, cap surface substrate selection must be balanced with the need to provide erosion protection. In some areas, the desired habitat substrate and erosion substrate are similar and both functions can be achieved by one cap surface substrate (e.g., gravel). In other cases, if the cap is to perform its overall function to isolate contaminants, the erosion protection requirements outweigh habitat substrate requirements, and an erosion protection layer must be placed that provides lesser value as habitat. As noted above, in these cases, CWA habitat mitigation for surface substrate impacts may be needed and is discussed more in Appendix M (Attachment 1).

6.2.5.1 Effectiveness Evaluation

The primary effectiveness issue for capping is whether the contaminant and physical characteristics of the Site allow caps to sufficiently minimize dissolved flux of contaminants to surface sediments and surface water (the bioactive zones where exposure could occur). If the contaminant isolation is effective, capping is effective overall. Given that sufficiently robust erosion protection can be designed and maintained for almost any circumstance in a riverine system, the potential physical erosion of the cap and physical resuspension/transport of the underlying contaminated sediment is handled as an implementability issue in the next subsection.

As described above, a one-dimensional contaminant transport model was used to evaluate if an engineered sediment cap would be effective in reducing contaminant flux to the overlying water column. Specifically, the steady-state model of Lampert and Reible (2009) was used in the screening-level analysis. Reible’s steady-state model estimates the contaminant concentrations in the surficial (bioturbation) sediment layers of a cap once steady-state conditions are achieved in the cap. As the dissolved contaminants move upward through the cap, they are predicted to undergo biodegradation (for organic compounds) while at the same time partitioning onto the cap material. Bioturbation mixes the surface layer, further reducing surface concentrations. The model calculates the contaminant concentrations in the bioturbation layer as a balance between the flux from the underlying contaminant isolation layer, the flux leaving the bioturbation layer, and the benthic boundary layer in the overlying water column. The source code publicly available at http://www.ce.utexas.edu/reiblegroup/downloads.html and is widely used throughout the United States. This simple cap model or ones like it are typically employed for FS-level cap effectiveness evaluations (e.g., AECOM 2010 and Parsons et al. 2005).

For the purpose of the screening-level capping effectiveness analysis, the contaminants in Table 3.1-3 were evaluated. These contaminants were selected for this analysis as described in Section 3.1 and Appendix C.

The predicted concentration estimates from the cap modeling were compared at the following application points and using the following criteria, consistent with the LWG April 21, 2011 presentation of this approach and EPA's May 18, 2011 "Comments on LWG 4/21/2011 presentation of 'Remedial Technologies' for the Feasibility Study" (Appendix O; EPA 2011d):

- Predicted water column concentrations over the entire water column above the cap were compared to fish consumption water criteria to account for:
  - Fish moving vertically through the water column
  - Fish moving over large horizontal areas
  - People potentially consuming fish over large areas
- Predicted water column concentrations over the entire water column above the cap were compared to water MCLs to account for possible, but unlikely, drinking water withdrawal scenarios.
- Predicted surface water concentrations 1 cm above the cap isolation layer were compared to ecological chronic water criteria to account for epibenthic aquatic species that are relatively stationary. This point estimate provides a conservative screening given that potential population-level epibenthic effects and fish effects would only be expected to occur over wider horizontal spatial scales.
- Predicted average sediment contaminant concentrations in the top 10 cm of the cap isolation layer were compared to sediment RGs, where RGs were available for the IC list. This includes for the benthic risk pathway using the minimum Level 3 Endpoint SQVs from the FPM, which is used in the calculation of benthic MQs. Together, the RGs and SQVs are appropriate indicators of protectiveness for both bioaccumulation and benthic risk pathways for the ICs.

Figure 6.2-26 shows the locations for these comparison points, and Appendix Hc (Section 3) contains a summary of the water quality criteria as well as sediment RGs and SQVs used in the comparison. Details of the cap model inputs, cap modeling results, and sensitivity discussion are presented in Appendix Hc (Section 3).

> *Capping was determined to be a viable Site-wide technology in terms of contaminant isolation effectiveness for all SMAs.*

The screening-level analysis using conservative modeling assumptions indicates that a 1-foot thick layer of sand, as part of an overall engineered cap design including armor as necessary, would provide the appropriate contaminant isolation for all SMAs with some limited exceptions in portions of some SMAs. For these limited exceptions, further analysis indicated that these areas could easily be capped using:

- Alternative, slightly less conservative input assumptions for some parameters that are well within the uncertainties associated with the input value estimates that would be resolved in remedial design phase
- Small changes to the assumed cap materials, particularly with regard to OC content of the materials, that are well within, for example, naturally occurring OC content of suitable maintenance dredge sediments that could be used as a source of cap materials
- In a few very limited cases, active capping (described in more detail in Section 6.2.6) layers as an additional component to the cap.

Therefore, capping was determined to be a viable Site-wide technology in terms of contaminant isolation effectiveness for all SMAs.

6.2.5.2 Implementability Evaluation

As described above, a screening-level analysis was performed to determine the stable particle size for a cap armor layer to protect the cap from erosional forces such as wind- and vessel-generated wave action, river currents during extreme events, and propwash. The analysis was performed using the procedures and methods described in USACE (2006) and Maynord (1998). Appendix Hc (Section 4) presents the details of the cap armor analysis. The stable particles sizes range from sand-sized particles to riprap materials. Based on this analysis, the sediment caps can be designed to withstand erosional forces at the Site.

> *The placement of sediment caps within active navigation areas above current or likely future navigation and maintenance dredge depths would clearly be incompatible with Site uses.*

However, there are some Site use constraints that would limit cap placement in some areas. The placement of sediment caps within active navigation areas above current or likely future navigation and maintenance dredge depths would clearly be incompatible with Site uses. Placement of caps in areas below the likely maintenance depths could also create a potential for cap damage during maintenance dredging, unless sufficient depth safety factors were included.

Figure 6.2-27 shows the boundaries of the federal navigation channel (NC areas) and FMD areas within the Site. The current authorized federal navigation channel elevation for the Lower Willamette River is -43 feet CRD. There is the potential that future authorized depth of the channel could be an additional 5 feet below the current depth, or -48 feet CRD. An additional 3-foot advanced maintenance/overdredge allowance is typical for USACE maintenance dredging contracts based on the water depths where the dredging will occur and the accuracy of mechanical dredging equipment. In addition, the USACE recently required a 2-foot-thick operational buffer between the top of in situ caps and the bottom of future maintenance or navigation dredging within the Lower Duwamish River. The purpose of the buffer is “to minimize the risk of breaching remediation protective capping and exposure of contaminants while allowing the dredging to remain cost effective” (USACE 2010). This buffer zone could be non-contaminated material or simply a water buffer.

Given all these factors, the assumed total resulting clearance or vertical offset needed between the top of a cap and the current navigation depth is 10 feet. The individual components making up this depth as discussed above are shown in Figure 6.2-28, and equate to the top of a cap in the navigation channel being at elevation -53 feet CRD or deeper.

Many FMD areas are similar to the federal navigation channel in that the top of the sediment caps would need to be placed with a similar vertical offset from the navigation depth to protect the integrity of the cap, particularly where the FMD areas provide access for large ships between the navigation channel and a shoreline dock. In shallower FMD areas, the required elevations would not be as great as for the navigation channel, but a similar vertical offset between the FMD depth and the top of a cap would be needed (i.e., an approximately 5-foot offset is assumed for the draft FS).

Adding an assumed total cap thickness of 6 feet (including armor layers resistant to likely propwash forces in navigation areas consistent with capping technologies described above) to the 10-foot vertical offset results in a total depth required depth of 16 feet beyond the current navigation depths that would need to be dredged before placement of a cap could take place. Thus, any contaminants that would be capped after environmental dredging would need to be deeper than -59 feet CRD within NC areas and FMD areas with navigation depths equivalent to the NC. In FMD areas with shallower navigation depths contaminants would need to be 11 feet deeper than the navigation depth for each individual FMD area, per the assumption above of a 5-foot offset instead of the 10-foot offset for navigation channel areas). Contamination in NC and FMD areas does not generally exist at the Site deeper than these elevations.

There are a few localized SMAs where the contamination is deep enough such that environmental dredging to place a cap might be a cost-effective option for relatively small portions of the SMA within NC and FMD areas. The locations of cores with this depth of contamination or greater are shown in Figure 6.2-27 and include a few cores in SMAs 3, 6, 9U, 17S, and 25. Tables 6.2-8 and 6.2-9 detail the specific navigation channel river miles and FMD areas where environmental dredging and capping back may be feasible, using the largest overall SMA footprint and RALs (SMA F) and the various assumed navigation depths for each FMD area. Samples from SMA F are shown because this is the largest overall active remedy footprint and has the deepest depths of contamination per Section 5.10; therefore, it is most inclusive of potential dredge and cap back areas. Given the limited nature of these areas across the Site, environmental dredging and capping back in these areas was generally not included in the development of alternatives for the draft FS. However, this technology process option should remain available for SMA-specific designs, particularly given that future development plans or more information collected as part of remedial design could redefine or expand the areas suitable for this option.

For FMD areas that have navigation depths shallower than the -43 foot CRD value assumed for the navigation channel, the exact Site uses now and in the future that require these different maintenance depths are often less certain. Consequently, it is generally possible in these areas that institutional controls could be included in the remedy that allows either: 1) caps up to a new shallower FMD dredge depth, and/or 2) environmental dredging and capping back up to existing or new shallower FMD dredge depths.

The USACE (2010) also recommended a 10-foot horizontal buffer zone between the authorized federal channel and the edge of an in situ cap to minimize horizontal positioning errors that could cause cap breaching. This 10-foot-width is based on typical bucket size that would be expected to be used for navigation or maintenance dredging, and is assumed for draft FS purposes.

One other potential constraint to capping is working in and around structures such as docks and piers that exist in many SMAs. Capping can typically be achieved in these situations by casting material from nearby areas under the dock or structure in question. A typical approach for this is mechanical placement with a “telebelt,” which can be used to project material a considerable distance. This method relies on gravitational settling of cap materials in the water column. The cap materials may also be placed by hydraulic methods. That is, the cap materials can also be entrained in a water slurry and carried to the capping area wet, where they can be discharged by pipe into the water column at the water surface or at depth. Both of these methods would allow the cap to be placed in and around structures along the shoreline. As a result, capping in and around subSMAs with structures is considered implementable for the draft FS.

Also, caps placed on DSL submerged aquatic lands (most of the Site) will require obtaining land access and/or lease agreements from DSL. Thus, the logistics and costs of obtaining these agreements should be factored into implementation of capping. For draft FS purposes, purchase of DSL land is included in cost estimates for capping in these areas (Appendix K, Table 3).

Finally, when placing caps, there may be a need for an additional horizontal allowance to ensure coverage of the contaminated sediment area. Such allowances are usually determined in remedial design of specific SMAs, based on data density available at that time. However, a general additional horizontal placement allowance for caps was added to all cap area costs (see Appendix K, Section 4.3).

6.2.5.3 Conclusions

Based on the screening-level analysis, the engineered sediment cap technology was retained for detailed evaluation in all subSMAs except:

The remediation dredge and cap option should be carried through to remedial design for potential detailed evaluation in all Future Maintenance Dredge areas, as needed.

- Engineered sediment caps were screened out for NC areas due to implementability considerations
- Engineered sediment caps were screened out for the FMD areas that require navigation depths similar to the federal navigation channel (-40 CRD feet or greater) due to implementability considerations

Engineered sediment caps either as capping alone or as part of a dredge and cap option were retained for the remaining shallower FMD areas. However, given the design level and SMA-specific issues involved, environmental dredging and capping back was generally not included in the development of alternatives for the draft FS. Regardless of this draft FS-level screening, the remediation dredge and cap option should be carried through to remedial design for potential detailed evaluation in all FMD areas, as needed.

6.2.6 Active Capping Screening

A standard isolation cap, like those described in Section 6.2.5 above, is designed to reduce the flux of contaminants from underlying sediments to the water column, primarily through adsorption of contaminants onto the cap material. Reactive materials can be placed within the contaminant isolation layer of the cap (an “active” cap) to supplement this adsorption process or to provide some other physical/contaminant processes that reduce the mobility of the contaminants. Given the use of reactive materials, active capping represents one innovative form of in situ treatment. It is discussed here instead of Section 6.2.4, given that this form of treatment is integrated into the functions of a cap. There may be conditions where the in situ treatment discussed in Section 6.2.4 appears potentially effective, but may not be implementable due to some of the physical forces discussed previously (e.g., wave action or propwash forces). In these cases, it may be feasible to provide in situ treatment in some of these areas if it is integrated into a cap that provides stability of materials.

Use of reactive materials may also be warranted where evaluations of standard capping indicate that a sufficiently thick cap cannot be created to adequately reduce the flux of contaminants over time. As described in EPA (2005a), examples of innovative materials used in active caps include engineered clay aggregate materials (e.g., AquaBlok™), and reactive/adsorptive materials such as AC, apatite, coke, organoclay, zero-valent iron, and zeolite. Composite geotextile mats containing one or more of these materials (i.e., reactive core mats) are available commercially. These materials act on reducing contaminant flux in the following manner:

- Zero-valent iron products that dechlorinate some chlorinated compounds (such as chlorobenzenes); these may also be capable of precipitating other compounds
- Carbon, coke, or coal to increase the adsorptive properties in the sediment cap, thus reducing the flux of organic compounds
- Organoclays that increase adsorptive properties, particularly for low-soluble organics, NAPLs, and oils
- Activated alumina incorporated into the sediment cap to increase adsorption processes and enhance surface binding
- Additives such as Biosoil™ that provide nutrients to enhance degradation of certain organic compounds and may increase the adsorptive capacity of the sediment cap
- Additives such as Aquablok™, a mixture of gravel and bentonite that reduces permeability and advective transport
- Apatite phosphate to encourage adsorption and reaction of metals
- Natural organic materials to enhance adsorption of certain organic compounds and reduce contaminant flux.

Like standard engineered caps, an active cap may provide an acceptable surface sediment concentration at future steady-state conditions; in which case, the chemical isolation design life for the cap is theoretically infinite. In other cases, standard engineered or active caps may exceed an acceptable surface sediment concentration after a long time period (e.g., 100 years) and require maintenance or augmentation at that time. Caps with active layers tend be used in areas with higher underlying sediment concentrations of highly mobile contaminants, and thus are more likely to have finite design lives. For this screening evaluation, capping design lives in excess of 100 years were generally considered acceptable, which is consistent with design lives for many types of in-water engineered structures in general.

6.2.6.1 Effectiveness

Active caps would be effective in all areas where the engineered caps discussed in Section 6.2.5 are effective, because the active layer would simply augment the effectiveness of the standard cap. As discussed in Section 6.2.5, there were a few limited areas where standard engineered capping would potentially be less effective or its effectiveness was less certain. One option to increase the certainty in those locations is the addition of an active cap layer.

The use of active caps may be considered in areas of SMAs 9U and 14, where groundwater plumes exist. Upland groundwater source controls that will reduce the potential transport of contaminants in upland groundwater to the river are under design in both these SMAs. Once these controls are in place, natural attenuation of the remaining under-river plumes is expected. However, given this attenuation may take some time to occur, active capping could be considered in sediment remedial design as part of remedial options that consider capping or dredge/capping approaches in these SMAs. Active capping could also be considered in other situations, such as limited areas within the Site that have substantial levels of NAPL or similar materials, or simply elevated sediment contaminant concentrations combined with relatively high groundwater velocities. However, capping in groundwater plume areas likely represents one of the most relatively difficult capping applications within the Site. Thus, the effectiveness of active capping in these particular situations was evaluated to determine whether active capping can be considered generally effective throughout the Site.

A screening-level analysis was performed for three contaminants associated with groundwater plumes in SMAs 9U and 14: benzene, chlorobenzene, and vinyl chloride. These representative contaminants were used in the screening-level evaluation as they are mobile and at elevated concentrations in these areas. The screening evaluated whether an active cap would meet available ecological water quality values for these three contaminants at the bottom of the bioturbation zone of the cap at 100 years after cap construction. A comparison to available water quality toxicity values was conducted for these contaminants because no project sediment RGs or benthic SQVs exist for these contaminants. For these three contaminants, no promulgated chronic water quality criteria are available, and therefore, alternate comparative values described in Appendix C were used in this evaluation as described in Appendix Hc (Section 3).

Reible's Active Cap Layer Model (available at http://www.caee.utexas.edu/reiblegroup/downloads.html) was used to simulate the effects of an organoclay mat for contaminant isolation. An organoclay mat was selected as an example of a commonly applied and commercially available active layer capping technology that is representative of a variety of technologies listed above that have the effect of increasing the adsorptive capacity of the cap for organic compounds. The one-dimensional model was used to predict the time variable transport of these contaminants within the cap. The model simulates the fate and transport of contaminants (dissolved and sorbed phase) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and exchange with the overlying surface water. The Reible model is being used to support the design of sediment caps at numerous sites around the United States, including Onondaga Lake in Syracuse, New York (Parsons and Anchor QEA 2011). Details on the model structure and underlying theory/equations are provided in Lampert and Reible (2009). For this modeling evaluation, the groundwater velocity was reduced to a rate consistent with upland groundwater source controls being in place.

The screening-level results indicate that an active cap would meet the ecological chronic screening values for each contaminant at the bottom of the cap bioturbation layer at 100 years in SMAs 9U and 14 (Appendix Hc, Section 3). Specifically, a 1-inch organoclay mat or similar would be sufficient for vinyl chloride. Mats or series of mats ranging in thickness from 1 to 5 inches would be required in SMA 14 for chlorobenzene and 1 to 7 inches in SMA 9U for benzene. These thickness ranges reflect the ranges of contaminant concentrations across these SMAs with the upper end of thickness ranges being representative of the absolute maximum observed concentrations in these areas. For these more limited areas of maximum concentrations, 6 to 7 inches of organoclay or similar material may not be a cost-effective capping approach as compared to more refined or targeted capping approaches and materials. For example, zero valent iron dechlorination for chlorobenzene and AC and/or with gypsum (for sulfate reduction) or ferric iron for benzene are likely more effective and targeted technologies. Thus, it appears likely that more targeted active cap materials would provide reasonable cost-effective capping solutions for these contaminants. Evaluations of alternative active cap materials and more advanced modeling appropriate for remedial design would be needed to confirm an exact appropriate active cap design in these areas. However, for the purposes of the draft FS, the above evaluation shows that such capping designs can likely be achieved and, therefore, active capping is screened in as effective for the entire Site.

6.2.6.2 Implementability

Similar to the engineered cap, active capping was not retained for NC or FMD subSMAs that require navigation depths similar to the federal navigation channel. Active capping was retained for consideration in FMD areas with dredge depths less than NC areas. Also, in general active capping, like engineered capping, could also be considered as part of a dredge and cap option in some areas in remedial design, but this combined technology was not considered further in this draft FS. Finally, active capping may also be an implementable way to introduce treatment components into areas where in situ treatment may not be implementable, i.e., WZ areas or FMD areas, where wave or propwash forces are particularly strong thus making the implementability of in situ treatment by itself uncertain.

6.2.6.3 Conclusions

The overall conclusion is that active capping (e.g., including innovative materials such as carbon, organoclay, or other reagents) is effective in all SMAs. Where engineered capping is equally effective (most of the Site), this simpler technology is generally used in these areas as an assumption for this draft FS. However, active capping is retained for remedial design in all areas in case new information comes to light after the draft FS that requires application of this technology. For draft FS purposes, the process option of an organoclay reactive core mat was selected to be representative of the active capping technology for alternative development in Section 7. This technology is representative of a wide array of process options for increasing adsorption of organic contaminants. Other process options should be retained for further evaluation and use in remedial design of specific SMAs. To assist EPA in assessing the potential impact on costs of using other types of active layers or using active caps versus standard caps, unit costs for several active layer types are included in Appendix K (Table 9) for reference.

The overall conclusion is that active capping (e.g., including innovative materials such as carbon, organoclay, or other reagents) is effective in all SMAs. Other process options should be retained for further evaluation and use in remedial design of specific SMAs.

6.2.7 Removal Screening

Removal is a technology commonly employed on contaminated sediment remediation projects. For sediment sites, removal can be accomplished from the water via environmental dredging and from the land via excavation. There is a large array of process options available to accomplish removal.

There are several steps necessary to accomplish a complete removal scenario, and each step has several process options. Generally speaking, the steps are:

1. Excavation – physically removing material from the current location
2. Conveyance – moving material to an offloading facility
3. Offloading – transporting the material from the water to the land
4. Processing – preparing the material for transportation and disposal (e.g., dewatering, amendment, treatment, etc.)
5. Transportation and Disposal – moving the material to its final disposal location.

For some process options, these steps may be combined. For other process options, these steps may occur in an alternate sequence. This section considers the first three steps listed above for removal screening. The remaining two steps are considered in Sections 6.2.7 (dewatering), 6.2.8 (ex situ treatment), and 6.2.9 (disposal) below.

There are a variety of technologies applicable to each step of the removal process. Table 6.2-10 summarizes commonly available technologies used in the removal process for sediment cleanup projects (EPA 2005a) and expands upon the general technologies and process options summarized previously in Table 6.1-1.

In addition to the specific steps necessary to accomplish removal, there are a variety of best management practices (BMPs) to limit the release and loss of contaminants that are typically employed during removal. The types of BMPs that are appropriate can vary for different process options. BMPs are important to minimize potential environmental impacts during removal, and some BMPs may have site-specific limitations on their applicability. BMPs are discussed in greater detail later in this section.

Because of the array of process options available for removal and due to the complexity and variety of SMAs across the Site, it is not possible to screen in or out all process options for each SMA. Therefore, a locally commonly used set of removal process options was selected to represent the overall GRA of removal in the screening evaluation and alternatives development process. Where any effectiveness or implementability issues are identified for the GRA using the representative process options, the ability to overcome or minimize those issues with variations using other removal process options was considered and factored into the overall determination of removal as an effective or implementable GRA. Using this approach, screening evaluations of removal as a GRA is considered based on the Site use and physical conditions of subSMAs previously introduced.

While the draft FS necessarily assumes a representative set of process options for the general screening and alternative development procedures, this does not imply that other process options are screened out from future consideration during remedial design. Unless specifically noted otherwise, all process options discussed in this section would be considered potential options for use during remedial design.

While the draft FS necessarily assumes a representative set of process options for the general screening and alternative development procedures, this does not imply that other process options are screened out from future consideration during remedial design.

Based on a general understanding of locally available equipment and typical local practice for removal on sediment cleanup projects, mechanical excavation with barge conveyance and mechanical offloading were assumed to be the representative process options for conduct of the screening evaluation. For example, the last two environmental dredging projects conducted in Portland Harbor (Terminal 4 Phase 1 and Gasco Early Action) were accomplished via mechanical dredging and barge conveyance. It is important to note that the hydraulic dredging option could be either more or less expensive than the mechanical excavation process option, depending on SMA-specific characteristics, and may be determined to be a preferred option for some SMAs during remedial design. Because alternate technology/process options could be either less or more expensive than the draft FS selected option, the use of a consistent process option for all alternatives does not consistently bias cost estimates either higher or lower.

Numerous potential options for offloading sediment from barges to upland transport (e.g., trains or trucks) are available around or near the Site. The ideal offload site would be located on the water and have dock space and a sufficiently deep berth to accommodate one or two material barge(s). The ideal location would also include ready access to off-Site transportation links, and would have improvements such as paved surfaces and controlled drainage features (although pavement and drainage can typically be added or improved relatively cost-effectively). The ideal facility would also have sufficient acreage to accommodate stockpiling, material rehandling and sorting, debris separation, cost-effective dewatering, staging for load out, and water management. The actual location, layout, and size of the offloading site would typically be matched to the remedial contractor's production process (equipment, production rate, etc.), and there could be more than one location used for offloading during remedy implementation. The two projects mentioned above used offloading facilities along the Columbia River. The Site was also briefly reviewed to determine potential offloading locations and a number of potential locations that already have dock structures and potential access by truck or rail were noted including Vigor docks at the tip of Swan Island peninsula, the Arkema Site, and portions of the Terminal 4 and Terminal 2 area. The siting and design of an offloading facility is a remedial design issue. However, this brief survey indicated that there are no major implementability challenges likely to locating or creating such a facility.

The environmental dredging described and evaluated in this draft FS is focused on removal of sediment contamination as a result of CERCLA substances. The purpose of environmental dredging is to remove targeted sediments from specified areas and depth intervals to meet specific RALs or cleanup levels.

Dredging to remove sediments from the river is also commonly conducted for reasons other than contaminant removal, especially to maintain or obtain water depths and areas sufficient to accommodate commercial shipping vessels and their attendant fleet. This is referred to as 'navigation dredging' or 'maintenance dredging.' The purpose of maintenance dredging is to remove sediments to provide authorized depths within the defined boundaries of the navigation channel and adjacent berthing areas. The USACE is responsible for maintaining the federal navigation channel in Portland Harbor, and the Port of Portland is the state-designated local project sponsor that provides all lands, easements, and rights-of-way required for navigation dredging, which includes placement sites for dredged material. In addition, the Port of Portland and many private companies on the Willamette River operate shipping berths as part of the region's navigation infrastructure. The shipping berths typically require regular maintenance dredging in order to maintain the safe operating depth required for the vessels serving the region. In addition, as vessel sizes increase, berths may require deepening. Finally, new facilities are constructed from time to time and new berthing areas must be dredged.

Since the 40-foot channel improvement project in the 1960s, navigation maintenance dredging on the Willamette River federal navigation channel is typically required on a 3 to 5 year cycle, with amounts of dredged material varying between cycles and locations on the river. The total volume of maintenance dredging in the navigation channel between 1973 and 1995 was approximately 4.4 million cy equating to an average of about 200,000 cy per year. Thus, routine maintenance dredging is needed to maintain commercial shipping, which is a federally committed use of the river in Portland Harbor.

6.2.7.1 Effectiveness

Environmental dredging is a potentially effective remediation technology in most cases, as discussed in the EPA guidance (2005a). However, there is a large body of literature and project experience summarized in Patmont and Palermo 2007, USACE 2008a, and Bridges et al. 2010 that indicates dredge residuals can limit removal effectiveness, particularly when trying to achieve low concentrations relative to material concentrations.

The USACE has compiled a number of research documents in summary reports that describe specific issues related to residuals (USACE 2008b), and provide tools for estimating the potential for generating residuals during removal (USACE 2008a).

Residuals are categorized as either undisturbed residuals or generated residuals (USACE 2008b). Undisturbed residuals occur where sediments uncovered by removal cannot be physically removed for any of a number of reasons, such as:

- Sediment overlying bedrock or hardpan

- Sediment covering highly uneven surfaces
- Sediment located near piers, piling, or utilities that are left in place
- Presence of debris or boulders
- Incomplete understanding of the horizontal and vertical extents of material
- Inappropriate selection of removal elevation
- Inaccuracy in meeting design elevations
- Design constraints that intentionally do not target complete removal.

Generated residuals are those materials dislodged during removal and subsequently redeposited on the bottom of the waterbody. There are number of causes of generated residuals (USACE 2008b), which can potentially result in material redepositing within or adjacent to the removal footprint:

- Sediments dislodged by the dredge head but left behind due to dredge operation and/or equipment limitations
- Sediments dislodged during debris removal operations
- Attempting removal in difficult conditions (e.g. debris fields or hard bottom)
- Sediment that sloughs into the dredge cut from adjacent undredged areas or otherwise moves due to slope failure.

Past practices of "chasing" generated dredge residuals through multiple cleanup passes have often failed to meet project-specific action levels (USACE 2008b).

Generally speaking, understanding whether residuals are undisturbed or generated is important because each category of residuals could pose different challenges, and prediction methods are different. Undisturbed residuals might be amenable to a cleanup pass. Generated residuals may or may not trigger a need to actively manage these materials, depending on potentially unacceptable risk. Past practices of "chasing" generated residuals through multiple cleanup passes have often failed to meet project-specific action levels (USACE 2008b). Continued research is advocated to understand the contaminant fate and transport due to potential migration of residuals, the transient nature of exposure during and after removal actions are completed, and the relative efficacy of physical controls such as silt curtains (USACE 2008b).

Because of the limitations residuals place on removal effectiveness, the representative set of removal process options used in screening and alternative development incorporates specific actions to manage residuals. The effectiveness of potential residuals management strategies was evaluated according to the methods described in Appendix Ib, using Site-specific sediment data and assumptions about the likely range of process options that would be used to implement removal at the Site.

Residuals management strategies have been widely applied (and successful) at environmental dredging projects throughout the United States and thus will likely be very similar to the strategy anticipated to be developed during SMA-specific remedial designs.

Based on this evaluation, the single cleanup pass and suitable cover material was considered an appropriate strategy to carry forward for residuals management under the removal alternatives for draft FS purposes. The selected strategy is consistent with recently accepted strategies used at other sediment cleanup sites (e.g., Lower Fox River) and recognizes the limitations associated with attempting to manage residuals through multiple cleanup passes. It is important to note that this residuals-management strategy is only a draft FS-level assumption. Residuals management strategies similar to that outlined above have been widely applied (and successful) at environmental dredging projects throughout the United States and thus will likely be very similar to the strategy anticipated to be developed during SMA-specific remedial designs.

If additional residuals dredging is required in remedial design (i.e., dredging to the attainment of a RAL in the residuals or similar), the timing required for implementation for the remedy will be much longer, volumes will be much higher (potentially by 2.5 to 3 times the estimates presented in this draft FS), and costs will be significantly higher as well.

Thus, the representative removal process options for the draft FS include active residuals management using a single cleanup pass, after removal to the neatline, followed by placement of a suitable cover layer (e.g., sand). (Note that post-dredge cover is similar to EMNR in concept, as described above, and is not the same as capping. Unlike capping, cover is not intended to completely isolate the underlying sediments or residuals.) If an approach including additional residuals dredging is required in remedial design (i.e., dredging to the attainment of a RAL in the residuals or similar), the timing required for implementation for the remedy will be much longer, volumes will be much higher (potentially by 2.5 to 3 times the estimates presented in this draft FS), and costs will be significantly higher as well.

Based on the above, removal (as represented by the process options of mechanical dredging, residual management, and barge conveyance) was determined to be an effective remedial technology for all SMAs.

6.2.7.2 Implementability

Removal is implementable where access to sediments can be reasonably achieved, particularly in and around robust structures, and where stable slopes can be maintained. Each of these issues is discussed below.

6.2.7.2.1 Structure/Access Issues

There are a number of situations where more robust structures represent a significant access barrier to removal. For example, heavy docks with closely spaced piles that support large loads typically present implementability challenges for removal due to limited access and the fact that many structures are designed assuming that the existing soils will provide lateral support to the foundation system. Figure 6.2-29 shows the various structure access issues. The subSMAs at the Site with structures of this type were defined in Section 5.4 as follows:

- Designated "SS" – Areas located beneath structures including a 5-foot offset from the structure face. The offset is based on the average depth of contamination across the Site and is assumed to minimize environmental dredging-related impacts to structures.
- Designated "SN" – Areas surrounded by in-water or upland obstructions.
- Designated "SU" – Areas surrounded by in-water structures with shoreline characteristics that appear to be accessible by land-based construction equipment.
- Designated "SL" – These areas are partially surrounded by in-water structures, such that in-water access is restricted to one narrow entrance and exit point.

There are two general process options that are typically considered for removal under such structures: 1) small dredge systems such as diver assisted suction dredges; and 2) removal of the structure followed by sediment removal and possible replacement of the structure.

The first option does not directly address the issue of structural stability. Due to the range of structures (size, location, current use, and condition) and the size and complexity of the Site, an engineering evaluation of the potential effect of removal on each structure's stability is not feasible at the draft FS level. Further, such small scale environmental dredging operations have very low production rates and may still encounter difficulties in effectively removing all material from under complex dock structures with numerous pilings and other structural elements. Thus, the duration of such operations is very long and the costs tend to be very high per unit of material removed.

The second option addresses the issues of both structural stability and access. Once the structure is removed, more conventional removal process options can be used and would likely be nearly as effective as open water environmental dredging. However, the structure removal and possible replacement process adds significant logistics and duration, as well as cost, to the removal operation. For example, typical overwater structure demolition, dredging, and reconstruction costs, not including design work, were approximately estimated as follows:

The total unit area cost for removing a structure, environmental dredging, and then replacing that structure ranges from $300 to $550/foot^2. In comparison, capping under docks, as described in previous sections, is estimated to cost approximately $15/foot^2.

- Typical overwater demolition costs
  - Engineer's estimates $40 to $45/foot^2 (unpublished data)

   - Pacific Northwest Bid Tabs \$13 to \$18/foot^2
- Typical environmental dredging costs
   - Dredge and disposal 5 feet deep = \$40 to \$68/foot^2
   - Dredge and disposal 1 foot deep = \$78 to \$133/foot^2
- Typical overwater construction costs
   - Engineer's estimates \$275 to \$350/foot^2 (unpublished data)
   - RSMeans (2010) municipal wooden pier[17] \$210/foot^2

Using these values, the total unit area cost for the complete operation of removing a structure, environmental dredging, and then replacing that structure ranges from \$300 to \$550/foot^2. In comparison, capping under docks, as described in previous sections, is estimated to cost approximately \$15/foot^2, orders of magnitude difference. Using the cost factors in Appendix K (Table 7), structural removal and replacement would be expected to increase cleanup costs by a factor of 2 to 5 times across various alternatives.

For RI/FS purposes, sediment data underneath most structures at the Site were not collected. Rather, sediment data, if needed, would be collected during SMA-specific remedial design and remedial action. As such, any assumption of sediment remediation under structures is based on extrapolation from nearby data that are not under structures.

Thus, based on the above issues of difficulties of effectively removing material under existing robust structures, potential structural impacts due to removal, increased remediation duration for such operations, uncertainties about the presence of contamination under docks, and the cost magnitudes of removal and replacement of docks as compared to potentially more effective capping technologies, a simplifying assumption was made that removal beneath heavy docks and immediately adjacent to active large structures will not be included in the comprehensive alternatives for the draft FS. Appropriate offsets are assumed that are considered protective of these types of structures for removal based alternatives, as discussed in Section 5.10.

As noted above, this screening is conducted only for the purposes of the draft FS, and removal under structures and docks either by small-scale environmental dredging or removal and possible replacement of structures can continue to be considered for remedial design on an SMA-specific basis, where appropriate. In some cases, detailed geotechnical and structural analysis may be necessary to evaluate removal adjacent to or under structures during remedial design. In other cases, some less functional structures may be amenable to removal as an integrated component of the remedial design, although it is not possible to make such decisions Site-wide at a draft FS-level evaluation. To assist EPA in assessing the potential added costs to requiring removal under structures as part of Proposed Plan development, unit costs for removal and replacement of structures

[17] Data from 2010 RSMeans Heavy Construction item 06 13 33.52 0020, adjusted to Portland, Oregon using a location cost factor of 99.2 percent.

are included in Appendix K (Table 7) for reference such that this cost can be added to any specific SMA or alternative desired.

While large and access-limiting structures impose constraints on removal, certain “light” structures (e.g., floating docks) are assumed to be movable, and certain small structures (e.g. catwalks, isolated small dolphins) are assumed to be replaceable to accommodate removal in this draft FS. In these cases, removal was retained as implementable for the draft FS and these structures are noted in Figure 5.4-1.

Also, another type of access issue can be created if the depth of impacted sediments to be removed is very deep. As noted in Section 5.10, in some cases the DOI is 30 feet or even greater. Although these deep DOIs are used for volume determinations in the draft FS, it may be technically infeasible in many cases to remove material to these depths, particularly along the shoreline (e.g., due to structure instability created and/or slope stability issues, which is discussed more below).

In summary, for the draft FS:

- Removal under light structures identified in Figure 5.4-1, such as catwalks and floating docks, is implementable
- Removal in subSMAs type SL and SU behind limited access structures is implementable using either smaller water-based equipment or land-based equipment
- Removal in subSMAs type SS under robust structures is not implementable
- Removal in subSMA type SN behind structures with no reasonable access is not implementable.

6.2.7.2.2 Slope Stability Issues

Removal operations conducted at the toe of slopes or on slopes themselves have the potential to destabilize the slope or damage adjacent structures if the removal is not properly engineered to consider slope stability. Slope stability is a function of the depth of the removal, the design side slope, the geotechnical strength characteristics of the slope material, and any loads (current or future) at the top of the slope. The selection of a stable slope angle during design should consider all of these factors, which can vary widely across a given site. Given the complexity of slope stability issues, it is not practical to consider detailed slope geometry and to design area-specific side slopes for purposes of the draft FS.

It is possible to reasonably simplify the issue of slope stability by using draft FS-level assumptions about potential stable slope angles based on prior project experience and knowledge of typical regional geotechnical engineering strength characteristics of Site soils. While this type of simplification is reasonable for development of the draft FS, more detailed consideration of slope stability will be necessary during remedial design as the factors described above become more clearly defined.

Bank soils along the Lower Willamette River are expected to vary in gradation and relative density. Typical friction angles for naturally deposited loose to medium dense (relative density 25 to 50 percent) silt and sand materials range from 28 to 34 degrees (Department of Defense 2005). Engineered armored slopes (gravel, rock, and riprap) have even higher friction angles. Typical dredge cut side slopes in the Pacific Northwest are on the order of 3H:1V, which is a slope angle of approximately 18 degrees. Thus, for typical riverbank soils, the infinite slope factor of safety (Lambe and Whitman 1969) is often acceptable if a planning-level dredge cut side slope of 3H:1V is assumed.

To maintain a stable slope along the banks, the dredge cut side slope is typically extended from the limit of environmental dredging on the top of the bank down to the dredge cut elevation. If a steeper cut could be made from the top of bank, more material could be removed than with a flatter side slope. As a conservative draft FS-level assumption, a steeper 2H:1V side slope was assumed for volume estimates, although it is expected that this side slope will be refined during remedial design and in some areas a flatter slope might be necessary to maintain shoreline stability. This concept is illustrated in Figure 5.10-3.

6.2.7.3 Removal Best Management Practices (BMPs)

As previously described, short-term water quality impacts and residuals generation can be associated with contaminated sediment removal construction activities. These construction impacts can be mitigated to some degree using operational and barrier control BMPs. This subsection provides a summary review of a wide array of water quality and dredge residual BMPs and discusses the screening of these removal process options for draft FS purposes.

Operational controls impose limitations on the operation of the equipment being used for removal activities. For environmental mechanical dredging, the representative process option assumed for this draft FS, typical operational control BMPs that usually reduce resuspension and loss of contaminated sediments include the following:

- Requiring a debris sweep prior to dredging in known debris areas (debris caught in dredging equipment can cause additional resuspension and release of contaminated sediments.)
- Properly selecting the dredge bucket for site conditions (i.e., soft sediment versus debris and/or hard digging)
- Minimizing the potential for slope failures by maintaining stable side slopes during dredging (e.g., shallow top-to-bottom cuts)
- Slowing the rate of dredge bucket descent and retrieval (increasing dredge cycle time)
- Limiting operations during relatively high water velocity conditions (turbulence in the vicinity of the dredge bucket during high-flow conditions can cause additional resuspension and release of contaminated sediments)

- Preventing “sweeping” or leveling by pushing bottom sediments around with dredge equipment to achieve required elevations
- Preventing interim stockpiling of dredge material on the river bottom
- Preventing the overfilling of conventional clamshell (i.e., “open”) buckets
- Requiring the slow release of excess bucket water at the water surface
- Preventing over-filling of barges to minimize spillage from barges
- Separating sediment solids from barge return water through filtration.

Additional and different operational BMPs are applicable to environmental hydraulic dredging operations (USACE 2008a). These BMPs are not reviewed in detail here but would be considered for any hydraulic dredging operations evaluated in remedial design.

While the effectiveness of operational controls in improving water quality can be difficult to assess (USACE 2008a, 2008b), several projects have demonstrated the effectiveness of specific operational controls (e.g., barge effluent filtration; Port of Seattle 2005; minimizing the potential for slope failures by maintaining stable side slopes; Foth and Van Dyke et al. 2001; general operational controls, Terminal 4 Phase 1 Removal Action; Port of Portland 2009, Table 6.2-11). In particular, the Phase 1 Removal Action at Terminal 4 used a series of operational controls that were modified in response to water quality monitoring results, effectively controlling turbidity without the use of engineered barrier controls. However, operational controls reduce production rates and increase the overall project duration. Thus the advantages of applying operational controls need to be considered in light of this reduction in efficiency and appropriately balanced (USACE 2008a).

Engineered barrier controls at environmental dredging and capping sites typically include two different technologies (USACE 2008a):

- Silt curtains and silt screens
- Rigid containment (e.g., sheetpiles or cofferdams)

Each of these engineered barrier controls are discussed below. A summary of project experience related to the use of operational and engineered controls, the pros and cons of the various options, and specific issues to be considered for operational and engineered controls is provided in Table 6.2-11.

Silt Curtains/Screens

Silt curtains and screens have proven effective in reducing surface water turbidity in relatively quiescent environments and are a common BMP used to retain suspended sediment plumes at environmental dredging sites located in low-energy environments (Francingues and Palermo 2005). They can also be effective at isolating the work zone and diverting some of the river flow around the work zone. However, their application in moderate- or high-energy areas (which are common at the Site) can be complicated, often requiring frequent repair and maintenance (see references in Table 6.2-11). In addition, water passes below or around fabric curtains because they are not typically sealed with the bottom, and water also discharges around the curtains when they are opened to allow the necessary passage of work equipment. As discussed in Bridges et al. (2010), based on a review of the available data, there is considerable uncertainty as to whether silt curtains are effective in retaining contaminants within the curtain footprint, and there are also concerns that contaminants can migrate through the bottom of the curtain anchor system while the curtain is in place and/or upon curtain removal. Releases of this type have been observed at specific sites noted in Table 6.2-11.

A relatively detailed evaluation of the effectiveness of silt curtains for environmental dredging was recently performed by Alcoa (under EPA oversight) within a relatively low-energy environment of the Lower Grasse River (Connolly et al. 2007). Water quality monitoring performed both inside and outside of the silt curtains revealed that the curtains had little effect in controlling downstream dredging-related releases of total or dissolved PCB concentrations. Moreover, concentrated flow conditions beneath the silt curtains resulted in localized scour and resuspension, which periodically increased downstream contaminant transport. These conditions, which have also been observed at other environmental dredging projects (see specific references in Table 6.2-11), limit the ability of the curtain to effectively contain dredging-related contaminant releases to the work area (EPA 2005a).

The use of silt curtains and screens have significantly reduced overall dredge production rates, and typically lead to significantly extended schedules to complete remediation, consequently increasing the impact from the dredging operation.

Implementability concerns have also been documented on several projects, including the Lower Grasse River (Connolly et al. 2007), the San Jacinto River (Anchor QEA 2011b), and other environmental dredging projects that deployed silt curtains (EPA 2005a; also see references in Table 6.2-11). For example, short-term pressure waves and flow increases in the Lower Grasse River routinely damaged the silt curtains. These issues are exacerbated in deeper water, which requires a deeper curtain that can act as a bigger "sail," which can also be difficult to effectively anchor. The displaced curtains can also become a hazard to navigation and/or block access to the work area, and the curtains often need to be frequently repositioned or reanchored. Generally, the use of silt curtains and screens have significantly reduced overall dredge production rates (e.g., see Connolly et al. 2007), and typically lead to significantly extended schedules to complete remediation, consequently increasing the impact from the dredging operation.

Rigid Containment

As discussed in Bridges et al. (2010), rigid containment barriers (e.g., sheetpiles or cofferdams) are occasionally used to contain resuspension during environmental dredging operations, particularly in high-energy environments, although with different technological limitations. While several case studies have demonstrated reductions of dredging-related releases outside of the sheetpile-enclosed area (relative to releases that would have occurred without containment), release of contaminants beyond the barrier still occurs, as in practice it has not been possible to place a water-tight barrier. For example, during the Hudson River Phase 1 environmental dredging project, roughly 1 percent of the mass of PCBs dredged within sheetpile enclosure areas was released through the barrier, largely due to leakage through ports at the interlocks (Anchor QEA and Arcadis 2010). The hard bottom, variable texture, and/or debris conditions that occur at the Portland Harbor Site, along with dynamic river forces, pose particular technological challenges that could lead to separation of the barrier interlocks, which would contribute to releases through the barrier. Necessary barrier design features such as pressure equalization ports also allow transport of dredging-related releases beyond the barrier.

In high-energy environments, the use of rigid containment barriers can also have unintended and undesirable environmental consequences. For example, a sheetpile enclosure placed in a mid- to high-energy reach of the Tittabawassee River led to local scour of sediments outside of the sheetpile wall, in some cases to depths of over 12 feet (Konechne et al. 2010). In addition to potential water and sediment quality impacts related to such scour, the loss of lateral support at the toe of the sheetpile will increase the unbalanced load on the wall and could cause it to fail. These types of unintended and undesirable consequences can be difficult to predict and can occur at any time after installation of the containment structure because they result from localized flow conditions that are transient in nature. In the case of the Tittabawassee River, the scour was not noted until after the removal was completed and post-construction bathymetry was evaluated.

On the Hudson River Phase 1 project, one of the unintended and undesirable consequences of sheetpile containment was the concentration of dissolved-phase PCBs in the water column behind the sheetpile wall and exceedance of air quality criteria in the work area (Anchor QEA and Arcadis 2010).

Removal of rigid barriers can also have unintended and undesirable consequences. Adhered sediment can be resuspended into the water column during pile pulling, resulting in resuspension of deeply buried contaminants. Recontamination of adjacent sediment cap areas occurred during removal of a wall at Colman Dock in Seattle, due to mobilization and release of deeply buried PAHs in the area (Ecology 1995).

Specific to the Lower Willamette River, technical evaluations completed as part of the Gasco Early Action project identified that sheetpiles: 1) would lead to penetration of contamination along the wall configuration to much deeper depths and leave stranded contamination following removal of the sheetpiles; 2) would greatly increase the construction durations and the duration of construction impacts; 3) would not lead to the complete containment of NAPL and dissolved contaminant releases from the containment area; 4) would temporarily impound a large volume of water in which construction activities could create substantially concentrated contaminant loads, which could cause adverse impacts upon release when containment is removed; and 5) would potentially create significant health and safety risks for construction workers (Anchor 2005b).

Finally, there are technical limitations related to the implementation of a standard sheetpile wall as rigid containment. Based on a contractor review of potential sheetpile use at the Gasco site, a maximum practical depth of water for sheetpiles at the Site is approximately 35 to 40 feet. Beyond that depth, the sheets cannot be embedded sufficiently to resist the lateral forces imposed by the water pressure. In areas deeper than 35 to 40 feet, a cellular cofferdam would need to be constructed for rigid containment. Cellular cofferdams have considerable implementability issues including the time required for construction and the hazard to navigation they would create once in place. Because of the construction duration, it is not practical to construct and remove a cellular cofferdam structure to accommodate seasonal work windows.

One potential advantage of rigid barriers such as sheetpile walls at this Site that EPA has indicated (June 29, 2011 resolutions to EPA April 27, 2011 Comments on the FS Tools memoranda; see Appendix O) is that they might allow extension of construction windows and allow removal to occur year-round once the barriers are in place. However, it is unclear whether the level of construction impacts outside construction windows associated with that approach would be allowed. Under such an approach, it is assumed that the installation and removal of barriers, at least, would still have to take place during allowed construction windows. Any potential advantage of using rigid containment needs to be considered in light of the increased project duration as well as increased potential for impacts related to floodplains, scour, and other unintended consequences previously discussed. In addition, the installation of sheetpile containment would increase the removal focused alternative costs by 15 to 20 percent per the cost factors presented in Appendix K (Table 8).

Environmental Dredging Releases and Water Quality Impacts

Table 6.2-12 provides a summary of case studies regarding documented releases related to contaminated sediment dredging projects, mostly focused on PCBs. The release rates observed across these studies are generally in the range of 2 to 4 percent, with most of the releases being in the bioavailable dissolved form. As demonstrated by these case studies, there are no documented differences in these release rates between projects that use barrier controls and those that do not. Although all of the studies involving barrier controls used silt curtains or similar barriers, it is not expected that this predominantly dissolved phase release can be effectively contained by any technology, even sheetpile walls, which like silt curtains, do not provide a watertight barrier (as discussed above). Because of the dissolved nature of these releases, it would appear unlikely that resource agencies (e.g., NMFS) would allow removal outside normal construction windows with rigid barriers such as sheetpile walls in place as hypothesized above.

In order to evaluate the potential need to include the barrier control process option as a component of the removal alternative, preliminary dredge water quality evaluations of an unrestricted environmental dredging scenario were performed for the draft FS as described in Appendix Ia. Limited access environmental dredging and/or structure removal operations are expected to result in similar water quality and sediment residuals conditions. Based on the evaluation described in Appendix Ia, exceedances of acute water quality criteria beyond a distance of 100 meters downstream of dredging operations (per EPA's December 2009 FS comments; EPA 2009c; Appendix O) are not anticipated across the majority of the Site, with some relatively localized exceptions for specific SMAs. This indicates that there is likely little water quality benefit from deploying barrier controls, relative to their disproportionate impacts on implementability, schedule, and cost. Thus, barrier controls were not retained as a component of the draft FS removal alternatives. Mitigation of potential water quality impacts associated with removal is included through operational control BMPs, which are accounted for in cost development through adjustment of production rates.

Based on the documented issues with effectiveness and implementability of rigid containment, and the limited documented benefit associated with such controls, consideration of rigid containment as a removal BMP is generally not warranted for remedial design. Consideration of silt curtains during remedial design may be appropriate in limited application; however, as previously stated, any potential advantage needs to be considered in light of the increased potential for impacts related to floodplains, scour, and other unintended consequences previously discussed. As requested by EPA, to assist in assessing the potential added costs to requiring silt curtains or sheetpile walls as part of Proposed Plan development, approximate unit costs for adding silt curtains or sheetpile walls to removal in SMAs shoreward of the navigation channel (where navigation and deep water implementability issues are less likely) are included in Appendix K (Table 8).

Based on the documented issues with effectiveness and implementability of rigid containment, and the limited documented benefit associated with such controls, consideration of rigid containment as a Removal BMP is generally not warranted for remedial design.

6.2.7.4 Dewatering

After removal, dredged sediment may be managed in a number of ways as discussed above. Prior to re-handling, transport, further ex situ treatment, or disposal, the dredged sediment may require dewatering to reduce the sediment water content. Dewatering is a form of ex situ treatment because it reduces the volume and mobility of contaminants. Dewatering technologies are commonly used to reduce the amount of water in dredged sediment and to prepare the sediment for on-Site consolidation, or upland transport and off-Site disposal. Further, the dewatering effluent may need to be treated before it can be disposed of properly or discharged back to receiving water, and this represents another important form of ex situ treatment. Dewatering is discussed here instead of in the ex situ treatment section (Section 6.2.8) because of its common application in environmental dredging projects. Several factors must be considered when selecting an appropriate dewatering treatment technology including physical characteristics of the sediment, selected dredging method, and the required moisture content of the material to allow for the next re-handling, treatment, transport, or disposal steps in the process.

Three categories of dewatering that are regularly implemented include passive dewatering, mechanical dewatering, and reagent enhanced dewatering/stabilizing methods. The following sections discuss the effectiveness and implementability of various dewatering process options applicable to the Site.

6.2.7.4.1 Passive Dewatering

Passive dewatering (also referred to as gravity dewatering) is facilitated through natural evaporation, consolidation, and drainage of sediment porewater to reduce the dredged sediment water content. Passive dewatering is usually applied to mechanical dredging process options when space permits. Passive dewatering is most often facilitated through the use of an onshore temporary holding facility such as a dewatering lagoon or temporary settling basin. In-barge settling and subsequent decanting can also be an effective passive dewatering method and can reduce the overall time needed for onshore passive dewatering operations. Passive dewatering techniques can also be applied to sediment that has been hydraulically dredged where the resulting slurry is pumped into a consolidation site and the sediment slurry is allowed to settle, clarify, and dewater by gravity after the site has reached capacity. Water generated during the dewatering process is typically discharged to receiving waters directly, or after some level of treatment, or may be captured and transported to an off-Site treatment and discharge location. Normal passive dewatering typically requires little or no treatability testing, although characteristics of the sediment such as grain size, plasticity, settling characteristics and NAPL content are typically considered to determine specific dewatering methods, to size the dewatering area, and to estimate the timeframe required for implementation.

Passive dewatering is generally effective and capable of handling variable process flow rates. Passive dewatering is fairly simple but this method can require significant amounts of space (depending on the volume of material processed and the settling characteristics of the sediment) and time for significant water content reduction. Passive dewatering is a widely implemented dewatering technology for mechanically dredged sediments. It is also amenable to hydraulic dredging with placement into a settling basin or with the use of geotextile tubes[18] to confine slurry and sediment during passive dewatering. Hydraulic dredge sediment dewatering with geotextile tubes has been implemented at several sites but typically requires project-specific bench-scale evaluations during remedial design to confirm its compatibility with Site sediments and to properly select and size the geotextile tubes.

Depending on the desired moisture content of the sediment, the subsequent processing or handling steps, the volume of material to be dewatered, available space, and the ability to effectively manage the dewatering effluent, passive dewatering can be a highly

[18] A geotextile tube is a fabric enclosure that can be used to contain hydraulic dredge slurry and facilitate dewatering. The fabric is typically a woven geotextile that is selected so that the filtering characteristics of the textile allow discharge of relatively non-turbid effluent from the tube during dewatering. Containment by the tube imposes lateral stress on the dredge slurry, which facilitates more rapid dewatering of the dredge solids than would otherwise occur under passive (gravity) settling conditions.

implementable dewatering technology option. Passive barge dewatering was retained as a representative passive dewatering process option for inclusion in the development of alternatives. Other passive dewatering options should be retained for consideration in remedial design of specific SMAs.

6.2.7.4.2 Mechanical Dewatering

Mechanical dewatering involves the use of equipment such as centrifuges, hydrocyclones, belt presses, or plate-and-frame filter presses to separate coarse materials, or squeeze, press, or otherwise draw out water from sediment pore spaces. Mechanical dewatering is typically used in combination with hydraulic dredging to reduce the water content of the dredge slurry prior to beneficial reuse (e.g., sands retained from particle separation methods), ex situ treatment (e.g., thermal), and/or disposal of the dewatered sediment. Mechanical dewatering may also be used in combination with mechanical dredging if the dredge material is hydraulically reslurried from the barge. Sufficient onshore space is needed to accommodate the selected dewatering equipment, but this space is usually less than required for passive dewatering. A mechanical dewatering treatment train usually includes treating the dewater prior to discharge.

The mechanical dewatering treatment train typically includes screening to remove materials such as debris, rocks, and coarse gravel. If appropriate, polymers may be added for thickening prior to dewatering. These steps result in a dewatered cake that achieves project-specific volume and weight reduction goals of the dredged sediment. The mechanical dewatering process can be scaled to handle large volumes of sediment, but requires operator attention, consistent flow rates, and consistent sediment feed quality.

Mechanical dewatering is generally an effective technology for both hydraulic and mechanical dredging and has been widely implemented for a range of sediment types and sediment end uses (e.g., beneficial reuse and upland disposal) and is likely the most effective method of achieving moisture content reduction over shorter timeframes than passive dewatering. Bench-scale tests are often performed during remedial design to develop the specific process design, select equipment, and to select polymer additives if appropriate.

6.2.7.4.3 Reagent Additive Dewatering

Reagent additive dewatering is an innovative ex situ treatment method in the category of stabilization/solidification (S/S) methods, which are discussed along with other categories of ex situ treatment in Section 6.2.8. This technology does not remove water in the sense that passive and mechanical dewatering do; rather, reagent additive dewatering binds the water within the sediment matrix, increasing the mass of sediment relative to other dewatering technologies through both the added weight of the reagent and the added weight of the bound water. This added mass results in higher costs for landfill disposal compared to dewatering technologies that remove water. S/S treatment is when cementatious, pozzolanic, or adsorptive materials are blended into the sediment to dewater the material via hydration caused by chemical reaction, or by adsorption. This dewatering method can provide three types of treatment benefits: dewatering of dredged sediment, immobilization of leachable contaminants (typically metals contamination), and/or enhancement of geotechnical properties. For situations where dewatering is the single goal, the most cost-effective, available and effective reagent or absorptive additive is used, which depending on site conditions and economics could include quicklime, Portland cement, fly ash, diatomaceous earth, or sawdust, among others. Reagent mixtures can be optimized to provide enhanced strength or leachate retardation to meet specific project requirements.

Dewatering by the addition of reagents is effective and has similar or smaller space and operational requirements as mechanical dewatering. In some cases, reagent addition and mixing can be conducted as part of the dredge material transport and rehandling process, either on the barge or as dredge material is loaded into trucks or rail cars. In other cases it can be added and mixed after offloading to the upland staging area. Also reagent addition may be used in combination with other forms of dewatering (e.g., filter press) and ex situ treatment. Bench-scale testing is often necessary to determine the optimum reagent mixture prior to construction. However, case study information is available from other projects on the types of reagents used for sediments of various water contents, and this information is sufficient to determine the general effectiveness and implementability of this technology for this draft FS.

The reagent addition to dewater sediments has been successfully demonstrated. For example, the Gasco Early Action used in-barge application and mixing of Portland cement as well as diatomaceous earth at the transload facility as a final dewatering "polishing" step. This approach required no extra upland treatment space or major changes to the transport and transload steps that would have otherwise been used.

Like other elements of the removal process, a wide range of dewatering process options are likely feasible at the Site. Thus, for draft FS purposes, reagent additive dewatering has been selected as a representative process option, along with passive barge dewatering. Specifically, the addition of diatomaceous earth is included in all alternatives involving removal of sediments as described more in Section 7.3.7. This process option was selected because, in comparison to other process options, it can have smaller space and logistical requirements, can be equally cost-effective in many cases, and is a proven technology within Portland Harbor. As with other removal process options that are selected throughout this section to be representative of the overall removal option for the draft FS, this dewater process option selection is not intended to limit or screen out use or further evaluation of other feasible dewater process options in SMA-specific remedial design.

6.2.7.5 Removal Conclusions

The removal and associated BMP and dewatering technologies discussed in this section have all been well demonstrated to be effective and implementable for a range of site conditions. As discussed above, many of the technologies discussed are applicable to the Site, but because of the wide array of potential technologies and process options, a few representative removal and associated process options have been selected for use in the development of detailed alternatives for the draft FS. This is a draft FS selection process only and is not intended to limit or screen out use or further evaluation of other feasible removal process options in SMA-specific remedial design.

For the purpose of developing remedial alternatives in the draft FS the following process options are used in Section 7:

- Removal:
  - Mechanical excavation with barge conveyance and mechanical offloading (either at a transload facility or an in-water CDF, see Section 6.2.9) is the assumed removal process option for the draft FS.
  - Hydraulic dredging or land-based type excavation equipment may be determined to be a preferred process option for specific SMAs or subSMAs in remedial design.
  - Removal under robust structures is generally not included in the development of alternatives for the draft FS, but is retained for further evaluation in remedial design of specific SMAs. Cost factors for demolition and replacement of structures for specific SMAs are provided in Appendix K (Table 7). Removal under "light" structures is included in the draft FS.
- Residuals management:
  - A cleanup pass and post-dredge cover placement are considered an appropriate representative strategy to address residuals generated from the removal.
  - Other potential process options (e.g., additional dredge passes) are retained for further evaluation in remedial design of specific SMAs.
- BMPs:
  - Operational BMPs apply to all removal options and are demonstrated to be effective at mitigating water quality impacts; therefore, they are included in all draft FS alternatives involving removal.
  - Barrier controls (e.g., silt curtains and rigid barriers) are not included in the draft FS alternatives development but are retained for further evaluation as appropriate in remedial design of specific SMAs, subject to consideration of the potential consequences of their use during remedial action. Cost factors for the addition of barrier controls to specific SMAs are included in Appendix K (Table 8).
- Dewatering:
  - Reagent dewatering (i.e., the use of diatomaceous earth) was included in the draft FS alternative development as a representative dewatering process option. Other reagents discussed above will be retained for consideration during the remedial design of specific SMAs.

- In-barge dewatering was included in draft FS alternative development as a representative dewatering option that is assumed to take place to some degree during barge filling with all alternatives involving removal.
- Mechanical dewatering and other passive dewatering process options were not generally included in the development of alternatives for the draft FS. However, the wide range of dewatering process options is retained for consideration during remedial design of specific SMAs.

6.2.8 Ex Situ Treatment Screening

The process to identify and screen ex situ treatment technologies began with the preparation of the Treatability Study Technical Memorandum (Anchor 2007). The document was prepared to survey all technologies typically considered in sediment remediation FSs and determined whether or not pre-FS bench- or pilot-scale studies would be necessary to evaluate technology effectiveness. The memorandum determined and EPA agreed that no bench- or pilot-scale treatment studies were needed to complete the draft FS (see EPA's February 15, 2008 comments on the Treatability Study Technical Memorandum; Appendix O). This document was followed by an additional screening step presented in *Draft Treatment Technology Screening Tables* dated June 5, 2009 (Anchor QEA 2009a). Since preparation of those documents, additional screening has been performed to refine the technology evaluation based on any new advances in ex situ treatment methods as well as EPA's comments and LWG responses (Appendix O) on treatment technologies that took place since 2007 including:

- EPA's February 15, 2008 comments and LWG's March 28, 2008 responses on the Treatability Study Technical Memorandum as well as EPA's May 15, 2008 responses to LWG response to comments.
- EPA's July 9, 2009 comments and LWG September 3, 2009 responses on the Treatment Technology Screening Tables.
- EPA's April 27, 2011 comments on the FS Tools Memoranda and Treatment Technology Screening Tables
- LWG and EPA's June 29, 2011 FS Tools Comments Resolutions
- EPA's May 18, 2011 comments on the LWG April 12, 2011 presentation of "Remedial Technologies" for the Feasibility Study
- LWG responses to EPA's May 18, 2011 comments contained in Appendix O.

Appendix S provides the updated screening results, where seven ex situ treatment technology process options were screened through as most applicable to this Site and identified as needing further evaluation prior to alternative development. This section provides further evaluation of these seven ex situ treatment technology process options. Detailed descriptions of the seven technologies discussed in this section are provided in the Treatability Study Technical Memorandum (Anchor 2007). Also, Appendix S contains supporting information to the evaluation of the seven technologies, which include:

- Land Treatment/Composting (Biological)
- S/S (Physical)
- Particle Separation (Physical)
- Sediment Washing (Physical/Chemical)
- Low- and High-Temperature Thermal Desorption (Thermal)
- Incineration (Thermal)
- Vitrification (Thermal)

Each of these technologies is discussed below in terms of screening against the effectiveness and implementability criteria. In addition, dewatering as an overall ex situ treatment technology is retained for use in comprehensive alternative development as described in Section 6.2.7.4.

6.2.8.1 Effectiveness

To determine the effectiveness of the screened list of the seven ex situ treatment technology process options identified above, case studies with site conditions similar to Portland Harbor were reviewed. Based on the information obtained, an additional semi-quantitative screening was performed for each SMA (described in Appendix S and summarized in this section) to determine which process options would be effective in treating sediment to acceptable treatment levels.

The determination of "acceptable levels" that treatment processes must attain is complex and is directly related to the ultimate destination of the treated material and the potential exposures that would reasonably take place at that destination. Potential destinations of treated material generally fall into the following categories:

- Aquatic Fill: in-water placement (e.g., habitat mitigation/restoration materials, contaminated sediment capping material, or CAD cover material)
- Unrestricted-Use Fill: placement in nearby uplands ranging from industrial to residential land uses as suitable fill soil (potentially in Oregon or Washington)
- Restricted-Use Fill: placement at a variety of destinations including:
  - Fill for upland remediation projects (e.g., between an upland soil remediation cover and contaminated disposed materials)
  - Fill for in-water remediation projects (e.g., between underlying contaminated sediments and a cap, CAD cover, or nearshore CDF cover, where treated material is not on the surface of the caps/structures)
  - General fill at industrial sites

- Landfill daily cover
- Industrial Raw Material Alternatives: for example, aggregates for a variety of uses, cement additives, road or parking lot bed fill material, mine quarry reclamation, etc.). (See Anchor QEA 2009c for more information on the range of potential uses of post-treated materials.)
- Disposal Facilities: sediment treatment may be required to allow for placement in a CAD or CDF, or per RCRA prior to final off-site landfill disposal.

Each destination and/or potential post-treatment application of the material has its own specific potential set of exposures and, thus, might require varying levels of treatment for these destinations. Further, the economics of treated material use at some of these destinations will have a direct bearing on the cost-effectiveness of treating contaminated sediments to meet acceptable levels at any one of these destinations. For example, even if some contaminated sediments could be treated to acceptable levels for use as clean in-water cap or habitat restoration material, the cost of treating those sediments will need to be weighed against the cost of commercially available materials. For example, if the cost of treatment is orders of magnitude greater than the cost of obtaining suitable sand from an upland quarry or from navigation dredging projects for capping materials, then the benefits of treating contaminated sediments to these low levels are reduced. This is particularly true if the same contaminated sediments could be disposed untreated in an upland landfill, CAD, or CDF at much lower cost, which would often be the case.

Clearly, a large array of potential future destinations and uses of treated material exist and the likelihood of many of them is closely linked to the costs of alternate materials for the same use and the costs of disposing contaminated sediments untreated. For a draft FS-level evaluation, two representative destinations for treated sediments that appear to have a relatively high potential likelihood in economic terms were selected to determine acceptable treatment levels (ATL) for screening the seven treatment technologies evaluated here. These two representative post-treatment applications and associated ATLs include:

- Unrestricted placement as upland soil at or near the soil surface at locations with residential land uses or similar.
  - Unrestricted use ATL screening values (ATL 1[19]) were established based on the most relevant screening criteria developed by DEQ: the human health Risk Based Concentrations (RBCs) for residential use (OAR 340-122), published regional background concentrations (Ecology 1994), and ecological Level II screening levels (DEQ 1998b).
  - ATL 1 screening values are also based on DEQ Case-Specific Beneficial Use Performance Criteria per OAR 340-093-280. Actual proposed post-treatment applications would be subject to DEQ review and approval, including a public notice period. For the purposes of this draft FS evaluation, it is assumed that

[19] The specific ATL 1 values used in the screening are described more in Appendix S.

approval for the proposed use would be a relatively straightforward process because sediment would be treated to levels meeting the most restrictive DEQ criteria protective of human health, groundwater, and ecological resources.

- Restricted placement as upland soil at or near the soil surface at locations with industrial land uses or similar.
  - Restricted use ATL screening values (ATL 2) were established based on the most relevant screening criteria developed by DEQ: human health RBCs for occupational use and published regional background concentrations. The specific ATL 2 values used in the screening are described more in Appendix S (Table 9).
  - ATL 2 screening values are also based on DEQ's Standing Beneficial Use Determination "d"; therefore, per OAR 340-093-0270, no additional review or approval by DEQ is required if the specific conditions of the use are met. The biggest challenge to implementing restricted placement uses is identifying cost-effective projects that can accept material with characteristics similar to the treated sediment that is produced.

Because nearly all of the post-treatment applications of Site sediment will be likely located outside of the CERCLA Site boundaries, local ARARs were considered in the selection of ATLs for this draft FS evaluation. In general, dredged sediment is classified as solid waste in Oregon and Washington; therefore, their respective solid waste regulations (OAR 340-093 and WAC 173-303) serve as the initial basis for establishing criteria allowing for alternative management of treated sediment in lieu of landfilling. Promulgated risk-based criteria established under each state's respective cleanup rules (OAR 340-122 and WAC 173-340) are also relevant. In general, both Oregon and Washington regulations provide similar procedures for exempting dredged sediments from the solid waste rules (i.e., alternative solid waste management options). "Clean dredged material (sediment)," which is generally defined as sediment meeting open-water disposal criteria, is categorically exempt from the Oregon and Washington regulations. For sediment not meeting the definition of "clean," beneficial use exemptions for cases where a material would be used in lieu of virgin resources in a manner that would not pose a potentially unacceptable risk to human health or environmental resources for a given application can be applied for. As discussed in the bullets preceding this paragraph, ATL screening levels are based on criteria expected to be approved via DEQ's case-specific performance criteria. Because DEQ and the Washington State Department of Ecology soil cleanup criteria are similar, for simplicity, the DEQ criteria were used in the development of ATLs (refer to Appendix S, Section 4.3 for additional information regarding selection of ATLs).

These ATLs and associated uses are most representative for a draft FS-level evaluation because consideration of other destinations, such as aquatic habitat fill, typically requires lower treatment levels, and screening based on those lower levels would not result in the additional selection of treatment technologies beyond those included in the current draft FS evaluation. Destinations that require potentially higher treatment levels, such as incorporation into a CDF below a cover layer or use as landfill daily cover, may be identified in the future, but the exposures and ATLs associated with those destinations would be highly specific to the projects involved and cannot be easily defined at this time. Further, attempted estimation of such levels might result in screening in multiple technologies that eventually may be found to have only very limited and specific applications. Finally, although current DEQ solid waste management policy allows case-specific evaluations of restricted uses based on higher acceptable criteria, pre-approved standing beneficial use determinations that allow the most flexibility in selecting material placement locations are based on stringent criteria equivalent to the “clean sediment” definition [OAR 340-093-0270(5)].

Selection of these representative ATLs is a draft FS-level determination only to facilitate further evaluation of technology effectiveness. Each of the seven ex situ treatment technologies should continue to be available for potential use in remedial design at specific SMAs. The potential appropriate use of these technologies would be determined on a project-specific basis during remedial design consistent with each SMA’s conditions, the economics of the particular potential destinations, the availability of potential destinations and reuse options at that time, and the overall Site-wide economics (e.g., the comparative cost of disposal of untreated materials in an operating Site CDF or off-Site disposal) prevailing at the time of remedial design.

The above DEQ criteria were selected because they are the most appropriate ARARs for placement of materials in the uplands in Oregon. As part of the FS Tools comments (Appendix O; EPA 2011c), EPA provided LWG with a table of additional potential screening criteria for clean fill including the following types of criteria: national freshwater and marine aquatic sediment screening values, DEQ sediment risk screening levels, and EPA residential and industrial soils regional screening levels (RSLs). EPA indicated aquatic values would be relevant to in-water material placement, which is not included in the representative treated material destinations for reasons discussed above. The values provided to LWG are generally equivalent to DEQ’s definition of clean sediment under OAR 340-093. EPA RSLs are superseded by the Oregon ARARs for soil disposal decisions within Oregon and outside the boundaries of this CERCLA Site (which does not extend into upland soils areas).

The following sections provide a summary of the demonstrated effectiveness for each technology process option and the results of the semi-quantitative screening against the ATLs. The screening performed in this section was based on the average contaminant concentrations for the sediment volumes in each of SMAs 1 through 26 defined based on each of the Site-wide footprints of SMAs B through F (see Section 5.10 for sediment volume determination methods). Appendix S (Section 4) contains details of the average contaminant concentration calculations, the estimated post-treatment concentrations for each technology, and the comparison of the post-treatment concentrations to the ATLs described above.

Where ex situ treatment process options were found to potentially meet ATL 1 screening levels in the semi-quantitative evaluation, these options were generally retained for consideration in the development of comprehensive alternatives in Section 7. Where process options were found to potentially meet ATL 2 screening levels in the evaluation, these options are noted here, but are not generally used in the development of comprehensive alternatives in Section 7. The reasons for this relate to the issues described above and include the fact that the occurrence and general availability of projects or reuse opportunities applicable to these higher acceptable levels is difficult to predict and the economics of treating material for these more restricted uses versus obtaining clean materials (e.g., quarry sand or clean upland fill) from other locations is uncertain. In addition, it is unclear whether or not these higher screening levels will remain relevant in the future in light of DEQ's evolving dredged material management policies established by OAR 340-093. However, as noted above, these are only draft FS-level decisions and all of these seven technologies should be retained for consideration in remedial design of specific SMAs when details on specific restricted use projects, Site economics, and most recent Oregon disposal policies can be further evaluated.

The results of the screening evaluation of each of the seven ex situ treatment technology process options are discussed in the following subsections.

6.2.8.1.1 Land Treatment/Composting (Biological)

Land treatment and composting are biological treatment technology process options that are regularly implemented for soil remediation projects. Demonstrations have shown that properly designed ex situ bioremediation systems can treat petroleum hydrocarbons, solvents, non-persistent pesticides, and wood preservatives (e.g., PAHs) on relatively small scales and in ideal conditions, and reductions in contaminant concentrations up to 85 to 90 percent could be achieved (EPA 2004). There are also several limitations that are associated with the selection of bioremediation as a treatment option for multi-contaminant sediments (e.g., different organisms may be required to metabolize the range of contaminants present; some contaminants may be efficiently reduced under aerobic, while others under anaerobic conditions). While bioremediation cannot degrade inorganic contaminants, bioremediation may be used to change the valence state of inorganics and cause adsorption, immobilization onto soil particulates, precipitation, uptake, accumulation, and concentration of inorganics in micro- or macroorganisms.

PCBs and persistent organic pesticides (e.g., DDT) are relatively resistant to bioremediation techniques. A demonstration project was performed on Savannah River soils to study the effects of an enhanced bioremediation on PCBs and various pesticides (e.g., DDT, DDE, DDE, and endrin) (Beul et al 2003). The results indicated that PCB concentration reductions of up to 70 percent were possible. Reductions in pesticide concentrations observed in the same study ranged from 30 to 90 percent. The range of contaminant reductions observed in the Savannah River study was used in the semi-quantitative technology evaluation. The results indicate that land treatment and composting will likely not be effective in treating Site sediments to below unrestricted use criteria (i.e., ATL 1 screening values). In most SMAs, PCBs and metals will persist above the ATL 1 screening level. Therefore, these biological technologies were not considered effective and were not retained as process options for draft FS alternative development. However, sediments from a few SMAs may be able to be treated to below the ATL 2 screening levels and land treatment and composting may be effective process option if a specific, cost-effective restricted use is identified during remedial design.

6.2.8.1.2 Stabilization/Solidification (Physical)

This technology involves adding amendments (e.g., cement or organoclay) to excavated sediment that immobilize and/or bind contaminants within the stabilized or solidified product (EPA 2009e; Paria and Yuet 2006). Contaminants are not destroyed during this process and pre-treatment concentrations of contaminants that exceed ATL 1 and ATL 2 screening values would exist after treatment. Because of this, a third set of ATLs based on the demonstrated effectiveness of the technology for a given contaminant and criteria established for protection of groundwater were designated. These ATLs are specific to the effectiveness evaluation of stabilization/solidification. For those contaminants (typically metals and non-volatile organics), it may be possible to obtain approval for restricted post-treatment applications and uses if the conditions of DEQ's case-specific performance criteria are met. Therefore, S/S would likely be effective if a specific, cost-effective restricted use is identified for some SMAs with primarily metals issues during remedial design. For example, this process option could be used to allow CDF disposal of contaminated sediments that might not otherwise be allowed to be placed in a CDF.

While no characteristic potential hazardous wastes and only very limited areas of listed potential hazardous waste have been identified within the Site (see Section 5.5), S/S is also an effective treatment method for contaminated sediments that are potentially hazardous wastes that would require treatment per RCRA prior to final disposal in a landfill. This technology reduces the leachability of such materials so that they meet TCLP limits are used to evaluate whether or not a material is a characteristic hazardous waste. Therefore, S/S would also be potentially effective to treat hazardous wastes that may be identified as part of future design studies.

Also, as noted in Section 6.2.7.4, S/S has wide application as a dewatering ex situ treatment option that may have additional benefits of reducing leaching of some contaminants, particularly metals. Therefore, this technology process option is considered potentially effective in treating sediments through reduction in water content Site-wide.

6.2.8.1.3 Particle Separation (Physical)

Particle separation is a technology process option that does not immobilize or destroy contaminants; however, it reduces waste volumes that would otherwise require subsequent landfill disposal. Particle separation may also recover clean sand that can be used in a range of upland uses. Particle separation has been recently implemented as part of two large-scale (greater than 250,000 cy) sediment remediation projects: the Lower Fox River in Wisconsin (Tetra Tech et al 2009) and the Hudson River in New York (Anchor QEA and Arcadis 2010). For the Lower Fox River project, total PCB concentrations were reduced from 1.9 parts per million (ppm which is mg/kg when referring to sediments and mg/L when referring to water) (unprocessed sediment) to approximately 0.3 ppm (sand fraction only), which is above the PCB ATL 1, but below the ATL 2 value. Similarly, the coarse material fraction from the Hudson River did not meet the New York PCB soil cleanup level of 1 ppm, which is higher than the PCB ATL 2. While data were only obtained for PCBs, it is expected that reductions in concentrations of other organic contaminants that tend to be associated with sediment fines and sediment organic carbon (e.g., PAHs) would also occur for the sand fraction after treatment. However, because the PCB data for both projects evaluated did not achieve PCB concentrations below the ATL 1 screening value (0.22 ppm), particle separation was not considered effective and was not retained as a process option for draft FS alternative development. Because the PCB data evaluated could potentially meet the PCB ATL 2, particle separation may be an effective process option if a specific, cost-effective restricted use is identified for some SMAs during remedial design.

6.2.8.1.4 Sediment Washing (Physical/Chemical)

A number of process options exist for sediment washing, but few have transitioned to full-scale applications. The BioGenesis^{SM} Advanced Sediment Washing system has been demonstrated as part of the WRDA Sediment Decontamination Program and at various international locations in Europe and Asia (BGW and MWH 2009; Estes et al 2011). BioGenesis^{SM} recently completed a summary report for the pilot study conducted on sediment from the Passaic River Superfund Site (BGE 2011). Concentrations of PCBs and BaP in untreated sediment were approximately 0.4 ppm and 2 ppm, respectively. After treatment concentrations remained above 0.2 ppm for both constituents, which is above the PCB and BaP ATL 1 values, thus likely prohibiting unrestricted post-treatment applications. Overall, the results of demonstration studies indicate on average that PCBs, PAHs, and metals concentration reductions ranging from 50 to 90 percent are possible (BGE 2011).

Sediment treated with the BioGenesis^{SM} process is often used as feedstock for manufactured soil production. The WRDA and Passaic River studies also included a final polishing step after treatment, which included blending the sediment with organic matter to produce topsoil. Sampling conducted after topsoil production indicates that PCBs, PAHs, and metals concentration reductions could increase up to 95 percent; however, the increased reductions are primarily attributed to dilution rather than actual contaminant destruction (BGE 2011).

As discussed in Appendix S (Section 4.4), the semi-quantitative screening process considered the average range of demonstrated percent contaminant reductions. Reductions up to 70 percent were used to evaluate whether or not ATL values could be achieved within each localized SMA. Based on the evaluation, it is expected that residual concentrations of pesticides, PAHs, PCBs, and various metals above ATL 1 screening values will persist after sediment washing is performed. However, in various SMAs it is possible that sediment washing may be effective enough to achieve DEQ restricted use criteria (Appendix S, Section 4.6.4). Because sediment washing is unlikely to attain unrestricted criteria, it is not considered an effective process option for draft FS alternative development. However, because it has the potential to meet the less restrictive criteria, this process option should be retained for consideration in remedial design at specific SMAs where specific restricted destinations and uses that are cost-effective might be identified.

6.2.8.1.5 Thermal Desorption (Thermal)

Thermal desorption is a thermal-induced physical process where contaminants and water are vaporized from a solid matrix and transported to a gas treatment system. The bed temperatures and residence times designed into these systems will volatilize selected contaminants but will typically not oxidize them. Based on the operating temperature of the desorber, thermal desorption processes can be categorized into two groups: high temperature thermal desorption, which operates at temperatures between 600 and 1,000°F, and low temperature thermal desorption, which operates at temperatures between 200 to 600°F (Anchor 2007).

The efficiency of the low- and high-temperature units is contaminant-specific and generally controlled by the boiling point of the contaminant (or in the case of certain metals, the temperature at which sublimation occurs) (FWEC and Battelle 1998). Accordingly, percent contaminant reductions in low-temperature systems are on the order of 80 to 90 percent and generally focus on LPAHs or fuels. High-temperature systems are generally effective in reducing concentrations of PCBs and HPAHs, and have some effect on volatilizing metals (Anchor 2007). Thus, similar to biological technologies, low-temperature thermal desorption would not be effective in treating sediment to below ATL 1 values (Appendix S; Section 4.3), and it is not considered an effective process option for draft FS alternative development.

While high-temperature units are more effective at treating a wider range of Site contaminants, the results of the semi-quantitative screening indicate that residual concentrations of PAHs, PCBs, and some metals will generally persist above ATL 1 values after treatment. In the case of PCBs and BaP, this is partially due to the strong bond that exists between the sediment organic carbon fraction and contaminants with high organic carbon/water partitioning coefficients. When sufficient organic carbon is present, these contaminants are relatively less amenable to the thermal separation process in comparison to other contaminants with weaker bonding (e.g., naphthalene) (FWEC and Battelle 1998). Within a few SMAs (21 and 22), it is possible that high-temperature thermal desorption could be effective in meeting ATL 1 values. Overall, the contaminant concentrations in these SMAs are relatively low and prior to treatment, no contaminants exceed ATL 2 values based on restricted uses (Appendix S; Section 4.3).

In addition, because high-temperature thermal desorption is a high-energy consumption method, it is typically reserved for media that possess high concentrations of highly toxic contaminants. However, unlike technologies that operate at even higher temperatures (e.g., incineration and vitrification), thermal desorption is not effective in reducing contaminant concentrations to very low levels for contaminants with boiling points close to maximum operating temperatures. This is discussed more in the implementability evaluation section. Therefore, high temperature desorption is not considered potentially effective for all SMAs. However, because it has the potential to meet the less restrictive criteria in some SMAs, this process option should be retained for consideration in remedial design.

6.2.8.1.6 Incineration (Thermal)

Incineration destroys a range of chemicals, such as PCBs, solvents, dioxin, and pesticides by thermally decomposing the contaminants via oxidation at temperatures greater than 1,600°F. However, incineration does not destroy metals though moderate concentration reductions occur via volatilization. In some cases, supplemental treatment (via other methods such as stabilization) is necessary to address residual metals contamination (NRC 1997b). The efficiency of the process depends on three main parameters: temperature of the combustion chamber, residence time of the sediment in the combustion chamber, and turbulent mixing of the sediment. The JCI/Upcycle rotary kiln system that is capable of producing lightweight aggregate is an example of an incineration process option that has completed bench- and pilot-scale testing on contaminated sediment. Organic contaminant concentration reductions up to 99.9 percent are possible and metal concentration reductions can typically range between 40 and 95 percent (Estes et al 2011). Higher removal efficiencies can be achieved and are required under RCRA for the treatment of various hazardous wastes. Organic contaminant reductions greater than 99.99 percent are possible by adjusting the operational parameters of the combustion chamber; however, these adjustments often result in significant cost increases (EPA 1997b).

For the purpose of evaluating effectiveness of incineration, the JCI/Upcycle rotary kiln system was selected as the representative incineration system and a 99.9 percent contaminant reduction was used in the semi-quantitative evaluation. The results of that evaluation indicate that post-treatment concentrations would be below ATL 1 values at this Site for most SMAs. Supplemental metals stabilization may be required in SMAs 6, 13, 14, 17S, 18, 19, and 24 to address concentrations above unrestricted use criteria. In general, incineration is typically used to treat hazardous waste and, although effective, is typically not used to treat media with low-level contamination. This issue is discussed more in the implementability section below. Therefore, the use of incineration to treat typical Site sediment is not an effective application of the technology. Incineration could be considered potentially effective to treat RCRA hazardous waste that may be identified as part of future design studies.

6.2.8.1.7 Vitrification (Thermal)

Vitrification is a thermal solidification process, conducted at temperatures greater than 2,900°F to melt the sediment particles, that results in the formation of a glass aggregate. The high temperatures destroy any organic constituents with very few by-products and metals are incorporated into a glass structure that is resistant to leaching. The primary vitrification process options include the Minergy Glass Furnace Technology and the Gas Technology Institute Cement-Lock™ Technology. Both vendors have completed full-scale demonstrations indicating that contaminant removal efficiencies greater than 99 percent for organic contaminants and between 80 and 95 percent for metals. However, to date, neither of these technologies has performed a demonstration project with a processing rate greater than 1 cy/hr. Therefore, it is uncertain whether or not these vitrification units are able to maintain the demonstrated decontamination efficiency levels for long periods of time necessary to treat large sediment volumes (Estes et al. 2011).

The semi-quantitative technology evaluation of vitrification was performed using an organic contaminant percent reduction of 99.99 percent and metals reductions up to 95 percent. The evaluation indicates that vitrification may be effective in treating Site contaminants to below unrestricted use criteria in all SMAs, except for SMAs 6, 14, 17S, and 19 where supplemental metals stabilization may be required. However, because vitrification is one of the most energy-intensive treatment technologies, it is typically used to treat hazardous waste or materials with very high concentrations of contaminants and, although effective, is typically not used to treat media with low-level contamination. This issue is discussed more in the implementability section below. Therefore, the use of vitrification to treat typical Site sediment is not an effective application of the technology. Vitrification could be considered potentially effective to treat RCRA hazardous waste that may be identified as part of future design studies.

6.2.8.2 Implementability

Implementability was evaluated for the ex situ treatment technologies discussed above that were found to be effective in terms of potentially meeting the unrestricted use criteria (ATL 1 screening levels). As noted above, ex situ technologies that potentially meet only the restricted criteria (ATL 2 screening levels) should be retained for use and further evaluation in remedial design, but these technologies are not further evaluated in this section. In summary, based on the results of the effectiveness section above, the following ex situ treatment technologies that were found to be potentially effective are evaluated here for implementability issues:

- S/S
- Incineration
- Vitrification

There are a number of implementability issues that are common to ex situ treatment technologies in general including:

- For ex situ treatment to be implementable, it must be possible to remove the sediments from their current location. Thus, ex situ treatment is only potentially implementable where removal is effective and implementable as determined in the removal section above. In summary, removal was found to be implementable and effective in at least portions of all SMAs, although in some subSMAs complete removal was not found to be implementable.

- In order for a treatment technology to be considered implementable, it should be demonstrated effective on a scale similar to the conditions being evaluated. Although this is not applied as a rigid rule in the implementability screening, technologies that are only demonstrated on scales smaller than most of the localized SMAs are considered less certain to be implementable at this Site. To date, of the three ex situ technologies selected for further evaluation, only S/S has been implemented on a scale with a treatment production rate greater than 1 cy/hour.
- The sediment must be removed, transported (e.g., by barge), and transloaded to an upland facility where property is available for stockpiling areas and treatment equipment. Stockpiling and treatment facilities located beyond the footprint of the CERCLA Site boundary will be subject to environmental reviews and permitting requirements established by local and Oregon regulations.
- These facilities must be developed to include any necessary BMPs to minimize potential environmental impacts during treatment (e.g., spillage of contaminated sediments, minimization of rainfall/runoff from stockpiled sediment or treated sediment, odor and air emission controls, oil/hydraulic fluid spill containment, containment of untreated water and discharge of treated water, etc.). Finally, the treated material and any treatment residuals (e.g., wastewater and concentrated sludges) must be potentially stockpiled and eventually transported to their final destination(s).
- In many cases, the treatment facility sizes will be quite large to allow for stockpiling of enough dredged sediment so that processing could occur throughout the year when environmental dredging outside of the environmental work window is not allowed. Depending on size requirements, to find a suitably sized site, the treatment facility may need to be located several miles away from the river.
- Pre-treatment steps (e.g., dewatering and debris removal) are necessary to prepare the sediment for efficient treatment. These steps must be included in either the transport/transload process and/or built into the treatment facility.
- For most of the technologies, treatment residuals (e.g., wastewater and emissions control systems waste) will be produced. Wastewater will be generated by dewatering steps and this water will either require treatment prior to discharge to the Lower Willamette River or disposal at a publicly owned treatment works (POTW) facility. In some cases, such as for the emissions control waste, the treatment residuals may consist of media that is more impacted than the untreated sediment.
- It may be difficult to match treated materials to specific destinations and uses as noted above. In the event that such matches cannot be identified in a timely manner, it may be necessary to establish a long-term stockpiling area that can hold several seasons of treated sediment.

In addition, to these general implementability issues for ex situ treatment, implementability considerations specific to each technology are discussed below.

6.2.8.2.1 Stabilization/Solidification (Physical)

There are no additional implementability considerations specific to S/S. However, this technology has an advantage in that it simultaneously eliminates free water from the sediments, and thus, eliminates some of the logistical considerations associated with some of the other technologies. This technology also provides a secondary benefit as geotechnical properties are enhanced after mixing and subsequent placement of the treated material as fill. For these reasons, stabilization/solidification is considered generally implementable Site-wide.

6.2.8.2.2 Incineration (Thermal)

Incineration is an energy intensive treatment technology that requires dewatering and debris removal pre-treatment steps. As a result, it is one of the most costly treatment technologies to implement. It also requires extremely specific types of facilities to either be built on-Site, or transport to existing permitted locations outside the State of Oregon. For this reason, incineration is typically used to treat hazardous level wastes and, although effective, is typically not used to treat media with low-level contamination. As discussed in Section 5.5, there is very little known or suspected hazardous level or PTM waste at the Site. Transport and disposal of the small amount of Site sediments that are hazardous or PTM to the relatively nearby subtitle C facility in Oregon (Section 6.2.9) would likely be much more cost-effective than developing an on-Site treatment facility. Consequently, incineration is not considered further in draft FS alternative development. This technology should be retained for potential consideration at specific SMAs in remedial design that have known or future determined hazardous level or PTM wastes.

6.2.8.2.3 Vitrification (Thermal)

The same basic implementability issues apply for vitrification as discussed above for incineration. In addition, the two vitrification vendors that have completed sediment treatment pilot demonstrations have not completed projects with treatment production rates greater than 1 cy/hr. As discussed in Section 5.10, dredge volumes could range from approximately 200,000 cy to over 6,000,000 cy. Typical environmental dredging projects of this size target approximately 100,000 to 200,000 cy per year. To minimize the number and size of stockpiles necessary to store untreated sediment, treatment production rates would need to increase by a factor of 50 to 100. The efficiency and effectiveness of vitrification as a sediment decontamination process option is untested at such increased rates and it is difficult to predict if the technology would reliably scale-up. Consequently, vitrification is not considered further in draft FS alternative development. This technology could be retained for potential consideration at specific SMAs in remedial design that have known or future determined hazardous level or PTM wastes. However, because the incineration thermal technology process option has been more consistently demonstrated to operate at higher processing rates and several existing facilities are operational throughout the United States, it is recommended that incineration be implemented over vitrification.

6.2.8.3 Ex situ Treatment Conclusions

Seven ex situ treatment technologies were screened through to final evaluations in the draft FS and three innovative technologies were found to be potentially effective:

- S/S (Physical) – Was found to be potentially effective for metals leaching reduction in some local SMAs, contaminant leaching reduction in SMAs that may be found to have hazardous wastes during remedial design, and as treatment method to reduce sediment water content, potentially in all SMAs.
- Incineration (Thermal) – Was found to be potentially effective on a limited basis for SMAs that may be found to have RCRA hazardous waste during remedial design.
- Vitrification (Thermal) – Was found to be potentially effective on a limited basis for SMAs that may be found to have RCRA hazardous waste during remedial design.

The other four process options (land treatment/composting, particle separation, sediment washing, and thermal desportion) were not found to be effective, but because they might meet less restrictive end use criteria in some SMAs, should be retained for potential consideration in remedial design.

Of the three potentially effective ex situ treatment technologies, S/S was found to be implementable, and incineration and vitrification were generally found to not be implementable as compared to disposal without treatment at nearby landfills. However, incineration should be retained for potential limited use in SMA-specific remedial designs, where known or future determined hazardous level or PTM wastes may be present.

6.2.9 Disposal Screening

Disposal is the final component of a sediment remediation process train that starts with removal and ends with placement (i.e., disposal) in a final location where potential environmental impacts can be controlled and limited. This process train can also include ex situ treatment between removal and disposal as one option. Disposal can be either within an in-water disposal facility, specifically engineered for the sediment remediation, or within an upland landfill disposal facility, which can include operating commercial landfills. As discussed in Section 6.2.8.1, environmentally dredged sediment may also be used in lieu of other suitable materials under beneficial use regulations. Beneficial use of dredged sediment can be considered in remedial design as an option to disposal where appropriate uses are identified.

A disposal site screening process was performed to identify a manageable number of disposal options for consideration as components of remedial alternatives in the draft FS. Prior to the start of the draft FS, a list of potential disposal options was assembled and information about these options was gathered and evaluated, resulting in early screening of some disposal options. These early disposal evaluation and screening steps were reported in several documents and associated comments/responses including:

- *Draft Disposal Site Inventory Preliminary Screening Report* (Anchor Environmental 2004)
- *Draft Disposal Site List* (Anchor Environmental 2008b)
- *Screening of Disposal Facilities for the Feasibility Study* (Anchor QEA 2009a).
- EPA July 10, 2009 comments on the Screening of Disposal Facilities for the Feasibility Study (Appendix O)
- Disposal Site Screening Evaluation presentation to EPA on December 14, 2010, which addressed EPA July 10, 2009 comments
- EPA January 28, 2011 comments on the December 14, 2010 presentation (Appendix O)
- LWG June 21/22 Draft FS Key Elements Check in presentation, which contained identification of specific disposal options to be paired with alternatives.

The disposal options evaluated in the screening process represent a variety of disposal methods that would effectively contain dredged sediment. They are not the only methods suitable for management of dredged sediment (other disposal options may be identified in remedial design that would offer comparably effective, permanent, and implementable containment of dredged sediment), but the disposal options considered in the screening represent the range of disposal methods available. This section presents the final steps of the screening process performed for the draft FS and includes additional screening evaluations specific to this draft FS.

6.2.9.1 Summary Description of Disposal Options

As noted above, the basic types of disposal options are upland CDFs or landfills (either built specifically for a project or an existing commercial facility), nearshore CDFs and CADs. Figure 6.1-2 presents schematic representations of each type of disposal option.

The screening conducted by Anchor QEA (2009a) identified 14 potential disposal options that were brought into the disposal site screening evaluation. The 14 potential disposal options were:

- Upland disposal
  - (1) A generic new upland near-harbor disposal site (i.e., upland CDF)
  - Commercial licensed upland landfills
    - (2) Hillsboro Landfill (Hillsboro, Oregon)
    - (3) North Wasco County Regional Landfill (The Dalles, Oregon)
    - (4) Columbia Ridge Landfill (Arlington, Oregon)

    - (5) Roosevelt Regional Landfill (Roosevelt, Washington).
    - (6) Subtitle C landfill at Chemical Waste Management of the Northwest Landfill (Arlington, Oregon)

- In-water CADs
  - (7) Willamette RM 4/5 CAD
  - (8) Willamette RM 9 CAD
  - (9) Columbia RM 102 CAD
  - (10) Ross Island CAD
  - (11) Swan Island Lagoon CAD (SMA 17S)
- Nearshore CDFs
  - (12) Swan Island Lagoon CDF (SMA 17S)
  - (13) Terminal 4 CDF (SMA 6)
  - (14) Arkema CDF (SMA 14).

These 14 disposal options are described in detail in Appendix Ja. The locations of these options are shown in Figure 6.2-30 (in-water CADs and CDFs) and Figure 6.2-31 (upland landfills). Upland disposal options involve placing material above the waterline either in a nearby location that would be specifically designed for the project (upland CDF) or at an operating commercial landfill (Figure 6.1-2). Upland CDFs/landfills are designed and operated to minimize loss of contaminants, particularly leaching of contaminants out of sediments and into surrounding groundwater. For CADs, the confining surface covers of such facilities would be completed below water (Figure 6.1-2). In a CAD, dredged sediments are placed in an aquatic location in a naturally occurring depression, excavated cell, or an area segregated from surrounding surface waters with a submerged berm or other containment structure. The CAD is covered with suitable material and an erosion-resistant layer, if needed, after the contaminated sediment is placed. In one design concept for nearshore CDFs, a disposal cell is created by building a berm or other barrier from the shoreline to isolate the cell from adjacent surface water. The cell is then filled with contaminated material up to the water line. Following the placement of contaminated sediment, a cover of suitable material, potentially including suitable navigational dredged material, is placed to a final elevation that is above the water line (Figure 6.1-2). CDFs are similar to CADs except that the vertical berm or barrier is the primary system that minimizes transport of sediment contaminants back into the surrounding water, given that the final cover surface is above the waterline.

It should be noted that the generic new upland near-harbor site noted above was screened out from further evaluation because: 1) no sites within the immediate vicinity of the Site were identified that have appropriate physical characteristics for an upland disposal site; and 2) no property owners expressed an interest in constructing or allowing the construction of such a disposal site.

Two of the disposal options were considered for limited purposes, whereas the other disposal options are all considered viable for material from the most of the Site, subject to limitations associated with waste-acceptance criteria. The Chemical Waste Management of the NW Landfill is permitted under Subtitle C of the RCRA for the disposal of hazardous waste. It was retained in the screening for the disposal of materials that do not meet the acceptance criteria for any of the other disposal options. The volume of such material is expected to be very small and the locations within the Site that potentially contain such material are discussed in Section 5.5. The Arkema CDF is specific to material from SMA 14. For the draft FS purposes, it is assumed that no material from outside of SMA 14 would be placed in the Arkema CDF.

Methods for transporting material to disposal sites vary depending on the type of site and its location relative to transportation infrastructure. Applicable transportation options for the representative removal method used in this draft FS (i.e., mechanical dredging, see Section 6.2.7 for more discussion) include barge, rail, and truck. Barges would be used to transport material from the dredge locations to in-water disposal sites or to transloading facilities where the material would be offloaded from barges and transferred to upland transport options (rail or truck), which would then transport materials to upland disposal facilities. The relative merits of the various transport options are discussed in the following subsections on effectiveness and implementability. A significant factor in the development of remedial alternatives is the volumetric capacity of the disposal options as compared to the volumes of sediment that may be removed from the Site. The capacities of the various disposal options are summarized in the following sections and discussed in more detail in Appendix Ja. The volumetric capacities of the disposal options are also compared to the approximately estimated volumes of contaminated sediments associated with each of the overall SMA footprints, developed following methods described in Section 5.10. This comparison is discussed along with other implementability considerations in Section 6.2.9.2.2 and shows that under many scenarios, a combination of several disposal options will likely be needed, particularly for larger overall SMA footprints. This evaluation conservatively ignored disposal capacity that will be gained in the in-water disposal facilities due to consolidation settlement of the in situ sediment as the facility is filled.

The following section describes the additional screening evaluation of the disposal options based on the screening level effectiveness and implementability criteria.

6.2.9.2 Additional Screening of Disposal Options

The disposal option screening conducted here is for draft FS purposes only. Development of disposal sites requires interaction, support, and agreement among many different parties including the disposal site owner, parties willing to take contaminated sediment to the disposal site, as well as EPA, state, and other partner agencies. Further, the costs of removal, transport, and disposal as compared to other remedial options, as well as disposal site development costs, play a primary role in determining economically viable removal and disposal options. All of these interactions and factors that will play out in remedial design are impossible to predict at the draft FS stage. Thus, the disposal options discussed here should only be considered current examples of potential disposal sites, and it should be recognized that other equally viable disposal options may be identified, described, and developed between now and the time of remedial design of various SMAs. Consequently, both EPA and LWG agreed (see EPA's January 28, 2011 comments, Appendix O) that most disposal options, whether identified in the draft FS process or not, should be allowed further consideration in remedial design if the proponent involved can show that the disposal option is consistent with CERCLA and ARARs.

Disposal site performance standards directed by EPA were used to screen disposal sites. These disposal site performance standards only apply to the draft FS evaluations, and alternative standards may be developed during remedial design.

Disposal options were screened based on effectiveness and implementability considerations. Some of the factors considered in this screening and later in the detailed evaluation (discussed in Sections 8 and 9) are disposal performance standards that EPA directed for use this draft FS. These performance standards only apply to the draft FS evaluations, and alternative standards may be developed during remedial design. These factors are referred to as "FS CDF performance standards" in the remainder of this section.

6.2.9.2.1 Effectiveness

For the additional screening of disposal options, effectiveness evaluations considered both long-term and short-term effectiveness as described more below for each disposal type.

The primary long-term effectiveness consideration is the ability of the disposal facility to contain contaminants for as long as they pose potentially unacceptable risk to human health and the environment. The disposal facility must be capable of containing the contaminated material and control the release of contaminants from the material such that there is no significant impact on water or air near the facility. Significant factors for the evaluation of short-term effectiveness include the ability to control releases of contaminants during the construction of disposal units, the transportation of contaminated materials to the disposal units, placement of material in the disposal units, and closure of the units. Physical factors associated with transportation, such as additional traffic and potential collisions associated with the additional traffic, are also potential hazards associated with remedial implementation and, therefore, considerations in short-term effectiveness screening.

One aspect of effective long-term containment is the seismic stability of the disposal facility during and after a seismic event. This issue applies relatively equally to all disposal options. That is, strong ground motions associated with an earthquake could potentially cause damage to any of the disposal options discussed here. This issue is evaluated and discussed more in Appendix Jc. In summary, all disposal facilities must be designed to remain functional during a contingency level event (CLE), which represents an earthquake with a specified percent probability of exceedance. This requires a performance-based design that is uncommon in most structures. The FS CDF performance standards for a CLE allow that constructed structures, such as waterfront facilities and buildings, may suffer significant damage that requires major repairs that would impair operations. Structures for disposal facilities, such as a CDF containment berm, must be designed to strictly limit the probability of catastrophic failure that would result in the release of the contaminated sediments into the river. Minor damage that is repairable would be permitted. Therefore, the CLE is determined such that the associated seismic demands have a low probability of exceedance during the service life of the facility. If such an event occurs, the operators of the disposal sites are obligated, under various disposal facility legal agreements (i.e., consent decrees with EPA) and federal and state regulations, to maintain the facilities such that environmental damage is minimized and the facility is repaired. This concept is analogous to in-water structures, including remediation structures like caps that are designed and maintained around certain flood event standards (e.g., the 100-year flow event). In-water disposal options are sometimes singled out as more vulnerable to seismic hazards as compared to upland options, but because all disposal sites must be designed and constructed to meet seismic standards, this is not generally the case. It is also sometimes hypothesized that in-water structures have a greater potential for environmental damage; however, this view does not fully account for similar potential issues with groundwater contamination that could occur with upland landfills under the same type of seismic events.

Upland Disposal

All five of the upland disposal options are commercial landfills. Regarding long-term effectiveness, commercial landfills, which are designed, operated, and monitored to meet EPA and state regulatory criteria, provide effective long-term containment of contaminated sediment. The short-term effectiveness issues related to upland disposal options are primarily from potential environmental impacts associated with transporting the material from the Site to the disposal facilities. However, given routine implementation of BMPs, these short-term impacts can be mostly minimized.

Transportation is a significant factor for upland disposal because of the greater distance from the Site and greater potential impacts on traffic (as compared to in-water disposal). The short-term effectiveness of the transportation options was also evaluated. The first stage of transportation for any of the disposal options (assuming the dredging is performed mechanically) would be by barge. Contaminated sediments have been successfully transported by barge, including during early actions in Portland Harbor, without significant releases of contaminants or other impacts. Material would be offloaded from barges and loaded onto trucks or rail cars for transportation to the landfill. The transloading facility would be designed and operated to protect against releases of contaminated material. For a project of this size, upland transportation by rail is a feasible alternative to trucking, although the development of a transloading facility for rail loading is more complicated and requires more space than one for truck loading. Rail transport is also more limiting than trucking in that it is only compatible with landfills that are served by rail (Columbia Ridge Landfill, Roosevelt Regional Landfill, and

Chemical Waste Management of the Northwest). The primary advantages of rail are that it would have less impact on traffic and reduced probability of traffic accidents. Rail freight transportation incurs approximately 12 percent of the fatalities and 6 percent of the injuries as compared to trucking per trillion ton-miles, and the transportation employee injury rate for rail is approximately half of that for trucking (Moorman 2009). Transportation by rail also uses less fuel[20] and generates fewer exhaust emissions. The capacity of a single rail car is approximately two to three times the capacity of a truck-and-pup combination. Therefore, a single train of 50 or more cars may transport as much material as 150 truck trips of the same distance.

In-Water CADs

With regard to long-term effectiveness, all five of the potential CAD facilities could be designed and built to provide permanent effective containment of contaminated sediment. The capping analysis in Section 6.2.5 indicates that all of the contaminated sediments at the Site can be effectively capped in place to minimize the potential for contaminant migration, and therefore, these same sediments could be contained after placement in a CAD. Similarly, the CAD cover could be designed to resist erosion of the contaminant isolation layer with selection of an erosion-protection layer with appropriately sized material (e.g., gravel or riprap depending on the location).

The Swan Island CAD option is a somewhat different concept in that the CAD cell would be created by constructing a submerged berm rather than placing the sediment for confinement in a depression in the river bottom. Since the contaminated sediment would be confined at an elevation greater than the adjacent portions of the river, contaminants might also migrate laterally in addition to upward through the cover. As discussed later in this section and in more detail in Appendix Jb (Section 3), groundwater flow and bounding COC migration was modeled for the Swan Island CDF option and found to meet FS performance standards. The results of the CDF modeling, which indicate no significant impacts to water quality, suggest that the smaller volume of sediment that would be placed in the CAD would also have no significant effect on water quality.

The potential for contaminant migration through the cover is also proportional to the size of the cover if other factors, such as the transport properties of the contaminants and groundwater flow characteristics are equal. Therefore, a CAD site with greater overall depth and relatively steep sides would offer the advantage of greater disposal capacity relative to the areal extent of the cover. On this basis, all of the CADs appear similar except Willamette RM 4/5, which has a substantially smaller ratio of capacity to surface area. Table 6.2-13 provides a summary of the disposal capacities and cover sizes for the five CAD options.

With regard to short-term effectiveness, placing contaminated sediment in a CAD requires transport through the water column (e.g., placement via clamshell dredge or

[20] Rail transportation in a gondola car, the type of equipment that would be used for transportation of bulk material to the landfill, is 2.3 to 4.0 times more efficient (tons of cargo times miles traveled per gallon of fuel) than truck transportation (Federal Railroad Administration 2009).

barge release), which is subject to possible entrainment in the river flow and loss of contaminants downstream. Water quality would be more readily controlled during placement in areas that are relatively isolated from the primary river flow. The Swan Island Lagoon and Ross Island locations are promising relative to this screening factor, since both of these locations are protected from the open channel (Table 6.2-13).

As the remedial action is expected to require several years to complete, and in-water work periods are restricted to less than one-third of the year, it is expected that intermediate cover would need to be placed over contaminated sediment in the CADs at the end of each work period to mitigate potential impacts to receptors between periods of active placement of sediment in the CADs. Such an approach would effectively minimize any short-term impacts associated with contaminated sediments during these interim periods.

Overall, it appears that all of the CADs could be constructed to be effective, with the primary issue being potential short-term water quality impacts. In this regard, the Ross Island and Swan Island options are promising.

Nearshore CDFs

With regard to long-term effectiveness, all three of the potential CDFs could likely be designed and built to provide permanent effective containment of contaminated sediment. The Terminal 4 and Swan Island Lagoon CDFs are similar in that they are contained on three sides by existing shoreline and would be isolated from the Lower Willamette River by relatively short containment berms (Table 6.2-14). Groundwater flow and contaminant transport modeling (discussed in Appendix Jb; Section 3) was performed to demonstrate the long-term effectiveness of the containment of both options at a draft FS-level of detail. The design concept for both the Terminal 4 and Swan Island Lagoon CDFs is that the berms that contain the sediment would be permeable to groundwater and that the rate of contaminant transport is sufficiently low that predicted water quality at compliance points in and near the face of the berm would meet FS CDF performance standards (Appendix Jb, Section 3 and see EPA's February 18, 2010 FS CDF Performance Standards Comments and subsequent LWG and EPA responses in Appendix O).

The preliminary design concept for the Arkema CDF incorporates an upland barrier wall and circular cofferdams to limit horizontal groundwater movement. The surface of the CDF includes a low-permeability cover to limit infiltration. Extraction wells would further limit groundwater movement in and through the CDF to prevent unacceptable impacts to water quality (Arcadis 2010). The conceptual design for the Arkema CDF option is being developed, and the eventual design may be an EPA-approved configuration different from the preliminary design. If the Arkema CDF option were selected at SMA 14, quantitative analyses would be performed to demonstrate the effectiveness and permanence of the containment system.

With regard to short-term effectiveness, the placement of contaminated sediment in any of the three CDF options would be performed after the containment barriers were constructed, thereby facilitating the monitoring and control of water quality during placement. As discussed more in Appendix Jb (Section 2), the most likely environmental dredging and CDF disposal process options (i.e., mechanical dredging and transfer of material from the barge and into the CDF using a high solids pump and "make up" water from behind the CDF) for this Site are expected to result in little or no discharge to surface waters. In the less likely event of hydraulic dredging and placement in CDFs for some specific SMAs, potential water quality impacts for this scenario were modeled for the Terminal 4 and Swan Island Lagoon CDFs at a draft FS level of detail (Appendix Jb, Section 2). Consistent with the FS CDF performance standards, short-term water quality impacts are not expected based on elutriate test results from Portland Harbor SMAs combined with the implementation of construction BMPs. The conceptual design of the Arkema CDF would address methods to control potential impacts from the construction and placement of sediment in the CDF (Arcadis 2010) and would likely include the same overall array of approaches discussed for the other two CDFs.

Overall, each of the potential CDFs could likely be designed and constructed such that they are effective in the short and long term.

6.2.9.2.2 Implementability

One overall implementability consideration is that permitting requirements fundamentally differ between disposal options that reside within the CERCLA Site as opposed to those that are outside the Site. Options that are within the Site are part of the CERCLA Site and are required to meet the substantive requirements of all ARARs, but are not required to enter into the specific federal and state permitting processes and obtain such permits. Conversely, options that are outside the Site would have to enter into all the necessary permitting processes and obtain the actual permits for siting and operating such disposal sites. This issue does not generally apply to operating commercial landfills because they already have all the necessary permits and are compliant with relevant federal and state regulations. Thus, the off-Site disposal options that have this additional implementability consideration are the Ross Island and Columbia River CADs. Transloading facilities for upland disposal would require permitting as solid-waste transfer stations.

Upland Disposal

For upland disposal, the significant implementability considerations are availability of sufficient capacity, waste acceptance criteria, and availability of transportation options. All four of the Subtitle D landfills currently have sufficient capacity to receive the volume of sediments estimated to be associated with the SMA footprints as described in Section 5.10. The limiting factor for upland disposal capacity is the rate at which material could be transported to and placed in the landfill, rather than the total capacity, and the capacity to transport and place material in the landfills should be less limiting than the rate at which the sediment is likely to be dredged. The four Subtitle D landfills could likely receive the vast majority of waste types at the Site, although some relatively small volumes of sediments (per Section 5.5) could only be disposed at the Chemical

Waste Management of the Northwest landfill, which is permitted for the disposal of hazardous waste.

The Roosevelt and Columbia Ridge landfills are able to accept materials with free liquids, whereas most landfills can only accept waste that passes the “paint filter test” (a test that measures the free water content of materials). Relative to this project, this factor means that these two landfills can accept sediment that has not been stabilized with a dewatering amendment. As a practical matter, excess water would be decanted from the sediment to facilitate transportation to the landfill, improve the workability (material handling characteristics) of the sediment, and reduce disposal costs (by reducing the weight of material landfilled). Dewatering amendments may still be used to improve materials handling and reduce the potential of releasing contaminated water during transportation, but the rate of amendment could be less for disposal at these landfills than for disposal at the North Wasco County or Hillsboro landfills. Columbia Ridge and Roosevelt are also served by rail, which offers significant logistical and cost advantages over truck transport as discussed in the previous section. The North Wasco County and Hillsboro landfills are somewhat closer to the Site (offering shorter transportation distances) and generally offer lower tipping fees for disposal. Roosevelt landfill is located in Washington State, and consequently some additional regulations on the transport and disposal of materials may need to be addressed for this location including State of Washington Dangerous Waste regulations.

In-Water CADs

Major implementability considerations for in-water disposal include the availability of sufficient capacity, compatibility of the location with ongoing uses of the area that would be affected by the operation and the long-term presence of the facility, and future maintenance requirements for the closed facility.

The potential CAD site would need to offer sufficient disposal capacity to warrant the development and maintenance of the disposal site. All of the CADs have between 200,000 and 600,000 cy of capacity (Table 6.2-13). Table 6.2-15 compares the volumes of the various overall SMAs described in Section 5.10 to the capacities of the CAD and CDF disposal sites. The table shows that very few potential scenarios exist where Site volumes could all go to one of the CAD options; therefore, CADs are generally only an option as a component of an overall disposal plan that involves multiple sites including non-CAD options. The Ross Island location offers the greatest disposal capacity of the CAD disposal options based on available bathymetry and potential lateral limits of a CAD outside of reclamation areas, although this capacity is diminishing with each passing year, as discussed more below.

Constructing and filling potential CAD sites in the navigation channel would be subject to interruptions to accommodate other uses of the river. The Swan Island Lagoon and Ross Island CAD options would not be affected by this consideration because they are both outside of the open channel, although the Swan Island Lagoon option would eliminate current navigation uses in this area entirely.

As noted above, it is expected that interim cover would need to be placed over contaminated sediment in the CADs at the end of each annual (fish window) construction period. This approach would result in lost capacity of the CADs and would have greater impact on options with lower starting capacity. Also, approaches that involve filling CADs for more than a few years would be infeasible due to the loss of capacity from multiple interim covers. Thus, CADs would likely have less flexibility with regard to accepting volumes from multiple localized SMAs that are remediated over time.

Long-term maintenance of a CAD cover in the navigation channel would require institutional controls, such as an RNA that places limits on anchoring (e.g., only in emergency situations) and restrictions on future maintenance/navigation dredging, to protect the cover and the contaminated sediment. The Swan Island Lagoon and Ross Island locations are both outside of the navigation channel, and the Columbia River location is also mostly outside of the navigation channel. All CAD covers would have to be inspected and maintained to ensure the erosion layer was performing as designed over time. Also, all CADs would require DSL access and/or lease agreements.

The size of the cover required to close the CAD is an important consideration in terms of future maintenance requirements. The effort required to monitor and maintain the cover is proportional to the size of the cover. Therefore, a CAD site with greater disposal capacity relative to the size of the cover is advantageous considering the associated maintenance requirements. With regard to the ratio of capacity to cover size, the Ross Island and Columbia River CAD options would appear to provide the greatest capacity-to-cover-size ratio (Table 6.2-13).

There are several considerations that make the Ross Island CAD option likely incompatible with ongoing use of the location. The site is owned by Ross Island Sand and Gravel (RISG), and the company has committed to state agencies to accept no contaminated sediment in the Ross Island lagoon. Further, RISG has expressed no interest in actively pursuing the CAD concept for this site, and the company is currently restoring the lagoon in compliance with their dredge and fill permit. The expected completion date of Ross Island reclamation is likely sooner than the earliest reasonable timeframe for implementing the majority of Portland Harbor remedial actions (GeoDesign 2011). (This is based on the aggressive set of assumptions for remedial actions as follows: EPA Proposed Plan completed in 2013, EPA ROD issued in 2014, a reasonable set of SMA remedial designs that could provide substantial volume completed in 2016, and first construction started in 2017.) Based on these factors, the Ross Island CAD option appears to have substantial implementability challenges.

The Swan Island Lagoon CAD is the most promising of the CAD options. Although some ongoing uses of the location would need to be adjusted during and after completion of the CAD, the assumed footprint of the facility for this draft FS was selected to minimize impacts on major current uses at the mouth of the lagoon. The location, outside of the river channel, would not affect primary navigation channel uses. The geometry of the location, in an isolated embayment, would facilitate the construction of the containment (a berm constructed along one of the short sides of the CAD footprint) and future maintenance (as erosive forces would be far less than for a location in the open river channel). Finally, unlike the other CAD options (except possibly Ross Island), the Swan Island CAD would provide a substantial amount of shallow water habitat, which may be important in the context of the goal to integrate and enhance habitat mitigation/restoration per project Management Goal 3 discussed in Section 3.

Nearshore CDFs

The major implementability issues with CDFs are similar to those for CADs: availability of sufficient capacity, compatibility with ongoing uses, and future maintenance requirements for the closed facility. Generally, the CDF capacities are greater than the CAD capacities for those CDF options that would be expected to receive materials from elsewhere on the Site (i.e., the Arkema option is intended as an SMA 14 specific option only), but are not as great as the upland landfills. There are no significant issues of compatibility with ongoing or future uses for any of the CDF options. Terminal 4 is operated by the Port of Portland, which has also developed the plans for the CDF including plans for operational changes to accommodate the CDF. The preliminary Arkema CDF concept incorporates new vessel berthing, and the layout addresses the proximity to the navigation channel so the CDF will not impede vessel traffic. For the draft FS, the Swan Island Lagoon CDF footprint was selected to minimize impacts to the major ongoing uses at the mouth of the lagoon. However, construction plans would need to incorporate relocation of some unavoidably impacted uses toward the head of the lagoon. Future maintenance issues for all CDFs would be similar to that of CADs, i.e., berm faces would have to be inspected and maintained over time to ensure erosion protection is performing as designed. Limitations on anchoring of large vessels on berm faces (RNAs) would also have to be implemented, but the CDF options would have relatively limited issues of this type as compared to CADs. Also, all CDF options would require DSL access and/or lease agreements for at least a portion of the CDF footprint, although for the Terminal 4 CDF, most of the proposed CDF area is not owned by DSL. Finally, construction of the proposed CDFs would result in some unavoidable loss of aquatic functions. These potential losses would be offset by requirements for compensatory mitigation as discussed in Section 13 of Appendix M.

6.2.9.2.3 Conclusions of Disposal Screening

The overall conclusions from the disposal option screening above are as follows:

- The five upland disposal options all would offer effective long-term containment of material from the Site. There are significant differences in the short-term effectiveness and implementability of the options particularly with respect to the transportation options associated with the Columbia Ridge and Roosevelt landfills.
  - The Chemical Waste Management of the Northwest landfill is retained specifically for the small amounts of materials that may not meet the

acceptance criteria of the other disposal options (e.g., potential hazardous wastes).

- The Columbia Ridge and Roosevelt Regional landfills are retained as they provide the flexibility to transport material from the Site to the disposal facility by rail or truck. Rail transportation offers significant advantages in terms of safety and fuel efficiency.

- This conclusion is not intended to suggest that the other landfill options (North Wasco County and Hillsboro) would not provide effective permanent disposal and/or reasonable transport options for Site sediments. Rather, they are not incorporated into the detailed evaluation of remedial alternatives because they are not consistent with the overall set of process option assumptions used for this draft FS (i.e., rail transport). As noted previously, these are example process options for draft FS purposes only, and North Wasco County and Hillsboro landfills should be retained for potential use in SMA-specific remedial designs as found to be appropriate at that time.

- The five CAD disposal options can be designed to be effective (with some possible short-term water quality impacts) but have multiple implementability challenges, particularly in comparison to CDFs and upland disposal options. The CAD option with the fewest current implementability issues is Swan Island.
  - Consequently, only the Swan Island CAD is retained for draft FS alternative development.
  - Importantly, this screening decision should not be interpreted to suggest that CADs cannot be effectively designed, constructed, and maintained at the Site. Rather, this conclusion simply recognizes that other disposal options are likely more effective and implementable overall than the Columbia River, Ross Island, and two Willamette River CAD options and, therefore, are best suited for use in draft FS-level evaluations.

- The three CDF options can be designed to be effective, and all three CDF options are implementable.
  - Consequently, all three CDF options are retained for use in draft FS remedial alternative development.

This menu of screened through disposal options is used to develop comprehensive remedial alternatives in Section 7 that incorporate various example combinations of the screened through disposal options. In the case of upland disposal options, the Columbia Ridge and Roosevelt landfills offer essentially the same effectiveness and implementability. Due to the similarity of effectiveness, implementability, and transport distance and method (which impacts costs) associated with these two options, only one needs to be incorporated into remedial alternatives as a representative example for the detailed evaluation. Therefore, the Columbia Ridge Landfill was identified as a representative example of off-Site landfill disposal for the purposes of the draft FS evaluation. The transportation and disposal costs presented in this draft FS for off-Site disposal are based on loading sediment into rail cars in Portland and disposing of the sediment at Columbia Ridge. The other landfills considered in the screening (including Roosevelt, North Wasco County, and Hillsboro) as well as potentially other landfills not identified in this screening process, could be viable options for disposal and may be ultimately selected in remedial design of various specific SMAs. Given the similarities of the upland disposal options evaluated, such remedial design decisions are expected to still be consistent with the overall findings of this draft FS.

6.3 SUMMARY RESULTS OF TECHNOLOGY SCREENING AND CONCLUSIONS

6.3.1 Summary Results of Technology Screening

This subsection summarizes the results of the technology screening conducted in Section 6.2. Each technology was evaluated and screened against screening level effectiveness and implementability criteria as discussed above.

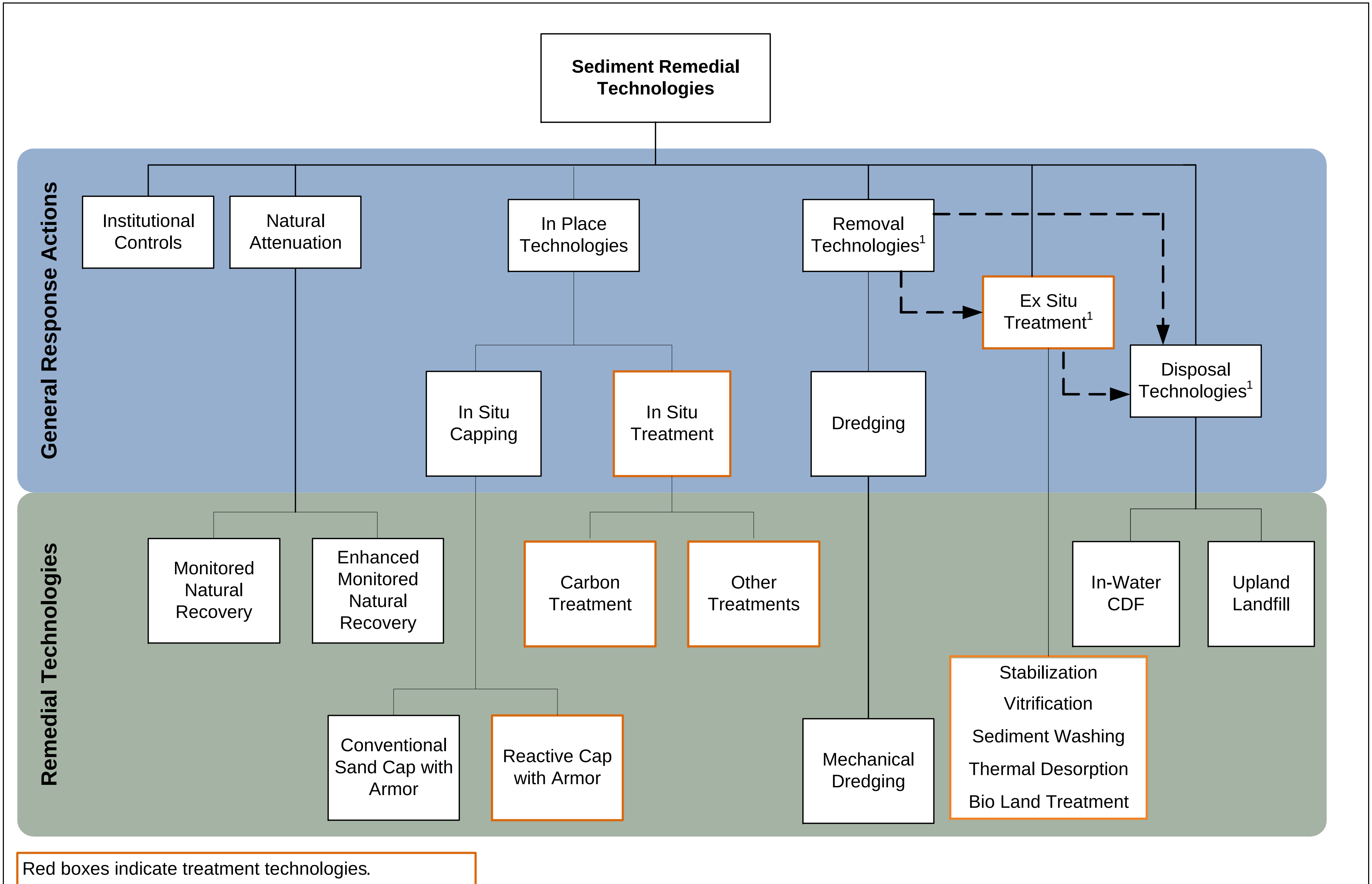
As discussed in Section 5.4, the Site was divided into subSMAs based on Site use and physical factors that most affect implementability of remedial alternatives. The implementability screening was conducted by comparing implementability issues for each technology to these categories of subSMAs. Table 6.3-1 summarizes the results of the implementability screening for these categories of subSMAs consistent with the discussions in the Section 6.2 text. The locations of the subSMAs relevant to each of these determinations are shown in Figure 5.4-1. It should be noted that ex situ treatment and disposal option implementability are not generally determined by the Site uses and conditions noted in this table, and specific discussions with regards to implementability of these technologies is discussed in Sections 6.2.8 and 6.2.9 and summarized in tables discussed below.

Effectiveness screening was conducted across varying spatial scales for each technology as discussed in the introduction to Section 6.2. Consequently, the combined implementability and effectiveness screening results are summarized here at an intermediate SMA-specific spatial scale. For the purpose of this summary, if a technology is retained in the screening within a subSMA, it is discussed here as being retained for the local SMA associated with that subSMA. Table 6.3-2 summarizes the results of the implementability and effectiveness screening by SMA. In addition, Tables 6.3-3 and 6.3-4 summarize the screening findings discussed throughout Section 6.2 in formats that EPA requested (December 18, 2009 FS comments; see Appendix O).

6.3.2 Conclusions

The overall conclusion represented by these summary tables is that a considerable number of technology and process options are likely effective and implementable across most of the SMAs at the Site including: institutional controls, MNR, EMNR, in situ treatment, capping, active capping, removal, ex situ stabilization treatment, and a large number of disposal options. These technologies are retained for alternative development in Section 7. As noted previously, all screening decisions are for draft FS purposes only and the vast majority of the technologies and process options evaluated in Section 6.2 should be made available for potential use in SMA-specific remedial designs as determined necessary based on specific conditions and any additional data gathered for those efforts.

The next section (Section 7) uses the menu of screened through technologies to assemble comprehensive remedial alternatives for the Site.



[1]These technologies are components of a process train. Ex situ treatment and disposal require removal first. Disposal technologies require removal and may require ex situ treatment.

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Figure 6.1-1
Portland Harbor RI/FS
Draft Feasibility Study Report
Relationship Between Sediment Remedial Technologies

This presents the general characteristics of each of the major sediment remedial technologies considered in Section 6

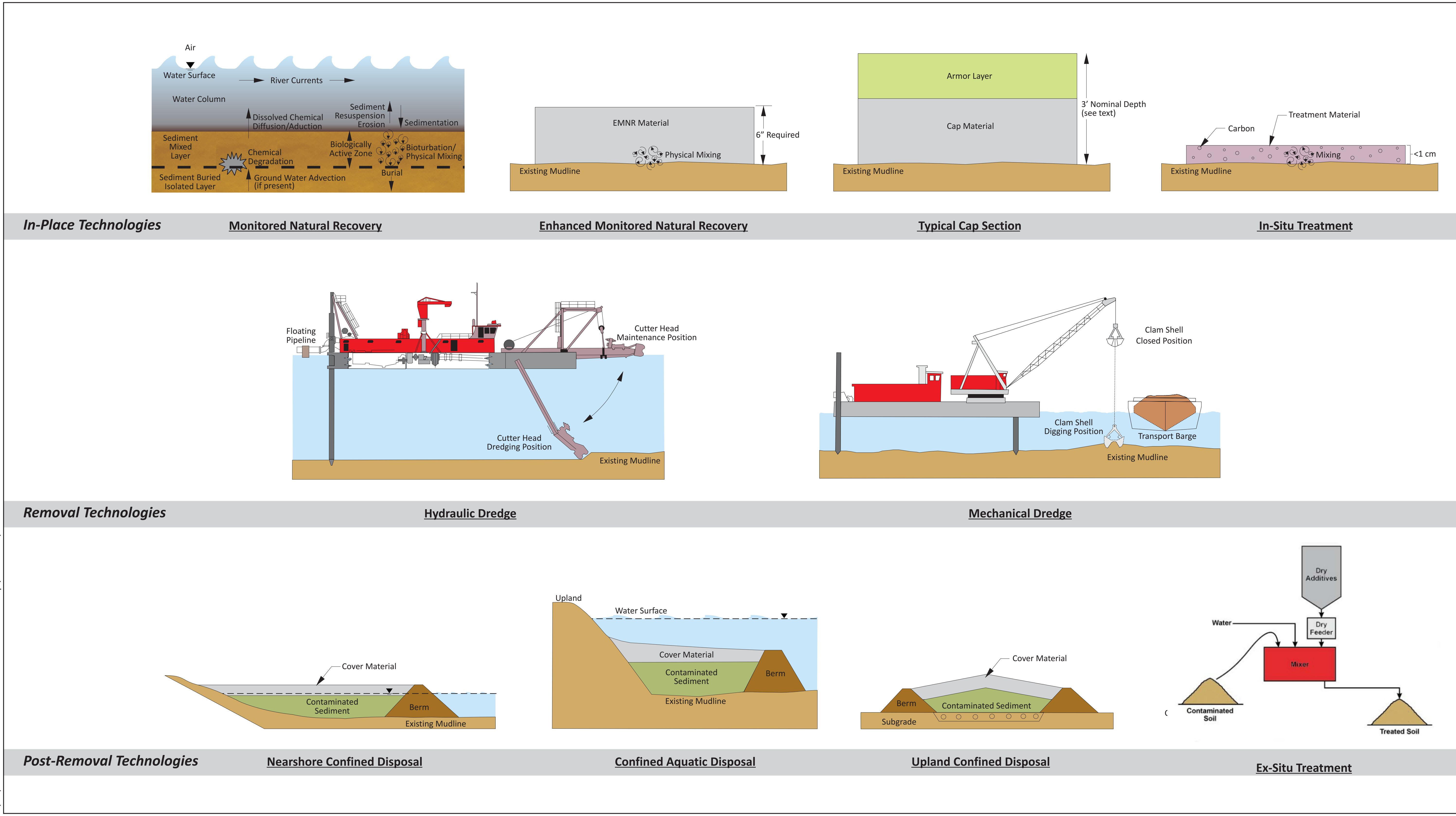

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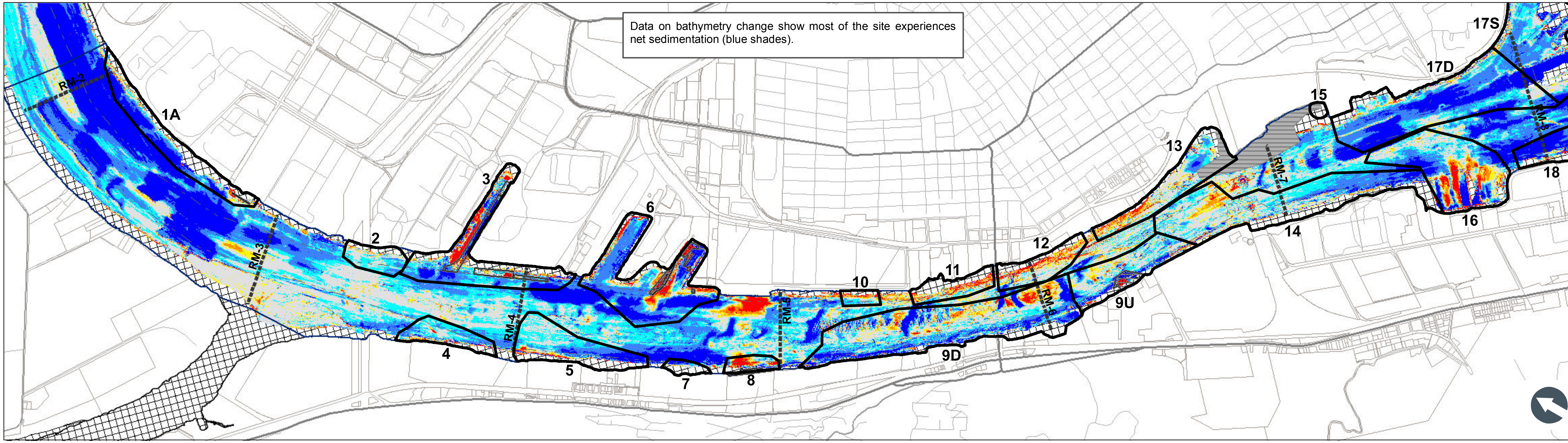
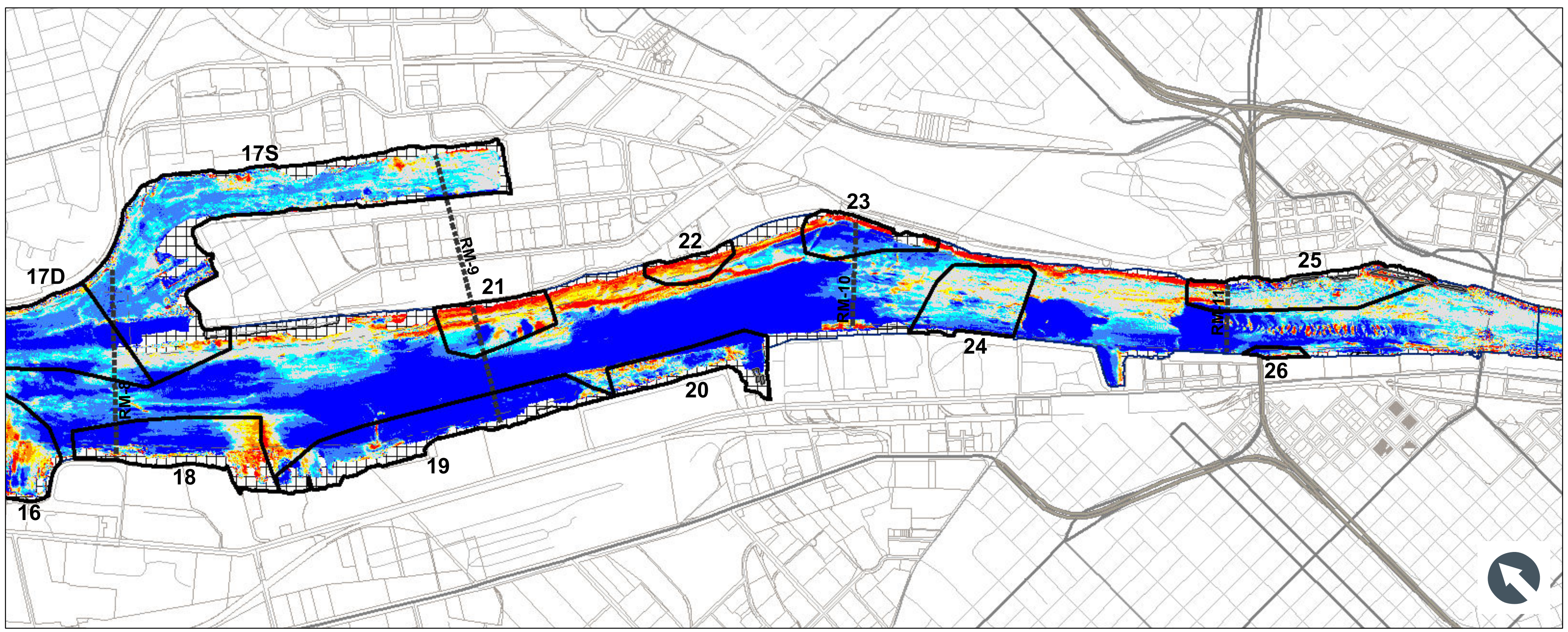
Figure 6.1-2
Portland Harbor RI/FS
Draft Feasibility Study
Sediment Remediation Technologies





LEGEND

- Dredge Areas 2003-2009

Bathymetric Change from 2003 to 2009 (cm)

- < -30
- -30 to -15
- -15 to -7.5
- -7.5 to 7.5
- 7.5 to 15
- 15 to 30
- > 30
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Shallow Water, Not Captured in Survey
- Existing Remediation Cap

Note: Bathymetric changes within +/- 7 5 cm (shown in light gray) represent no discernible change based on the veritical resolution of the surveys.

Feet

0 1,000 2,000 3,000 4,000

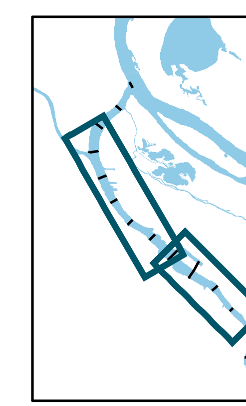


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Figure 6.2-1
Portland Harbor RI/FS
Draft Feasibility Study
Bathymetry Survey Comparison
Difference Between Surveys Conducted in 2003 and 2009

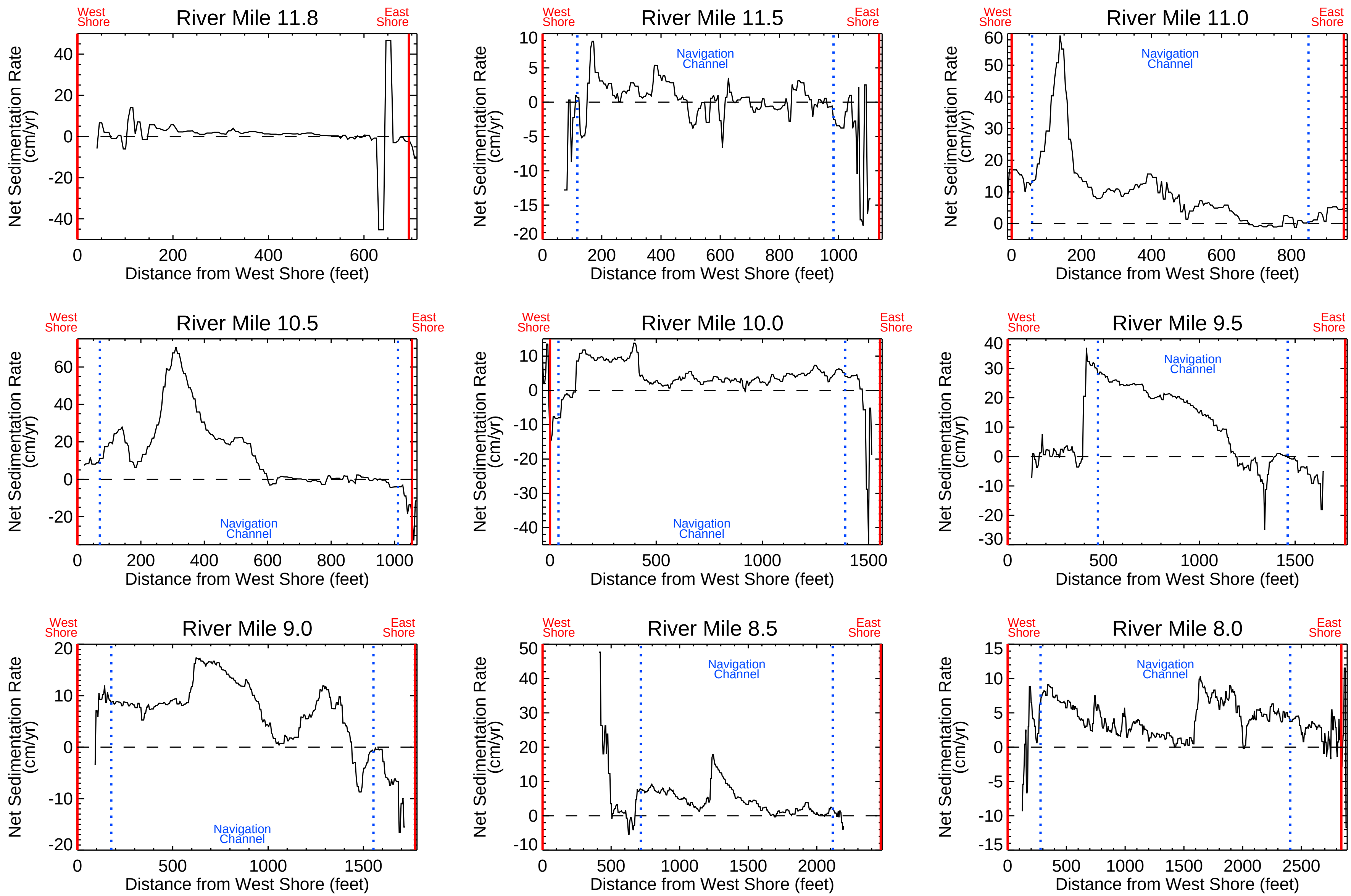

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Figure 6.2-2a

Portland Harbor RI/FS

Draft Feasibility Study

Lateral Cross-Sections of Net Sedimentation Rate Based on Multi-beam Bathymetry Surveys Conducted in 2003-2009

JCT/VKL - \\montd-vlist\d_drive\LWG\Analysis\Bathymetry\cross-sections\lwg_plot_bathy_data_cross_sections_120127_3x3L.pro Mon Mar 12 13:53:39 2012

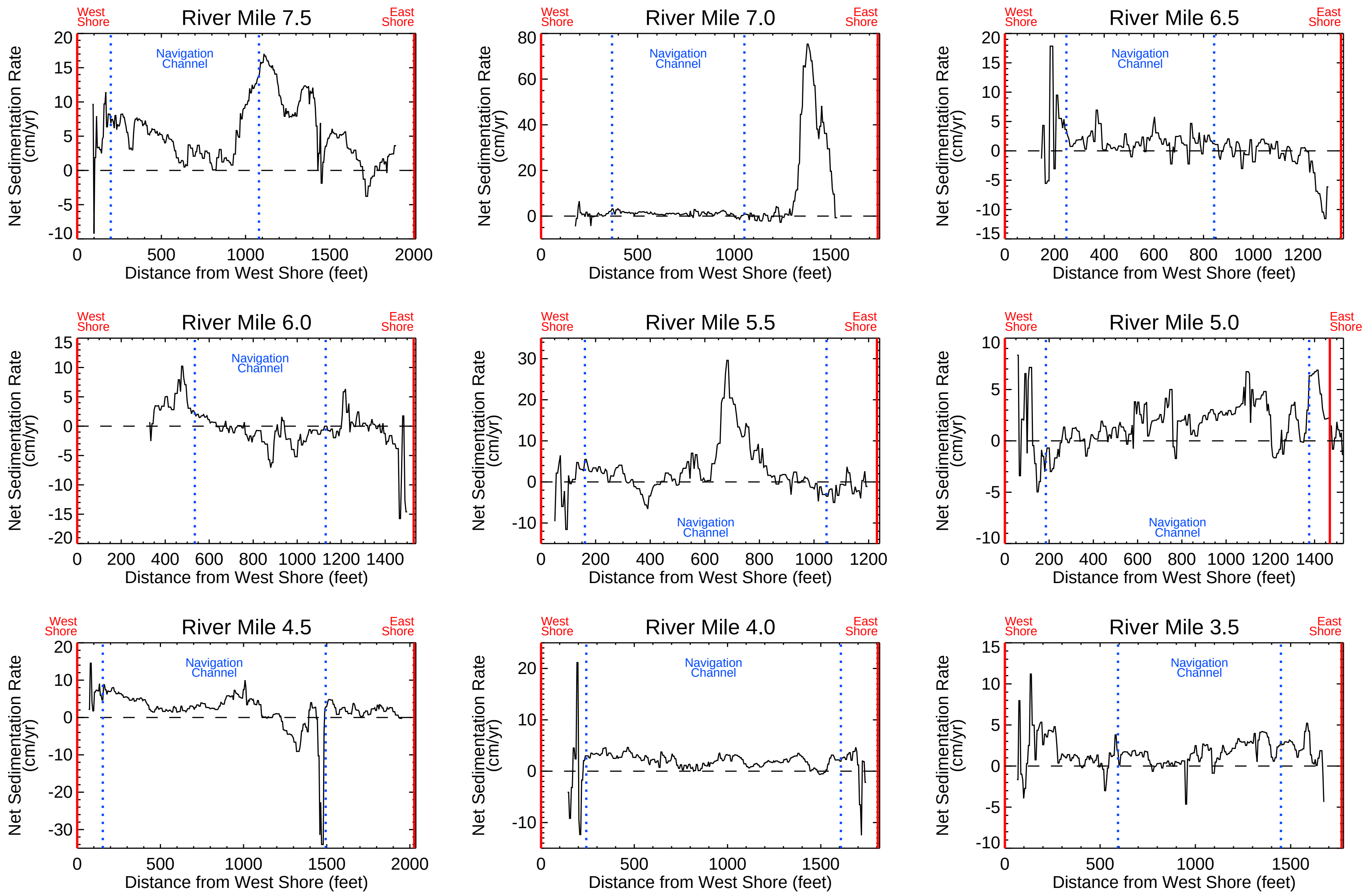

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Figure 6.2-2b

Portland Harbor RI/FS

Draft Feasibility Study

Lateral Cross-Sections of Net Sedimentation Rate Based on Multi-beam Bathymetry Surveys Conducted in 2003-2009

JCT/VKL - \\montd-vlist\d_drive\LWG\Analysis\Bathymetry\cross-sections\lwg_plot_bathy_data_cross_sections_120127_3x3L.pro Mon Mar 12 13:53:39 2012

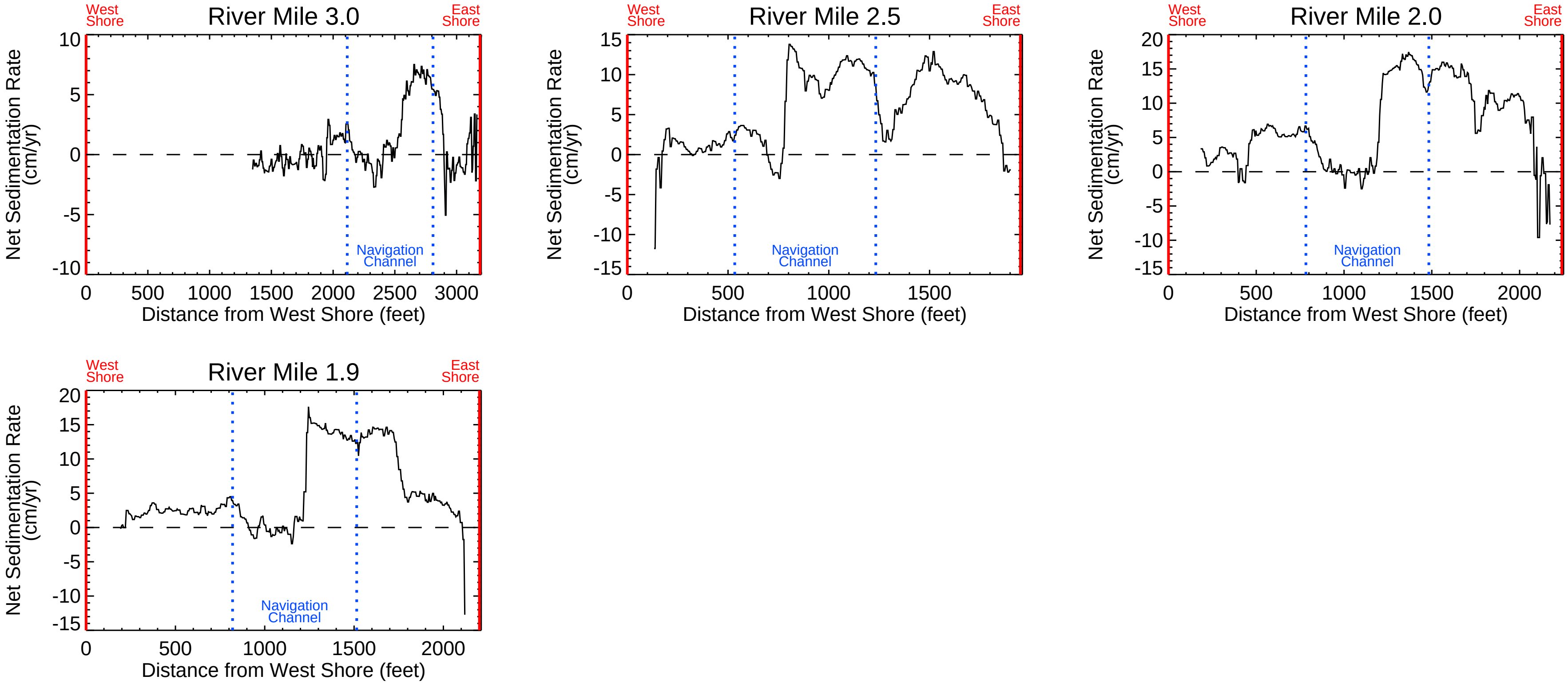

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Figure 6.2-2c

Portland Harbor RI/FS

Draft Feasibility Study

Lateral Cross-Sections of Net Sedimentation Rate Based on Multi-beam Bathymetry Surveys Conducted in 2003-2009

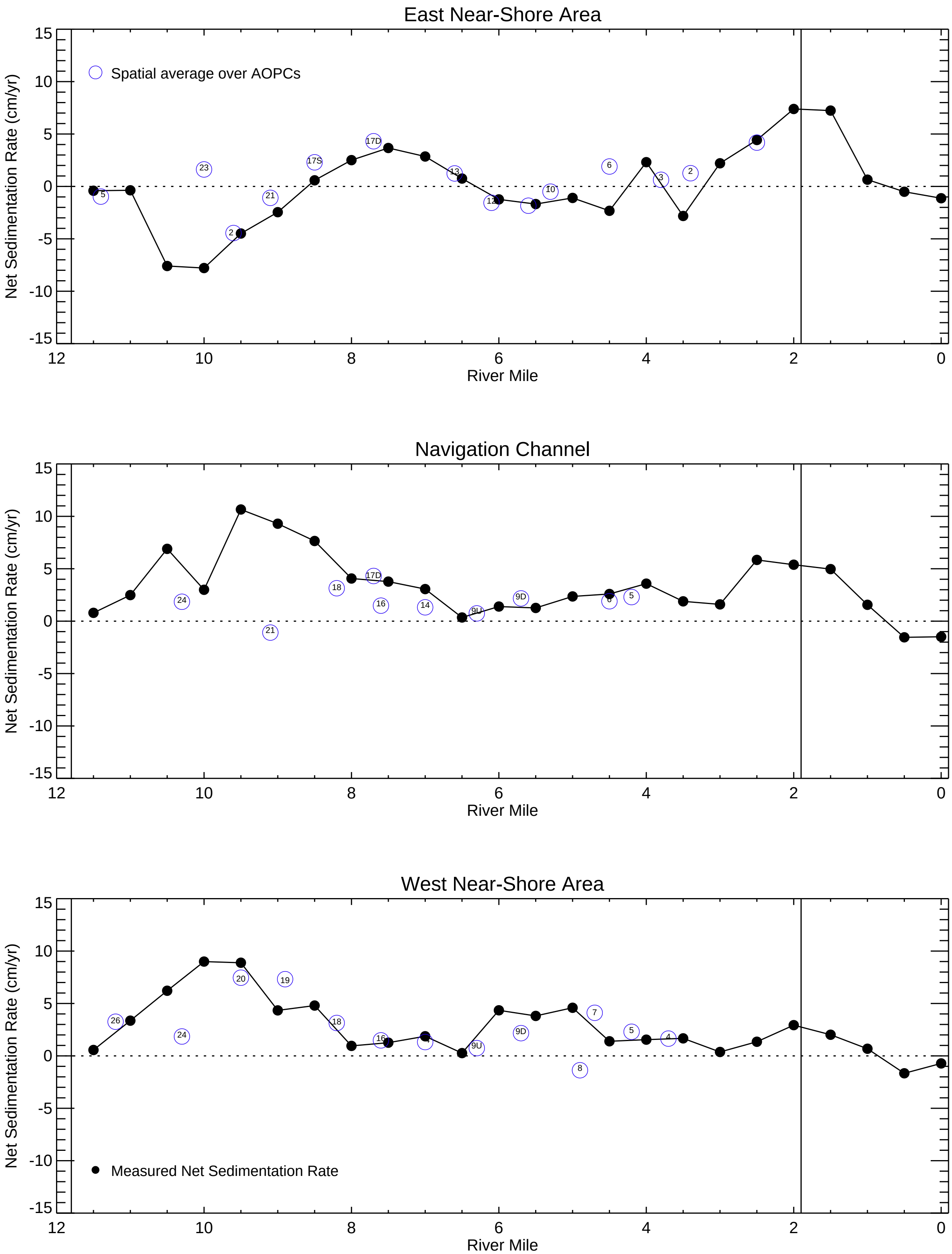

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Figure 6.2-3

Portland Harbor RI/FS

Draft Feasibility Study

Average Sedimentation Rates for 1/2-Mile Segments and by AOPC Calculated Based on Multi-beam Bathymetry Surveys Conducted in 2003 and 2009.

AOPC spatial averages are plotted at the river mile of the AOPC midpoint

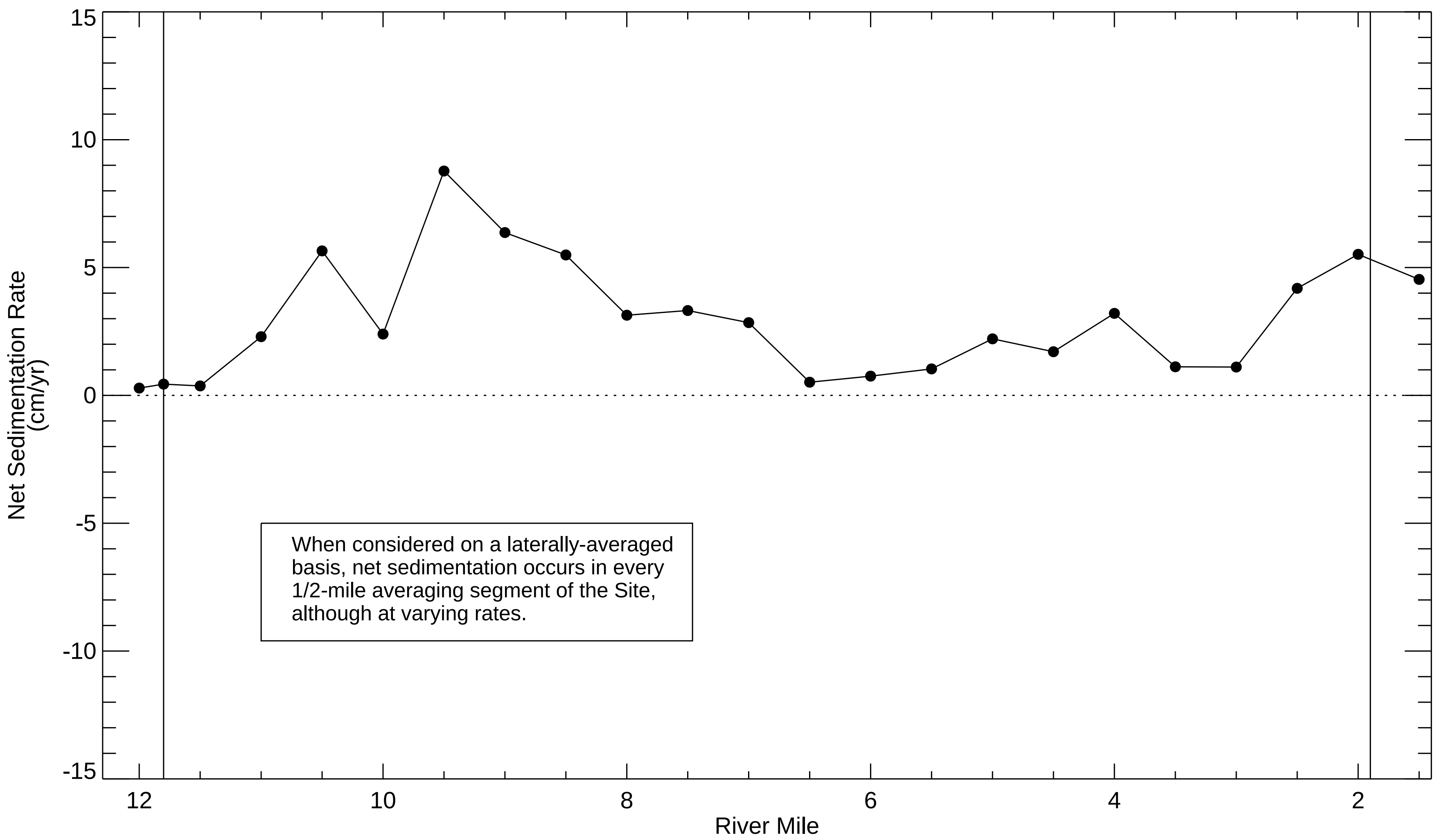


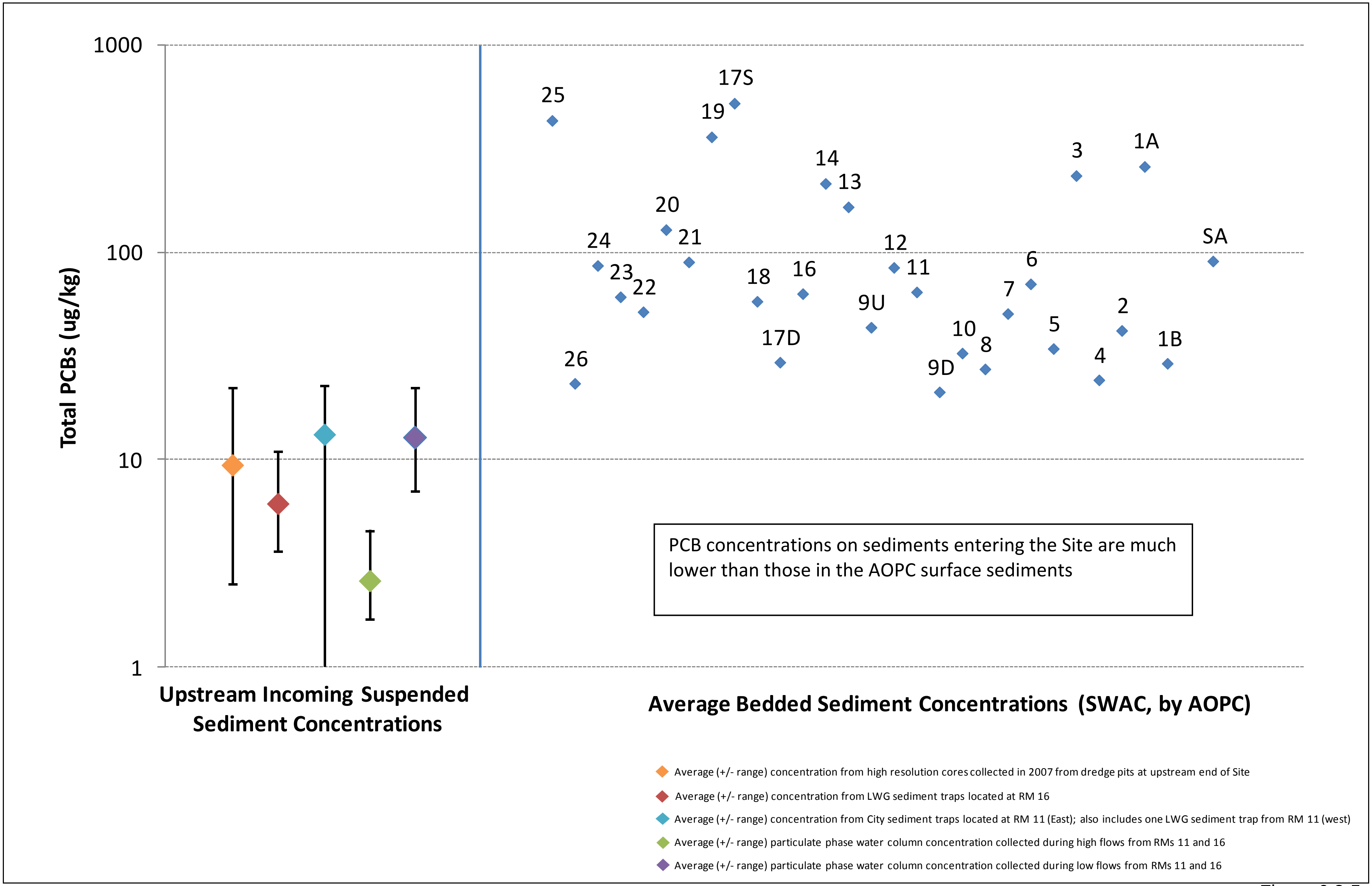
Figure 6.2-4

Portland Harbor RI/FS

Draft Feasibility Study

Lateral-Average Sedimentation Rates for 1/2-Mile Segments Calculated Based on Multi-beam Bathymetry Surveys Conducted in 2003 and 2009

Note: Data points represent cross-channel averages, at approximate 1/2 river mile intervals. Positive values represent net deposition; negative values represent net erosion.



Contaminant Concentrations on Incoming Suspended Sediments Compared with Study Area Bedded Sediments (Total PCB)

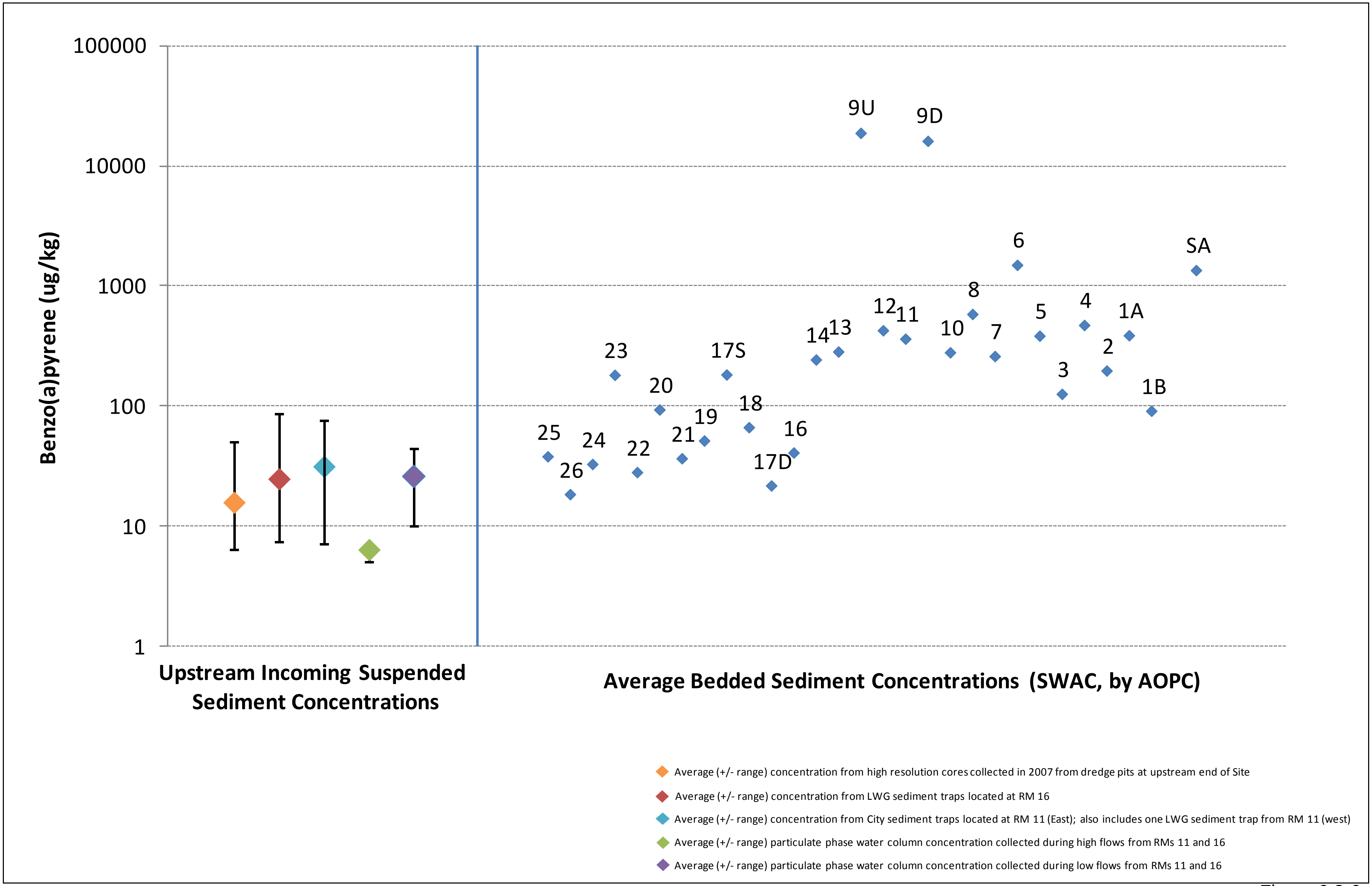


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Figure 6.2-6
Portland Harbor RI/FS
Draft Feasibility Study Report
Contaminant Concentrations on Incoming Suspended Sediments Compared with Study Area Bedded Sediments (BaP)

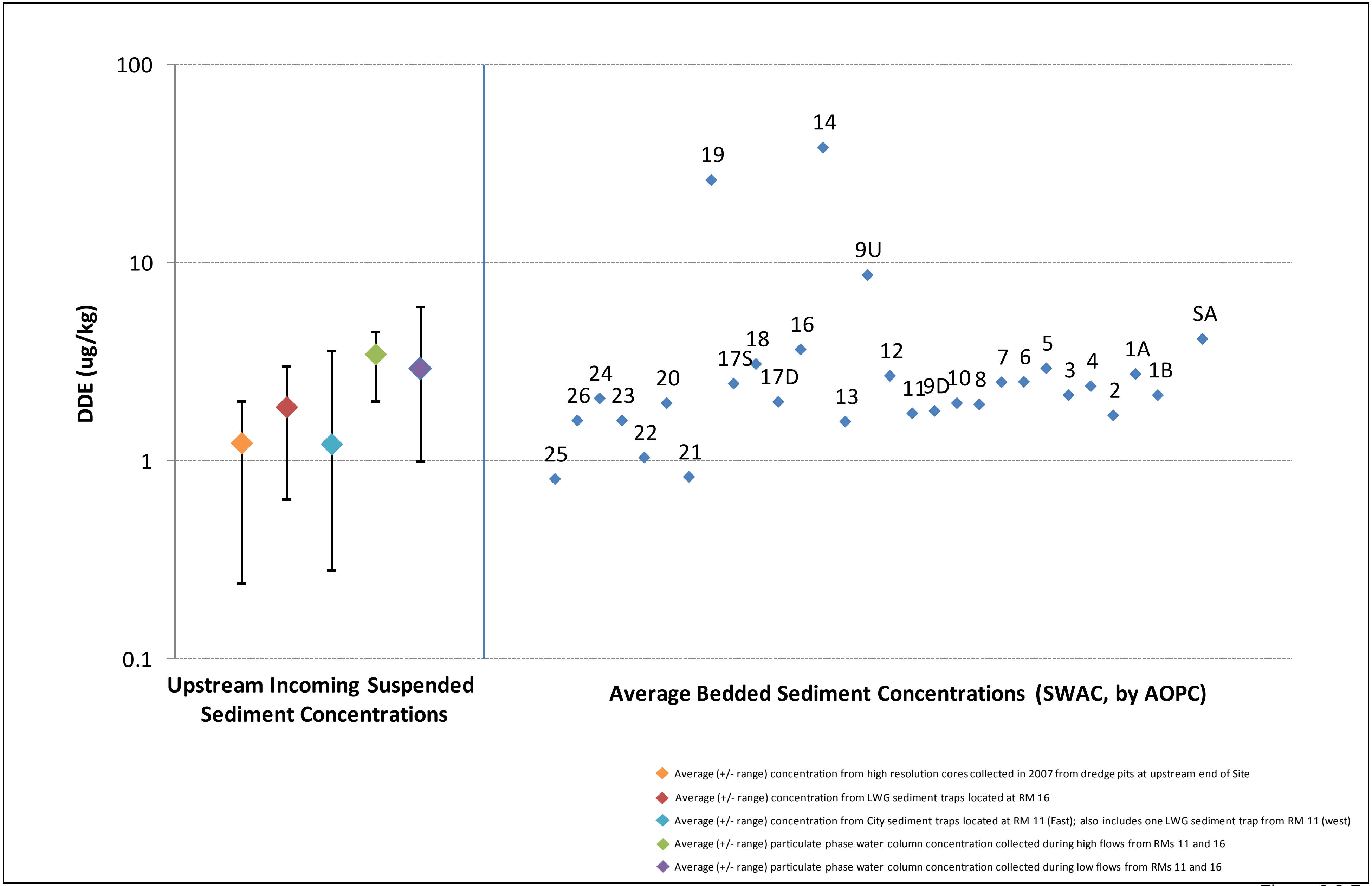

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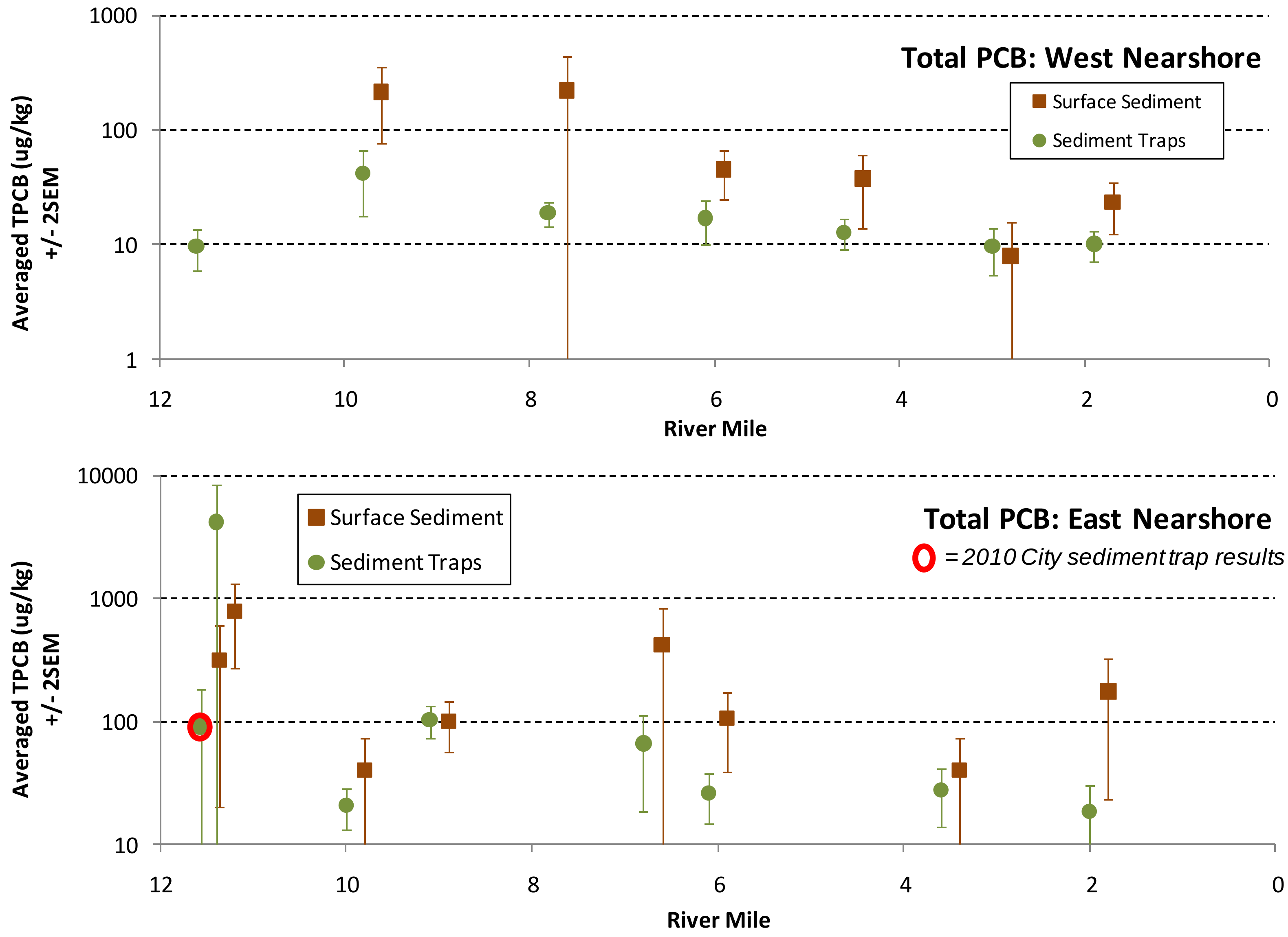
Figure 6.2-7
Portland Harbor RI/FS
Draft Feasibility Study Report
Contaminant Concentrations on Incoming Suspended Sediments Compared with Study Area Bedded Sediments (DDE)



Total PCB: West Nearshore
Surface Sediment
Sediment Traps
Averaged TPCB (ug/kg) +/- 2SEM
1000
100
10
1
12
10
8
6
4
2
0
River Mile
Total PCB: East Nearshore
= 2010 City sediment trap results
Surface Sediment
Sediment Traps
Averaged TPCB (ug/kg) +/- 2SEM
10000
1000
100
10
River Mile

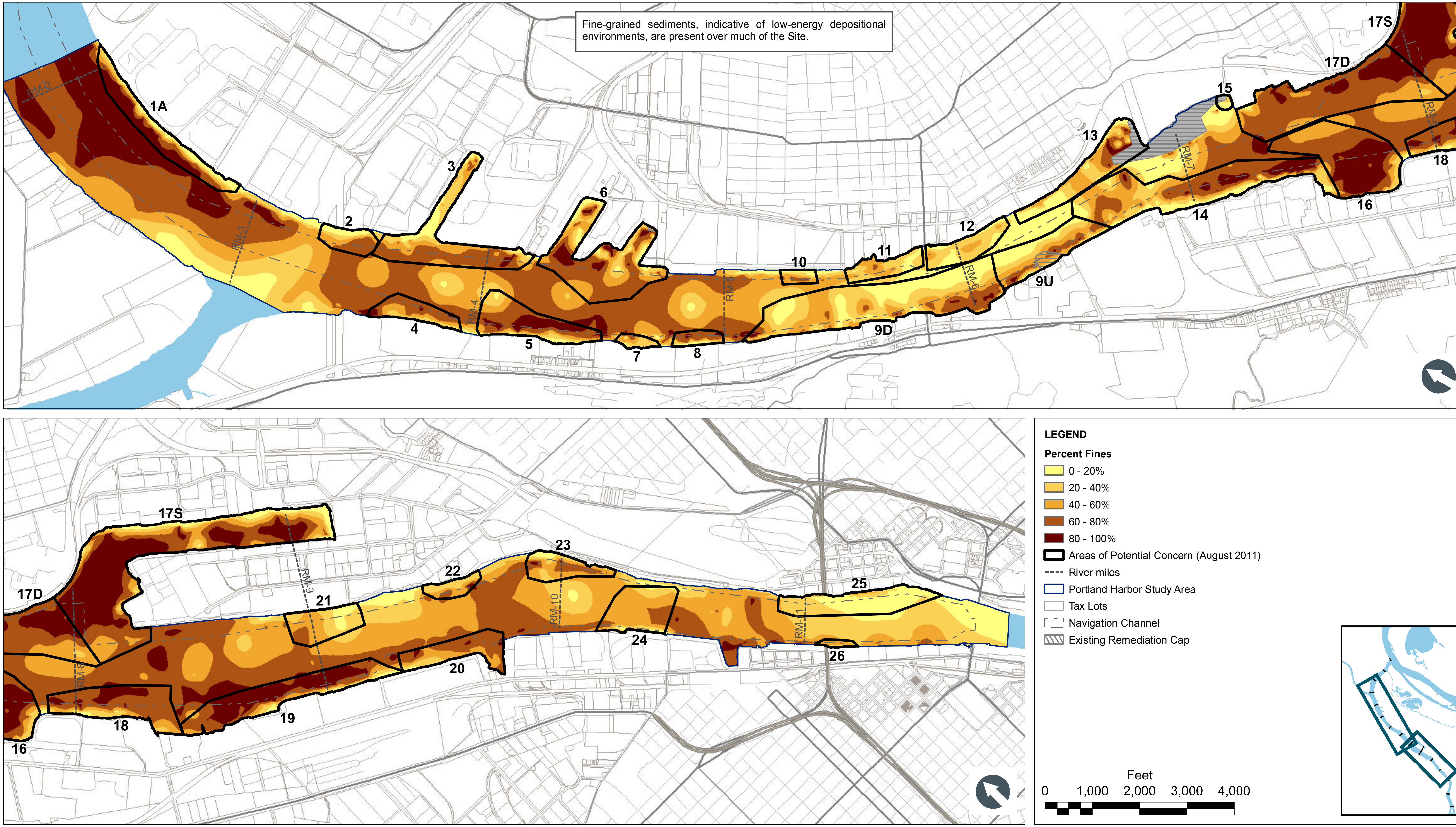


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Figure 6.2-9
Portland Harbor RI/FS
Draft Feasibility Study Report
Contoured Surface Sediment Texture, Percent Fines
River Mile 11 to 11.8

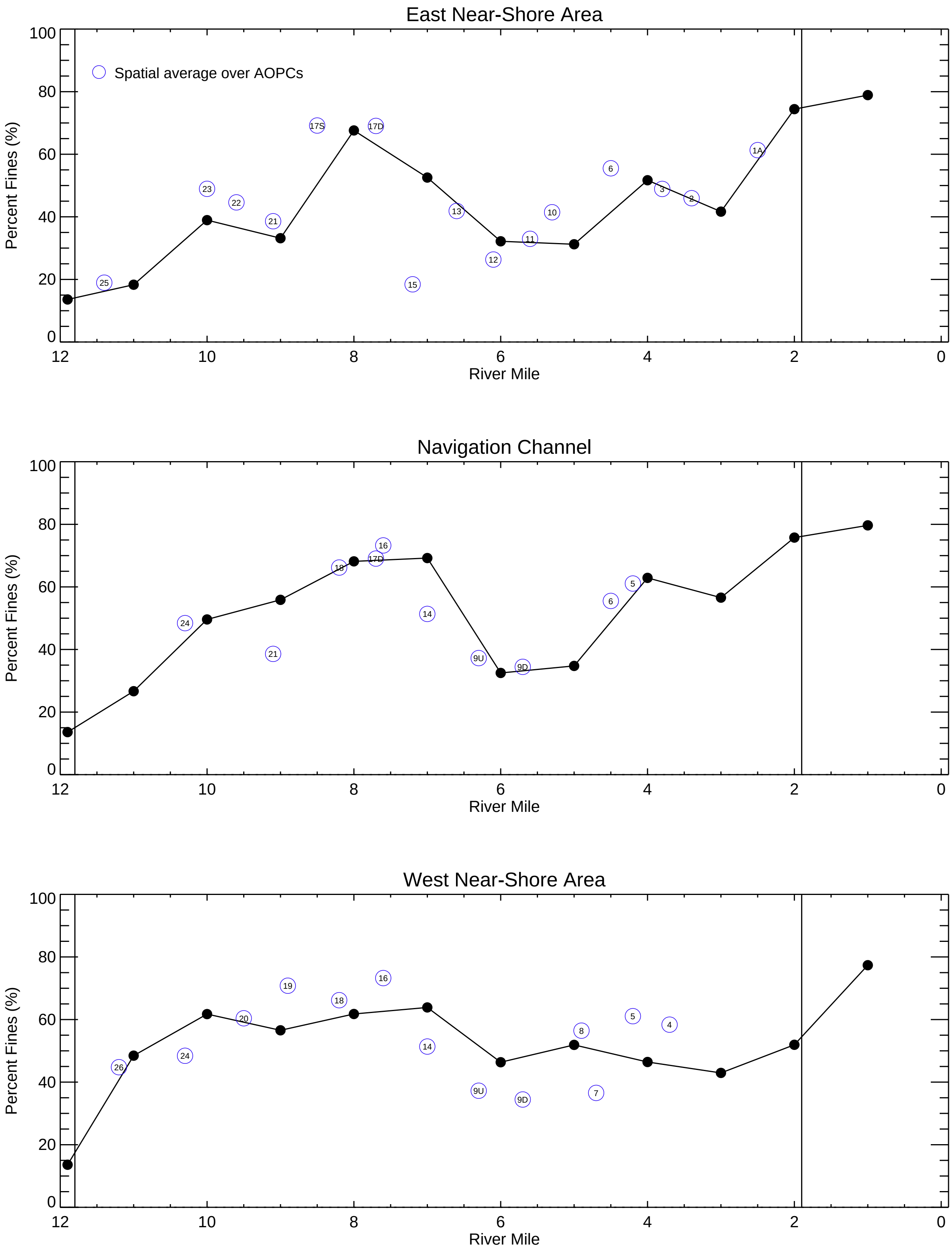

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Figure 6.2-10

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Surface Sediment Bed Type (Percent Fines) Averaged over 1-Mile Segments and AOPCs.

AOPC spatial averages are plotted at the river mile of the AOPC midpoint

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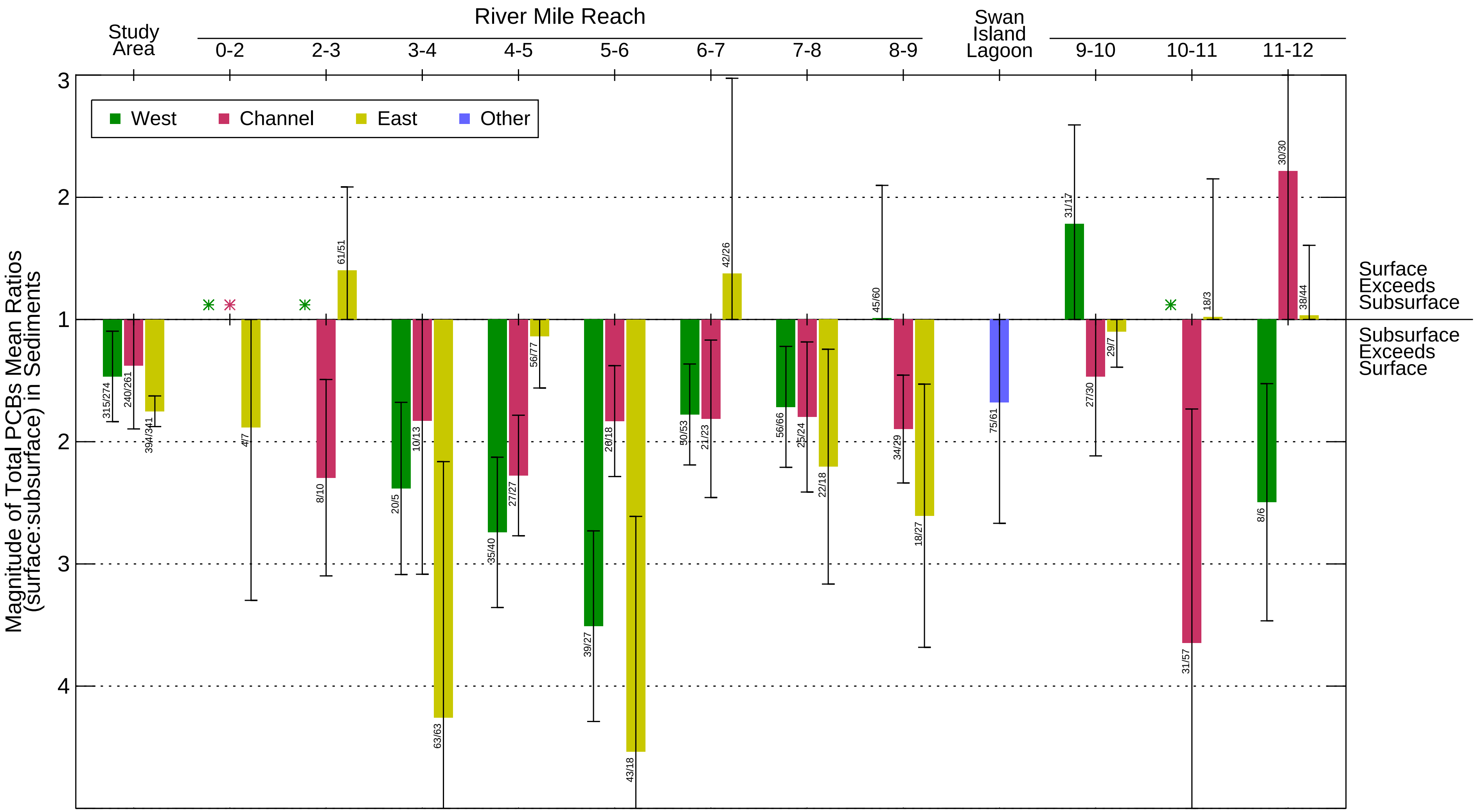

Ratios of surface to subsurface PCBs show that concentrations at the surface, reflecting more recently-deposited sediment, are lower than those at depth, consistent with natural recovery

** Total PCBs analyzed at surface only.*
XX/YY is the count of surface samples (XX) and subsurface samples (YY) included in ratio.

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Figure 6.2-11

Portland Harbor RI/FS
Draft Feasibility Study
Total PCBs Mean Surface/Subsurface Concentration Ratios in Sediment

Error bars represent approximate uncertainty bounds of the mean (clipped at ratio = 1) based on the methods described in 6.2.2.1.1

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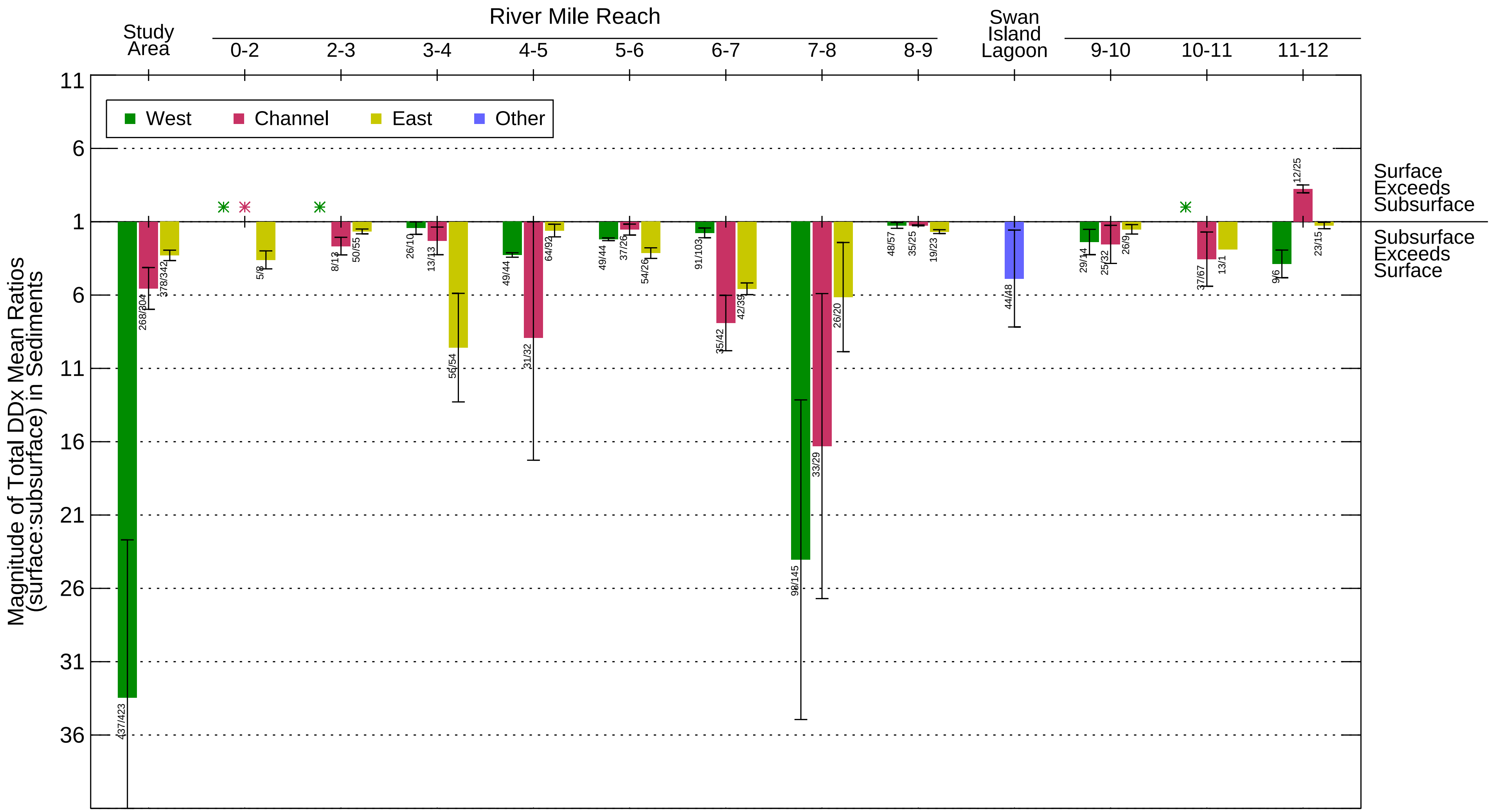

* Total DDx analyzed at surface only.
XX/YY is the count of surface samples (XX) and subsurface samples (YY) included in ratio.

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Figure 6.2-12
Portland Harbor RI/FS
Draft Feasibility Study
Total DDx Mean Surface/Subsurface Concentration Ratios in Sediment

Error bars represent approximate uncertainty bounds of the mean (clipped at ratio = 1) based on the methods described in 6.2.2.1.1

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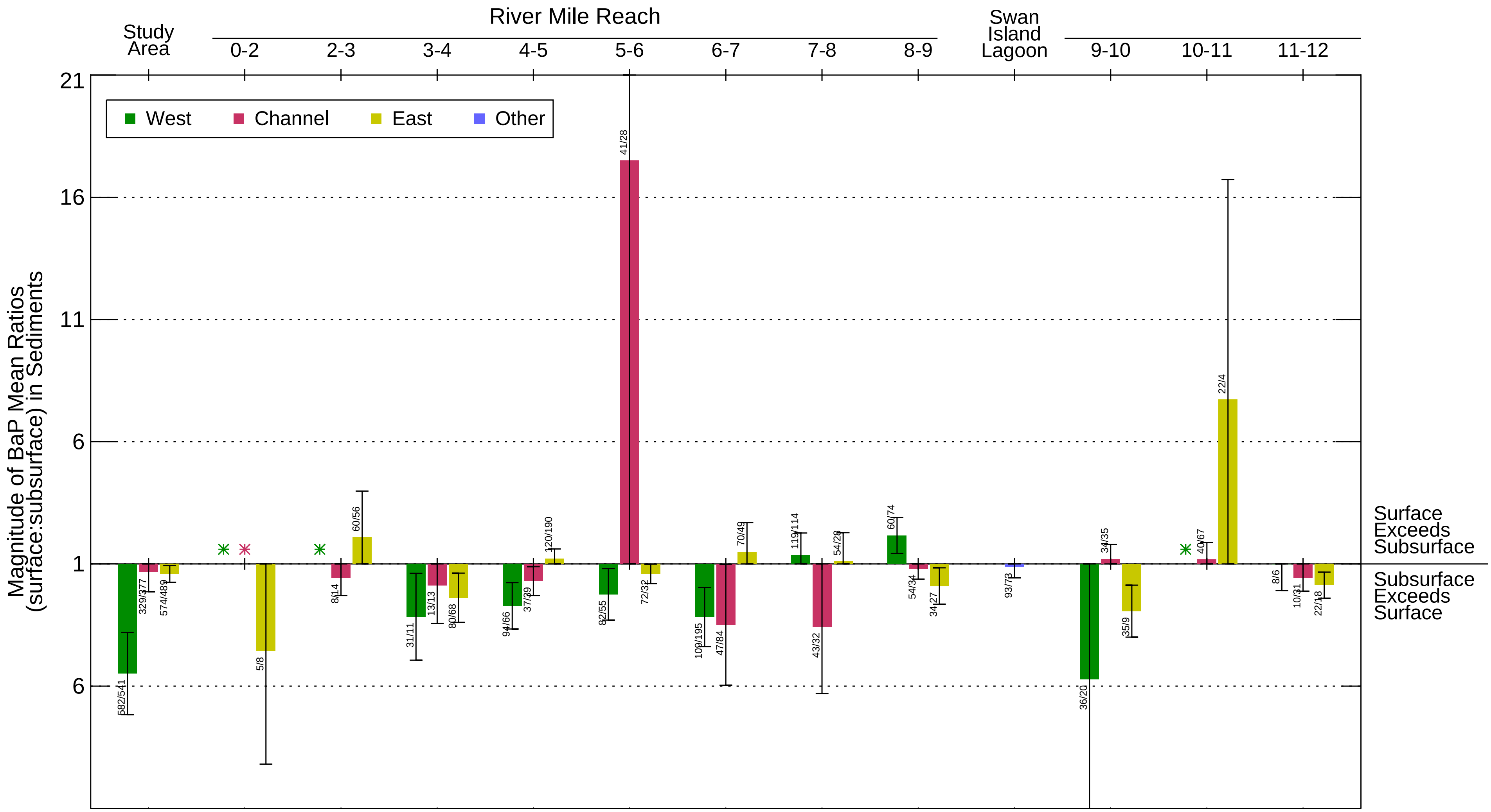

** BaP analyzed at surface only.*
XX/YY is the count of surface samples (XX)
and subsurface samples (YY) included in ratio.

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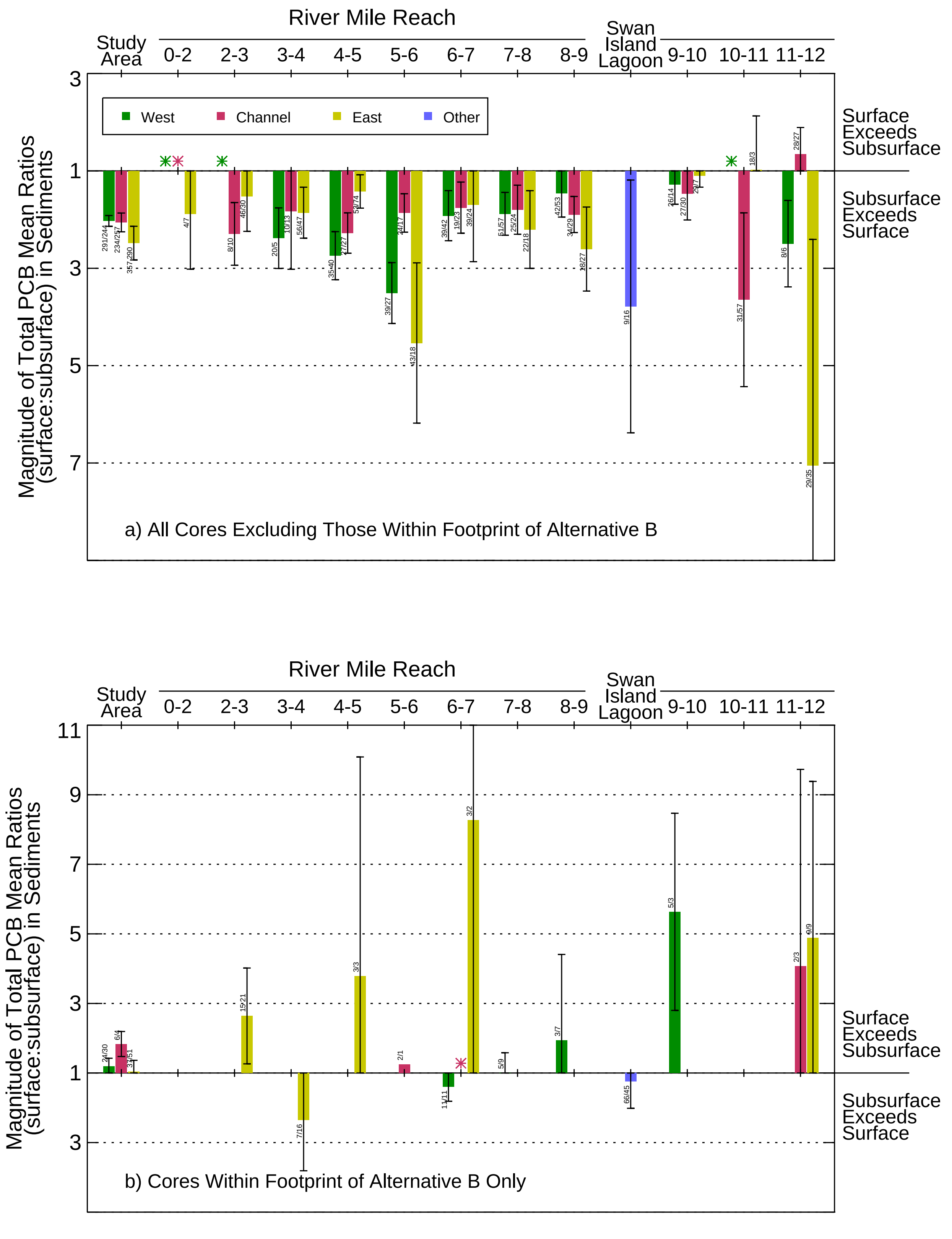
Figure 6.2-13

Portland Harbor RI/FS
Draft Feasibility Study
BaP Mean Surface/Subsurface
Concentration Ratios in Sediment

Error bars represent approximate uncertainty bounds of the mean (clipped at ratio = 1) based on the methods described in 6.2.2.1.1

MJR - B:\Projects\Lower_Willamette_Group\Lower_Willamette_Group_(010142-01)\Analysis\Sediment\LWG_Sediment_barchart_surface_v_subsurface_Ratios.pro Mon Mar 12 13:26:58 2012



* Total PCB analyzed at surface only
XX/YY is the count of surface samples (XX) and subsurface samples (YY) included in ratio.

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Figure 6.2-14

Portland Harbor RI/FS
Draft Feasibility Study
Total PCB Mean Surface/Subsurface Concentration Ratios in Sediment for Areas Inside and Outside of the Footprint of Alternative B

Error bars represent approximate uncertainty bounds of the mean (clipped at ratio = 1) based on the methods described in 6.2.2.1.1

MJR - B:\Projects\Lower_Willamette_Group\Lower_Willamette_Group_(010142-01)\Analysis\Sediment\LWG_Sediment_barchart_surface_v_subsurface_Ratios_Alternative_B.pro Mon Mar 12 13:23:59 2012

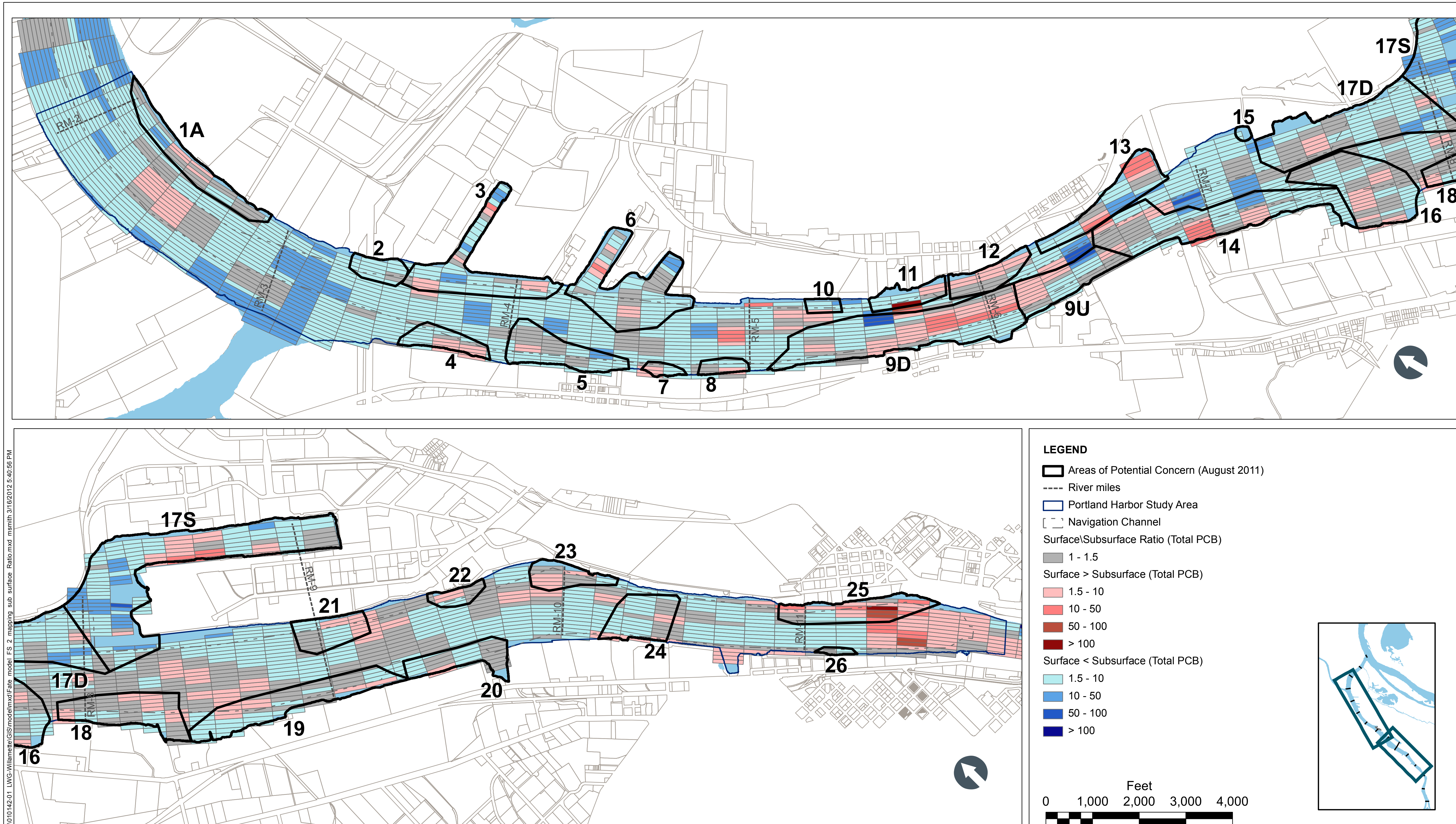

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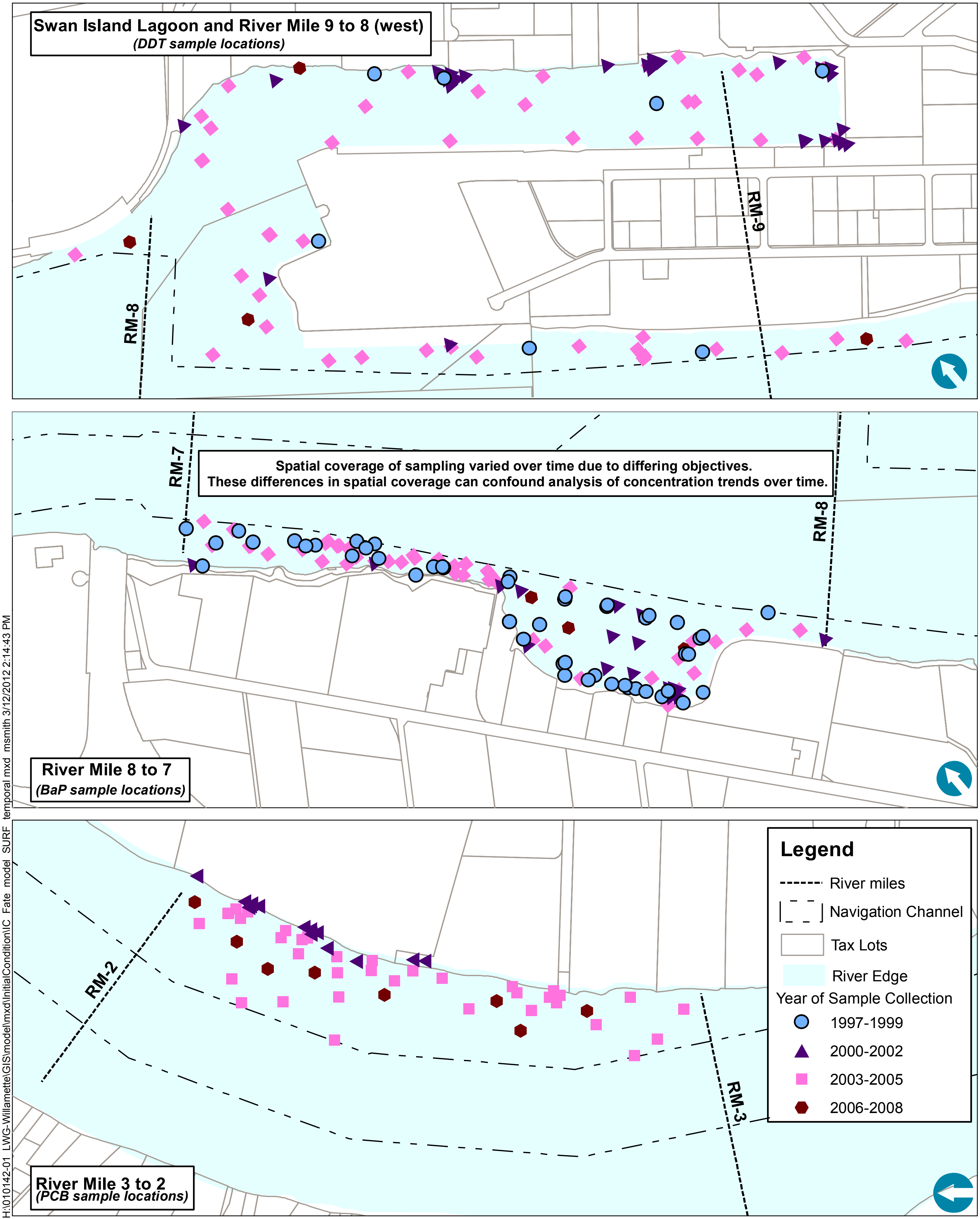
Figure 6.2-15
Portland Harbor RI/FS
Draft Feasibility Study
Spatial Variation in Surface/Subsurface Concentration Ratios for Total PCB
River Mile 1.9 to 11.8



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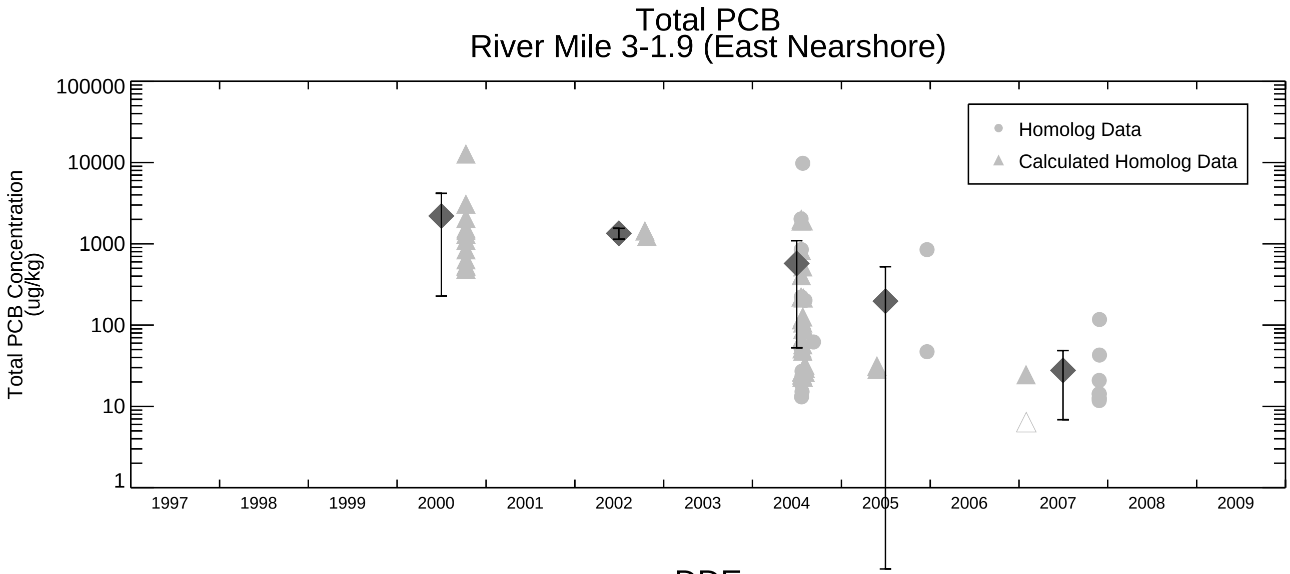
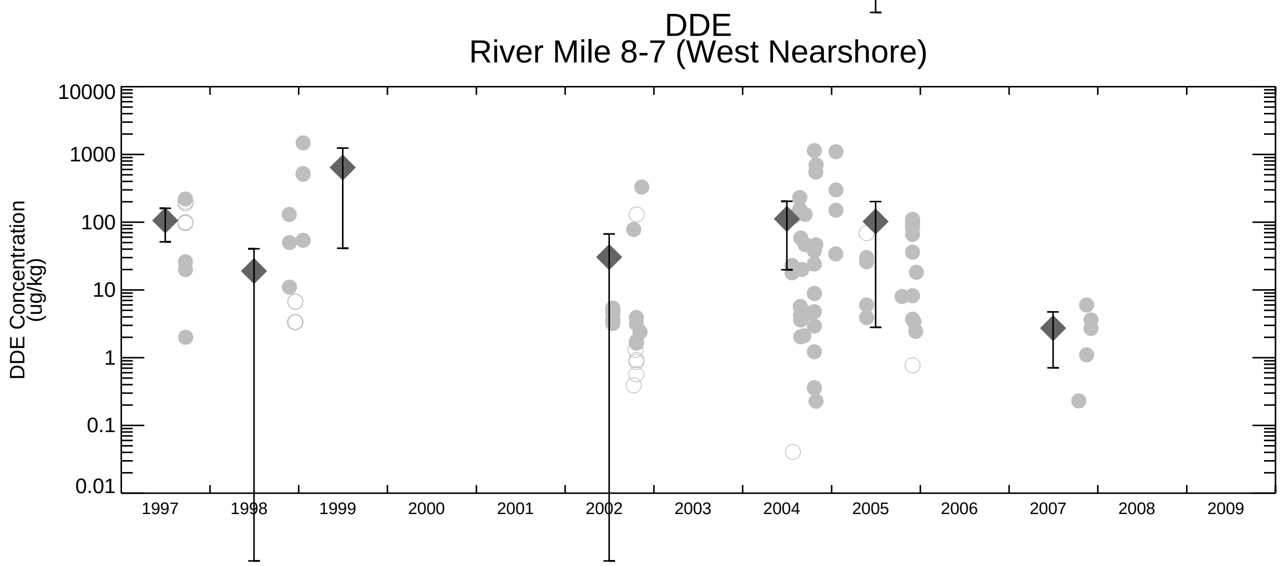
0 245 490 980
Feet

Figure 6.2-16
Portland Harbor RI/FS
Draft Feasibility Study
Example Spatial and Temporal Coverage of Surface Sediment Data





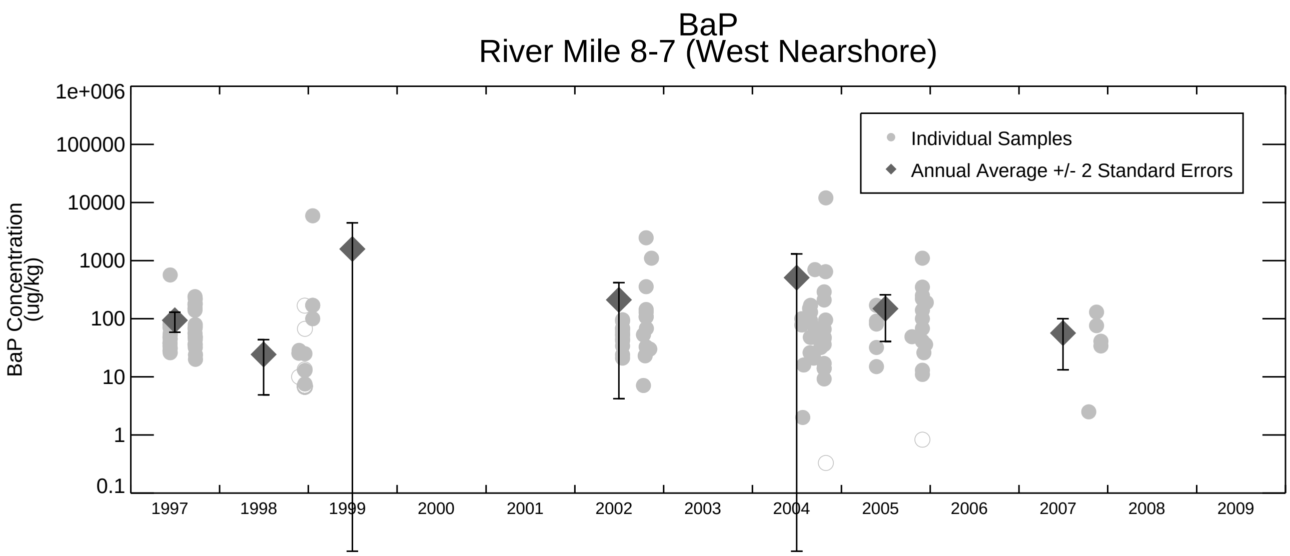


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Figure 6.2-17

Portland Harbor RI/FS

Draft Feasibility Study

Example Time Series of Surface Sediment (Top 1-ft) Data.

Open symbols represent non-detect data plotted at the detection limit.

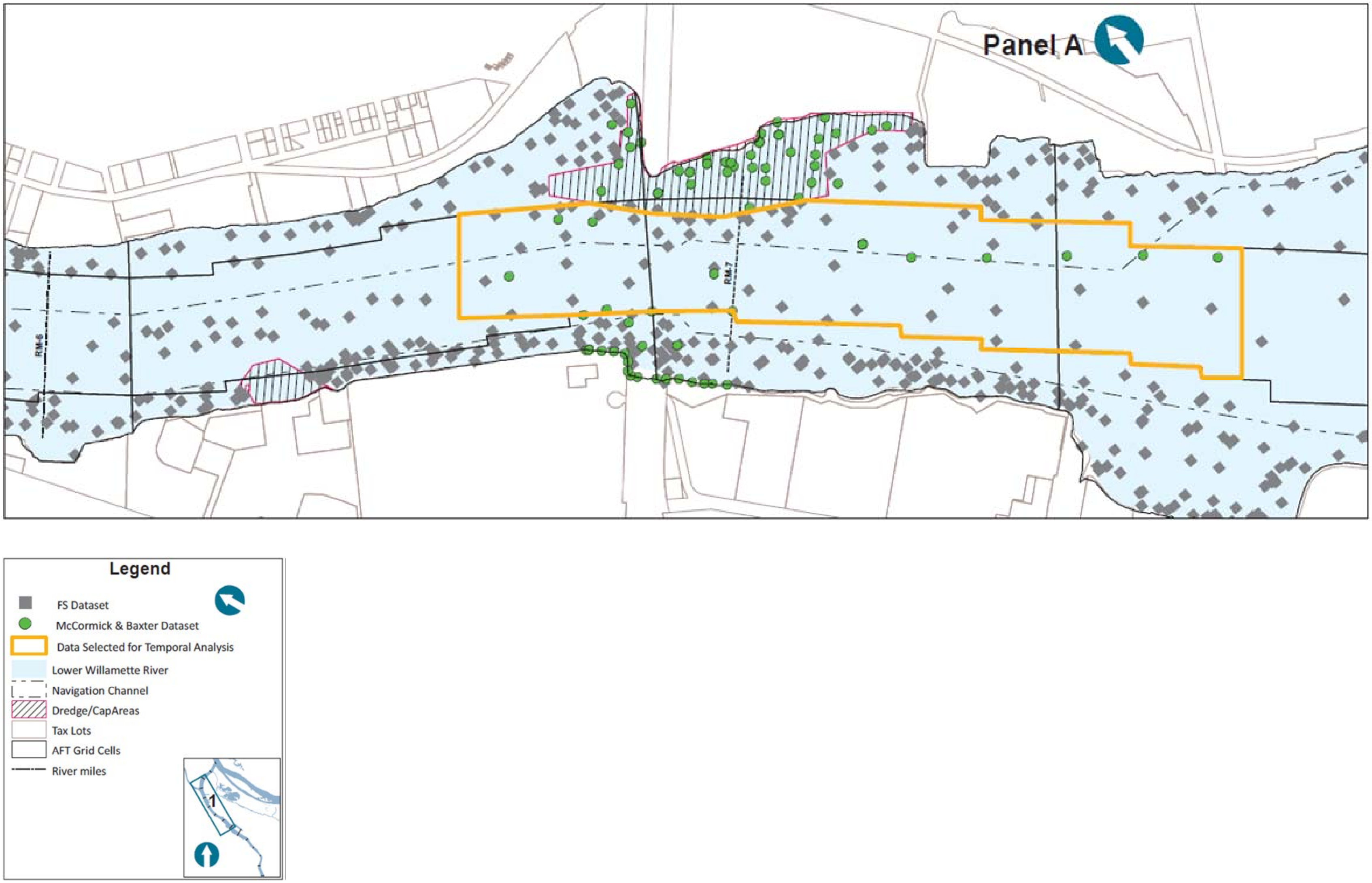

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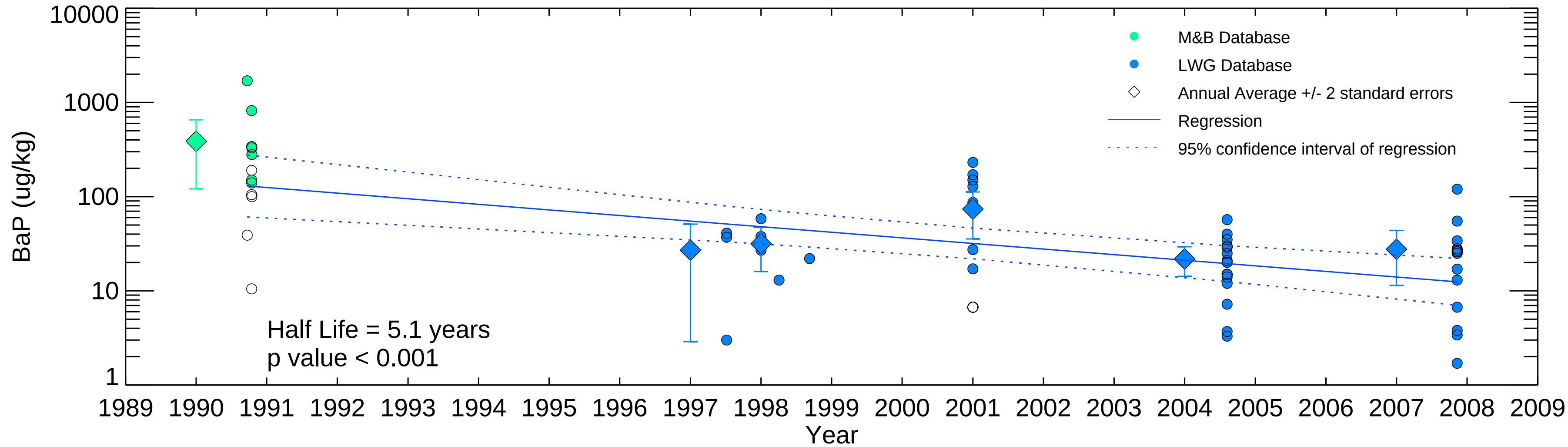
Figure 6.2-18
Portland Harbor RI/FS
Draft Feasibility Study Report
McCormick & Baxter Data Set Included in Temporal Analysis

Area having long-term data exhibits statistically significant decline in surface sediment PAH concentrations over time



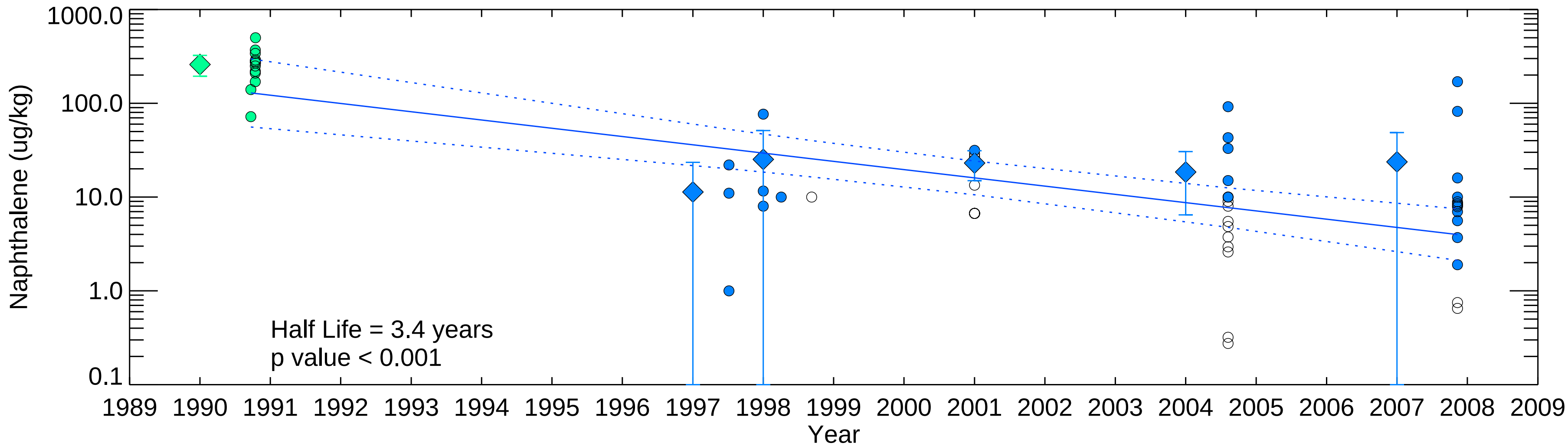


Figure 6.2-19

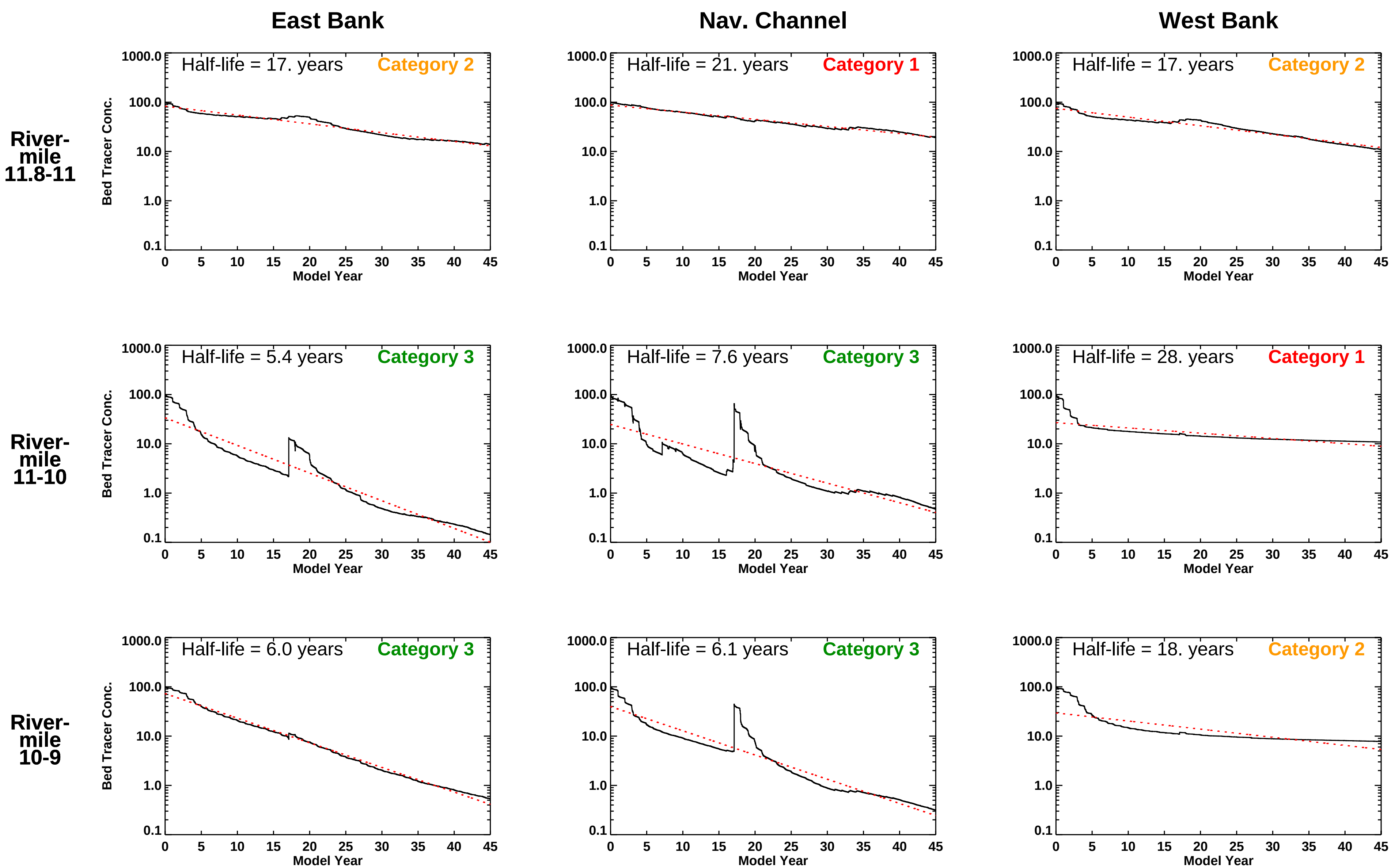
Portland Harbor RI/FS

Draft Feasibility Study

Evaluation of Long-term Surface Sediment Temporal Trends in the River Mile 7 Area

Non-detect samples set to 1/2 detection limit and plotted with open symbols.

MJR - B:\Projects\Lower_Willamette_Group\Lower_Willamette_Group_(010142-01)\Analysis\Sediment\LWG_Sediment_Temp_MB_figure6_2_19.pro Mon Mar 12 13:24:47 2012



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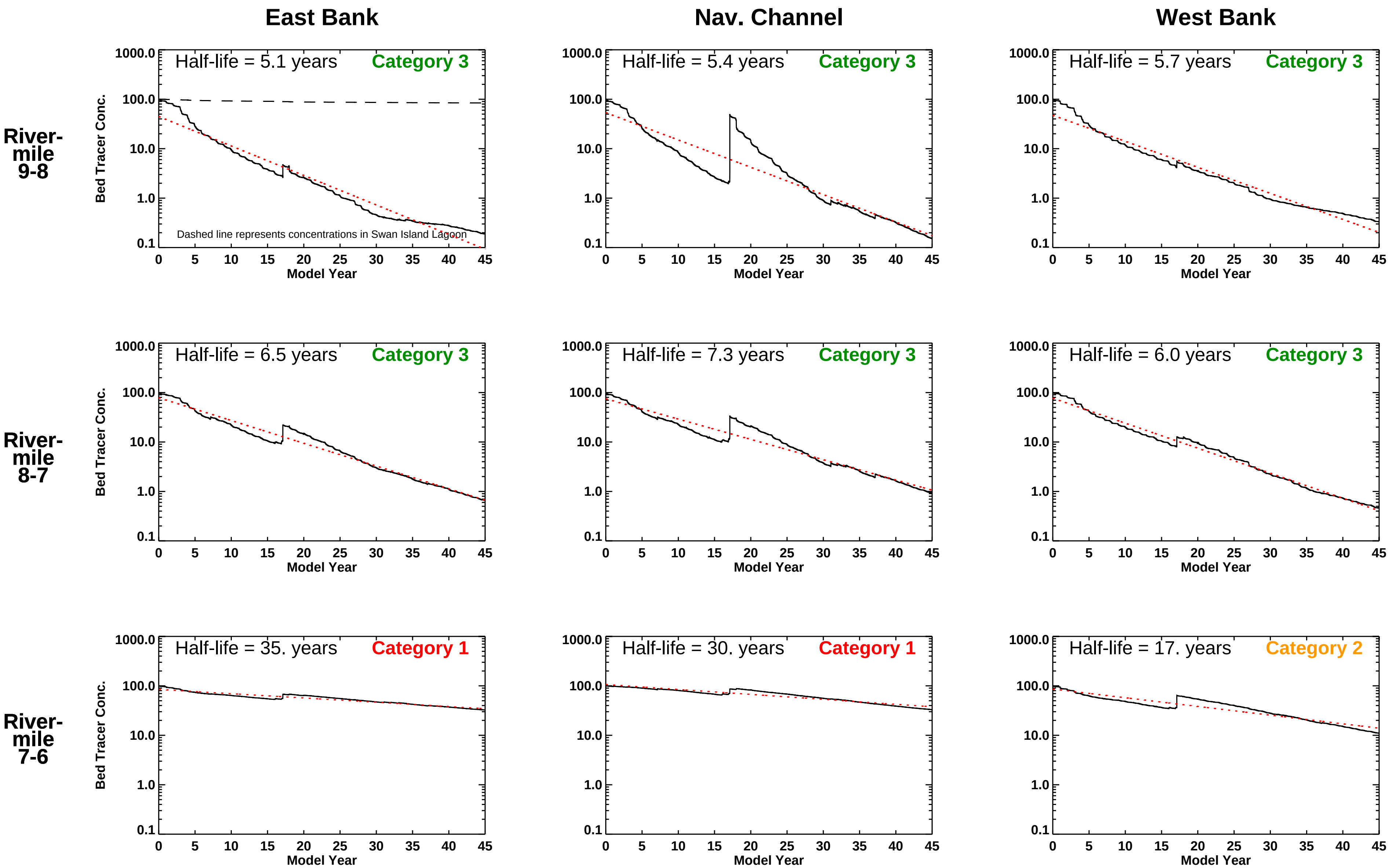
Model
Half-life fit

Category 1: Half-life > 20 years
Category 2: Half-life 10 - 20 years
Category 3: Half-life < 10 years

Figure 6.2-20a
Portland Harbor RI/FS
Draft Feasibility Study
Average Surface Sediment (Top 1-ft) Tracer Concentrations by River Mile.
Half-life calculated from model results spanning all years

DR - H:\010142-01_LWG-Willamette\model\Analysis\FS_Report\MNR_eval\plot_chem_bed_temp_EMW_bat_proj_45_SIL.pro Mon Mar 12 15:16:59 2012



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Model
Half-life fit

Category 1: Half-life > 20 years
Category 2: Half-life 10 - 20 years
Category 3: Half-life < 10 years

Figure 6.2-20b
Portland Harbor RI/FS
Draft Feasibility Study
Average Surface Sediment (Top 1-ft) Tracer Concentrations by River Mile.
Half-life calculated from model results spanning all years

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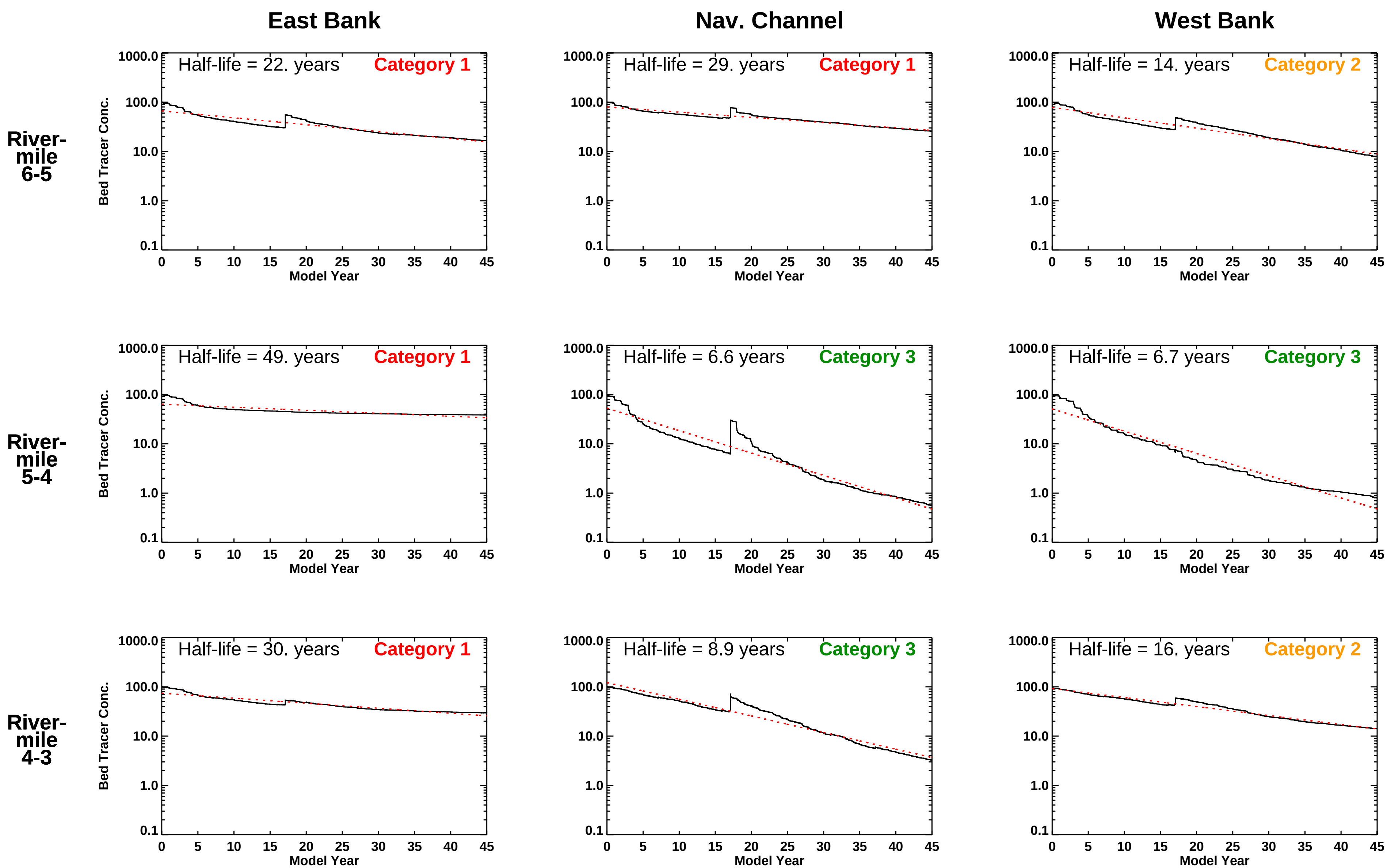

Model
Half-life fit

Category 1: Half-life > 20 years
Category 2: Half-life 10 - 20 years
Category 3: Half-life < 10 years

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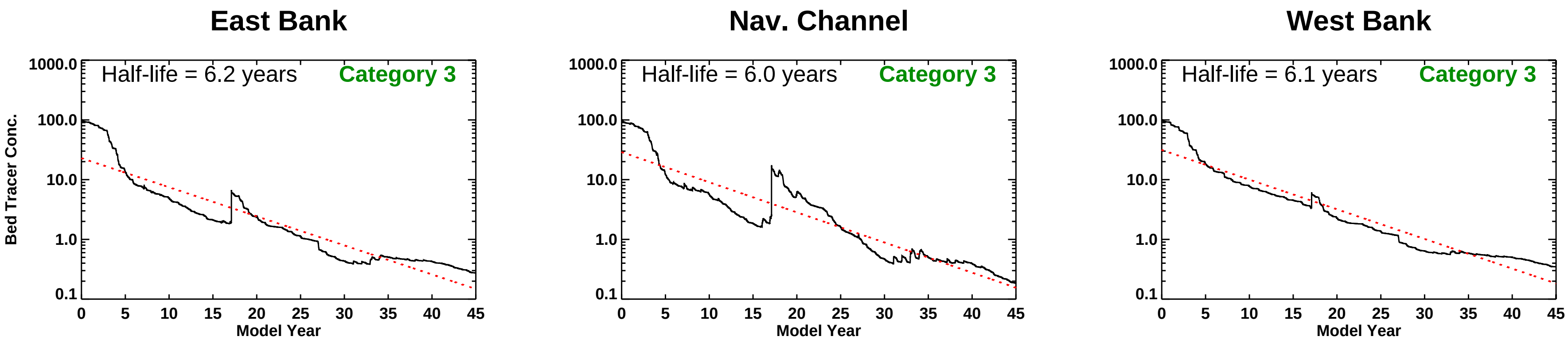
Figure 6.2-20c
Portland Harbor RI/FS
Draft Feasibility Study
Average Surface Sediment (Top 1-ft) Tracer Concentrations by River Mile.
Half-life calculated from model results spanning all years

DR - H:\010142-01_LWG-Willamette\model\Analysis\FS_Report\MNR_eval\plot_chem_bed_temp_EMW_bat_proj_45_SIL.pro Mon Mar 12 15:17:00 2012

River-mile 3-1.9



Model
Half-life fit

Category 1: Half-life > 20 years
Category 2: Half-life 10 - 20 years
Category 3: Half-life < 10 years

Figure 6.2-20d

Portland Harbor RI/FS

Draft Feasibility Study

Average Surface Sediment (Top 1-ft) Tracer Concentrations by River Mile.

Half-life calculated from model results spanning all years

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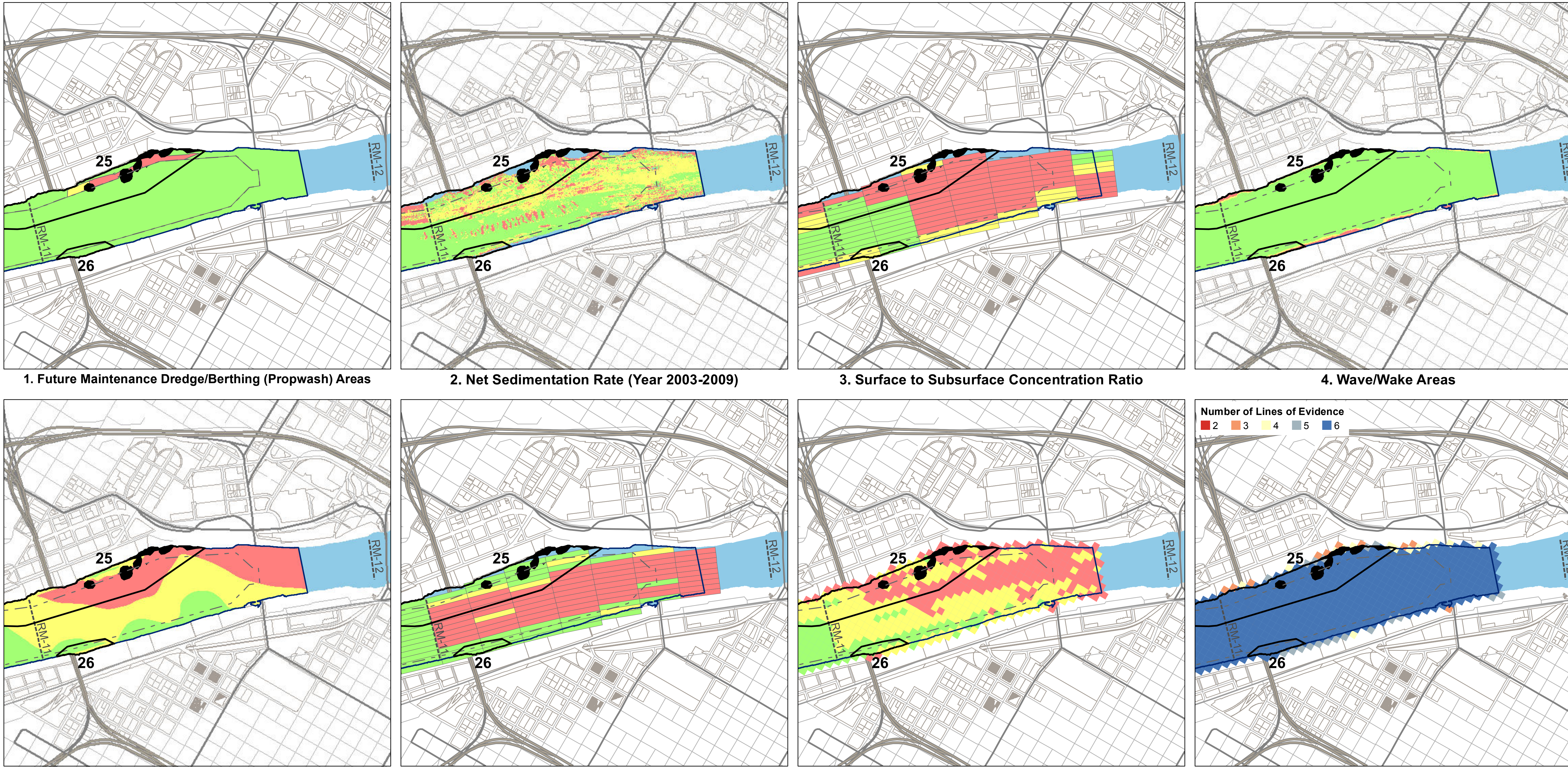


1. Future Maintenance Dredge/Berthing (Propwash) Areas

2. Net Sedimentation Rate (Year 2003-2009)

3. Surface to Subsurface Concentration Ratio

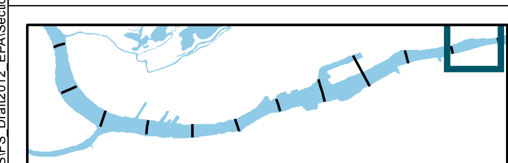
4. Wave/Wake Areas

5. Surface Sediment Grain Size

6. Long-term Recovery Rate Prediction

7. Overall Recovery Category (Weighted Average)

8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

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Figure 6.2-21a
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 11 to 11.8

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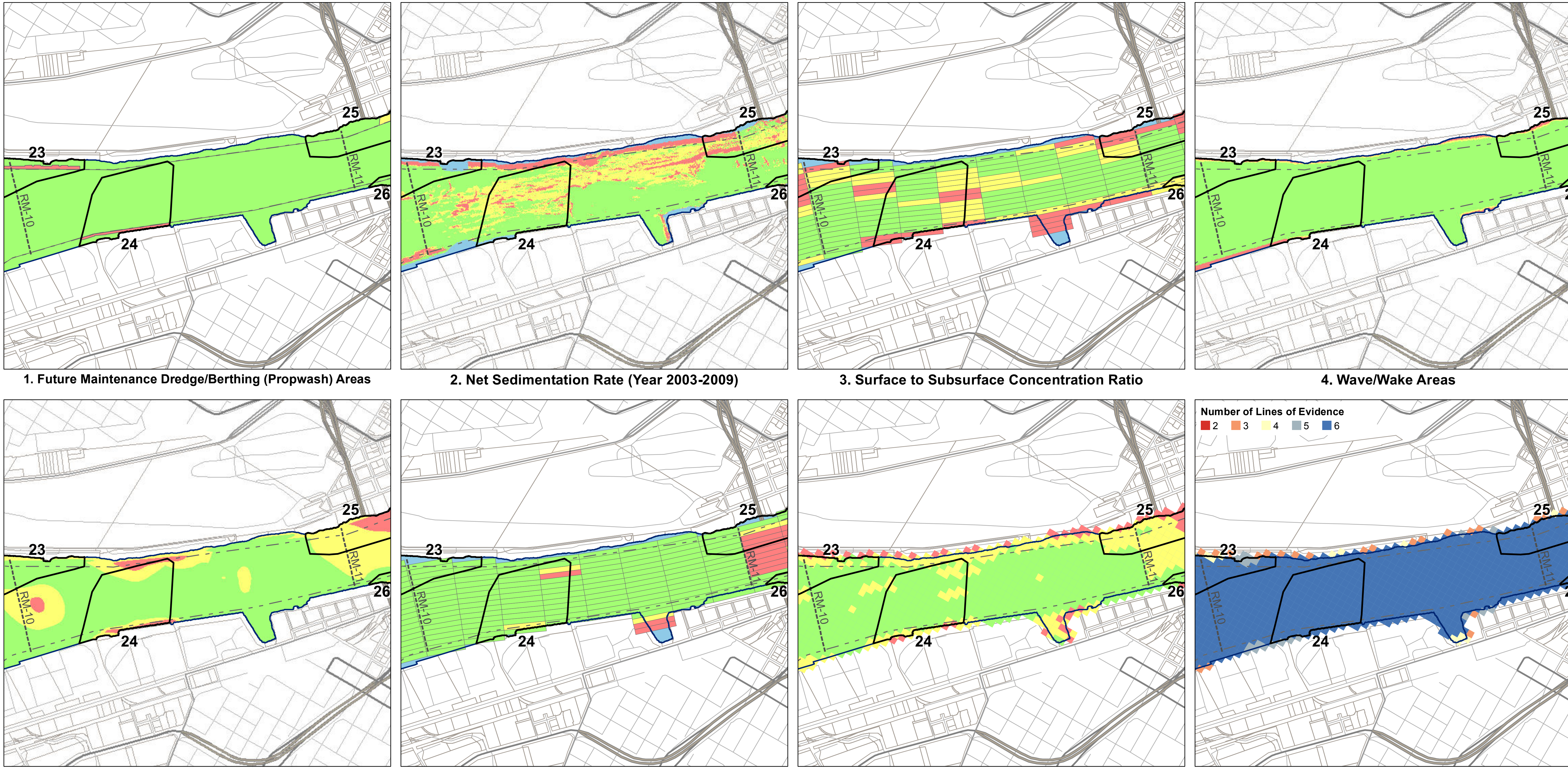
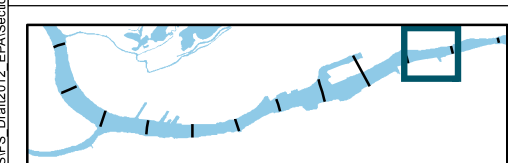


1. Future Maintenance Dredge/Berthing (Propwash) Areas
2. Net Sedimentation Rate (Year 2003-2009)
3. Surface to Subsurface Concentration Ratio
4. Wave/Wake Areas
5. Surface Sediment Grain Size
6. Long-term Recovery Rate Prediction
7. Overall Recovery Category (Weighted Average)
8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

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Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

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Figure 6.2-21b
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 10 to 11

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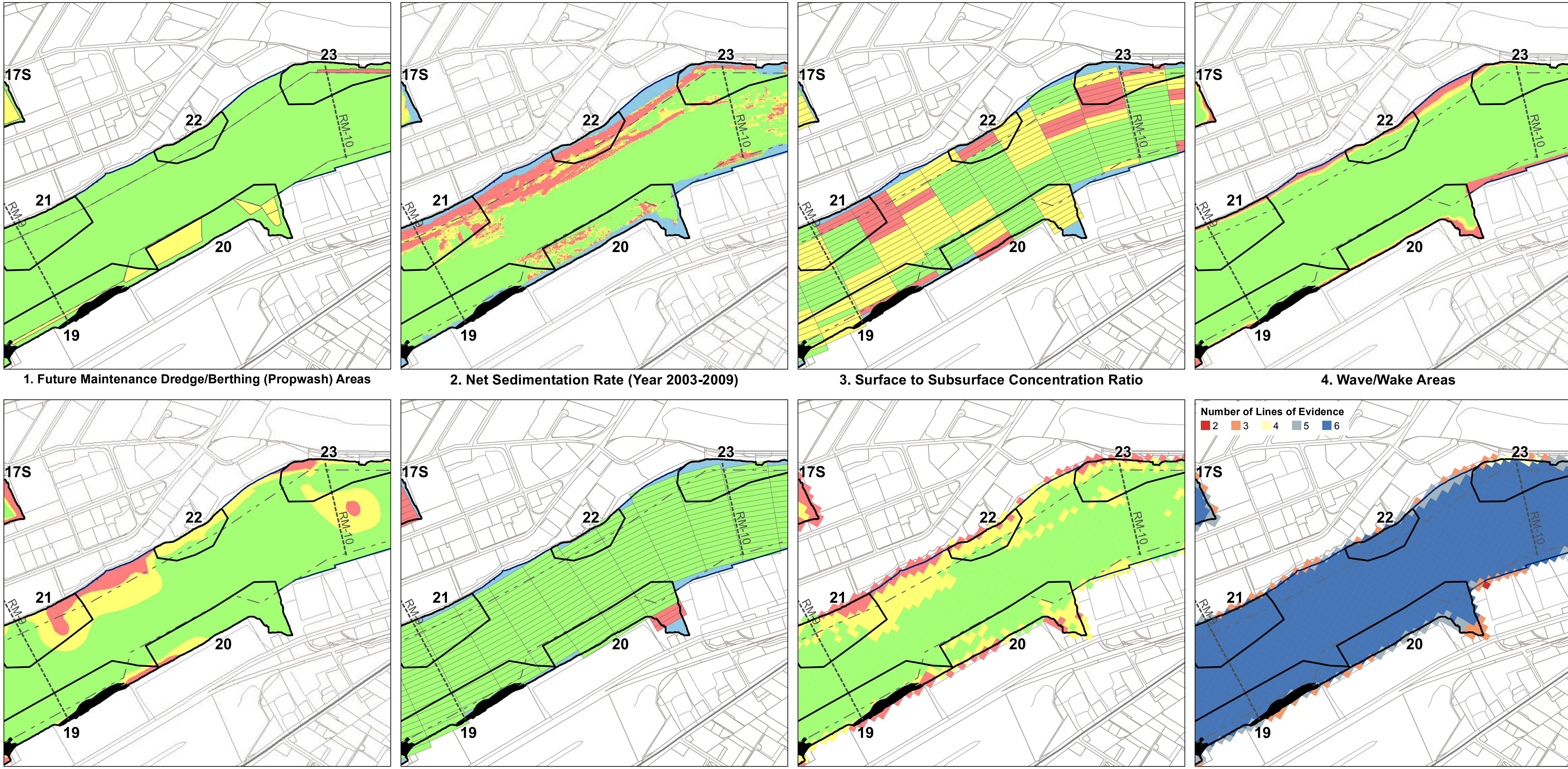


1. Future Maintenance Dredge/Berthing (Propwash) Areas

2. Net Sedimentation Rate (Year 2003-2009)

3. Surface to Subsurface Concentration Ratio

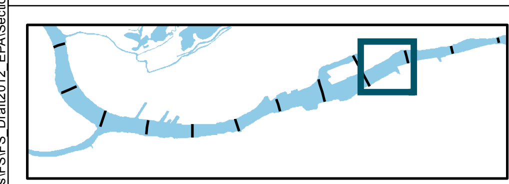
4. Wave/Wake Areas

5. Surface Sediment Grain Size

6. Long-term Recovery Rate Prediction

7. Overall Recovery Category (Weighted Average)

8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

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Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

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Figure 6.2-21c
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 9 to 10

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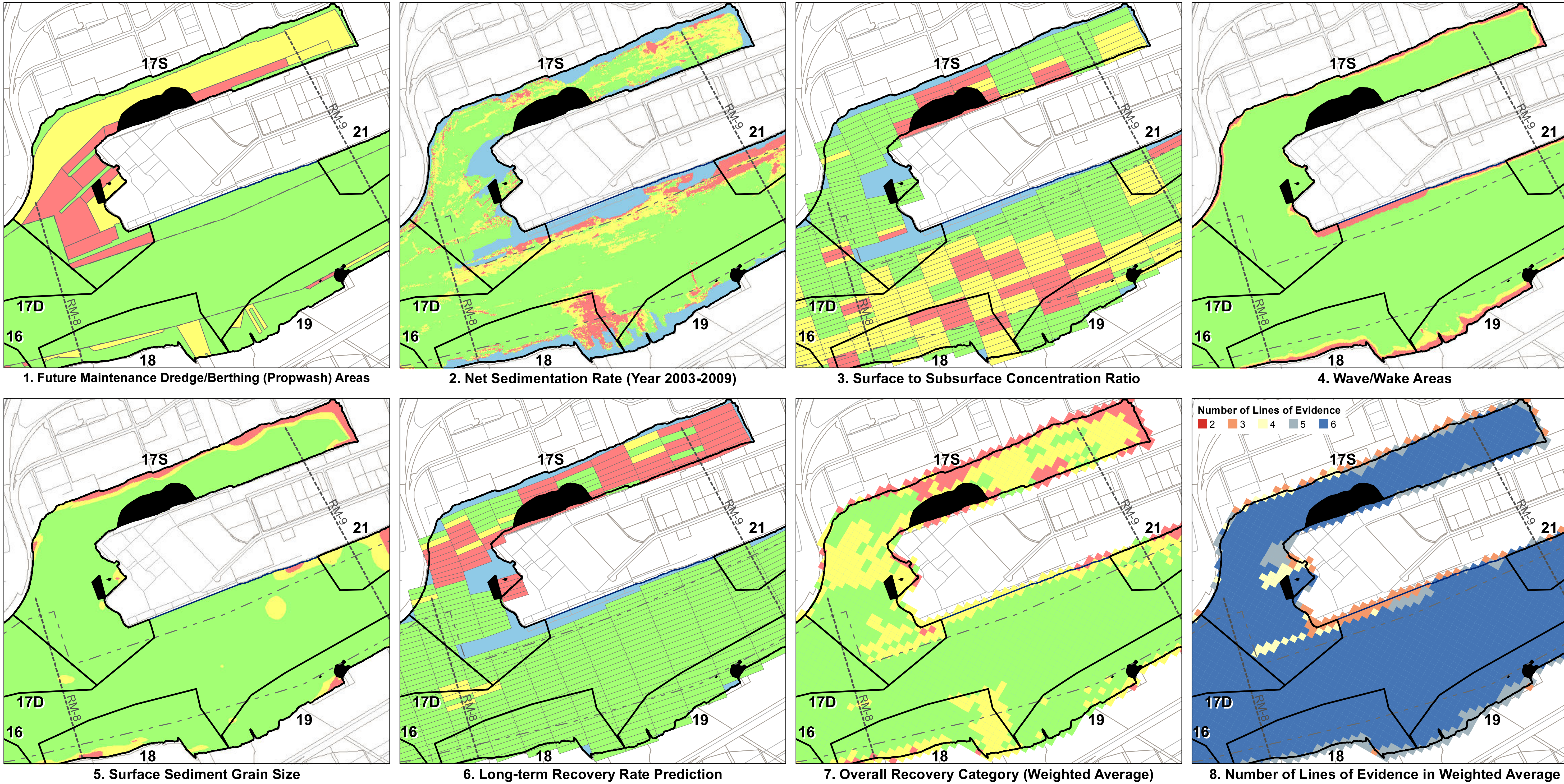

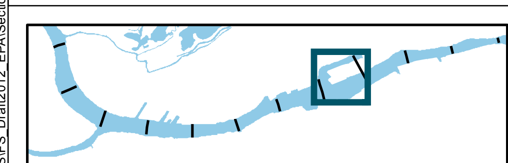

LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

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Figure 6.2-21d
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 8 to 9

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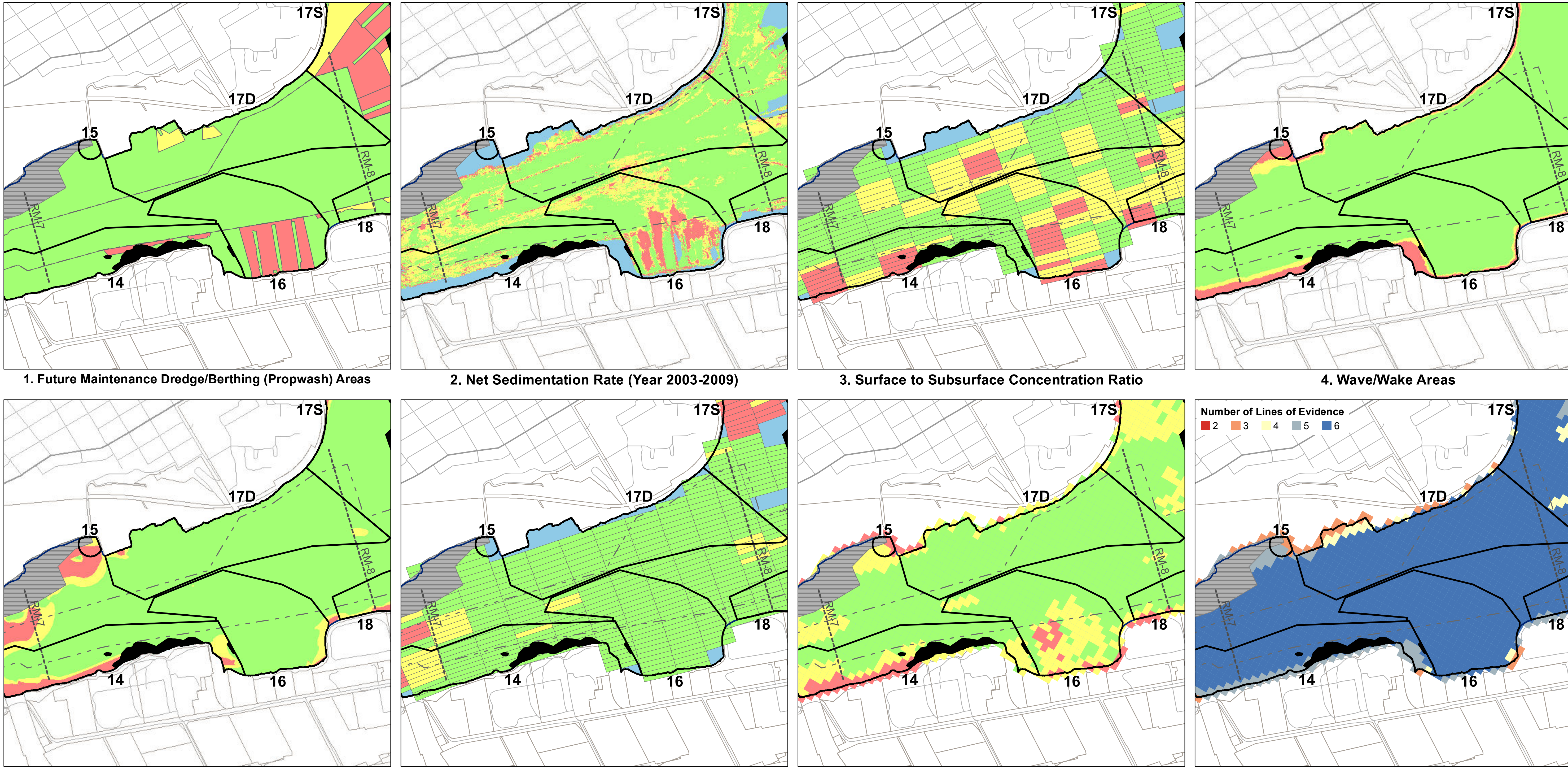


1. Future Maintenance Dredge/Berthing (Propwash) Areas

2. Net Sedimentation Rate (Year 2003-2009)

3. Surface to Subsurface Concentration Ratio

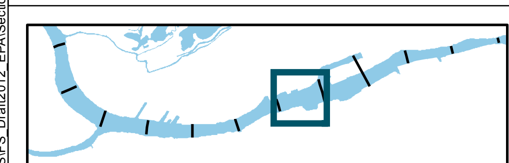
4. Wave/Wake Areas

5. Surface Sediment Grain Size

6. Long-term Recovery Rate Prediction

7. Overall Recovery Category (Weighted Average)

8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

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Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

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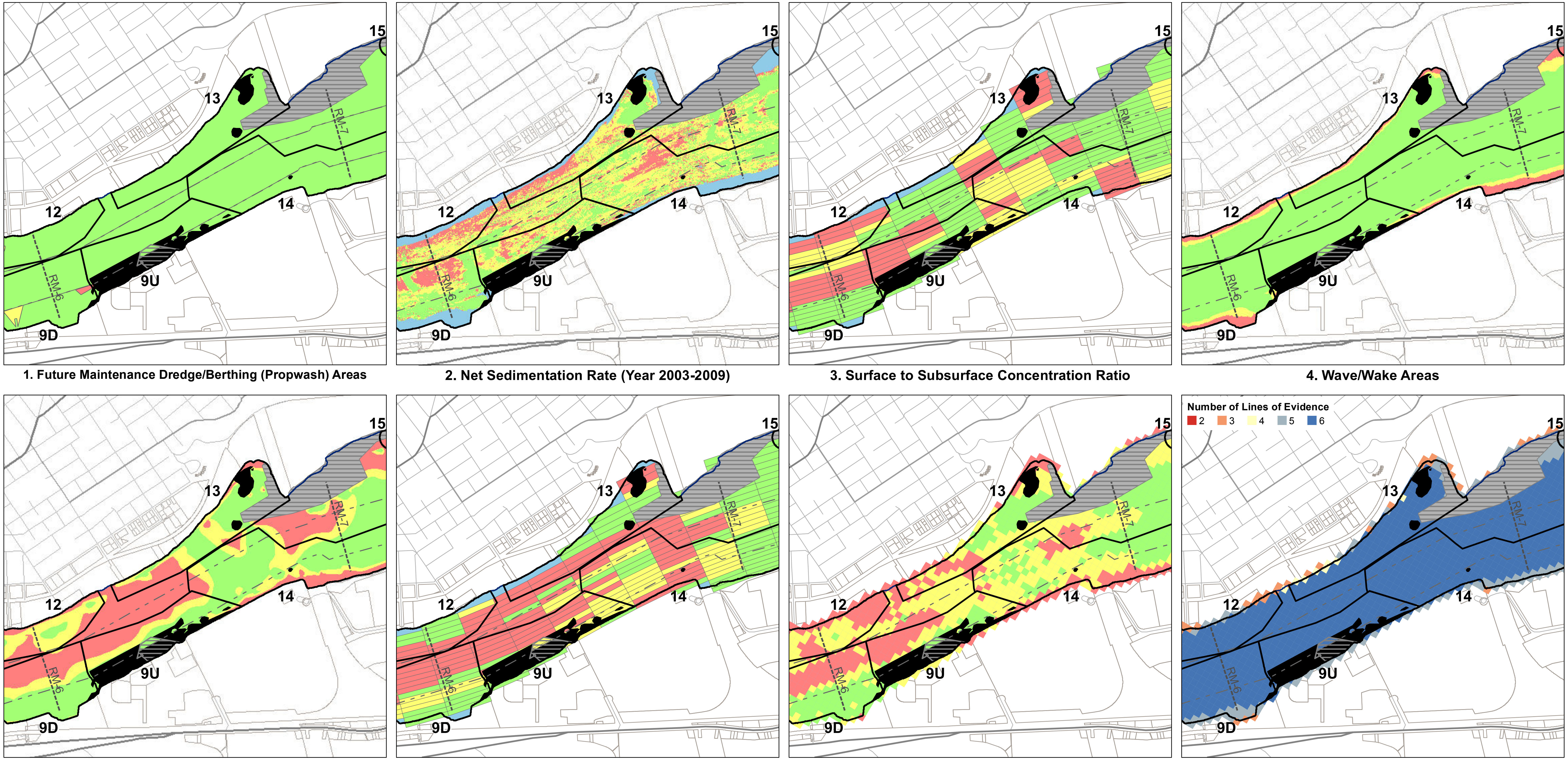
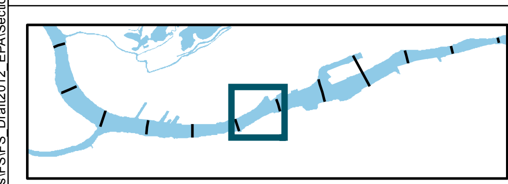
Figure 6.2-21e
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 7 to 8



1. Future Maintenance Dredge/Berthing (Propwash) Areas
2. Net Sedimentation Rate (Year 2003-2009)
3. Surface to Subsurface Concentration Ratio
4. Wave/Wake Areas
5. Surface Sediment Grain Size
6. Long-term Recovery Rate Prediction
7. Overall Recovery Category (Weighted Average)
8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

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Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

Figure 6.2-21f

Portland Harbor RI/FS

Draft Feasibility Study Report

MNR Empirical/Physical Weight of Evidence Evaluation

River Mile 6 to 7

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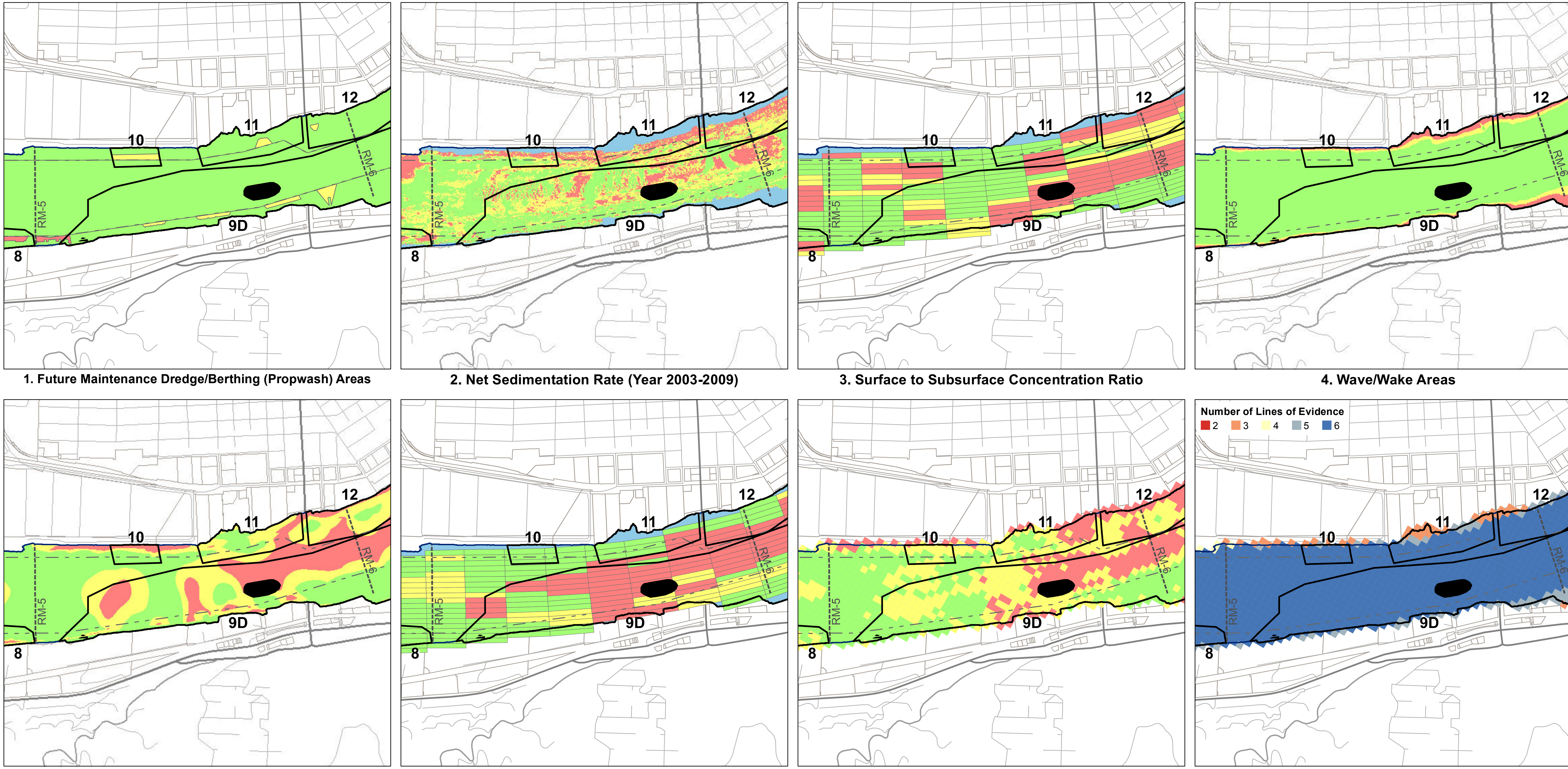


1. Future Maintenance Dredge/Berthing (Propwash) Areas

2. Net Sedimentation Rate (Year 2003-2009)

3. Surface to Subsurface Concentration Ratio

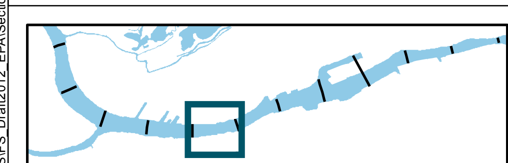
4. Wave/Wake Areas

5. Surface Sediment Grain Size

6. Long-term Recovery Rate Prediction

7. Overall Recovery Category (Weighted Average)

8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

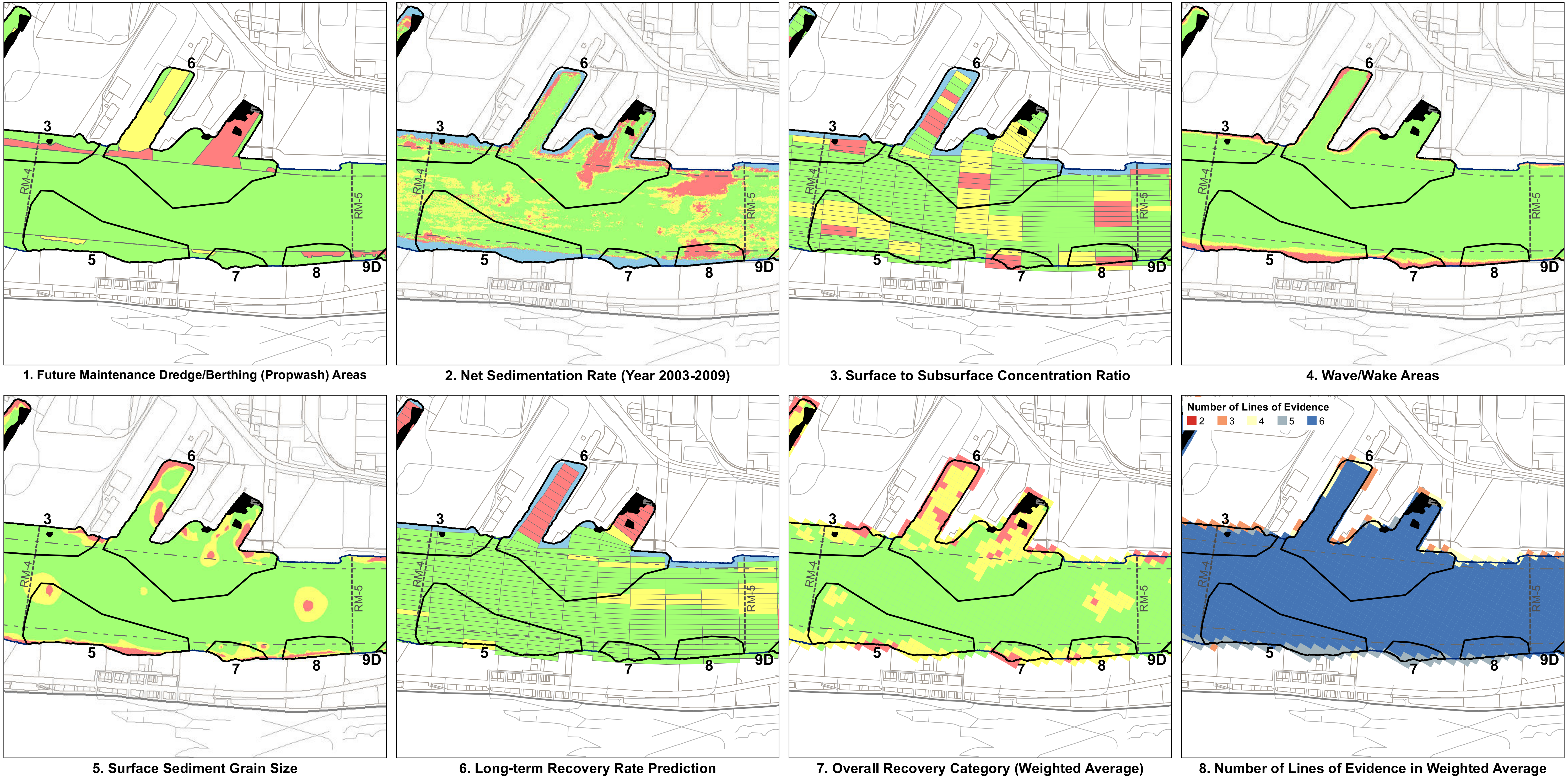
- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

Figure 6.2-21g
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 5 to 6



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

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LWG LOWER WILLAMETTE GROUP

Six independent lines of evidence based on empirical data, physical information, and sediment transport modeling were combined together to evaluate the effectiveness of MNR throughout the Site (see Panel 7). The average category scores range from 3 (indicating areas where MNR is expected to be effective) to 1 (indicating areas where MNR effectiveness is uncertain). Based on this series of maps, he relative amounts of each category are used to develop an overall assessment of MNR effectiveness for each river mile.

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Figure 6.2-21h
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 4 to 5

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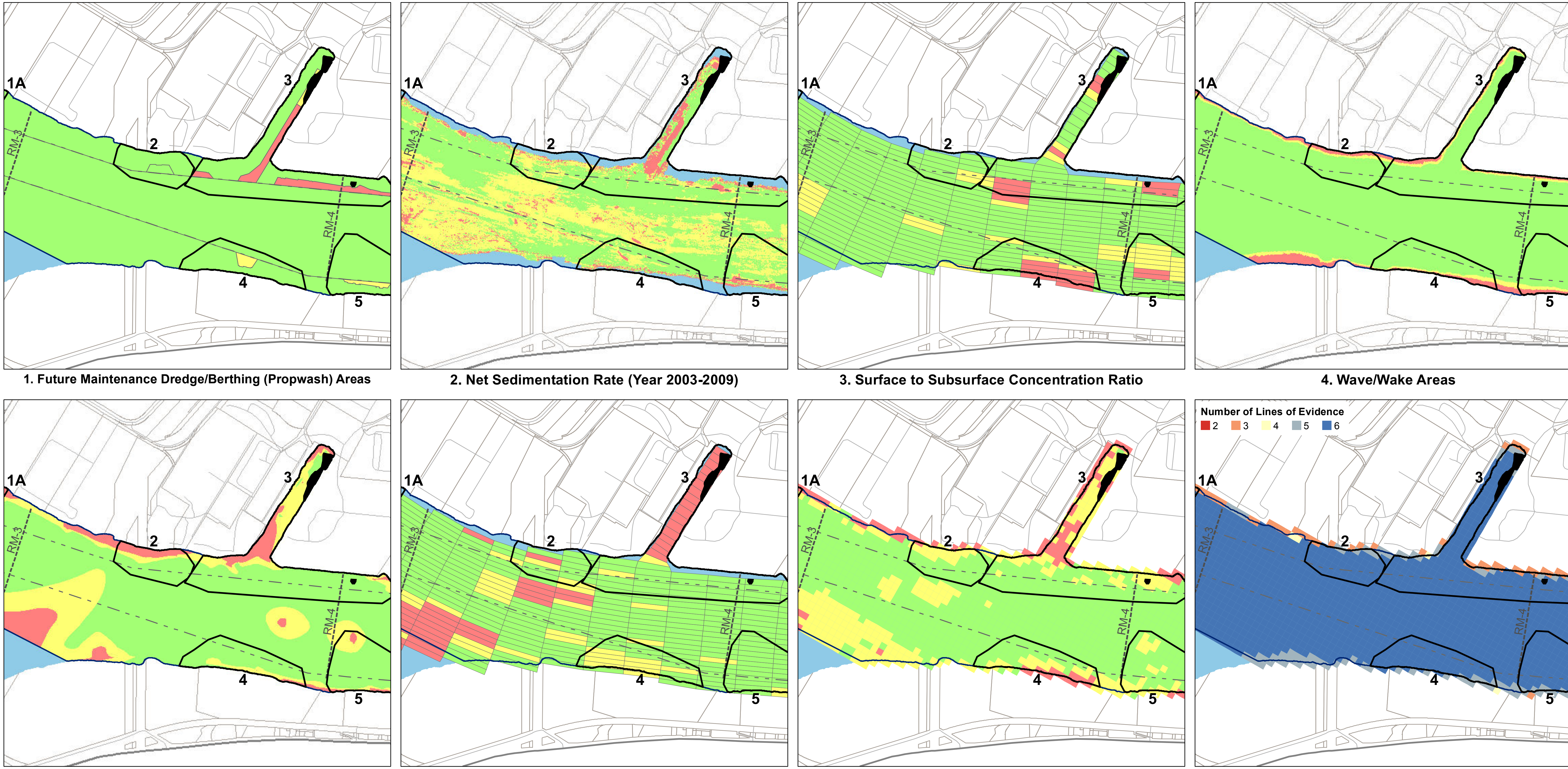


1. Future Maintenance Dredge/Berthing (Propwash) Areas

2. Net Sedimentation Rate (Year 2003-2009)

3. Surface to Subsurface Concentration Ratio

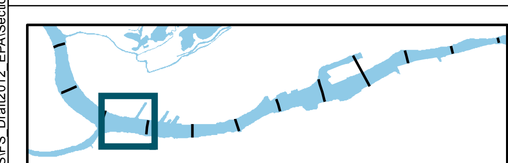
4. Wave/Wake Areas

5. Surface Sediment Grain Size

6. Long-term Recovery Rate Prediction

7. Overall Recovery Category (Weighted Average)

8. Number of Lines of Evidence in Weighted Average



LEGEND

- Category 3 - Areas expected to recover
- Category 2 - Areas where recovery is somewhat less certain
- Category 1 - Areas where recovery is uncertain
- No Category Assigned
- Existing Remedia ion Cap
- Areas of Potential Concern (August 2011)
- Alternative B
- River miles
- Portland Harbor Study Area
- Navigation Channel

Overall Recovery Category (Weighted Average)

Applies to Panel 7 Only

- 2.5 - 3.0 (Category 3)
- 2.0 - 2.5 (Category 2)
- < 2.0 (Category 1)

Feet

0 1,600 3,200

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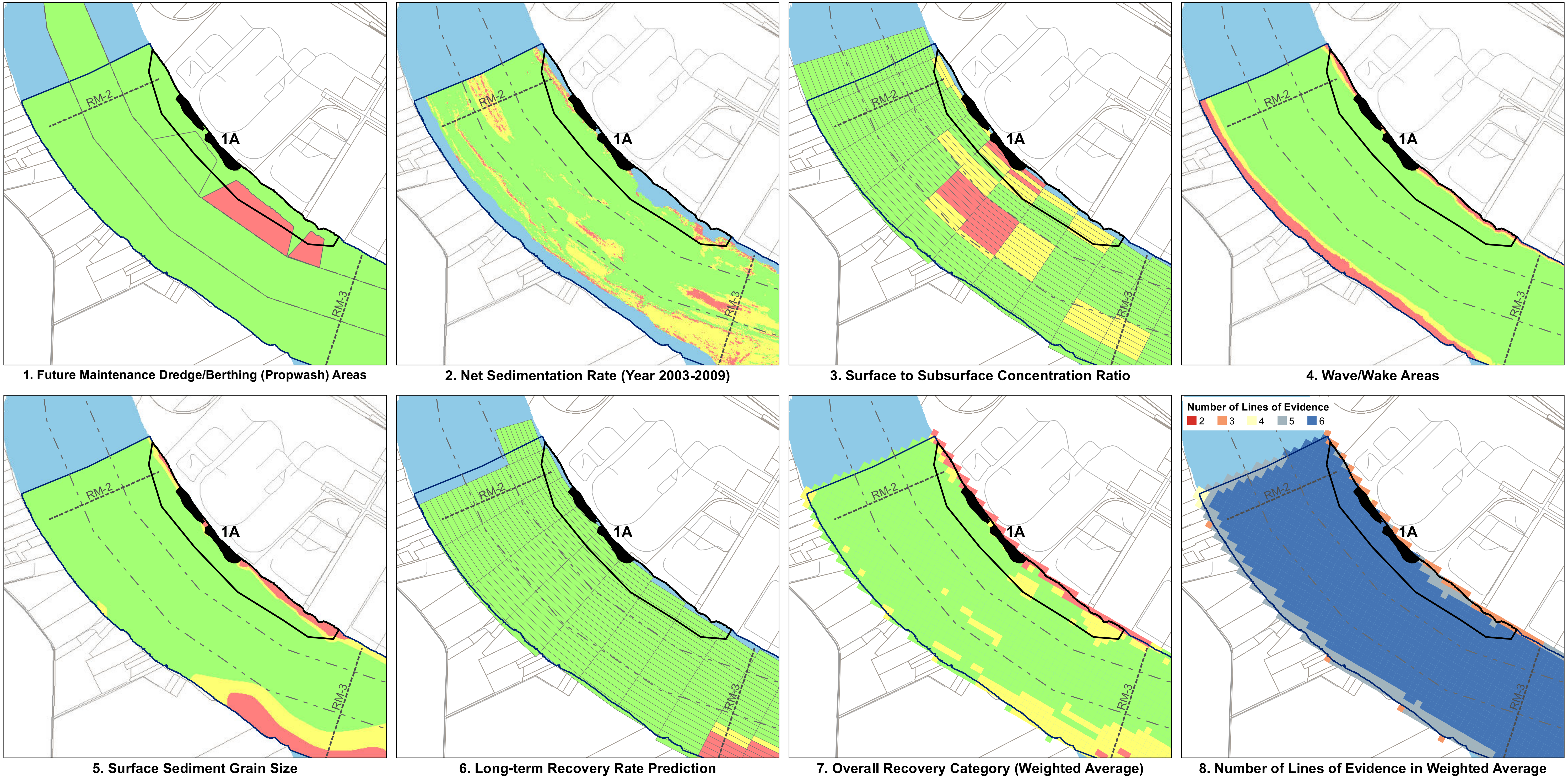
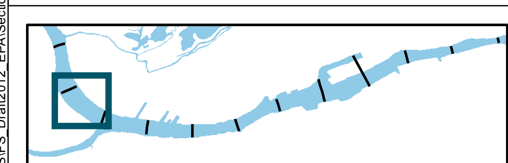
Figure 6.2-21i
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 3 to 4





LEGEND

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Feet

0 1,600 3,200

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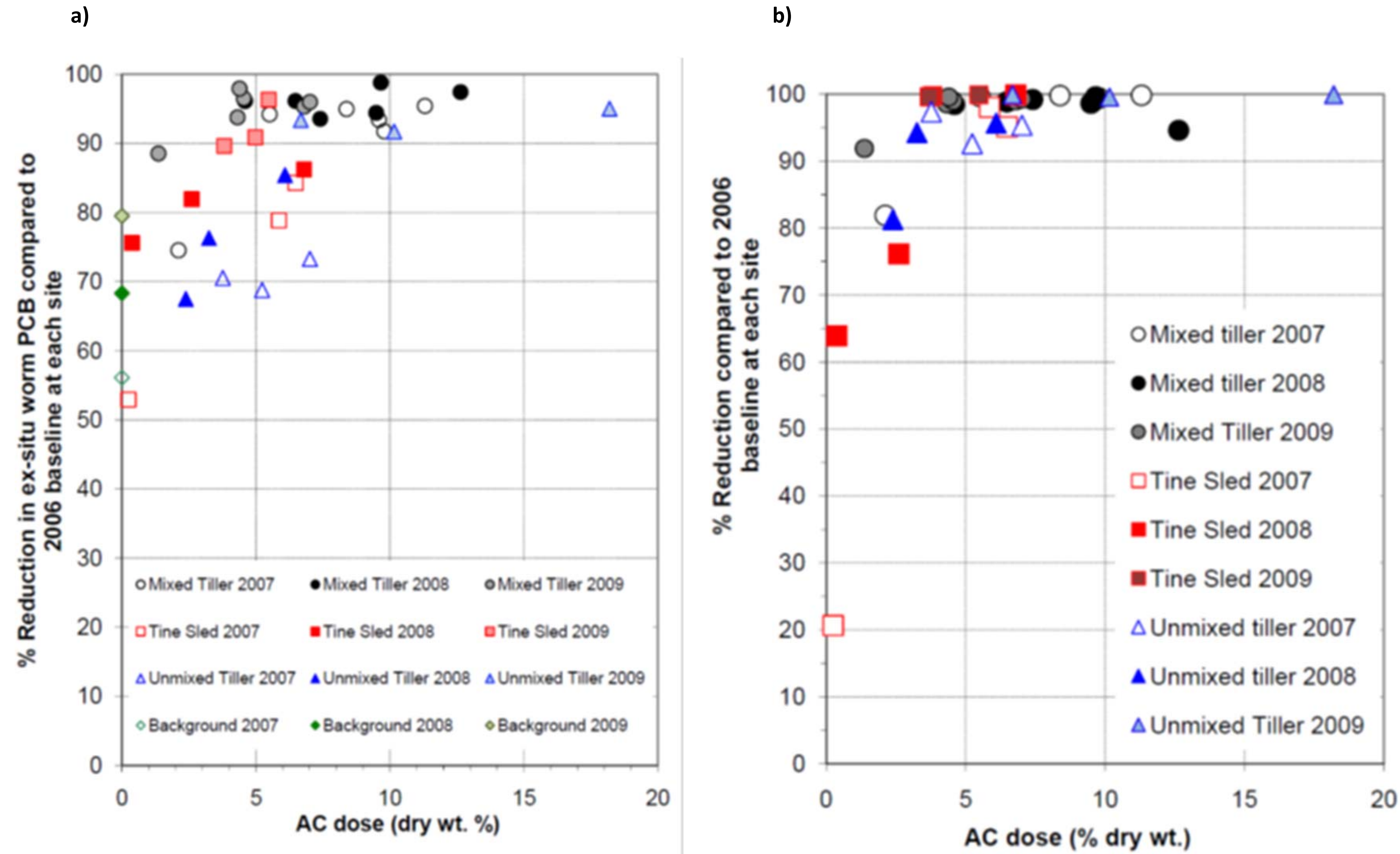
Figure 6.2-21j
Portland Harbor RI/FS
Draft Feasibility Study Report
MNR Empirical/Physical Weight of Evidence Evaluation
River Mile 1.9 to 3



This figure presents an example of the effectiveness of in situ carbon treatment in reducing the bioavailability of PCBs as observed in one study at another site. As the dose of carbon increases, the presence of PCBs in sediment worms decreases.

Adopted from Ghosh 2010

Figure 6.2-22
Portland Harbor RI/FS
Draft Feasibility Study
Percent Reduction in Bioavailability of Sediment PCBs to Deposit-Feeding Benthic Organisms (a) and Percent Reduction of Porewater Concentrations (b) for Various Activated Carbon (AC) Doses

This figure presents an example of successful placement of carbon on the sediment bed at another site using a camera that provides a profile of the sediment bed. The placed carbon appears as a dark layer at the top of the sediment bed.

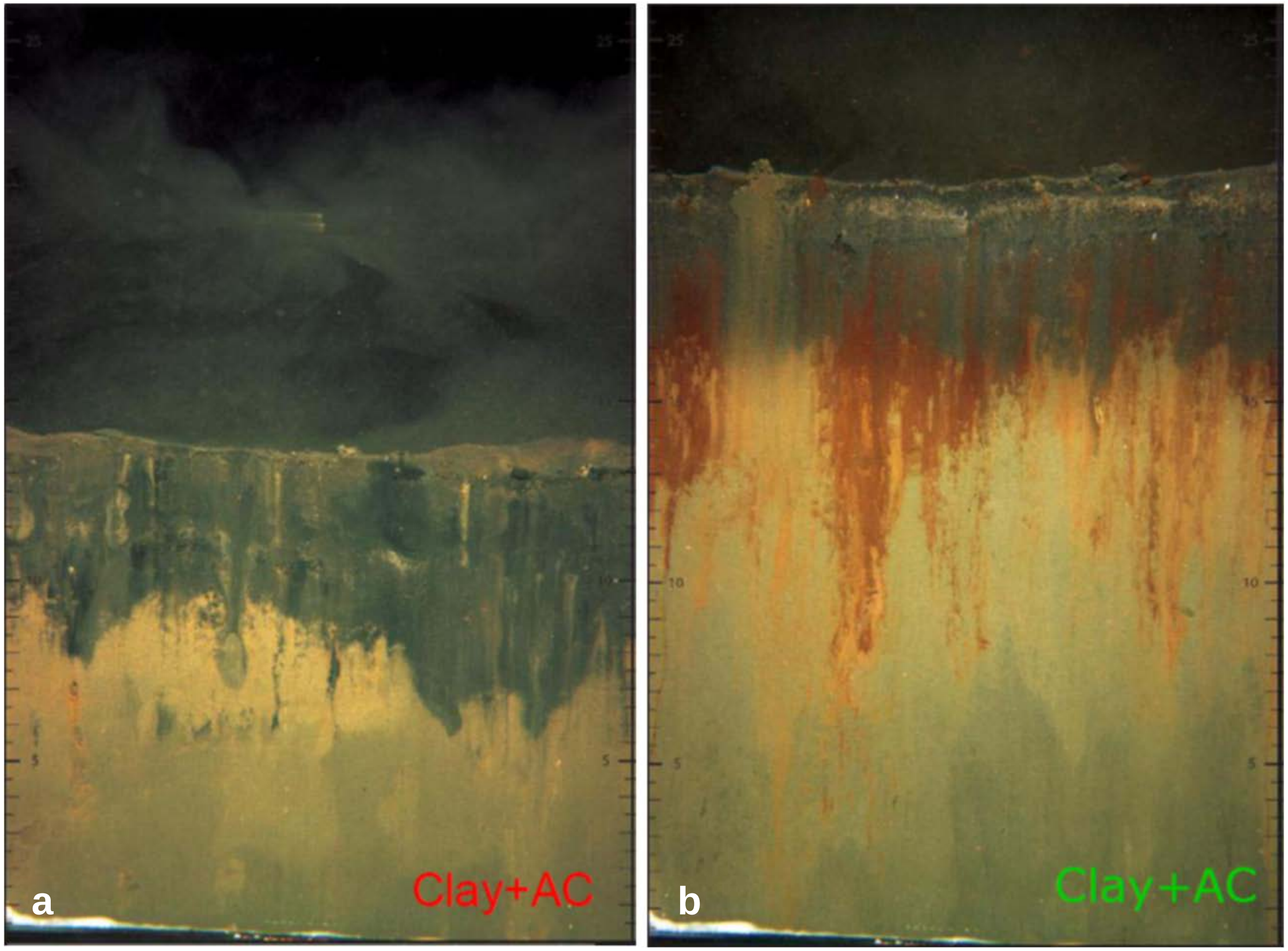
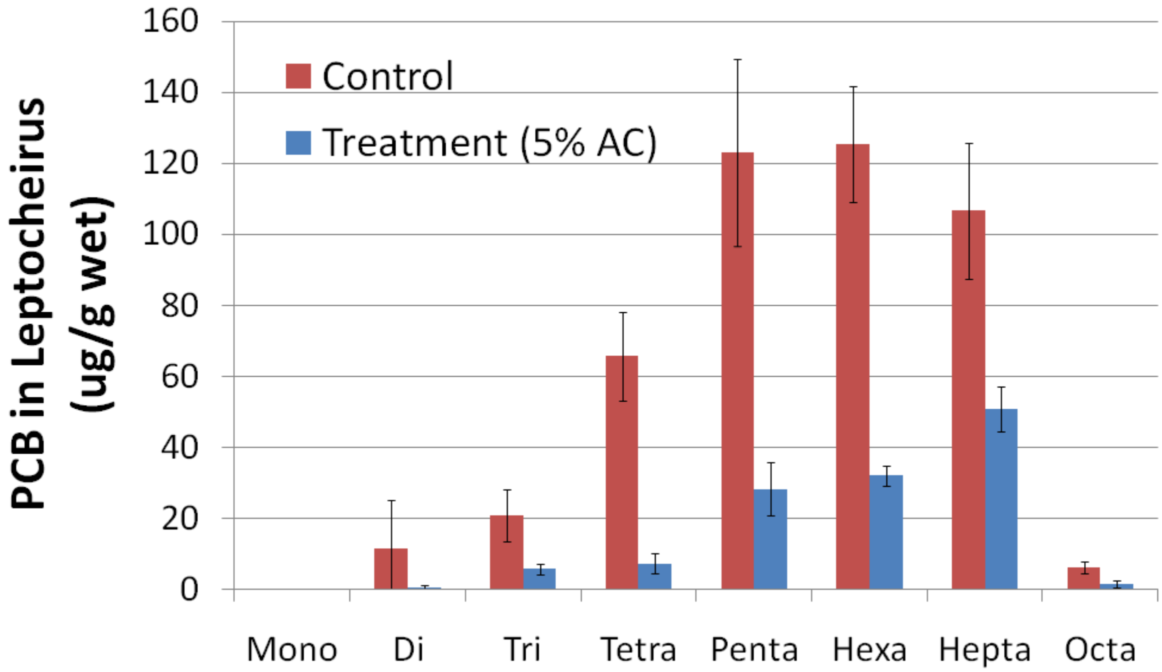


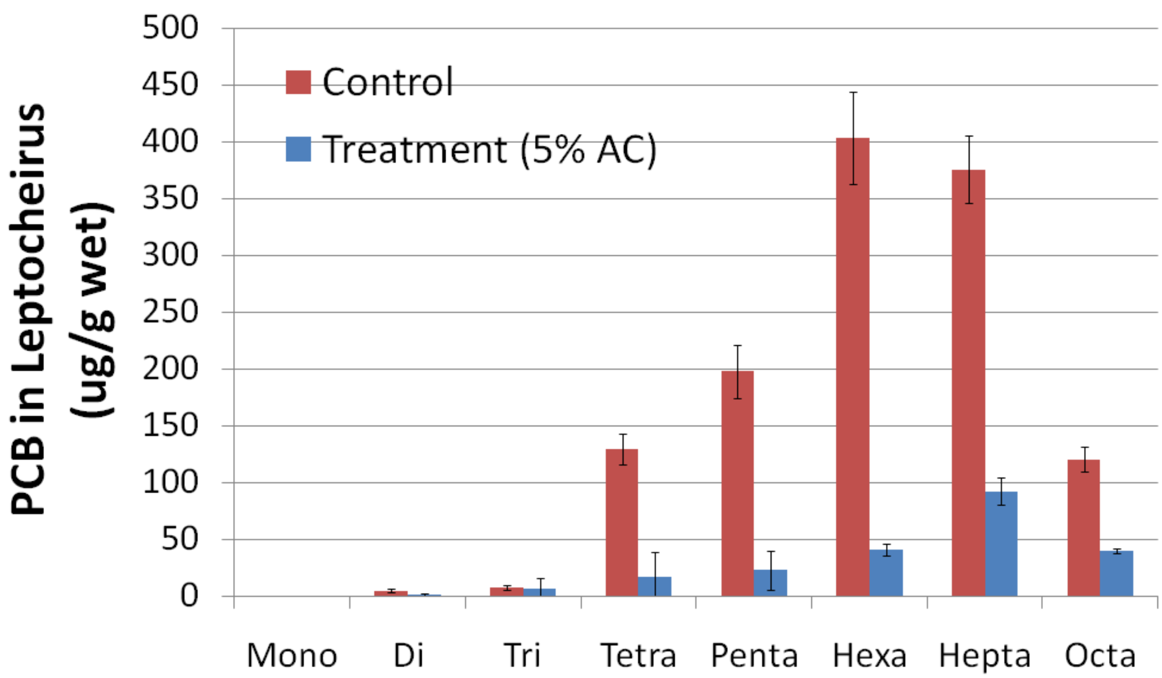
Figure 6.2-23
Portland Harbor RI/FS
Draft Feasibility Study
Post-Treatment SPIs from (a) Ormefjord and (b) Eidangerfjord from Eek et al. (2010)

This figure presents an example of reduction of PCBs in a small sediment crustacean due to carbon treatment observed at another site.

a) 14-day test



b) 60-day test



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Lower Willamette Group

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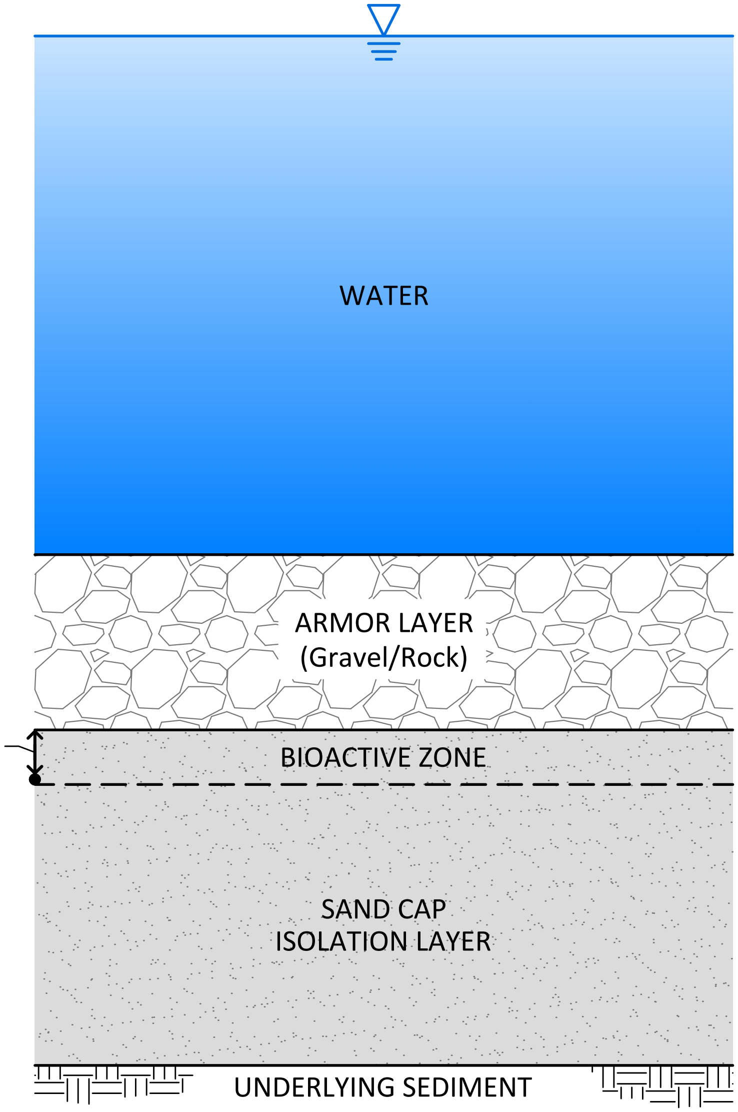
Figure 6.2-24
Portland Harbor RI/FS
Draft Feasibility Study
Bioaccumulation Tests Results for Estuarine Amphipods (L. Plumulosus) Adults and Second Generation Animals with 5% Activated Carbon (AC) Placement from Menzie 2011a.



Not to Scale

Figure 6.2-25
Portland Harbor RI/FS
Draft Feasibility Study
Conceptual Cap Section

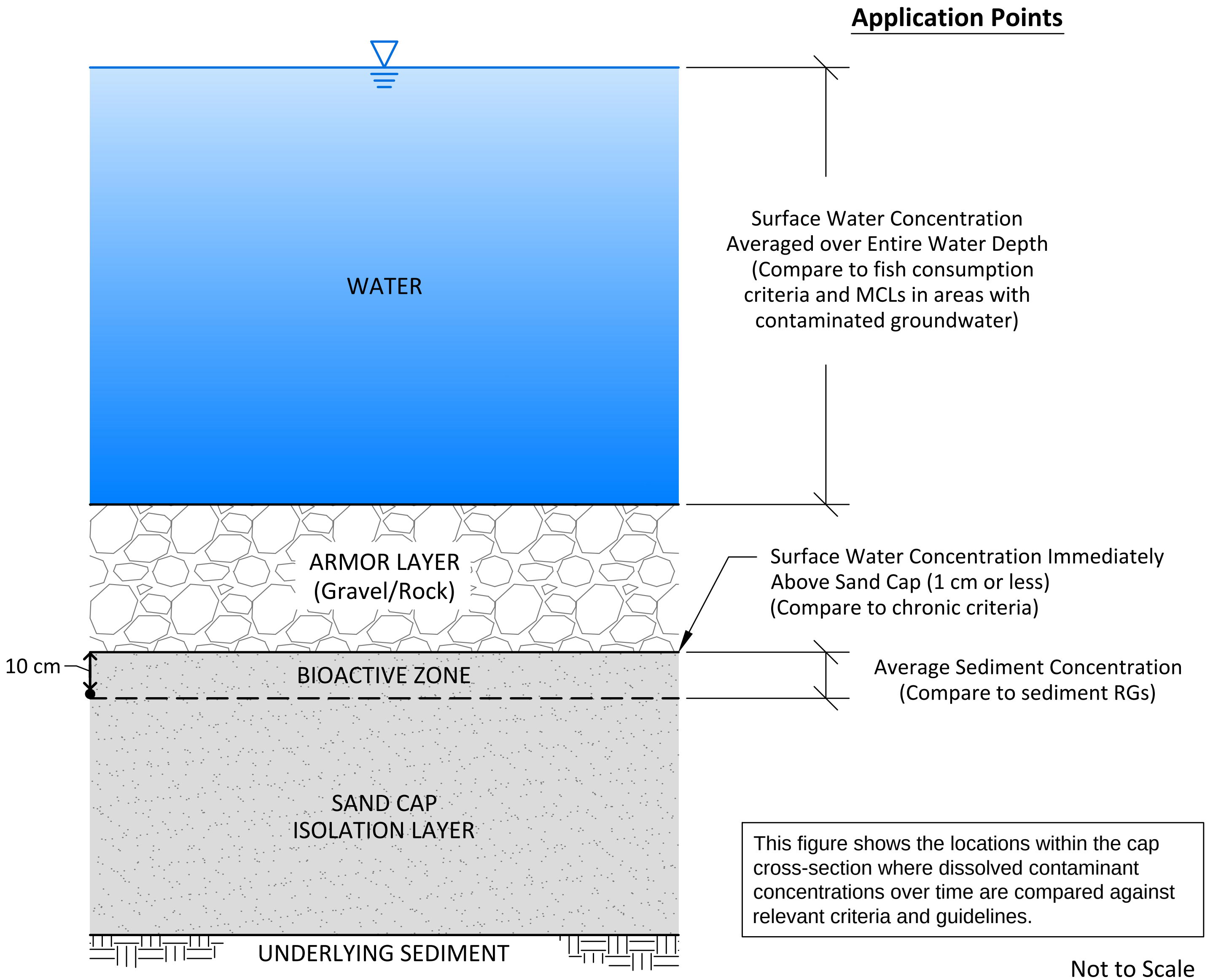


Figure 6.2-26
Portland Harbor RI/FS
Draft Feasibility Study
Sediment Cap Application Points

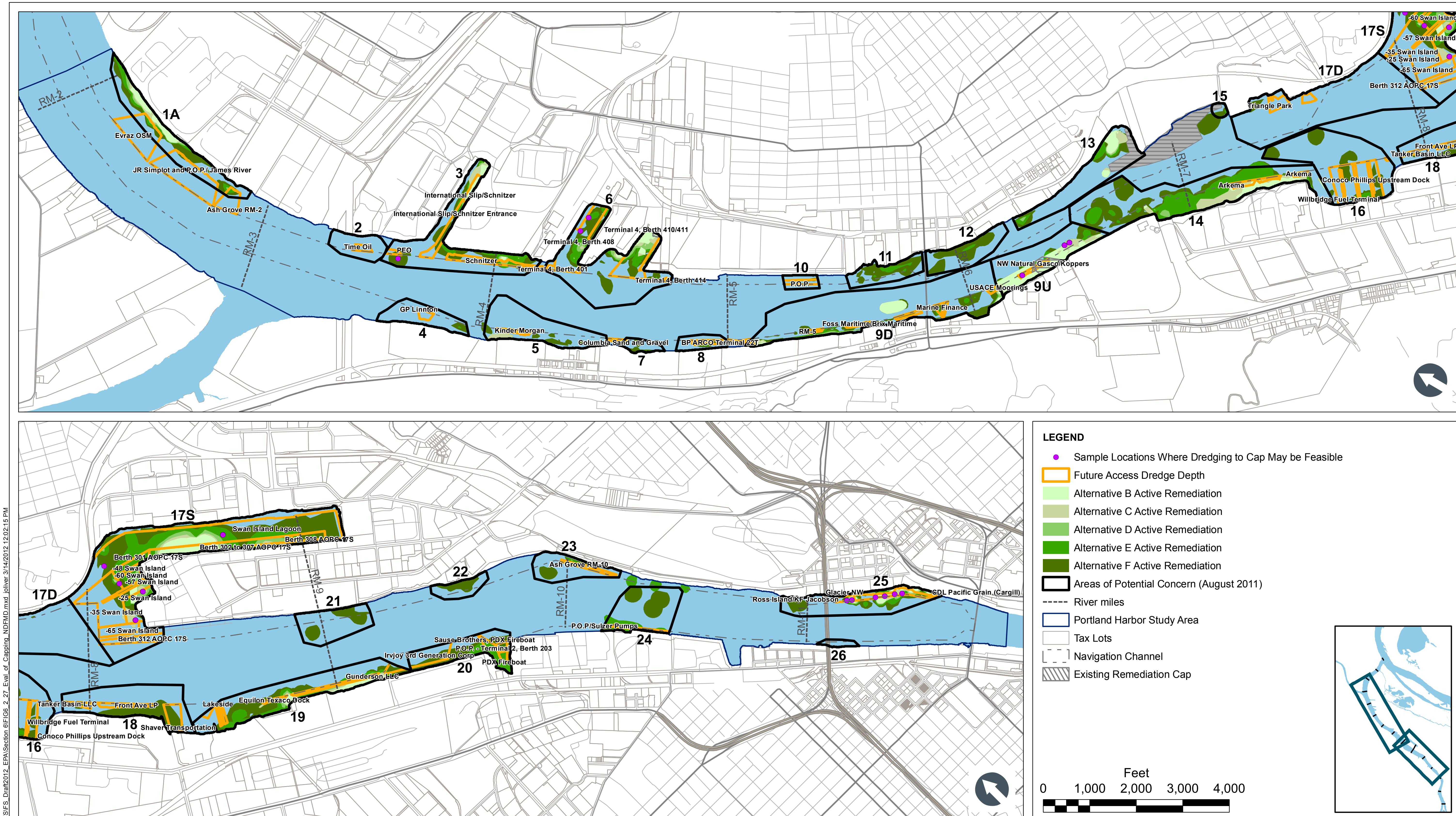


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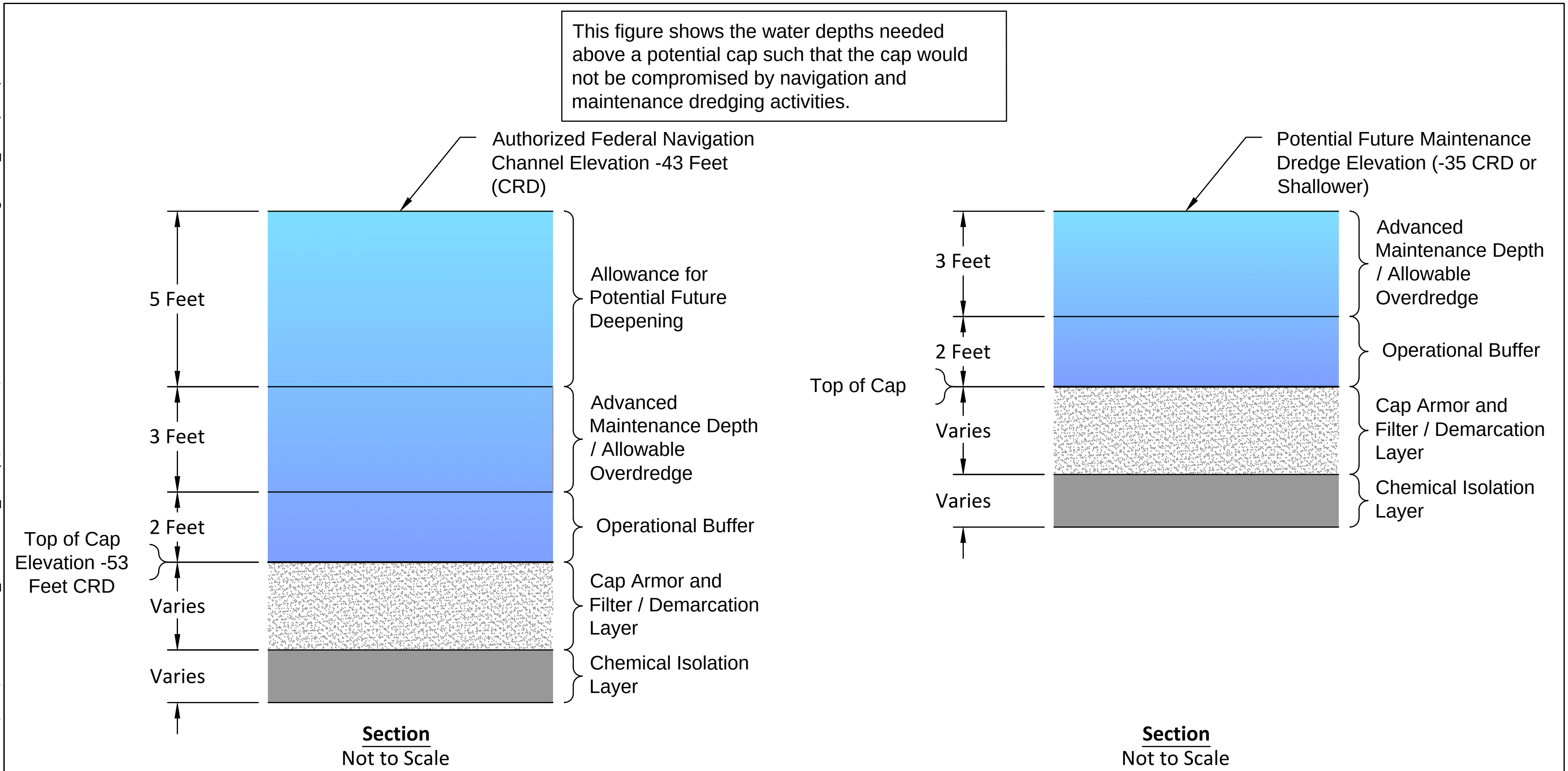
Figure 6.2-27
Portland Harbor RI/FS
Draft Feasibility Study
Evaluation of Dredging to Allow Cap Placement in Navigation Channel and Future Maintenance Dredge Areas

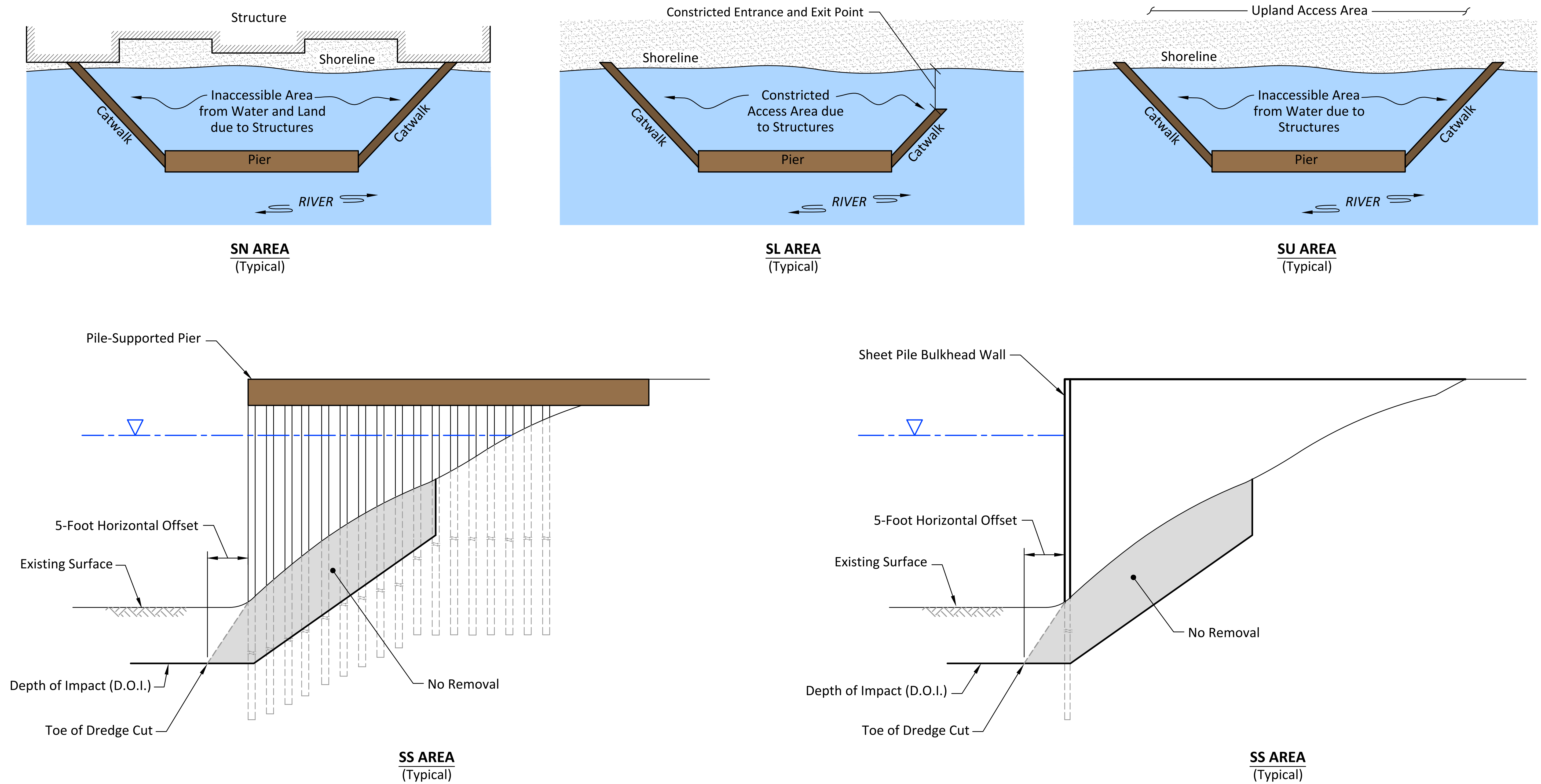


In Situ Cap Offset Requirements in Navigation Channels and Future Maintenance Dredge Areas Currently Maintained Equal to Navigation Channel Depths

In Situ Cap Offset Requirements in Potential Future Maintenance Dredge Areas Currently Maintained at Depths of 35 Feet CRD or Shallower

Figure 6.2-28
Portland Harbor RI/FS
Draft Feasibility Study
In Situ Cap Offset Requirements in Navigation Channels

This figure provides typical examples of how volumes are calculated in various situations in and around Site overwater structures.



Not to Scale

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Mar 16, 2012 9:25am heriksen

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LWG Lower Willamette Group

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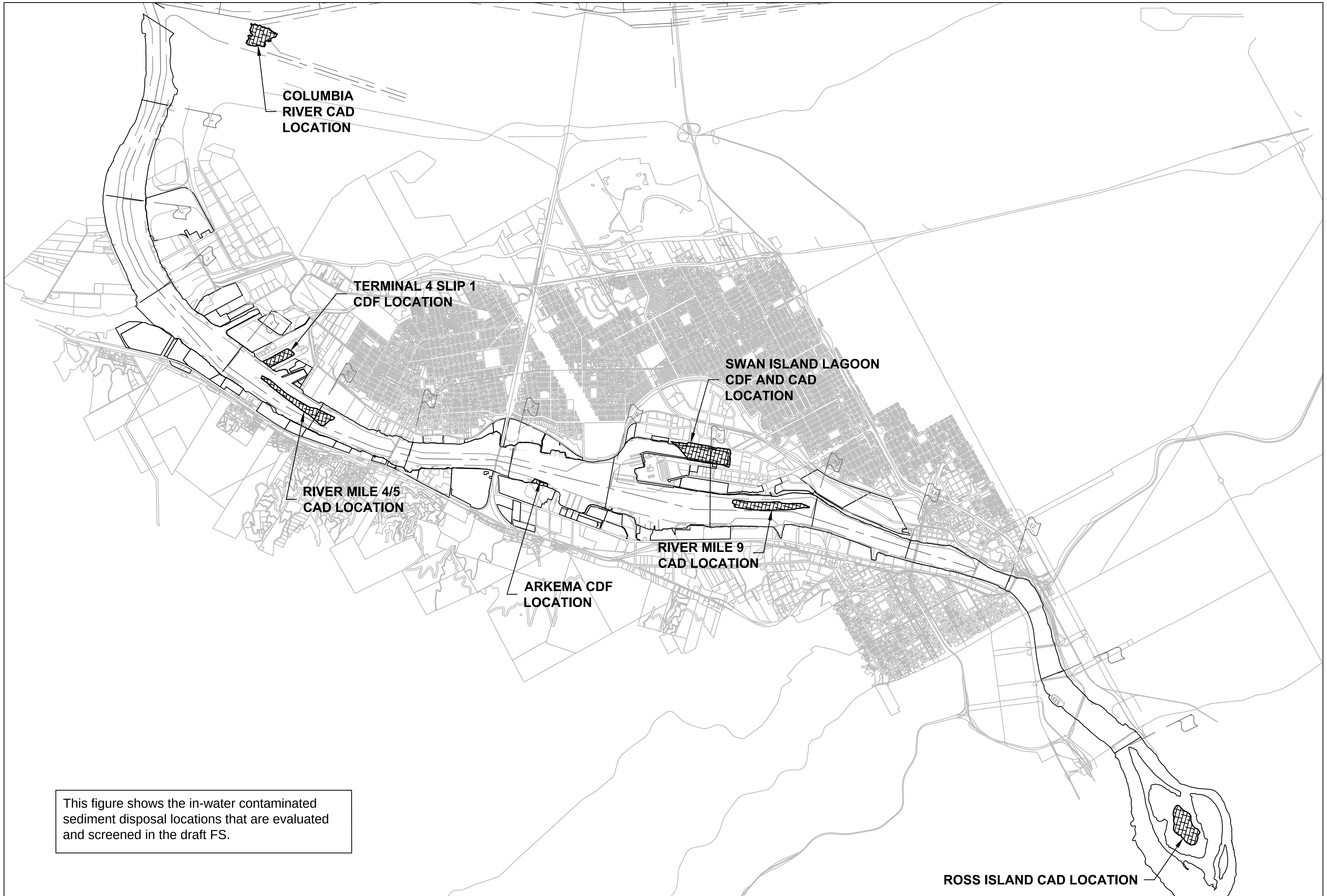
Figure 6.2-29
Portland Harbor RI/FS
Draft Feasibility Study
Structure Dredging Access Issues



SOURCE: Drawing prepared from data provided by Metro RLIS and the US Army Corps of Engineers.

NOTES:
CAD - Confined Aquatic Disposal
CDF - Confined Disposal Facility

K:\Projects\0142-LWG PRP Consortium\LWG Feasibility Study\Feasibility Study\0142-RP-002.dwg Figure 6.2-30

Mar 16, 2012 9:26am heriksen

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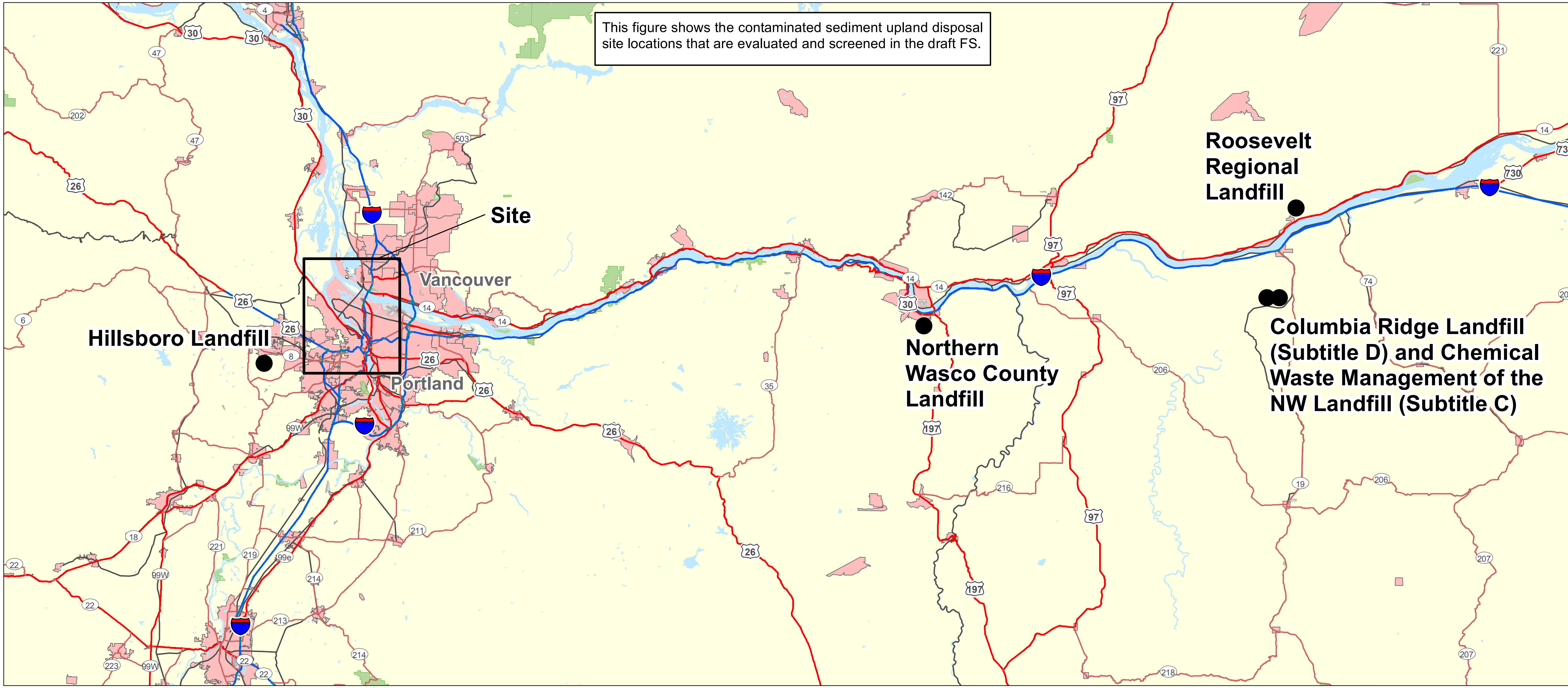
Figure 6.2-30
Portland Harbor RI/FS
Draft Feasiblity Study
In-Water Disposal Site Locations



LEGEND

● Potential Disposal Sites

Miles

0 6.5 13 19.5 26

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Figure 6.2-31
Portland Harbor RI/FS
Draft Feasibility Study
Upland Disposal Site Locations

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
No Action	None	Not Applicable	No Action
Institutional Controls	Governmental Controls	Commercial Fishing Bans	Commercial fishing bans are government controls that ban commercial fishing for specific species or sizes of fish or shellfish and are established by state departments of health or other governmental entities.
		Waterway Use Restrictions or Regulated Navigation Areas	Provides notice to navigation to prevent damage to caps, in-situ treatment, EMNR, etc.
	Proprietary Controls	Land Use/Access Restrictions	Restrictions, such as deed restrictions, easements, and covenants, placed in property related documents or physical barriers, such as fences.
		Structure Mainenance Agreements	Requirements for maintenance of in-water structures where caps or other in-situ technologies are co-located in river.
	Enforcement and Permit Tools	Permit Processes or Provisions of Administrative Orders or Consent Decrees	Legal tools, such as administrative orders, permits, and Consent Decrees (CDs), that limit certain site activities or require the performance of specific activities (e.g., to monitor and report on an IC's effectiveness). They may be issued unilaterally or negotiated.
	Informational Devices	Fish Consumption Advisories	Fish consumption advisories provide information to the public from state departments of health or other governmental entities on acceptable fish consumption rates and fish preparation techniques.
Monitored Natural Recovery	Monitored Natural Recovery	Monitored Natural Recovery (Many processes may exist to cause natural recovery, but because these processes are naturally occuring and simultaneous they cannot be parsed and selected as options in the draft FS or design process, and therefore, do not consitute process options.)	Use of ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. Involves acquisition of information over time to confirm that these risk-reduction processes are occurring and a contingency plan, if the expected processes are not occuring. These processes may include physical, biological, and chemical mechanisms that act together to reduce the risk posed by the contaminants (EPA 2005).

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
Monitored Natural Recovery	Enhanced Monitored Recovery	Thin Layer Suitable Material Placement	Enhancement of MNR (e.g., burial) through placement of a thin layer of suitable material (e.g., 6” of sand).
Containment in Place	Capping	Conventional Sand Cap	Physical isolation of contaminants with sand cover.
		Conventional Sand/Clay Cap	Physical isolation of contaminants with sand/clay cover.
		Armored Cap	Physical isolation of contaminants with sand cover and other structural elements (such as armor) as necessary to keep the cap stable.
		Composite Cap (e.g., HDPE, Geotextile)	Physical and/or chemical isolation of contaminants by layering heavy-duty composite protection mat designed for placement over sediments to guard against damage by erosion, scouring, heavy equipment or other forces.
		Habitat Cap	Physical isolation of contaminants with sand cover and other elements (such as gravel surface or plantings) to provide additional habitat value or features. Habitat features must also perform functions that provide any needed cap stability (like armored cap above).
		Active Cap	Placement of active capping layers such as activated carbon or organoclay to reduce contaminant flux through capping materials. Also, known as "reactive" capping.
	Contained Beneath a CAD/CDF	Contained Beneath a CAD/CDF	Contaminated sediments that are contained in place beneath a CAD or CDF (see below) that is being constructed to received materials removed from another location for disposal. In these cases, CAD/CDFs must be designed to contain both disposed and contained in place contaminated sediments.
In-Situ Treatment	Biological	Slurry Bioremediation	Addition of nutrients and other amendments to enhance bioremediation
		Phytoremediation	Use of plants to remediate contaminated sediments
		Aerobic Biodegradation	Bioremediation uses microorganisms to degrade organic contaminants in soil, sludge, and solids in situ. The microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Aerobic processes require an oxygen source, and the end products typically are carbon dioxide and water.

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
In Situ Treatment		Anaerobic Biodegradation	Bioremediation uses microorganisms to degrade organic contaminants in soil, sludge, and solids either excavated or in situ. The microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Anaerobic processes are conducted in the absence of oxygen, and the end products can include methane, hydrogen gas, sulfide, elemental sulfur, and dinitrogen gas.
		Imbiber Beads	Spherical plastic particles that absorb a very broad cross section of the organic contaminant spectrum.
	Chemical	Chemical Slurry Oxidation	Application of chemical oxidants to remediate contaminated sediments. Chemical oxidation typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert.
	Physical-Extractive Processes	Oxidation	Chemical oxidation typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert.
		Sediment Flushing	In situ flushing is defined as the injection or infiltration of an aqueous solution into a zone of contaminated soil/groundwater, followed by downgradient extraction of groundwater and elutriate (flushing solution mixed with the contaminants) and aboveground treatment and discharge or re-injection.
	Physical - Immobilization	Solidification/Stabilization	The addition of reagents that immobilize and/or bind contaminants to the sediment in a solid matrix or chemically stable form.
		Vitrification	Use of strong electrical current to heat sediment to temperatures above 2400ºF to fuse it into a glassy solid.
		Electrochemical Oxidation	Technology for degrade organic contaminants in situ by applying an alternating current across electrodes placed in the subsurface to create redox reactions.
		Carbon/Other Amendments	Carbon (granulated activated carbon [GAC] or other carbon materials) to reduce bioavailability of organic contaminants, other amendments to treat a wider range of COCs.

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
In Situ Treatment		Ground Freezing	The ground freezing process converts in situ pore water to ice through the circulation of a chilled liquid via a system of small-diameter pipes placed in drilled holes. The ice acts to fuse the soil or rock particles together, creating a frozen mass of improved compressive strength and impermeability. Brine is the typical cooling agent, although liquid nitrogen can be used in emergency situations or where the freeze is only required to be maintained for a few days
Removal	Dredging (environmental)	Mechanical Dredging	Use of clamshell, closed, hydraulic, or other buckets to remove contaminated sediment from a barge or other vessels.
		"Dry" Excavation	Use of excavators, buckets, etc. deployed from land based equipment. Can be "in the wet" or "in the dry" in combination with sheet piles, coffer dams, or other measures to remove water.
		Hydraulic Dredging	Use of hydraulic dredges (e.g., cutterhead, horizontal auger, plain suction, pneumatic, or specialty dredges) with various cutter and suction heads to remove contaminated sediments from the environment in a slurry phase.
		Small Scale Dredge Equipment	Diver assisted or hand held hydraulic dredging, Mud Cat, and similar small scale removal methods.
Disposal/ Confinement	Upland Commercial Landfill	Hillsboro	A disposal site where solid waste is buried between layers of soil and other materials in such a way as to reduce contamination of the surrounding land. Modern commercial landfills have a liner and groundwater leachate collection and treatment systems to keep contaminants from being transport into the soil and water around the landfill. Other commercial landfills were evaluated prior to the draft FS, as described more in Section 6.2.8.
		Northern Wasco County	
		Roosevelt Regional	
		Columbia Ridge	
		Chem Waste (Subtitle C)	
	Onsite Upland Landfill	No likely candidate property.	A disposal site where solid waste is buried between layers of soil and other materials in such a way as to reduce contamination of the surrounding land. Such a facility would be designed with liners and similar systems to minimize contaminants from being transported into the soil and water around the landfill.
	Confined Aquatic Disposal (CAD)	Willamette River (RM 4/5)	Pits excavated in open water or in pre-existing depressions in the aquatic environment that are filled, then covered with suitable material (e.g., cover).
		Willamette River (RM 9)	
		Swan Island Lagoon	
		Columbia River (RM 102.5)	
		Ross Island	

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
Disposal/ Confinement	Confined Disposal Facility (CDF)	Terminal 4 Slip 1	A facility built specifically for the disposal of dredged sediment in such a way that minimizes transport of contaminants to surrounding water and soils.
		Swan Island Lagoon	
		Arkema	
Ex Situ Treatment	Physical	In-barge Dewatering	Dewatering through passive dewatering on barge
		Lagoon Dewatering	Dewatering through placement in lagoon. Water discharge takes place on particles have settled out.
		Geotextile Tube Dewatering	Geotextile tubes allow water to migrate through membrane retaining sediments
		Mechanical Dewatering	Use of filter presses or other similar equipment
		Reagent Dewatering	Use of reagents to chemically absorb excess water.
		Particle Separation	Separation of sandier sediments with less contamination for beneficial reuse.
		Cement Solidification/Stabilization	Solidification/stabilization of contaminated sediments through addition of Portland cement.
Ex Situ Treatment	Physical	Sorbent Clay Solidification/Stabilization	Solidification/stabilization of contaminated sediments through addition of sorbent clays such as bentonite.
		Asphalt Emulsion	Treatment of contaminated sediments with asphalt emulsion to remove water and bind contaminants.
		Solar Detoxification	Technology for using concentrated sunlight to break down and destroy hazardous waste.
	Biological Methods	Land Treatment	Large scale land treatment to reduce contaminant concentrations through biological processes.
		Composting	Large scale land treatment to reduce contaminant concentrations through composting.

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
Ex Situ Treatment		Biopiles	Large scale land treatment to reduce contaminant concentrations through biopiles
		Fungal Biodegradation	Large scale land treatment to reduce contaminant concentrations through fungal plants.
		Slurry-phase Treatment	Biological treatment in a slurry phase.
		Enhanced Biodegradation	Acceleration of the natural bioremediation processes by providing oxygen, reducing agents, nutrients, and degrading microrganisms.
	Chemical	Acid Extraction	Use of acids to extract contaminants from dredged sediments.
		Solvent Extraction	Use of solvents to extract contaminants from dredged sediments.
	Physical/Chemical	Sediment Washing	An advanced form of particle separation, sediments are washed with water and oxidizing agents to remove contaminants.
		Chemical Oxidation/Reduction	Reducing/oxidizing agents are used to chemically convert toxic contaminants in excavated waste materials to less toxic compounds that are more stable, less mobile, and/or inert. Commonly used reducing/oxidizing agents are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.
		Dehalogenation	Removal of halogens (e.g., chlorine) through chemical dehalogenation reactions.
		Slurry Oxidation	Involves mixing an oxidizing agent with contaminated sediments. The oxidation process mineralizes most organic compounds to carbon dioxide, water, and salts. Typical oxidizing agents include: Sodium hypochlorite (or other hypochlorite compounds), Hydrogen peroxide, Chlorine, Chlorine dioxide, Potassium permanganate, and Ozone.

Table 6.1-1. Summary GRAs, Remedial Technologies and Process Options for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description
Ex Situ Treatment		Radiolytic Dechlorination	Radiolytic (electron beam) and photolytic (ultraviolet, UV) dechlorination of polychlorinated biphenyls (PCBs).
	Thermal Methods	Incineration	Treatment through thermal decomposition of organic contaminants and volatilization of some metals at temperatures typically greater than 900ºC (1650ºF).
		Pyrolysis	Chemical decomposition induced in organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430ºC (800ºF).
		High Temperature Thermal Desorption	Heating of contaminated sediment to drive off and capture contaminants. Involves the application of heat (320 to 560ºC or 600 to 1,000ºF) to excavated wastes to volatilize organic contaminants and water. Typically, a carrier gas or vacuum system transports the volatilized water and organics to a treatment system, such as a thermal oxidation or recovery unit.
		Low Temperature Thermal Desorption	Involves the application of heat (90 to 320ºC or 200 to 600ºF) to excavated wastes to volatilize organic contaminants and water. Typically, a carrier gas or vacuum system transports the volatilized water and organics to a treatment system, such as a thermal oxidation or recovery unit.
Ex Situ Treatment	Thermal Methods	High Pressure Oxidation	This category includes two related technologies: wet air oxidation and supercritical water oxidation. Both processes use the combination of high temperature and pressure to break down organic compounds.
		Vitrification	Process in which solids (e.g., sediments) and contaminants are heated in a rotary kiln or furnace melter at tempertures upto 1600ºC (2900ºF).

Table 6.2-1. Site-specific Empirical Information Used to Evaluate MNR Effectiveness

Site-Specific Information Listed in USEPA (2005) Sediment Guidance	Portland Harbor Site Dataset(s)
Identification and characterization of ongoing sources	• FS Source Control Inventory Tables (Section 2.5.1 and Appendix Q) • Stormwater Sampling Data • Upstream Transect Surface Water Data • Groundwater/TZW Sampling Data • NPDES Discharge Data
Evaluation of geomorphology, long-term accretion, and erosion	• Sediment Bathymetric Surveys • Sediment Trap Data • Radioisotope Data
Characterization of bed sediment types	• Sediment Grain Size Data • Sediment Profile Imaging Survey Data
Evaluation of historical trends in contaminant concentrations in biota, sediments, and/or surface water	• Sediment Contaminant Concentrations • Biota Contaminant Concentrations
Evaluation of sequestration mechanisms	• Contaminant and TOC Concentrations on Incoming (Upstream) Sediment Particles • Sediment Trap Data • Sediment Bathymetric Surveys
Determination of the depth of the surface mixed layer	• Radioisotope Data • Sediment Profile Imaging Survey Data
Measurement of suspended solids and contaminant transport during high-energy (e.g., storm) events	• Water Column Suspended Sediment Data • Water Column Contaminant Concentration Data • Sediment Trap Data
Measurement of sediment erosion properties	•Sedflume Core Data

Note:

NPDES - National Pollutant Discharge Eliminations System

TZW - transition zone water

TOC - total organic carbon

MNR - Monitored Natural Recovery

Table 6.2-2. Site-wide Net Sedimentation Rates Estimated from Multi-beam Bathymetric Survey Data

Start Date	End Date	Duration	Calculated Average Net Sedimentation Rate (cm/yr)
Jan-02	May-03	16 months	0
May-03	Mar-04	10 months	2.1
Mar-04	Jan-09	58 months	3.5
Jan-02	**Jan-09**	**7 years (TOTAL)**	**2.6 (OVERALL AVERAGE)**

Table 6.2-3. Summary of Empirical Datasets and Their Application in Modeling

Dataset	Application in Modeling
Sediment Bathymetry Changes (Deposition and Erosion Rates)	Sediment transport model calibrated (on multiple spatial scales) to replicate long-term bed elevation changes (2003-2009)
Sediment Grain Size Data	Used to specify sediment bed types (i.e., areas of cohesive and non-cohesive sediments) and composition (grain size) in the sediment transport model
Temporal Trends in Sediment Contaminant Concentrations	Contaminant fate model calibrated to reproduce observed sediment temporal trends (or lack thereof) over multiple spatial scales
Surface and Deep Sediment Concentrations	Used to specify sediment initial conditions in contaminant fate model
Contaminant Concentrations on Incoming (Upstream) Sediment Particles	Used to specify upstream boundary condition in contaminant fate model
Study Area Sediment Traps	Used to calibrate water column particulate-phase concentrations predicted by the contaminant fate model

Table 6.2-4. Criteria for Assigning Recovery Categories Outside of SMAs[1]

Line of Evidence		Recovery Categories: Category 1 (Recovery Uncertain)	Recovery Categories: Category 2 (Recovery Less Certain)	Recovery Categories: Category 3 (Predicted to Recover)
Physical Conditions	Future Maintenance Dredge / Berthing (Propeller Wash) Areas	Likely deep FMD / berthing areas	Shallow-use FMD / berthing areas	Outside likely FMD areas
Physical Conditions	Wave/Wake Areas	High elevation wave zone areas (6-13 ft NAVD88)	Low elevation wave zone areas (0-6 ft NAVD88)	Outside wave zone areas
Empirical Data	Net Sedimentation Rate (Multi-Beam Bathymetry Surveys)[2]	< -1 cm/yr net sedimentation (i.e., net erosion)	-1 to +1 cm/yr net sedimentation[3]	> 1 cm/yr net sedimentation (net deposition)
Empirical Data	Surface Sediment Grain Size (Percent Fines)	< 20% fines	20-40% fines	> 40% fines
Empirical Data	Sediment Surface to Subsurface Concentration Ratios[4]	Surface:subsurface ratio > 1.5	Surface and subsurface within a factor of 1.5	Subsurface:surface ratio > 1.5
Sediment Transport Model	Long-term bed "tracer" simulation to evaluate recovery rate and potential for disruption by extreme flow event	Half life > 20 years	Half life 10 to 20 years	Half life < 10 years
Overall Weight of Evidence	**Calculate average of all six lines of evidence listed above**	**Average Score < 2**	**Average Score 2 to 2.5**	**Average Score > 2.5**

Notes:

1) Evaluation of recovery potential was only conducted in portions of the Site outside the footprint of the smallest active remedial alternative (Alternative B).

2) Evaluation of net sedimentation conducted using analysis of bathymetric change between 2003 and 2009 multi-beam bathymetric surveys.

3) Corresponds to bathymetric changes that are within +/- 7.5 cm between 2003 and 2009, which represent no discernable change in bathymetry based on the vertical resolution of the surveys.

4) Focus of this analysis is on total PCB since PCBs tend to bound the remedial footprints and results for BaP and DDx are similar to those for PCBs.

Table 6.2-5. Summary of River Mile Sediment Contaminant Concentrations (µg/kg) in the Navigation Channel Only as Compared to the Lowest RALs Used in the Draft FS

River Mile	Total PCB	BapEq	Sum DDD	Sum DDE	Sum DDT
Lowest RAL	**75**	*****	**50**	**20**	**60**
RM 2-3 Surface SWAC	27	231	2.85	2.51	2.06
RM 2-3 Subsurface Median	30	180	4.1	3.9	1.7
RM 3-4 Surface SWAC	27	390	2.65	1.97	4.18
RM 3-4 Subsurface Median	79	335	7.65	5.5	4.6
RM 4-5 Surface SWAC	26	320	3.23	2.16	2.94
RM 4-5 Subsurface Median	50	335	8.8	5.1	4.2
RM 5-6 Surface SWAC**	22	18,900	7.65	2.53	6.71
RM 5-6 Subsurface Median	26	375	5.2	0.75	1.2
RM 6-7 Surface SWAC	58	6,540	22.2	4.99	15.9
RM 6-7 Subsurface Median	105	2,300	43	7.5	16.8
RM 7-8 Surface SWAC	37	40.8	9.24	3.87	11.3
RM 7-8 Subsurface Median	60	38.5	22	8.35	37
RM 8-9 Surface SWAC	31	39.5	1.7	2.21	1.85
RM 8-9 Subsurface Median	19.5	19	1.7	2	1.6
RM 9-10 Surface SWAC	38	53	1.54	1.71	1.16
RM 9-10 Subsurface Median	21	18.5	1.55	1.85	1.55
RM 10-11 Surface SWAC	43	64.6	1.47	1.73	2.01
RM 10-11 Subsurface Median	77	37.5	3.45	2.7	4.95
RM 11-11.8 Surface SWAC	66	36.9	2.51	1.22	6.46
RM 11-11.8 Subsurface Median	33	31	1.53	1.4	1.85

Indicates value above the lowest RAL

* The lowest BaPEq RALs are estimated to attain sediment direct contact RGs that do not apply to the navigation channel. For comparison, the lowest Level 3 Benthic SQVs for HPAHs is 610,000 µg/kg. The highest median benthic MQ for subsurface samples in the navigation channel is 0.53 for RM 6 to 7, which is below the 0.7 threshold generally used in the draft FS.

**BaPEq SWACs in RM 5 to 7 are largely driven by a few much older USACE samples in the navigation channel that do not meet risk assessment data quality criteria. Some of these stations were reoccupied under the Gasco Sediment Order in 2011, where it was found concentrations are much lower and generally consistent with more recent nearby LWG data that are much lower (Barth pers. comm. 2011).

Table 6.2-6. Summary of Weight of Evidence Assessment of Natural Recovery by River Mile

River Mile	Combined Average Natural Recovery Category	Comments
11.8 – 11	1	Small fraction of Category 3 in the river mile; long-term net erosion predicted over a large portion of the river mile.
11 – 10	3	Limited region of Category 2 along eastern shore.
10 – 9	3	Limited regions of Category 1 and 2 in east nearshore and a portion of west nearhore.
Swan Island Lagoon	1	Multiple LOEs suggest MNR effectiveness is uncertain, including pesence of high surface concentrations and low sedimentation rate.
9 – 8	3	
8 – 7	3	Region of Category 2 in Willbridge Terminal area.
7 – 6	2	Mix of Category 1, 2, and 3 areas.
6 – 5	2	Upper portion is Category 2 (with some 1 and 3), lower portion is mix of Category 3 and 2.
5 – 4	3	Natural recovery somewhat more uncertain in T4 slips and along western shore
4 – 3	3	Natural recovery less certain in International Slip
3 – 1.9	3	

Notes:

Category 3: combined LOEs indicate MNR would be effective in the river mile as a whole.

Category 2: combined LOEs indicate natural recovery will likely occur in the river mile as a whole, but the degree of effectiveness is less certain.

Category 1: combined LOEs indicate effective natural recovery is uncertain in the river mile as a whole.

Table 6.2-7. Summary of In Situ Treatment Field Demonstrations

Site/Location	Target COCs	Amendment	Treatment Date
Hunter's Point, CA (two trials)	PCBs	Mechanically-mixed AC	Aug-04 and Jun-06
Grasse River, NY	PCBs	Unmixed and mechanically-mixed AC	Sep-06
Trondheim Harbor, Norway	PAHs	Slurried AC (with and without clay)	May-07
Grenlandfjord, Norway	Dioxin	Slurried AC (with clay)	Sep-09
Fiskerstrand, Norway	TBT	Slurried AC (with limerock)	Sep-10
Bailey Creek, VA	PCBs	AC in SediMite^{TM}	Aug-09
Canal Creek, MD	PCBs, DDT, Merecury	AC in SediMite^{TM}	Dec-10

Note: Adopted from Ghosh et al 2011.

Table 6.2-8. Feasibility of Capping Cores in the Navigational Channel

River Mile	Permitted Navigation Channel Depth (CRD)	Required Access Depth with Offset Requirements (CRD)	Required Access Depth with Offset Requirements (NAVD88)	Elevation of Bottom of Cap Including Offset Requirements and Cap Thickness (CRD)	Elevation of Bottom of Cap Including Offset Requirements and Cap Thickness (NAVD88)	Depth of Impact (feet)	Elevation of Impact (NAVD88)	Depth of Impact Below Elevation Needed to Install Cap (feet)	Environmental Dredge and Cap Back Feasible?
2	-43.0	-53.0	-48.0	-59.0	-54	NA	NA	NA	No
3	-43.0	-53.0	-47.9	-59.0	-54	11	-57.3	-3.4	Yes
4	-43.0	-53.0	-47.9	-59.0	-53.9	1	-27.0	0.0	No
5	-43.0	-53.0	-47.9	-59.0	-53.9	5	-49.9	0.0	No
6	-43.0	-53.0	-47.8	-59.0	-53.8	15	-54.5	-0.7	Yes
7	-43.0	-53.0	-47.8	-59.0	-53.8	10	-40.0	0.0	No
8	-43.0	-53.0	-47.8	-59.0	-53.8	1	-32.0	0.0	No
9	-43.0	-53.0	-47.8	-59.0	-53.8	17	-39.0	0.0	No
10	-43.0	-53.0	-47.8	-59.0	-53.8	11	-46.2	0.0	No
11	-43.0	-53.0	-47.8	-59.0	-53.8	8	-53.5	0.0	No

Notes:

*The table shows samples that are in SMA F since it is the alternative with the largest footprint and the deepest DOI, so it is most inclusive

NA=No Data in river mile

Table 6.2-9. Feasibility of Capping Cores in Future Maintence Dredge Areas

River Mile	FMD Area	Potential Future Maintenance Dredge Depth (CRD)	Potential Future Maintenance Dredge Depth (NAVD88)	Required Depth with Buffer Offset (CRD)	Required Depth with Buffer Offset (NAVD88)	Elevation of Bottom of Cap Including Buffer Offset and Cap Thickness (CRD)	Elevation of Bottom of Cap Including Buffer Offset and Cap Thickness (NAVD88)	Elevation of Impact (NAVD88)	Depth of Impact Below Elevation Needed to Install Cap	Environmental Dredge to Cap Feasible?
2	Evraz OSM	= to NC	= to NC	-53.0	-48.0	-59.0	-54.0	NA	NA	No
2	JR Simplot and P.O.P/James River	= to NC	= to NC	-53.0	-48.0	-59.0	-54.0	NA	NA	No
2	Ash Grove RM-2	= to NC	= to NC	-53.0	-48.0	-59.0	-54.0	-20	0	No
3	International Slip/Schnitzer	-30.0	-24.9	-35.0	-29.9	-41.0	-35.9	-34	0	No
3	International Slip/Schnitzer Entrance	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	-40	0	No
3	Time Oil	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	NA	NA	No
3	PEO	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	NA	NA	No
3	GP Linnton	-30.0	-24.9	-35.0	-29.9	-41.0	-35.9	NA	NA	No
4	Kinder Morgan	-30.0	-24.9	-35.0	-29.9	-41.0	-35.9	-32	0	No
4	Terminal 4, Berth 408	-25.0	-19.9	-30.0	-24.9	-36.0	-30.9	-36	-3	**Yes**
4	Terminal 4, Berth 410/411	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	-46	0	No
4	Schnitzer	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	NA	NA	No
4	Terminal 4, Berth 401	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	NA	NA	No
4	Terminal 4, Berth 414	= to NC	= to NC	-53.0	-47.9	-59.0	-53.9	NA	NA	No
4	Columbia River Sand and Gravel	-20.0	-14.9	-25.0	-19.9	-31.0	-25.9	NA	NA	No
4 and 5	BP ARCO Terminal 22T	-35.0	-29.9	-40.0	-34.9	-46.0	-40.9	-18	0	No
5	Marine Finance	-30.0	-24.9	-35.0	-29.9	-41.0	-35.9	-35	0	No
5	Foss Maritime/Brix Maritime	-25.0	-19.9	-30.0	-24.9	-36.0	-30.9	-17	0	No
5	Cathedral Park	-10.0	-4.9	-15.0	-9.9	-21.0	-15.9	NA	NA	No
5	P.O.P	-25.0	-19.9	-30.0	-24.9	-36.0	-30.9	NA	NA	No
6	NW Natural Gasco/Koppers	-30.0	-24.8	-35.0	-29.8	-41.0	-35.8	-39	-1	**Yes**
6	USACE Moorings	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	-33	0	No
7	Arkema	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	-32	0	No
7	Conoco Phillips Upstream Dock	-32.0	-26.8	-37.0	-31.8	-43.0	-37.8	-31	0	No
7	Willbridge Fuel Terminal	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	-33	0	No
7	Triangle Park	-30.0	-24.8	-35.0	-29.8	-41.0	-35.8	NA	NA	No
7	Tanker Basin LLC	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	NA	NA	No
Swan Island	-25 AOPC 17S	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-53	-20	**Yes**
Swan Island	-35 AOPC 17S	-35.0	-29.8	-40.0	-34.8	-46.0	-40.8	-48	-5	**Yes**
Swan Island	-57 AOPC 17S	-57.0	-51.8	-58.8	-58.8	-64.8	-59.6	-64	0	No
Swan Island	-60 AOPC 17S	-60.0	-54.8	-61.8	-61.8	-67.8	-62.6	-42	0	No
Swan Island	Berth 301 AOPC 17S	-36.0	-30.8	-43.0	-37.8	-49.0	-43.8	-33	0	No
Swan Island	Berth 302 to 307 AOPC 17S	-36.0	-30.8	-43.0	-37.8	-49.0	-43.8	-33	0	No
Swan Island	Berth 312 AOPC 17S	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	NA	NA	No
Swan Island	Swan Island Lagoon	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-36	-3	**Yes**
Swan Island	Berth 308 AOPC 17S	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-18	0	No
Swan Island	Swan Island Lagoon	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-26	0	No
8	Equilon Texaco Dock	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	-38	0	No
8	Gunderson LLC	-30.0	-24.8	-35.0	-29.8	-41.0	-35.8	-21	0	No
8	Shaver Transportation	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-15	0	No
8	Front Ave LP	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	NA	NA	No
8	Lakeside	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	NA	NA	No
9	Gunderson LLC	-30.0	-24.8	-35.0	-29.8	-41.0	-35.8	-29	0	No
9	Irvjoy 3rd Generation Corp	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-20	0	No

Table 6.2-9. Feasibility of Capping Cores in Future Maintence Dredge Areas

River Mile	FMD Area	Potential Future Maintenance Dredge Depth (CRD)	Potential Future Maintenance Dredge Depth (NAVD88)	Required Depth with Buffer Offset (CRD)	Required Depth with Buffer Offset (NAVD88)	Elevation of Bottom of Cap Including Buffer Offset and Cap Thickness (CRD)	Elevation of Bottom of Cap Including Buffer Offset and Cap Thickness (NAVD88)	Elevation of Impact (NAVD88)	Depth of Impact Below Elevation Needed to Install Cap	Environmental Dredge to Cap Feasible?
9	PDX Fireboat	-10.0	-4.8	-15.0	-9.8	-21.0	-15.8	-15	0	No
9	Port of Portland - Terminal 2, Berth 203	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	-11	0	No
9	Sause Brothers/PDX Fireboat	-25.0	-19.8	-30.0	-24.8	-36.0	-30.8	NA	NA	No
10	Ash Grove RM-10	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	NA	NA	No
10	P.O.P/Sulzer Pumps	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	NA	NA	No
11	CDL Pacific Grain (Cargill)	= to NC	= to NC	-53.0	-47.8	-59.0	-53.8	-53	-2	No
11	Glacier NW	-36	-30.8	-46.0	-40.8	-52.0	-46.8	-53	-2	**Yes**
11	Ross Island/KF Jacobson	-21.0	-15.8	-26.0	-20.8	-32.0	-26.8	NA	NA	No

Note:
*The table shows samples that are in SMA F since it is the alternative with the largest footprint and the deepest depth of impact (DOI), so it is most inclusive
NA=No Data in FMD area
"= to NC" = Required Depth is Assumed to be Equal to Navigation Channel per Figure 6.2-24

Table 6.2-10. Common Environmental Removal Process Options

<table>
<tr><th>Step</th><th colspan="2">Process Technology
Mechanical Removal</th><th>Process Technology
Hydraulic Removal</th></tr>
<tr><td rowspan="2">Excavation</td><td>Wet</td><td>Conventional clamshell
Enclosed bucket (wire)
Articulated mechanical</td><td>Cutterhead
Horizontal auger
Plain suction
Pneumatic
Specialty</td></tr>
<tr><td>Dry</td><td>Various mechanical methods (e.g. conventional clamshell, articulated closed bucket, open bucket, dragline bucket</td><td>Diver-assisted suction</td></tr>
<tr><td rowspan="2">Conveyance</td><td>Wet</td><td>Barge</td><td rowspan="3">Pipeline</td></tr>
<tr><td>Dry</td><td>Barge
Truck
Rail</td></tr>
<tr><td>Offloading</td><td colspan="2">Various mechanical methods
Conveyor
Pipeline</td></tr>
</table>

Table 6.2-11. Resuspension Control Options for Environmental Dredging Matrix of Advantages and Disadvantages and Project Examples

			Case Study Information		
			Project Example	**Report or Technical Document Reference**	**Project Specific Notes**
1. Engineering controls: sheetpile enclosures					
Advantages	1.A1	Reduced transport of resuspended sediments	Multiple projects	--	--
Disadvantages	1.D1	Difficult to install, maintain, and work around, slows remedy construction	Hudson River - New York	Anchor QEA 2010a	890 LF of sheetpile used to contain 1.56 acre area. Installation required 7 weeks and removal required 6 weeks. The 4-week dredge event required dedicating a dredge to the inside of the sheetpile area, where it could not be productive during sheetpile installation & removal and thus had very low overall productivity.
	1.D2	Reduced production	Published Guidance	EPA 2005	Dependent on site-specific scale and other conditions; conceptual design
	1.D3	Obstruction to navigation	Published Guidance	EPA 2005	Dependent on site-specific scale and other conditions; conceptual design; Require compliance with Coast Guard Regulations
	1.D4	Induced turbulent flow and scour outside of containment	Tittabawassee River Reach D - Michigan	Konechne, et.al. 2010	Scour depths of up to 12 feet below mudline along the sheetpile alignment were noted after sheetpile was removed
			Published Guidance	EPA 2005; USACE 2008	--
	1.D5	Dry excavation can lead to containment failure in adjacent upland areas	Velsicol Chemical Corp./Pine River - Michigan	EPA 2010	Adjacent upland containment wall damage discovered during dry excavation.
	1.D6	Increased chance of river flooding	Published Guidance	EPA 2005	Dependent on site-specific scale and other conditions; conceptual design
	1.D7	Installation may drive contaminants deeper; removal of piling can create a release	Gasco Tar Body Early Action - Oregon (2004)	Anchor Environmental 2005a	Potential for sloughed sediments being released to river during sheetpile removal is described in the EE/CA
			Colman Dock - Seattle	Ecology 1995	Piles pulled during wing wall and structure demolition caused recontamination of adjacent cap area when adhered sediments were resuspended during pulling.
			Published Guidance	EPA 2005	--
	1.D8	Allows transport of dissolved contaminants (not impermeable)	Hudson River - New York	Anchor QEA 2010a	Flow through equalization ports and gaps in the sheetpile connections caused downstream transport of PCBs
			Grasse River - New York	Connolly, et. al. 2007	Containment system extensively engineered and monitored for effectiveness. Dissolved phase and particle bound PCBs were found to have migrated beyond the containment
			GM Massena, St. Lawrence River Remediation Project - New York (1996)	EPA 2003	Turbidity exceedances reported at overflows at low steel sheets during storms and high waves
			Published Guidance	EPA 2005; USACE 2008	--
	1.D9	Release of dissolved and suspended contaminants concentrated inside containment	Hudson River - New York	Anchor QEA 2010a	Dissolved phase PCBs became concentrated in contained water column, resulting in exceedance of air emissions standards during dredging. Residuals released downstream after removal of sheetpile containment.
			Published Guidance	USACE 2008	--
	1.D10	Release of residuals inside containment	Published Guidance	USACE 2008	--
	1.D11	High cost of materials	Published Guidance	USACE 2008	Dependent on site-specific scale and other conditions; conceptual design

Table 6.2-11. Resuspension Control Options for Environmental Dredging Matrix of Advantages and Disadvantages and Project Examples

			Case Study Information		
			Project Example	**Report or Technical Document Reference**	**Project Specific Notes**
2. Engineering controls: Silt curtains/silt screens					
Advantages	2.A1	Reduced transport of resuspended sediments	Multiple projects	--	--
	2.A2	Lower cost materials conmpared to sheetpiles			
Disadvantages	2.D1	Only feasible in quiescent conditions	Gasco Tar Body Early Action - Oregon (2004)	Anchor Environmental 2005b	Silt curtains used in currents greater than 1fps require aggressive anchoring that is difficult to reposition durign construction
			Fox River SMU 56/57 Phase I - Wisconsin (1999)	EPA 2003	Woven geotextile perimeter permeable curtain anchored to river and shore; Curtain performed well under velocity conditions of 2 to 3 fps, experienced damage when velocity neared 4.5 fps
			Kinnickinnic River - Michigan (2009)	EPA 2009	Silt curtains were used prior to implementation of a bubble curtain. Curtains were difficult to manage due to variable river flow and seiche conditions
			Multiple projects	Bridges et. al. 2010	--
	2.D2	Difficult to install and maintain	Gasco Tar Body Early Action - Oregon (2004)	Anchor Environmental 2006	Silt curtain was damaged and repaired on multiple occasions.
			Ford Outfall - Monroe, MI (1997)	Tams 2000	Silt curtain damaged due to unauthorized vessel traffic
			Outboard Marine - Waukegan, IL (1992)	EPA 2003	Silt curtain required multiple repair events due to high winds and currents
			United Heckathorn - San Francisco (1997)	EPA 2006	Silt curtain was damaged and repaired on multiple occasions. The use of a temporary, emergency curtain was required.
			GM Massena, St. Lawrence River Remediation Project - New York (1996)	EPA 2003	Use of silt curtain was abandoned because it could not be maintained in variable flow conditions
			San Jacinto River Waste Pits Time Critical Removal Action - Texas (2011)	Anchor QEA 2011a	Turbidity curtain was continually subject to movement during tide and wind shifts. Regular maintenance and anchor resetting was required; curtain impeded access to work area; hydrodynamic river forces damaged the curtain during construction
			Multiple projects	Bridges, et. al. 2010	--
	2.D3	Obstruction to navigation	Manistique River - Michigan	EPA 2003	Silt curtain could not be placed at mouth of river so as to not restrict river traffic
			East Waterway Phase 1 Removal Action - Seattle (2005)	Anchor Environmental 2003	Silt curtains not used in part because of obstruction to navigation at active Port
	2.D4	Allows transport of dissolved contaminants (not impermeable)	Gasco Tar Body Early Action - Oregon (2004)	Anchor Environmental 2006	Downstream transport of dissolved phase contaminants occurred despite use of silt curtain
			GM Massena, St. Lawrence River Remediation Project - New York (1996)	EPA 2003	Double silt curtain system abandoned after being determined to be ineffective due to variable current speed and direction
			Grasse River - New York	Connolly, et. al. 2007	Containment system extensively engineered and monitored for effectiveness. Dissolved phase and particle bound PCBs were found to have migrated beyond the containment
			Published Guidance	USACE 2008	--
	2.D5	Velocities under silt curtain cause scour			
			New Bedford Harbor - Massachusetts (1995)	EPA 2003	Silt curtain containment originally selected, but later abandoned due to their continuous disturbance of bottom surface

Table 6.2-11. Resuspension Control Options for Environmental Dredging Matrix of Advantages and Disadvantages and Project Examples

			Case Study Information		
			Project Example	**Report or Technical Document Reference**	**Project Specific Notes**
3. Engineering controls: Cofferdams/caissons/removable dams (e.g., geotubes)					
Advantages	3.A1	Allows removal "in the dry"	Multiple projects	--	--
Disadvantages	3.D1	Feasible under limited site conditions	Velsicol Chemical Corp./Pine River - Michigan	EPA 2010	ROD recognized the cofferdams might only be practicable in certain portions of the site
	3.D2	Difficult to install and maintain, slows remedy construction	Rock Bay - Victoria, B.C. (2009)	Hemmera and Anchor QEA 2010	Caisson dredging; caisson control was difficult, debris hindered placement of caisson; multiple caisson placements caused metal fatigue and damage to caisson during the course of work
			Grand Calumet River - Indiana	EPA 2003	Three cells contained within cofferdams BMPs required in the event of action limit exceedance included: decreasing dredge speed, additional resuspension controls, suspension of dredging operations
	3.D3	Reduced production	Rock Bay - Victoria, B.C. (2009)	Hemmera and Anchor QEA 2010	Caisson dredging production rates averaged 13.8 cubic meters per day
	3.D3	Obstruction to navigation	Similar to 1.D3	See 1.D3	--
	3.D4	Induced turbulent flow and scour outside of containment	Similar to 1.D4	See 1.D4	--
	3.D5	Increased chance of river flooding	Similar to 1.D5	See 1.D5	--
	3.D6	Installation may drive contaminants deeper	Similar to 1.D6	See 1.D6	--
	3.D7	High cost of materials	Similar to 1.D11	See 1.D11	--

Table 6.2-11. Resuspension Control Options for Environmental Dredging Matrix of Advantages and Disadvantages and Project Examples

			Case Study Information		
			Project Example	Report or Technical Document Reference	Project Specific Notes
4. Operational controls					
Advantages	4.A1	Reduced resuspension	Black River - Ohio	EPA undated	Oil booms only; Sediment concentrations reduced from 8.8-52 mg/kg to 1.6-3.7 mg/kg two years after dredging; 1997 Sampling indicated that the river and its biota are healthier and do not contain elevated levels of PAHs
			Terminal 4 Phase 1 Removal Action	Anchor QEA 2009	Turbidity levels were effectively reduced using operational BMPs, including preventing bucket overfilling, pausing the dredge bucket near the mudline, slowing the rate of bucket closure and ascent, and complete emptying of the dredge bucket on the material barge
			East Waterway Phase 1 Removal Action - Seattle (2005)	Anchor Environmental and Windward Environmental 2005	Barge filtration was demonstrated to prevent WQ impacts; 1 failure of barge filter fabric was picked up by the WQ monitoring, and once repair was made exceedance stopped.
	4.A2	Increased production	Hylebos Waterway, Commencement Bay (2003)	DOF 2002	Lack of contained dredge area selected because of need for constant repositioning of the dredge
	4.A3	Faster remedy construction	Multiple projects	--	--
	4.A4	Lower cost removal remedy	Multiple projects	--	--
Disadvantages	4.D.1	May not be effective	Published Guidance	USACE 2008	Additional study recommended to understand limitations of operational controls
	4.D.2	Increased transport of resuspended sediments	Multiple projects	--	--

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Table 6.2-12. Release Case Studies

Project	Environmental Dredging Activity	BMPs	Source of Release Estimate	Contaminant Mass Released	Primary Reference
1995 Grasse River NTCRA Pilot Study	3,000 cy of sediment and debris removed using hydraulic dredge for sediments	Dredging operation BMPs and silt curtains	Caged fish monitoring	Adjacent fish tissue concentrations increased 50x; 0.9 km downstream fish tissue concentrations increased 5x	"Non-Time Critical Removal Action (NTCRA) Pilot Dredging in the Grasse River" presentation to the NAS Panel on Risk-management Strategy for PCB-Contaminated Sediments. November 8, 1999.
1999-2000 Fox River SMU 56/57 Dredging Pilot Study	82,000 cy removed using hydraulic cutterhead dredge	Dredging operation BMPs and silt curtains	Water quality monitoring data collected 100 to 200 ft downstream of the dredge, outside of silt curtains	Average **2.2%** of dredged PCB mass released into water column, with roughly 30% as dissolved phase PCBs	Steuer, J.J. 2000. A mass-balance approach for assessing PCB movement during remediation of a PCB-contaminated deposit on the Fox River, Wisconsin. USGS Water-Resources Investigations Report 00-4245.
2004 Duwamish/ Diagonal Early Action	70,000 cy removed using clamshell mechanical dredge	Dredging operation BMPs	Fate/transport and food web modeling to simulate measured fish tissue PCB increases during and after dredging	Fish tissue increases simulated assuming an average **3%** (range: 1 to 6%) of dredged PCB mass released and available for bioaccumulation	Stern. J. H. 2007. Temporal effects of dredge-related releases on fish tissue concentrations: Implications to achieving net risk reduction. SETAC North America 28th Annual Meeting, Nov. 2007, Milwaukee, WI.
2005 Grasse River Remedial Options Pilot Study	25,000 cy removed using hydraulic cutterhead dredge	Dredging operation BMPs and silt curtains	Water quality monitoring data collected more than 2,000 ft downstream of the dredge, outside of silt curtains	Average **3%** of dredged PCB mass released into water column, with more than 50% as dissolved phase PCBs	Connolly J.P., Quadrini J.D., and McShea L.J. 2007. Overview of the 2005 Grasse River Remedial Options Pilot Study. In: Proceedings, Remediation of Contaminated Sediments—2007. Savannah, GA. Columbus (OH): Battelle.
2005 Lower Passaic River Dredging Pilot Study	4,000 cy removed using clamshell mechanical dredge	Dredging operation BMPs and rinse tank	Water quality monitoring data collected 400 ft downstream of the dredge over the 5 day dredging event	Average **3 to 4%** (range: 1 to 6%) of dredged dioxin mass released into water column	Lower Passaic River Restoration Project Team. 2009. Revision and Updates to the Environmental Dredging Pilot Study. Project Delivery Team Meeting. March 2009.
2009 Hudson River Phase I Dredging	280,000 cy removed using clamshell mechanical dredge	Dredging operation BMPs and silt curtains	Water quality monitoring data collected more than 10,000 ft downstream of the dredge, outside of silt curtains	Average **3 to 4%** of dredged PCB mass released into water column, with 70 to 90% as dissolved phase PCBs	Anchor QEA and Arcadis. 2010. Phase 1 Evaluation Report: Hudson River PCBs Superfund Site. Report prepared for General Electric, Albany, New York. March 2010.

Table 6.2-13. Summary of Select Characteristics of Confined Aquatic Disposal (CAD) Options

Disposal Site	Approximate Capacity (cy)	Cover Surface Area (acres)	Capacity: Cover Surface Area (cy/acre)	Top of Cover Elevation (feet NAVD88)	Navigation Channel
Willamette River Mile 4/5	201,000	36	6,000	-58	In Channel
Willamette RM 9	134,000	23	6,000	-53	In Channel
Columbia River	306,000	21	15,000	-56	Partial
Ross Island	585,000	37	16,000	-20	Off Channel
Swan Island	280,000	29	10,000	-4.4	Off Channel

Notes:
cy - cubic yards
NAVD88 - North American Vertical Datum of 1988

Table 6.2-14. Summary of Key Characteristics of Confined Disposal Facility (CDF) Options

Disposal Site	Approximate Capacity (cy)	Berm Face Area (sf)	Top of Cover Elevation (feet NAVD88)
Swan Island	1,360,000	63,000	32
Terminal 4	670,000	38,000	37
Arkema (1-berth)*	55,000	45,000	33
Arkema (2-berth)*	164,000	65,000	33

Notes:
cy - cubic yards
NAVD88 - North American Vertical Datum of 1988
sf - square feet

* Proposed Arkema CDF options use circular cofferdams for containment rather than berms. Dimensions from the Preliminary CDF Screening Evaluation (Arcadis 2010).

Table 6.2-15. Capacity of Individual Disposal Options Expressed as a Percentage of Anticipated Volumes of Contaminated Sediment

		Estimated Volumes of Contaminated Sediment[1] by Remedial Action Level (RAL) (cubic yards)[2]									
		RAL B		**RAL C**		**RAL D**		**RAL E**		**RAL F**	
		Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Disposal Option and Capacity[3] (cubic yards)		**490,500**	**708,300**	**675,800**	**978,300**	**807,100**	**1,165,000**	**1,500,200**	**2,160,900**	**3,662,100**	**5,346,600**
Hillsboro Landfill (Hillsboro, Oregon)	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
North Wasco County Regional Landfill (The Dalles, Oregon)	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Columbia Ridge Landfill (Arlington, Oregon)	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Roosevelt Regional Landfill (Roosevelt, Washington)	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chemical Waste Management of the NW Landfill (Subtitle C) (Arlington, Oregon)	**	**	**	**	**	**	**	**	**	**	**
Willamette River Mile 4/5 CAD	201,000	41%	28%	30%	21%	25%	17%	13%	9%	5%	4%
Willamette River Mile 9 CAD	134,000	76%	53%	55%	38%	46%	32%	25%	17%	10%	7%
Columbia River Mile 102 CAD	306,000	62%	43%	45%	31%	38%	26%	20%	14%	8%	6%
Ross Island CAD	585,000	119%	83%	87%	60%	72%	50%	39%	27%	16%	11%
Swan Island Lagoon CAD	280,000	57%	40%	41%	29%	35%	24%	19%	13%	8%	5%
Swan Island Lagoon CDF	1,360,000	277%	192%	201%	139%	169%	117%	91%	63%	37%	25%
Terminal 4 CDF	670,000	137%	95%	99%	68%	83%	58%	45%	31%	18%	13%
		Estimated Volumes of Contaminated Sediment in SMA 14 by RAL (cubic yards)[2]									
		RAL B		**RAL C**		**RAL D**		**RAL E**		**RAL F**	
		Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
		50,600	74,800	100,700	148,100	106,700	156,200	274,500	435,100	533,400	835,700
Arkema CDF, 1 berth	55,000	109%	74%	55%	37%	52%	35%	20%	13%	10%	7%
Arkema CDF, 2 berth	164,000	324%	219%	163%	111%	154%	105%	60%	38%	31%	20%

Notes:

NA - Sediment Management Area (SMA)-specific option that should not be compared to Site wide volumes.

[1] Estimated volumes of contaminated sediment (refer to Section 5.10). Excludes volumes from SMA 14, which is addressed separately for the Arkema CDF options.

[2] The impacted sediment volumes are estimated removal volumes consistent with volumes presented in Section 7 and do not include sediment confined beneath the CDFs. See Table 7.0-1 for the assumed CDFs for each alternative.

[3] Capacities of disposal facilities are conservative estimates that ignore volume that will be gained due to consolidation settlement of the in situ sediment as the facility is filled.

* Capacity of the landfill is essentially unlimited relative to the volume of sediment that may be removed from the Site. Disposal by this option would be limited by either the rate at which dredging can proceed or the rate at which sediment can be transported to the landfill.

** This facility, which is permitted for disposal of hazardous waste, would only be expected to receive contaminated sediments that do not meet acceptance criteria for any other disposal option.

Values of 100% or greater and cells shaded yellow indicate that the capacity of the disposal option exceeds the volume of contaminated sediment for that RAL.

Table 6.3-1. Summary of Technology Implementability Screening Results by subSMA Based on Site Uses and Physical Conditions (see Section 6.2 text for detailed descriptions of screening determinations)[1]

Label	Feature	Description	MNR[2]	EMNR	In Situ Treatment	Engineered and Active Capping	Full Removal	Ex Situ Treatment[5]
NC	Navigation Channel	Areas within the current federally authorized navigation channel.	YES	NO	NO	NO	YES	YES
FMD	Potential Future Maintenance Dredge Area	Approach areas located between the NC areas and docks where shipping access is needed now or in the future.	YES	POTENTIALLY	POTENTIALLY	SOME[3]	YES	YES
SS	Structure - Under	Areas located beneath structures including a 5 foot offset from the structure face. The offset is based on the average depth of impact across the Study Area.	YES	YES	YES	YES	LIMITED[4]	LIMITED[4]
SL	Structure – Limited Access	Areas where open water equipment is not accessible due to structures. Smaller water-based equipment would have to be used.	YES	YES	YES	YES	YES	YES
SU	Structure – Upland Removal	Areas where no water-based equipment can reach but access from shore is feasible.	YES	YES	YES	YES	YES	YES
SN	Structure – No Removal	Areas where access by water-based equipment is highly restricted and upland structures, utilities, and/or topography highly restrict access from shore.	YES	YES	YES	YES	NO	NO
OW	Open Water	Areas where there is no restrictions to dredging or capping equipment.	YES	YES	YES	YES	YES	YES
CAP	Remediation Cap	Existing Caps at Terminal 4 and McCormick and Baxter.	NO ACTION	NO ACTION	NO ACTION	NO ACTION	NO ACTION	NO ACTION
Other Considerations								
-wz	Wave Zone	Area above 0 NAVD88 subject to wake and wind generated waves.	YES	POTENTIALLY	POTENTIALLY	YES	YES	YES
-z	CDFs and CADs Footprints	Areas located beneath the potential CDF and/or CAD footprints.	IF CAD/CDF NOT CONSTRUCTED, SEE ABOVE DESIGNATIONS	IF CAD/CDF NOT CONSTRUCTED, SEE ABOVE DESIGNATIONS	IF CAD/CDF NOT CONSTRUCTED, SEE ABOVE DESIGNATIONS	IF CAD/CDF NOT CONSTRUCTED, SEE ABOVE DESIGNATIONS	IF CAD/CDF NOT CONSTRUCTED, SEE ABOVE DESIGNATIONS	IF CAD/CDF NOT CONSTRUCTED, SEE ABOVE DESIGNATIONS

Notes:

1 - All screening results in this table are for draft FS purposes only, and all technologies discussed here may be implementable under specific circumstances for specific SMAs as determined in remedial design.

2 - Per Section 6.2.2, the rate of MNR was found to be less certain in some small select areas of the Site, and some of these implementability factors were relevant to this determination. However, these small areas are not expected to significantly affect the overall course of natural recovery for the Site at spatial scales most relevant to the remediation goals (RGs). Consequently, MNR is shown to be generally implementable for all portions of the Site.

3 - Engineered caps were screened out for draft FS purposes for those FMD areas that are currently estimated to require navigation depths equal to the navigation channel (-40 feet CRD) or greater. Future development plans or more information during remedial design could redefine FMD areas so as to allow placement of an engineered cap in some or all of these areas.

4 - The SS designation includes some "light" structures that can be removed and reloacted to allow dredging underneath. These light structures are shown in Figure 5.4-1. Otherwise, removal was screened out as not implementable in SS areas.

5 - Ex situ treatment implementability is not typically controlled by the Site use and physical conditions in this table. Implementability issues related to removal before ex situ treatment are noted here. See Section 6.2.8.2 for more details on ex situ treatment implementability issues.

Table 6.3-2. Summary of Implementability and Effectiveness Screening by SMA[1]

SMA	Institutional Controls		Monitored Natural Recovery		Enhanced Monitored Natural Recovery		In situ Treatment		Engineered Capping		Active Capping		Removal including BMPs[2] and Dewatering		Contained Beneath CAD/CDF		Ex situ Treatment	
	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability	Effective-ness	Implement-ability
1															NA	NA	STB	STB
3															NA	NA	STB	STB
5															NA	NA	STB	STB
6																	STB	STB
7											R				NA	NA	STB	STB
8											R				NA	NA	STB	STB
9U											*				NA	NA	STB	STB
9D															NA	NA	STB	STB
10											R				NA	NA	STB	STB
11															NA	NA	STB	STB
12															NA	NA	STB	STB
13															NA	NA	STB	STB
14											*						STB	STB
15											R				NA	NA	STB	STB
16											R				NA	NA	STB	STB
17D											R				NA	NA	STB	STB
17S																	STB	STB
18											R				NA	NA	STB	STB
19															NA	NA	STB	STB
20											R				NA	NA	STB	STB
21															NA	NA	STB	STB
22											R				NA	NA	STB	STB
23											R				NA	NA	STB	STB
24															NA	NA	STB	STB
25															NA	NA	STB	STB

Notes:

1 - All screening results in this table are for draft FS purposes only, and all technologies discussed here may be implementable and/or effective under specific circumstances for specific SMAs as determined in remedial design.

2 - A variety of removal process options were found to be effective and implementable including various dewatering methods and operational water quality BMPs. Barrier BMPs were not retained for draft FS purposes as discussed in Section 6.2.7.

Technology is SCREENED IN for comprehensive alternative development for the draft FS in at least some subSMAs within the SMA.

R Active capping is effective, but engineered capping is equally effective. Active capping is retained but would only be further evaluated if new information becomes available in remedial design.

* Active capping is effective, and would be most likely to be employed in SMAs that have relatively mobile contaminants and groundwater plumes.

NA This technology is Not Applicable because a CAD or CDF option was not identified in this SMA.

Ex situ Effectiveness codes (if listed, these technologies were SCREENED IN for draft FS purposes):

BLT Biological Land Treatment

STB Stabilization. This technology is also retained as a potential dewatering process option.

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
No Action	None	Not Applicable	No Action	Required for consideration in all SMAs by NCP
Institutional Controls	Governmental Controls	Commercial Fishing Bans	Commercial fishing bans are government controls that ban commercial fishing for specific species or sizes of fish or shellfish and are established by state departments of health or other governmental entities.	Retained for all SMAs
		Waterway Use Restrictions or Regulated Navigation Areas	Provides notice to navigation to prevent damage to caps, in-situ treatment, EMNR, etc.	Retained for all SMAs
	Proprietary Controls	Land Use/Access Restrictions	Restrictions, such as deed restrictions, easements, and covenants, placed in property related documents or physical barriers, such as fences.	Retained for all SMAs
		Structure Maintenance Agreements	Requirements for maintenance of in-water structures where caps or other in-situ technologies are co-located in river.	Retained for all SMAs
	Enforcement and Permit Tools	Permit Processes or Provisions of Administrative Orders or Consent Decrees	Legal tools, such as administrative orders, permits, and Consent Decrees (CDs), that limit certain site activities or require the performance of specific activities (e.g., to monitor and report on an IC's effectiveness). They may be issued unilaterally or negotiated.	Retained for all SMAs
	Informational Devices	Fish Consumption Advisories	Fish consumption advisories provide information to the public from state departments of health or other governmental entities on acceptable fish consumption rates and fish preparation techniques.	Retained for all SMAs

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
Monitored Natural Recovery	Monitored Natural Recovery	Monitored Natural Recovery (Many processes may exist to cause natural recovery, but because these processes are naturally occurring and simultaneous they cannot be parsed and selected as options in the draft FS or design process, and therefore, do not constitute process options.)	Use of ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. Involves acquisition of information over time to confirm that these risk-reduction processes are occurring and a contingency plan, if the expected processes are not occurring. These processes may include physical, biological, and chemical mechanisms that act together to reduce the potentially unaccetpable risk posed by the contaminants (EPA 2005).	Retained for all SMAs
	Enhanced Monitored Recovery	Thin Layer Suitable Material Placement	Enhancement of MNR (e.g., burial) through placement of a thin layer of suitable material (e.g., 6" of sand).	Retained for all SMAs
Containment in Place	Capping	Conventional Sand Cap	Physical isolation of contaminants with sand cover.	Retained for all SMAs
		Conventional Sand/Clay Cap	Physical isolation of contaminants with sand/clay cover.	Retained for all SMAs
		Armored Cap	Physical isolation of contaminants with sand cover and other structural elements (such as armor) as necessary to keep the cap stable.	Retained for all SMAs
		Composite Cap (e.g., HDPE, Geotextile)	Physical and/or chemical isolation of contaminants by layering heavy-duty composite protection mat designed for placement over sediments to guard against damage by erosion, scouring, heavy equipment or other forces.	Retained for all SMAs
		Habitat Cap	Physical isolation of contaminants with sand cover and other elements (such as gravel surface or plantings) to provide additional habitat value or features. Habitat features must also perform functions that provide any needed cap stability (like armored cap above).	Retained for all SMAs

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
Containment in Place		Active Cap	Placement of active capping layers such as activated carbon or organoclay to reduce contaminant flux through capping materials. Also, known as "reactive" capping.	Retained for all SMAs
	Contained Beneath a CAD/CDF	Contained Beneath a CAD/CDF	Contaminated sediments that are contained in place beneath a CAD or CDF (see below) that is being constructed to received materials removed from another location for disposal. In these cases, CAD/CDFs must be designed to contain both disposed and contained in place contaminated sediments.	Retained for SMAs 6, 14, and 17S.
In Situ Treatment	Biological	Slurry Bioremediation	Addition of nutrients and other amendments to enhance bioremediation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
		Phytoremediation	Use of plants to remediate contaminated sediments	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
		Aerobic Biodegradation	Bioremediation uses microorganisms to degrade organic contaminants in soil, sludge, and solids in situ. The microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Aerobic processes require an oxygen source, and the end products typically are carbon dioxide and water.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
In Situ Treatment		Anaerobic Biodegradation	Bioremediation uses microorganisms to degrade organic contaminants in soil, sludge, and solids either excavated or in situ. The microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Anaerobic processes are conducted in the absence of oxygen, and the end products can include methane, hydrogen gas, sulfide, elemental sulfur, and dinitrogen gas.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Imbiber Beads	Spherical plastic particles that absorb a very broad cross section of the organic contaminant spectrum.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
	Chemical	Chemical Slurry Oxidation	Application of chemical oxidants to remediate contaminated sediments. Chemical oxidation typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
In Situ Treatment	Physical-Extractive Processes	Oxidation	Chemical oxidation typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Sediment Flushing	In situ flushing is defined as the injection or infiltration of an aqueous solution into a zone of contaminated soil/groundwater, followed by downgradient extraction of groundwater and elutriate (flushing solution mixed with the contaminants) and aboveground treatment and discharge or re-injection.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
	Physical - Immobilization	Solidification/Stabilization	The addition of reagents that immobilize and/or bind contaminants to the sediment in a solid matrix or chemically stable form.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
		Vitrification	Use of strong electrical current to heat sediment to temperatures above 2400ºF to fuse it into a glassy solid.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
		Electrochemical Oxidation	Technology for degrade organic contaminants in situ by applying an alternating current across electrodes placed in the subsurface to create redox reactions.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
		Carbon/Other Amendments	Carbon (granulated activated carbon [GAC] or other carbon materials) to reduce bioavailability of organic contaminants, other amendments to treat a wider range of COCs.	Retained for all SMAs.

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
In Situ Treatment		Ground Freezing	The ground freezing process converts in situ pore water to ice through the circulation of a chilled liquid via a system of small-diameter pipes placed in drilled holes. The ice acts to fuse the soil or rock particles together, creating a frozen mass of improved compressive strength and impermeability. Brine is the typical cooling agent, although liquid nitrogen can be used in emergency situations or where the freeze is only required to be maintained for a few days.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
Removal	Dredging (environmental)	Mechanical Dredging	Use of clamshell, closed, hydraulic, or other buckets to remove contaminated sediment from a barge or other vessels.	Retained for all SMAs.
		"Dry" Excavation	Use of excavators, buckets, etc. deployed from land based equipment. Can be "in the wet" or "in the dry" in combination with sheet piles, coffer dams, or other measures to remove water.	Retained for all SMAs for consideration in nearshore areas.
		Hydraulic Dredging	Use of hydraulic dredges (e.g., cutterhead, horizontal auger, plain suction, pneumatic, or specialty dredges) with various cutter and suction heads to remove contaminated sediments from the environment in a slurry phase.	Retained for all SMAs.
		Small Scale Dredge Equipment	Diver assisted or hand held hydraulic dredging, Mud Cat, and similar small scale removal methods.	Retained for all SMAs for consideration around structures.

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
Disposal/ Confinement	Upland Commercial Landfill	Hillsboro	A disposal site where solid waste is buried between layers of soil and other materials in such a way as to reduce contamination of the surrounding land. Modern commercial landfills have a liner and groundwater leachate collection and treatment systems to keep contaminants from being transported into the soil and water around the landfill. Other commercial landfills were evaluated prior to the draft FS, as described more in Section 6.2.8.	Retained for all SMAs.
		Northern Wasco County		Retained for all SMAs.
		Roosevelt Regional		Retained for all SMAs.
		Columbia Ridge		Retained for all SMAs.
		Chem Waste (Subtitle C)		Retained for SMA 9U consideration for RCRA hazardous waste, and any other SMAs where hazardous waste is designated in remedial design.
	Onsite Upland Landfill	No likely candidate property.	A disposal site where solid waste is buried between layers of soil and other materials in such a way as to reduce contamination of the surrounding land. Such a facility would be designed with liners and similar systems to minimize contaminants from being transported into the soil and water around the landfill.	Screened out for all SMAs due to lack of candidate property.
	Confined Aquatic Disposal (CAD)	Willamette River (RM 4/5)	Pits excavated in open water or in pre-existing depressions in the aquatic environment that are filled, then covered with suitable material.	Screened out for all SMAs due to implementability issues.
		Willamette River (RM 9)		Screened out for all SMAs due to implementability issues.
		Swan Island Lagoon		Retained for SMA 17S.
		Columbia River (RM 102.5)		Screened out for all SMAs due to implementability issues.
		Ross Island		Screened out for all SMAs due to implementability issues.

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
Disposal/ Confinement	Confined Disposal Facility (CDF)	Terminal 4 Slip 1	A facility built specifically for the disposal of dredged sediment in such a way that minimizes transport of contaminants to surrounding water and soils.	Retained for SMA 6 and other SMAs that might potentially dispose here.
		Swan Island Lagoon		Retained for SMA 17 and other SMAs that might potentially dispose here.
		Arkema		Retained for SMA 14.
Ex Situ Treatment	Physical	In-barge Dewatering	Dewatering through passive dewatering on barge	Retained for all SMAs.
		Lagoon Dewatering	Dewatering through placement in lagoon. Water discharge takes place on particles have settled out.	Retained for all SMAs.
		Geotextile Tube Dewatering	Geotextile tubes allow water to migrate through membrane retaining sediments	Retained for all SMAs.
		Mechanical Dewatering	Use of filter presses or other similar equipment	Retained for all SMAs.
		Reagent/Amendment Dewatering	Use of reagents to chemically absorb excess water (see solidification/stabilization) or other amendments (e.g., vermiculite) to adsorb excess water.	Retained for all SMAs.
		Particle Separation	Separation of sandier sediments with less contamination for beneficial reuse.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.
		Cement/QuickLime/Flyash Solidification/Stabilization	Solidification/stabilization of contaminated sediments through addition of Portland cement or similar amendments.	Retained for all SMAs.
	Physical	Sorbent Clay Solidification/Stabilization	Solidification/stabilization of contaminated sediments through addition of sorbent clays such as bentonite.	Retained for all SMAs.
		Asphalt Emulsion	Treatment of contaminated sediments with asphalt emulsion to remove water and bind contaminants.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
Ex Situ Treatment		Solar Detoxification	Technology for using concentrated sunlight to break down and destroy hazardous waste.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
	Biological Methods	Land Treatment	Large scale land treatment to reduce contaminant concentrations through biological processes.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.
		Composting	Large scale land treatment to reduce contaminant concentrations through composting.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.
		Biopiles	Large scale land treatment to reduce contaminant concentrations through biopiles	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Fungal Biodegradation	Large scale land treatment to reduce contaminant concentrations through fungal plants.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Slurry-phase Treatment	Biological treatment in a slurry phase.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Enhanced Biodegradation	Acceleration of the natural bioremediation processes by providing oxygen, reducing agents, nutrients, and degrading microrganisms.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
	Chemical	Acid Extraction	Use of acids to extract contaminants.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
Ex Situ Treatment		Solvent Extraction	Use of solvents to extract contaminants.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
	Physical/Chemical	Sediment Washing	An advanced form of particle separation, sediments are washed with water and oxidizing agents to remove contaminants.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.
		Chemical Oxidation/Reduction	Reducing/oxidizing agents are used to chemically convert toxic contaminants in excavated waste materials to less toxic compounds that are more stable, less mobile, and/or inert. Commonly used reducing/oxidizing agents are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Dehalogenation	Removal of halogens (e.g., chlorine) through chemical dehalogenation reactions.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Slurry Oxidation	Involves mixing an oxidizing agent with contaminated sediments. The oxidation process mineralizes most organic compounds to carbon dioxide, water, and salts. Typical oxidizing agents include: Sodium hypochlorite (or other hypochlorite compounds), Hydrogen peroxide, Chlorine, Chlorine dioxide, Potassium permanganate, and Ozone.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
		Radiolytic Dechlorination	Radiolytic (electron beam) and photolytic (ultraviolet, UV) dechlorination of polychlorinated biphenyls (PCBs).	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]
	Thermal Methods	Incineration	Treatment through thermal decomposition of organic contaminants and volatilization of some metals at temperatures typically greater than 900ºC (1650ºF).	Screened out for all SMAs due to likely implementability issues. Also, not fully effective in all SMAs.

Table 6.3-3. Summary GRAs, Remedial Technologies, Process Options, and Screening Findings for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Description	Screening Comments[1]
Ex Situ Treatment		Pyrolysis	Chemical decomposition induced in organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430ºC (800ºF).	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		High Temperature Thermal Desorption	Heating of contaminated sediment to drive off and capture contaminants. Involves the application of heat (320 to 560ºC or 600 to 1,000ºF) to excavated wastes to volatilize organic contaminants and water. Typically, a carrier gas or vacuum system transports the volatilized water and organics to a treatment system, such as a thermal oxidation or recovery unit.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.
		Low Temperature Thermal Desorption	Involves the application of heat (90 to 320ºC or 200 to 600ºF) to excavated wastes to volatilize organic contaminants and water. Typically, a carrier gas or vacuum system transports the volatilized water and organics to a treatment system, such as a thermal oxidation or recovery unit.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.
	Thermal Methods	High Pressure Oxidation	This category includes two related technologies: wet air oxidation and supercritical water oxidation. Both processes use the combination of high temperature and pressure to break down organic compounds.	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]
		Vitrification	Process in which solids (e.g., sediments) and contaminants are heated in a rotary kiln or furnace melter at tempertures upto 1600ºC (2900ºF).	Screened out for all SMAs due to likely implementability issues. Also, not fully effective in all SMAs.

Notes:
1 - Unless otherwise noted screening rationale and decisions are described in Section 6.2.
2 - Screening decisions described in the Treatment Technology Evaluation Tools Memorandum dated March 15, 2011 or previous documents cited there.
3 - Screening decisions described in Appendix S.

Ex situ treatment technologies that were screened through the Treatment Technology Evaluation Tools Memorandum and Appendix S screening evaluations for further evaluation in Section 6.2.

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
No Action	None	Not Applicable	Does not meet RAOs	Yes for all SMAs.	No significant cost differentiators identified
Institutional Controls	Governmental Controls	Commercial Fishing Bans	Limited to contaminants that accumulate in fish or shellfish. Mainly for commercial fisheries, not very effective for recreational fisheries. For controlling human exposures not ecological exposures. More effective if used in conjuction with more active technologies.	Requires commitment and cooperation of impmenting party to administer and acceptance of Native American tribes and public.	No significant cost differentiators identified
		Waterway Use Restrictions or Regulated Navigation Areas	When used in conjuction with in place technologies such as capping can provide protection of the cap and underlying sediments from human disturbance and human/ecological exposures. By itself, provides limited effectiveness for human health exposures and is not effective for ecological exposures.	Enforcement of restrictions in more actively used portions of large waterways is difficult or impossible. Requires commitment and cooperation of implementing party to administer and acceptance of Native American tribes and public.	No significant cost differentiators identified
	Proprietary Controls	Land Use/Access Restrictions	Better for controlling human exposures than ecological exposures. More effective if used in conjuction with more active technologies.	Requires commitment and cooperation of impmenting party to administer and acceptance of Native American tribes and public.	No significant cost differentiators identified
		Structure Maintenance Agreements	Better for controlling human exposures than ecological exposures. More effective if used in conjuction with more active technologies.	Requires commitment and cooperation of impmenting party to administer and acceptance of Native American tribes and public.	No significant cost differentiators identified
	Enforcement and Permit Tools	Permit Processes or Provisions of Administrative Orders or Consent Decrees	An action pursuant to the consent decree (CD), order, or permit generally will be effective only against the parties specified in these documents. For example, a provision in a CD or Agreed Order on Consent (AOC) may require a facility operator to secure a proprietary control to prevent a particular type of land use. However, the land owner may not be a party to the CD or AOC and, therefore, would not be obligated to convey the interest. Furthermore, the requirements of the CD may not be enforceable against any successor-in-title if the successor was not a party to the CD.	Through these instruments, EPA or another regulatory agency may be able to specify the restrictions and requirements for implementing, maintaining, and/or fixing a breach to the insitutional control in the enforceable document. If the responsible parties fail to carry out their obligations under a CD, order, or permit, EPA or another regulatory agency may be able to enforce those obligations under the appropriate CERCLA authority. The remedies available may include requiring the defendant to implement the institutional control or, in some circumstances, pay certain costs or penalties. Such payments may be required to reimburse an agency that has incurred the cost of implementing or maintaining the control, cover the costs incurred when addressing IC breaches, and/or pay penalties (stipulated and/or statutory).	No significant cost differentiators identified
	Informational Devices	Fish Consumption Advisories	Limited to contaminants that accumulate in fish or shellfish. Mainly for commercial fisheries, not very effective for recreational fisheries. For controlling human exposures, not ecological exposures. More effective if used in conjuction with more active technologies.	Requires commitment and cooperation of impmenting party to administer and acceptance of Native American tribes and public.	No significant cost differentiators identified
Monitored Natural Recovery	Monitored Natural Recovery	Monitored Natural Recovery (Many processes may exist to cause natural recovery, but because these processes are naturally occurring and simultaneous they cannot be parsed and selected as options in the draft FS or design process, and therefore, do not constitute process options.)	Using multiple lines of empirical evidence and predictive tools, appears to likely be effective in 7 of 10 river miles and potentially effective the remaining 3 river miles. Localized areas that are not conducive to MNR may exist, but would likely not cause unacceptable exposures on spatial scales most relevant to the risk assessments.	The effectiveness discussion addresses all of the natural and anthropogenic processes that are relevant to the determination of whether MNR is likely to be implementable. Monitoring and contingency planning is generally highly implementable, although it requires planning and coordination.	No significant cost differentiators identified
	Enhanced Monitored Recovery	Thin Layer Suitable Material Placement	Most applicable at areas where MNR implementable and partially effective or more uncertain.	EMNR potentially implementable in FMD coupled with new site use restrictions. Potentially implementable in wz areas as part of a larger program supplying EMNR materials to wider Site areas. EMNR considered not implemntable in the NC for draft FS purposes.	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Containment in Place	Capping	Conventional Sand Cap	A one-foot thick layer of sand, as part of an overall engineered cap design including armor as necessary, was found to provide the required contaminant isolation for all SMAs with some limited exceptions in portions of some SMAs. For these limited exceptions, further analysis indicated that these areas could easily be capped using design level parameters, small changes to cap design, or active capping approaches (see below).	Engineered sediment caps were found to be implementable with regards to erosion, site use, and slope stability issues in all areas of the Site except in NC areas due to future navigation dredging and in FMD areas that require navigation depths similar to the federal navigation channel. In shallower FMD areas capping after partial removal may be implementable and/or capping alone may be implementable, particularly if combined with institutional controls that change existing Site uses, if necessary.	No significant cost differentiators identified
		Conventional Sand/Clay Cap	Found to be effective per conventional sand cap evaluation. Inclusion of fine or clay materials in a cap is one type of augmentation to a sand cap that may make it more effective in some areas as noted above.	Same findings as conventional sand cap.	No significant cost differentiators identified
		Armored Cap	Found to be effective per conventional sand cap evaluation.	Same findings as conventional sand cap.	No significant cost differentiators identified
		Composite Cap (e.g., HDPE, Geotextile)	Found to be effective per conventional sand cap evaluation. Inclusion of geotextiles is one type of augmentation to a sand cap that may make it more effective in some areas as noted above.	Same findings as conventional sand cap.	No significant cost differentiators identified
		Habitat Cap	Found to be effective per conventional sand cap evaluation.	Same findings as conventional sand cap. Would not be implementable in areas that have high erosion forces that are incompatible to surface habitat layer (e.g., gravel). Other mitigation would need to be provided in these cases if habitat features are needed.	No significant cost differentiators identified
		Active Cap	Found to be effective per conventional sand cap evaluation. Inclusion of active layers in a cap is one type of augmentation to a sand cap that may make it more effective in some areas as noted above. Active capping was found to be effective in areas with highly mobile contaminants and groundwater plumes.	Same findings as conventional sand cap.	No significant cost differentiators identified
	Contained Beneath a CAD/CDF	Contained Beneath a CAD/CDF	Because capping of sediments in place was found to be effective, containing them in place beneath a CAD or CDF with similar covers and isolation mechanisms (e.g., berms) was also found to be effective. In these cases, CAD/CDFs must be modeled and designed to contain both disposed and contained in place contaminated sediments.	Same findings as for caps (see Section 6.2.9 for implementability issues regarding disposal options).	No significant cost differentiators identified
In-Situ Treatment	Biological	Slurry Bioremediation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Phytoremediation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
		Aerobic Biodegradation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Anaerobic Biodegradation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Imbiber Beads	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
In-Situ Treatment	Chemical	Chemical Slurry Oxidation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
	Physical-Extractive Processes	Oxidation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Sediment Flushing	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
	Physical - Immobilization	Solidification/Stabilization	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
		Vitrification	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
		Electrochemical Oxidation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
		Carbon/Other Amendments	Activated carbon, or similar, likely effective for a wide-range of organic contaminants and concentrations and some metals applicability. Range of other amendments potentially effective for other contaminants.	Potentially implementable in FMD coupled with new site use restrictions. Not considered implemntable in the NC for draft FS purposes.	No significant cost differentiators identified
		Ground Freezing	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
Removal	Dredging (environmental)	Mechanical Dredging	Dredging found to be effective for all SMAs with appropriate residuals and water quality control measures. Mechanical or hydraulic dredging may be equally effective depending on SMA-specific conditions.	Removal is implementable where access to sediments can be reasonably achieved and stable slopes can be maintained. Removal under robust structures and/or behind structures with no reasonable shoreline access is not implementable. Removal around and under other structures implementable with appropriate equipment and procedures.	Costs of removing and replacing robust structures are unreasonably high and were screened out. (Unit cost factors for dock removal and replacement are supplied in Appendix K for EPA use.)
		"Dry" Excavation	Dredging found to be effective for all SMAs with appropriate residuals and water quality control measures. In the dry excavation effective in nearshore areas where dry conditions can be engineered.	Found to be implementable but generally not used as part of select process options used in alternative development because it requires installation of rigid barriers (e.g., sheet pile walls) in most cases or only applies to higher elevations not regularly inundated. Limited application to areas that can be reached from shore, which can also be accessed by "wet" techniques.	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Removal		Hydraulic Dredging	Dredging found to be effective for all SMAs with appropriate residuals and water quality control measures. Mechanical or hydraulic dredging may be equally effective depending on SMA-specific conditions.	Removal is implementable where access to sediments can be reasonably achieved and stable slopes can be maintained. Removal under robust structures and/or behind structures with no reasonable shoreline access is not implementable. Removal around and under other structures implementable with appropriate equipment and procedures.	Costs of removing and replacing robust structures are unreasonably high and were screened out. (Unit cost factors for dock removal and replacement are supplied in Appendix K for EPA use.)
		Small Scale Dredge Equipment	Dredging found to be effective for all SMAs with appropriate residuals and water quality control measures. Small scale dredge equipment may be useful in hard to access areas, but may not be effective in removing all contamination around mutliple pilings and dense structures.	Removal is implementable where access to sediments can be reasonably achieved and stable slopes can be maintained. Small equipment removal under structures may cause stability and health and safety issues. Production rates are much less than other removal equipment. For these reasons, this option not generally used as part of select process options used in alternative development.	No significant cost differentiators identified
Disposal/ Confinement	Upland Commercial Landfill	Hillsboro	Commercial landfills were found to be effective because they are designed, operated, and monitored to meet EPA and state regulatory criteria. Slightly greater risk of short term impacts due to greater transport distances as compared to on-site disposal options.	All of the five upland commercial disposal options have sufficient capacity to receive a large proportion of sediments calculated to be associated with each overall SMA footprint. Hillsboro cannot accept wet waste and is not accessible by rail transport, both of which are logistical issues.	No significant cost differentiators identified
		Northern Wasco County	Commercial landfills were found to be effective because they are designed, operated, and monitored to meet EPA and state regulatory criteria. Slightly greater risk of short term impacts due to greater transport distances as compared to on-site disposal options.	All of the five upland commercial disposal options have sufficient capacity to receive a large proportion of sediments calculated to be associated with each overall SMA footprint. Hillsboro cannot accept wet waste and is not accessible by rail transport, both of which are logistical issues.	No significant cost differentiators identified
		Roosevelt Regional	Commercial landfills were found to be effective because they are designed, operated, and monitored to meet EPA and state regulatory criteria. Slightly greater risk of short term impacts due to greater transport distances as compared to on-site disposal options. Provides train transport option, which has somewhat less short term impacts as compared to truck transport.	All of the five upland commercial disposal options have sufficient capacity to receive a large proportion of sediments calculated to be associated with each overall SMA footprint. Roosevelt landfill is able to accept contaminated sediments in wet form without dewatering and is accessible by rail transport, both of which are significant logistical advantages. Dangerous Waste Regulations in Washington need to be considered and may be applicable to a small amount of Site sediments	No significant cost differentiators identified
		Columbia Ridge	Commercial landfills were found to be effective because they are designed, operated, and monitored to meet EPA and state regulatory criteria. Slightly greater risk of short term impacts due to greater transport distances as compared to on-site disposal options. Provides train transport option, which has somewhat less short term impacts as compared to truck transport.	All of the five upland commercial disposal options have sufficient capacity to receive a large proportion of sediments calculated to be associated with each overall SMA footprint. Columbia Ridge landfill is able to accept contaminated sediments in wet form without dewatering and is accessible by rail transport, both of which are significant logistical advantages.	No significant cost differentiators identified
		Chem Waste (Subtitle C)	Commercial landfills were found to be effective because they are designed, operated, and monitored to meet EPA and state regulatory criteria. Slightly greater risk of short term impacts due to greater transport distances as compared to on-site disposal options. Chem Waste is included because it accepts RCRA hazardous waste material, and consequently would likely only receive a small fraction of the Site volumes.	Chem Waste is accessible by rail transport and is primarily retained because of its ability to receive potentially hazardous waste, which is relevant to a small amount of Site sediments.	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Disposal/ Confinement	Onsite Upland Landfill	No likely candidate property.	No likely candidate property.	No likely candidate property.	No significant cost differentiators identified
	Confined Aquatic Disposal (CAD)	Willamette River (RM 4/5)	All five of the potential CAD facilities could be designed and built to provide permanent effective containment of contaminated sediment including preventing contaminant mobility and erosion of CAD covers. Short term water quality impacts would be greater for open water sites such as this.	Screened out for draft FS purposes for implementability considerations including that the capacity is relatively low for this site, particularly with need for seasonal covers and, given the location in the navigation channel, extensive RNAs or other navigation institutional controls would be needed.	No significant cost differentiators identified
		Willamette River (RM 9)	All five of the potential CAD facilities could be designed and built to provide permanent effective containment of contaminated sediment including preventing contaminant mobility and erosion of CAD covers. Short term water quality impacts would be greater for open water sites such as this.	Screened out for draft FS purposes for implementability considerations including that the capacity is relatively low for this site, particularly with need for seasonal covers and, given the location in the navigation channel, extensive RNAs or other navigation institutional controls would be needed.	No significant cost differentiators identified
		Swan Island Lagoon	All five of the potential CAD facilities could be designed and built to provide permanent effective containment of contaminated sediment including preventing contaminant mobility and erosion of CAD covers. Short term water quality impacts would be less for relatively isolated sites such as this. This option also has considerable potential to be part of overall habitat enhancements for the Site.	Implmentability considerations are less for this option, which was retained. The capacity is similar to other options, but it is located outside the navigation channel.	No significant cost differentiators identified
		Columbia River (RM 102.5)	All five of the potential CAD facilities could be designed and built to provide permanent effective containment of contaminated sediment including preventing contaminant mobility and erosion of CAD covers. Short term water quality impacts would be greater for open water sites such as this.	Screened out for draft FS purposes for implementability considerations including that the capacity is relatively low for this site, particularly with need for seasonal covers and, given the location in the navigation channel, extensive RNAs or other navigation institutional controls would be needed.	No significant cost differentiators identified
		Ross Island	All five of the potential CAD facilities could be designed and built to provide permanent effective containment of contaminated sediment including preventing contaminant mobility and erosion of CAD covers. Short term water quality impacts would be less for relatively isolated sites such as this.	Although the current capacity for this option is high and it is located outside the navigation channel, it was ccreened out for implementability considerations including that the capacity will be diminished or gone by the time remedial actions take place, the site owner has not taken an active interest in the option, and disposal criteria for the site would need to be changed to accept contaminated material.	No significant cost differentiators identified
	Confined Disposal Facility (CDF)	Terminal 4 Slip 1	All three of the potential CDFs could likely be designed and built to provide permanent effective containment of contaminated sediment. The Terminal 4 CDF is contained on three sides by existing shoreline and would be isolated from the Willamette River by a relatively short containment berm. Groundwater contaminant transport modeling indicated long term effectiveness could likely be acheived at water quality compliance points in and near the face of the berm consistent with EPA specified performance standards. Short term water quality impacts during facility filling could likely be minimized through procedural approaches that take advantage of the containment berm being in place.	This CDF capacity is greater than the CAD capacities, but are not so great as the upland landfills. There are no significant issues of compatibility with ongoing or future uses for this CDF options as compared to CADs.	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Disposal/ Confinement		Swan Island Lagoon	All three of the potential CDFs could likely be designed and built to provide permanent effective containment of contaminated sediment. The Swan Island Lagood CDF is contained on three sides by existing shoreline and would be isolated from the Willamette River by a relatively short containment berm. Groundwater contaminant transport modeling indicated long term effectiveness could likely be acheived at water quality compliance points in and near the face of the berm consistent with EPA specified performance standards. Short term water quality impacts during facility filling could likely be minimized through procedural approaches that take advantage of the containment berm being in place.	This CDF capacity is greater than the CAD capacities, but are not so great as the upland landfills. There are no significant issues of compatibility with ongoing or future uses for this CDF options as compared to CADs.	No significant cost differentiators identified
		Arkema	All three of the potential CDFs could likely be designed and built to provide permanent effective containment of contaminated sediment.	The CDF capacity is similar to CAD capacities, and therefore, this option is retained as a SMA-specific disposal option only. There are no significant issues of compatibility with ongoing or future uses for this CDF options as compared to CADs.	No significant cost differentiators identified
Ex-Situ Treatment	Physical	In-barge Dewatering	Generally effective for most sediments with control of production	No major implementability issues.	No significant cost
		Lagoon Dewatering	Generally effective for most sediments and compatible with both mechanical and hydraulic dredging.	Requires larger staging areas are required within close proximity to the project and may take significant time to achieve water quality desired.	No significant cost differentiators identified
		Geotextile Tube Dewatering	Generally effective for most sediments and compatible with both mechanical and hydraulic dredging.	Moderate staging areas are required within close proximity to the project and may take significant time depending on the percentage of fine sediment present. More logistically compatible with hydraulic dredging.	No significant cost differentiators identified
		Mechanical Dewatering	Generally effective for most sediments and compatible with both mechanical and hydraulic dredging.	Smaller staging areas required and shorter dewatering times. Requires significantly more and complex equipment and operational logistics.	No significant cost differentiators identified
		Reagent/Amendment Dewatering	Generally effective for most sediments and compatible with mechanical dredging.	Smaller or no (in barge) staging areas required and shorter dewatering times. Requires significantly less complex equipment and operational logistics than other options. Successfully used in two Harbor early actions. Therefore, retained as the representative example dewatering process for removal options.	No significant cost differentiators identified
		Particle Separation	Several SMAs do not possess percent sand fractions that are necessary for efficient particle separation processing. For those SMAs with sufficient sand (>40%), technology is unlikely to provide treatment to sufficiently low levels, and was therefore screened out. May be effective for specific restricted destinations and uses of treated materials as defined in remedial design.	Implementable with appropriate sediment grain sizes and moderately sized staging areas.	No significant cost differentiators identified
		Cement/QuickLime/Flyash Solidification/Stabilization	Likely to provide treatment to reduce leaching and allow placement of treated materials in a variety of destinations and uses including treatment of hazardous wastes to allow non-hazardous disposal. Therefore, was retained Site-wide as a process option.	This technology is implementable in small areas, with minimal equipment, and simultaneously eliminates free water from the sediments and improves geotechnical properties in one step. Therefore, stabilization/solidification is considered generally implementable Site wide.	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Ex-Situ Treatment	Physical	Sorbent Clay Solidification/Stabilization	Likely to provide treatment to reduce leaching and allow placement of treated materials in a variety of destinations and uses including treatment of hazardous wastes to allow non-hazardous disposal. Therefore, was retained Site-wide as a process option.	This technology is implementable in small areas, with minimal equipment, and simultaneously eliminates free water from the sediments. Therefore, stabilization/solidification is considered generally implementable Site wide.	No significant cost differentiators identified
		Asphalt Emulsion	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
		Solar Detoxification	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
	Biological Methods	Land Treatment	The technology is only been demonstrated for petroleum hydrocarbons, PAHs, and pesticides and has little to no effectiveness in treating PCBs and metals. Under ideal conditions, high PAH concentration reductions are possible, but it is difficult to achieve very low post-treatment concentrations. Therefore, the technology was not found to be effective. May be effective for specific restricted destinations and uses of treated materials as defined in remedial design	This technology requires large staging areas, takes extensive times, and may require large structures to control air emissions and prevent excessive rainfall from infiltrating the treatment area. High concentrations of contaminants can be toxic to microorganisms. Therefore, land treatment was screened out Site wide.	No significant cost differentiators identified
		Composting	The technology is only been demonstrated for petroleum hydrocarbons, PAHs, and pesticides and has little to no effectiveness in treating PCBs and metals. Under ideal conditions, high PAH concentration reductions are possible, but it is difficult to achieve very low post-treatment concentrations. Therefore, the technology was not found to be effective. May be effective for specific restricted destinations and uses of treated materials as defined in remedial design	This technology requires large staging areas, takes extensive times, and may require large structures to control air emissions and prevent excessive rainfall from infiltrating the treatment area. High concentrations of contaminants can be toxic to microorganisms. Therefore, composting was screened out Site wide.	No significant cost differentiators identified
		Biopiles	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Fungal Biodegradation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Slurry-phase Treatment	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Enhanced Biodegradation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
	Chemical	Acid Extraction	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Ex-Situ Treatment		Solvent Extraction	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
	Physical/Chemical	Sediment Washing	Unlikely to provide treatment to sufficiently low levels, and was therefore screened out. May be effective for specific restricted destinations and uses of treated materials as defined in remedial design. In this case, sediment washing may function better as a waste reduction technology, rather than a contaminant destruction technology.	Implementable with appropriate sediment grain sizes and moderately sized staging areas.	No significant cost differentiators identified
		Chemical Oxidation/Reduction	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Dehalogenation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Slurry Oxidation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
		Radiolytic Dechlorination	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[3]	No significant cost differentiators identified
	Thermal Methods	Incineration	Likely to provide treatment to sufficiently low levels to allow placement of treated materials in a variety of destinations and uses, but not effective for all SMAs. Primary technology vendors (such as the JCI/Upcycle Light-weight Aggregate technology) have not completed full-scale demonstrations of mobile units capbable of production rates required for this project; therefore, the consistency of large-batch effectiveness is uncertain. Therefore, the technology was retained for further evaluation with respect to implementability.	Vitrification is an energy intensive treatment technology that also often requires dewatering and debris removal steps. It also requires extremely specific types of facilities to either be built on site, or transport to locations outside the State. For this reason, incineration is typically not used to treat media with less than hazardous waste level contamination. In addition, facilities located outside of the CERCLA Site boundary would be subject to local permitting requirements, which could provide significant challenges. Transport and disposal of the small amount of Site sediments that are hazardous or PTM to the relatively nearby subtitle C facility in Oregon would likely be much more cost effective than developing an on-Site treatment facility. Consequently, this technology is screened out for the Site for draft FS purposes.	Extremely costly as compared to Subtitle C Disposal for small volumes of material. One of the most costly thermal treatment process options available.
		Pyrolysis	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		High Temperature Thermal Desorption	High temperature thermal desorption is generally effective in reducing contaminant levels for COCs with boiling points less than 560ºC (1000ºF), which generally includes all Site COCs with the exception of a few metals. Even with relatively high COC concentration reductions (e.g., up to 95%), it is difficult to meet the lowest treatment goals associated with unrestricted uses. Therefore, technology is unlikely to provide treatment to sufficiently low levels for all Site COCs and was screened out. May be effective for specific restricted destinations and uses of treated materials as defined in remedial design.	High temperature desorption is an energy intensive treatment technology that also often requires dewatering and debris removal steps. Based on the semi-quantitative evluation, it is unlikely that this technology would be effective treating PTM or sediment with hazardous waste level contamination. Transport and disposal of the small amount of Site sediments that are hazardous or PTM to the relatively nearby subtitle C facility in Oregon would likely be much more cost effective than developing an on-Site treatment facility. Consequently, this technology is screened out for the Site for draft FS purposes.	Extremely costly as compared to Subtitle C Disposal for small volumes of material

Table 6.3-4. Summary of Screening of Remedial Technologies for the Portland Harbor Superfund Site

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Ex-Situ Treatment		Low Temperature Thermal Desorption	Low temperature thermal desorption is most effective in treating fuels, some VOCs, and light PAHs with boiling points less than 320ºC (600ºF). Heavier PAHs and PCBs with higher boiling points typically do not respond to the process. Non-volatilizing metals are not treated at all by the technology. Therefore, technology is unlikely to provide treatment to sufficiently low levels for all Site COCs and was screened out. May be effective for specific restricted destinations and uses of treated materials as defined in remedial design.	Low temperature desorption is an energy intensive treatment technology that also often requires dewatering and debris removal steps. Based on the semi-quantitative evluation, it is unlikely that this technology would be effective treating PTM or sediment with hazardous waste level contamination. Transport and disposal of the small amount of Site sediments that are hazardous or PTM to the relatively nearby subtitle C facility in Oregon would likely be much more cost effective than developing an on-Site treatment facility. Consequently, this technology is screened out for the Site for draft FS purposes.	No significant cost differentiators identified
	Thermal Methods	High Pressure Oxidation	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	Screened out for all SMAs due to likely limited effectiveness and implementability issues.[2]	No significant cost differentiators identified
		Vitrification	Likely to provide treatment to sufficiently low levels to allow placement of treated materials in a variety of destinations and uses, but not effective for all SMAs. Primary technology vendors (such as the Minergy Glass Furnace Technology and the Gas Technology Institute Cement-Lock™ Technology) have not completed full-scale demonstrations of mobile units capbable of production rates required for this project; therefore, the consistency of large-batch effectiveness is uncertain. Therefore, the technology was retained for further evaluation with respect to implementability.	Vitrification is an energy intensive treatment technology that also often requires dewatering and debris removal steps. It also requires extremely specific types of facilities to either be built on site, or transport to locations outside the State. For this reason, incineration is typically not used to treat media with less than hazardous waste level contamination. In addition, facilities located outside of the CERCLA Site boundary would be subject to local permitting requirements, which could provide significant challenges. Transport and disposal of the small amount of Site sediments that are hazardous or PTM to the relatively nearby subtitle C facility in Oregon would likely be much more cost effective than developing an on-Site treatment facility. Consequently, this technology is screened out for the Site for draft FS purposes.	Extremely costly as compared to Subtitle C Disposal for small volumes of material. One of the most costly thermal treatment process options available.

Notes:

1 - Cost was generally not estimated or used in the technology screening step for this draft FS except in a few cases where noted (see discussion at start of Section 6.2 for the rationale for this approach).

2 - Screening decisions described in the Treatment Technology Evaluation Tools Memorandum dated March 15, 2011 or previous documents cited there.

3 - Screening decisions described in Appendix S.

Ex situ treatment technologies that were screened through the Treatment Technology Evaluation Tools Memorandum and Appendix S screening evaluations for further evaluation in Section 6.2

This section describes the overall process of development and assembly of comprehensive alternatives from the technologies screened in Section 6. A screening evaluation of alternatives was conducted and it was found that EPA's suggested Alternative G should be screened out and not used in the detailed evaluation of alternatives in Section 8. The alternatives are described in this section and include Alternative A (no action) as well as a series of alternatives with different balances of dredging, capping and MNR (Alternatives B through F). Two options were developed for each alternative, called removal focused and integrated (with a balance of removal and in-place technologies), for a total of 11 alternatives. Methods and results are also presented here for developing assumed technology process options, assigning disposal sites to each alternative, construction sequencing, and durations. These fully described comprehensive alternatives are evaluated in detail in Section 8.

7.0 DEVELOPMENT OF COMPREHENSIVE ALTERNATIVES

This section describes how comprehensive alternatives were developed from the technologies screened in Section 6. The development of alternatives was discussed extensively between EPA and LWG for this project (LWG 2011e, EPA 2011c, LWG 2011d, LWG 2011c, EPA 2011i, EPA 2011h, EPA 2011f, LWG 2011b, EPA 2011g, and see Appendix O). The LWG and EPA agreed to an approach that applied a representative range of technology combinations to the SMAs, the latter of which vary in size in accordance with the RALs.

Table 7.0-1 summarizes the alternatives developed consistent with EPA direction. Two options were created for each of Alternatives B through F,[1] based on the application of different types of remedial technologies across the alternative areas. One technology option is "removal focused" and the other is "integrated." Removal focused means that these options involve a large emphasis on removal and disposal of sediments. Integrated options include in-place remedial technologies (e.g., EMNR, in situ treatment, and various forms of capping). These two options are designated with an "-r" for removal focused options and "-i" for integrated options.

7.1 SCREENING THE ALTERNATIVES

Alternatives B through G are screened in this section using general evaluation criteria from the guidance. The screening evaluations focus on the primary criteria of effectiveness, implementability, and cost through more qualitative evaluations (EPA 1988), as follows:

- Effectiveness – Evaluated based on preliminary estimates of time zero sediment SWACs achieved by each alternative that were calculated for select RAL contaminants.
- Implementability – Evaluated based on the preliminary estimated construction duration of each alternative. As discussed more in Section 8, increasing duration of construction is correlated with increasing implementability issues including: 1) greater amounts of equipment and work has to be identified and organized; 2)

[1] An additional Alternative (G) was also evaluated in the screening of alternatives discussed in Section 7.1

greater administrative and procedural efforts are needed; and 3) because longer duration alternatives have larger areas of active remediation, more areas are affected and more entities are involved or affected by remediation efforts.

- Cost – Evaluated based on preliminary estimates of alternative costs that were calculated and compared.

Because LWG engaged in a dialogue with EPA in advance regarding alternatives as discussed in Section 7.0, relatively detailed estimates of time zero SWACs, durations, and costs were already available for Alternatives B through F. Those early estimates were very similar to those shown in Table 7.0-1. Preliminary estimates of these factors for Alternative G were developed based on the information available from these other alternatives as described below.

The surface area for the additional Alternative G was mapped using the RALs in Table 7.1-1 and the methods are described in Section 5 with the exception that total PCB and BaPEq RALs were mapped outside of AOPC boundaries. The resulting map is shown in Figure 7.1-1, and the total acreage for Alternative G is 591 acres (Table 7.1-2 compares the acreages of all the alternatives). Time zero SWACs were estimated using the background replacement assumption discussed in Section 4.5[2] and are summarized in Table 7.1-2.

Based on the acreages of all the alternatives and the duration and cost estimates in Table 7.0-1 for Alternatives B through F, approximate estimates of the likely duration and cost for Alternative G were calculated. This was accomplished by examining the correlation between alternative acreage and duration/cost for Alternatives B through F and then extrapolating that correlation to Alternative G based on its acreage. Figure 7.1-2 summarizes the correlation between alternative acreages and duration/cost. The figure shows the correlation between alternative acreage and duration or cost is extremely high. Thus, the approximate duration and cost of Alternative G was extrapolated from these correlations with a high degree of confidence and used for screening evaluation purposes (Table 7.1-3). (Note that alternatives shown in Figure 7.1-2, subsequent figures, and Table 7.1-3 contain two types of alternative options denoted with an “i” for integrated and an “r” for removal focused as discussed in Section 7.0. Thus, these options have different impacts, costs, and durations as shown in Table 7.1-3).

Based on these SWAC, duration, and cost estimates, the screening-level performance of the alternatives was plotted using total PCBs, BaPEq, and DDE SWACs in Figures 7.1-3, 7.1-4, and 7.1-5, respectively. Similar graphs for DDD, DDT, and 2,3,4,7,8-PCDF are provided in Appendix U (Section 1). All of these graphs show that as larger areas are actively remediated, the reduction in the SWAC becomes less and less (similar to the RAL curves presented in Section 4). Thus, Alternatives F and G provide a very small

[2] As discussed in Section 4.5, this is one of many possible methods to estimate time zero SWACs. Although more complex and accurate methods exist, the analysis in Section 4.5 indicates the differences in resulting SWACs are relatively minor, and the use of the background method is considered more than adequate for an alternatives screening-level evaluation.

additional improvement in potentially unacceptable risk reduction immediately following construction, with the sediment SWAC acting as the measure of that risk reduction. At the same time, Alternatives F and G require very large additions in alternative acreage with correspondingly large increases in construction costs and durations, which results in less desirable implementability issues and short-term impacts. Alternatives F and G are not cost-effective. Furthermore, the SWAC reductions under Alternatives F and G are small. For example, there is only a 2 ppb decrease in PCB Site-wide SWACs between these two alternatives (from 26 ppb to 24 ppb).

These estimates are all conducted on a Site-wide scale, which is appropriate for a screening-level analysis. Similar graphs were presented in Section 5.9 and Appendix Fa (Section 1) for Alternatives B through F for all contaminants with PRGs above background and consistent with the risk assessment at both Site-wide and smaller spatial scales as appropriate for any particular PRG. These graphs reveal the same general pattern of small incremental SWAC reductions for most contaminants and most spatial scales. Specifically, there is a decreasing ability to create SWAC reductions for most contaminants as the alternative acreage increases. Consequently, the findings of this alternative screening analysis are generally consistent across all contaminants and risk-appropriate spatial scales.

Based on this screening evaluation, Alternatives B through F are carried forward into the detailed evaluation of alternatives, but Alternative G is not. Although Alternative F also appears cost ineffective, it is carried forward to provide one example alternative that is on the asymptote of minimal change in SWAC consistent with the procedures discussed in Section 4.

Alternatives B through F are carried forward into the detailed evaluation of alternatives, but Alternative G is not. Although Alternative F also appears cost ineffective, it is carried forward to provide one example alternative that is on the asymptote of minimal change in SWAC.

7.2 REMEDIAL TECHNOLOGY OPTIONS FOR ALTERNATIVES

Based on the above screening, five alternatives (B through F) were selected for further development and detailed evaluation (Table 7.0-1) as well as Alternative A, which is a no action alternative as required under RI/FS guidance (1988). As shown in Table 7.0-1, Alternative A is assumed to have zero acres of active remediation and, therefore, zero volumes of removal and zero duration.

As discussed in Section 5.4, there are certain Site uses and physical characteristics that limit or prevent the implementation of either removal or in-place technologies in some instances. For example, environmental dredging under and behind certain docks can be difficult or impossible (see Section 6.2 for a discussion of screening dock removal and replacement), and capping in navigation areas may not be compatible with expected vessel traffic and docking needs. Thus, “removal focused” does not mean that removal takes place in all parts of every SMA, and “integrated” does not mean that there is no removal. “Removal focused” alternatives emphasize dredging over all other remedial technologies, and "integrated" alternatives include a combination of remedial technologies.

The assignment of technologies for removal versus integrated options is summarized in Table 7.2-1. These determinations are made using the subSMA types introduced and discussed in Section 5.4. Under the removal focused options, removal and disposal is assigned to all subSMAs except areas beneath robust structures (SS designation in Table 7.2-1) and areas behind robust structures with no construction access (SN in Table 7.2-1), which are assigned engineered capping. For integrated options, in-place technologies are assigned to all subSMAs except in the navigation channel (NC) and future maintenance dredge (FMD) areas, which are assigned removal and disposal. Figures 7.2-1 through 7.2-10 show maps of the technologies applied on this basis across the various SMAs and subSMAs for removal and integrated alternatives, respectively.

The draft FS assumes several specific technologies could all be used in the subSMAs that receive the general "in-place" technology assignments. This general level of determination is more than adequate for draft FS purposes, and the specific applications of in-place technologies in each subSMA would be determined during SMA-specific remedial designs based on more detailed engineering evaluations.

Where integrated options include in-place technologies, this refers to a suite of potential in-place technologies that might be applied to the appropriate subSMAs as defined above. This suite could include EMNR (thin-layer sand placement), in situ treatment (placement of AC or a similar reagent onto surface sediments), engineered caps (including armor layers, habitat layers, and/or other variations), or other similar in-place technologies. Thus, for draft FS purposes it is not assumed that any one of these specific technologies necessarily needs to be placed in the subSMAs that receive these "in-place" technology assignments, but rather any of these technologies could be used. This level of determination is more than adequate for draft FS purposes, and the specific applications of in-place technologies would be determined during SMA-specific remedial designs based on more detailed engineering evaluations. To reflect this potential future range of in-place technologies, two cost estimates were prepared for the integrated alternatives as shown in Table 7.2-1. One cost estimate assumes engineered caps in all of the in-place technology subSMAs, while the other cost estimate assumes in situ treatment in all of the in-place technology subSMAs, except the wave zone (-wz), which is assigned engineered capping, due to implementability issues discussed in Section 6.2.[3] These two cost estimates are expected to provide a wide enough range of cost estimates to cover the possible combinations of subSMA applications of the suite of in-place technologies.

For all evaluations in this draft FS, integrated alternatives are assumed to involve the cost estimate variation that emphasizes in situ treatment. This is a necessary simplifying assumption because full evaluation of both of the in-place cost variations would

[3] Although in situ treatment in the wave zone is not screened out in Section 6.2, it has more implementability challenges, and therefore, for alternative development purposes, in situ treatment is not assigned to the wave zone. SMA-specific remedial designs may determine in situ treatment is feasible in the wave zone in some situations.

essentially add another five alternatives to all draft FS analyses. However, the two cost estimates summarized in Table 7.2-1 allow an evaluation of the potential impact of the range of in-place technology assumptions on the detailed analyses of alternatives, given that cost would be the primary CERCLA FS evaluation criteria that would be affected by the range of possible in-place technology applications. This is because engineered capping is generally the most costly and in situ treatment the least costly in any given situation, except possibly EMNR. The variations of in-place technologies are essentially neutral, or nearly so, with respect to all of the other six CERCLA evaluation criteria considered in this draft FS. That is, the overall protectiveness; compliance with ARARs; long-term effectiveness; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; and implementability differences between capping and in situ treatment are generally minimal based on the screening evaluations conducted in Section 6.2. One minor exception is that in situ treatment provides a form of treatment while engineered capping does not. However, active capping, which is included in the alternatives in two select areas as described more below, provides a form of treatment analogous to in situ treatment.

Finally, it should be noted that in situ treatment is assumed to also be highly representative of more traditional EMNR (e.g., suitable sand placement) in terms of construction techniques, effect on the sediment bed, effectiveness of the remedy, and any potential implementability issues in particular areas related to stability of the material once placed and/or its incorporation into the sediment bed over time. Thus, the "in situ treatment" option evaluated for the integrated alternatives throughout the remainder of this draft FS can be viewed as in situ treatment and/or EMNR. As with other in-place technology variations, the exact extent and area in which in situ treatment versus EMNR should be used would be determined through SMA-specific remedial designs (i.e., post-ROD).

The "in situ treatment" option evaluated for the integrated alternatives throughout the remainder of this draft FS can be viewed as in situ treatment and/or EMNR. As with other in-place technology variations, the exact extent and area in which in situ treatment versus EMNR should be used would be determined through SMA-specific remedial designs (i.e., post-ROD).

7.3 TECHNOLOGY ASSIGNMENT ASSUMPTIONS

In addition to the framework for assigning technologies to the alternatives in Table 7.0-1, there were several additional specific technologies and process options incorporated into the alternatives as discussed in the next subsections.

Throughout Section 6.2, various process options are discussed for each technology type, as are a certain set of assumptions for each process option presented. In each case, the rationale for selecting one or two specific process options is presented, and is generally based on either reasonably implementable and/or the most

Process option selection (e.g., type of armoring for an engineered cap) will ultimately be determined in SMA-specific remedial designs.

likely process options to be applied at this Site. These are assumptions for the purpose of alternative development to reduce the number of alternative permutations for the draft FS to a manageable number that is generally representative of the technology types included in each alternative. This should not be inferred as an indication that these process options are necessarily preferred or superior as compared to all other potential process options. Process option selection (e.g., type of armoring for an engineered cap) will ultimately be determined in SMA-specific remedial designs. This section briefly summarizes the process option assumptions for the draft FS. The reader should refer to Section 6.2 for more discussion of the rationale for each of these selections. EPA requested that cost factors be supplied for certain additional process options, and these are included in Appendix K (Tables 4 through 10) and briefly noted below.

7.3.1 Institutional Controls

As discussed in Section 6.2, a detailed institutional control plan for the Site and specific SMAs cannot and should not be developed and presented at this draft FS stage of analysis; these detailed plans are more appropriately developed during remedial designs. Consequently, all the institutional controls retained in Section 6.2 are included in the comprehensive alternatives to recognize their general function and necessity within the remedy without attempting to craft a detailed institutional control plan for each alternative. A general description of likely contents of institutional controls is provided in Appendix T (Section 5.2). Costs of institutional controls are broadly estimated based on the controls described in Appendix T and applied to Alternatives B through F. Cost assumptions for institutional controls are provided in Appendix K (Section 2.4).

7.3.2 MNR

As described in Section 5, SMAs define areas of active remediation, and the above technology options focus on technologies applied within the SMAs. MNR is incorporated into each alternative for areas outside SMAs. As described in Section 6.2, multiple LOEs indicate that MNR is likely or at least potentially effective and implementable at spatial scales of assessment relevant to the risk assessments (i.e., potential exposure areas for human and ecological scenarios/receptors) for the Site. Based on these findings, areas of active remedy (SMAs) were not expanded to include areas of potentially limited natural recovery except in SMA 17S (Swan Island Lagoon), which is discussed more below. This approach is evaluated further in Section 8 to determine whether the combinations of active and MNR remedies represented by Alternative B through F are likely to be protective and meet ARARs.

Depending on the RGs EPA eventually selects in the Proposed Plan, many portions of the Site-wide AOPC may not require any remedial action at all (i.e., these areas may already be below the RGs that EPA eventually selects).

It is also important to note that much of the area outside the SMAs and in the Site-wide AOPC contains relatively low, and in some cases at or below background, sediment concentrations (see Section 5.9). Consequently, depending on the RGs EPA eventually selects in the Proposed

Plan, many portions of the Site-wide AOPC may not require any remedial action at all (i.e., these areas may already be below the RGs that EPA eventually selects). Thus, it should not be assumed that MNR is a necessity in all areas of the Site-wide AOPC, although for the purposes of this draft FS, MNR is assessed throughout this area.

As noted above, the potential for natural recovery in SMA 17S was further considered in light of the MNR evaluation in Section 6.2. The combined LOEs for much of this SMA indicated that natural recovery was "less certain" in this area, while at the same time much of the SMA has relatively elevated PCB concentrations (i.e., close to but below the RALs). The existing PCB SWAC for this area outside the Alternative B footprint (the smallest alternative footprint considered) is 234 ppb, the highest for any river mile in the Site.

Consequently, Alternatives B through F were refined to include EMNR in the main portion of SMA 17S, where PCB concentrations are generally highest in areas outside the active remediation areas in each alternative and natural recovery rates may be slow. Figures 7.2-1 through 7.2-10 show the locations of the EMNR placement in each alternative. EMNR was specifically added given that: 1) these areas are below the respective PCB RALs associated with SMAs B through F, and thus, under an approach of consistent RAL application across the Site, should not be active remediation areas; and 2) the primary cause of the potential ineffectiveness of MNR is a relative lack of sedimentation (see LOEs discussion in Section 6.2). Consequently, enhancing the sedimentation process through placement of suitable sand in areas already below the RALs in SMA 17S directly addresses the mechanism causing the potential lack of MNR in these areas. This approach will cause the SMA 17S area remedy to perform more consistently with most other river miles, where areas below the RALs are expected to recover, primarily through natural sedimentation process.

For EMNR to work in SMA 17S, compatibility with Site uses must be considered. Placement of a relatively thin EMNR layer in this area would have little if any impact on current navigation uses. That is, vessels would be able to continue to use this area consistent with current practices. As discussed in Section 5.6, propwash forces are estimated to increase mixing in the upper foot of the sediment bed, but generally are not expected to cause permanent erosion of the sediment bed, although localized exceptions likely exist near certain docks. Further, river current forces in SMA 17S are relatively low and would be unlikely to move any temporarily suspended EMNR materials to new downstream areas on a consistent basis. Consequently, although there are expected to be localized variations in the long-term incorporation of EMNR material into the SMA 17S sediment bed, EMNR would be expected to achieve lower SWACs across SMA 17S, thus reducing the potentially unacceptable risk levels over appropriate spatial scales most relevant to the RGs.

Also, although EMNR is the assumed refinement approach for draft FS purposes, much of the same goal of augmenting recovery outside SMAs in this area might also be achieved by in situ treatment (e.g., placement of activated carbon). Similar to EMNR, in situ treatment material would be expected to stay within this area and be incorporated into the sediment bed over time and would have similar or even less impact on navigation depths and uses.

As discussed in Section 5.6, some areas of buried contamination outside the SMAs determined via RALs were found in SMA 17S that could be uncovered through future deepening navigation dredging. Both the EMNR concept and measures to prevent the exposure of buried contamination noted in Section 5.6 would need to be integrated with a set of institutional controls for maintenance and/or deepening dredging in SMA 17S. If no changes to site uses are envisioned, these controls would allow preservation and maintenance of current navigation depths (minus an approximately 1 foot EMNR layer) but prohibit additional navigation deepening dredging beyond this current navigation depth. Alternatively, if new or deeper site uses are envisioned, the institutional controls could also allow for these contingencies, if the parties involved are willing and able to remove and dispose of any contaminated materials in a manner that is consistent with the remediation technologies described in this draft FS. Thus, deepening navigation dredging would need to be conducted with appropriate water quality BMPs, dispose of sediments in appropriate locations, and create a new sediment surface that meets the RALs eventually adopted by EPA. If necessary, this might require removing more material than would be strictly necessary to achieve the desired new navigation depths, and/or capping back after deepening navigation dredging to achieve the appropriate RALs.

7.3.3 EMNR

In addition to the specific addition of EMNR to augment MNR in areas around SMA 17S as discussed above, the specific EMNR process option assumed for the draft FS is broadcast placement of 6 to 12 inches of sand (i.e., from a suitable source such as navigation dredging material or upland quarry material).

7.3.4 In Situ Treatment

The assumed process option for in situ treatment is direct broadcasting of AC onto the sediment surface and incorporation of that material into the sediment bed via ambient mixing processes (e.g., bioturbation). As discussed in Section 6.2.3.1, this process option has been successfully applied at some sites and would be expected to be implementable in areas that are not routinely dredged for maintenance purposes or subject to high propwash or wave forces. Per Table 7.2-1, in situ treatment is assumed to occur in the integrated alternatives' low cost estimates in all areas of the Site except navigation channel, future maintenance dredge, and wave zone areas. Appendix K (Table 10) includes cost factors for placement of AC using another technique.

7.3.5 Engineered Capping

The assumed standard cap cross section includes 12 to 18 inches of sand for the chemical isolation layer and an armor stone sufficient to withstand erosive forces determined for any particular area (see Appendix Hc, Section 4 for armor sizing evaluations). Per Table

7.2-1, capping is assumed to occur for the integrated alternatives' high cost estimates in all areas of the Site, except navigation channel and future maintenance dredge areas, and in the wave zone for the low cost estimates. Capping is also assumed to occur in the removal focused alternatives under robust structures and areas behind structures where environmental dredging equipment cannot reach. Appendix K (Table 9) includes an additional cost factor for adding an active cap layer to engineered caps consistent with the active cap process options discussed next.

7.3.6 Active Capping

As noted above, for the purposes of most draft FS evaluations, integrated alternatives generally assume the use of in situ treatment in areas where in-place technologies are implementable. Nevertheless, cost estimates are also developed for a mostly capping option for the integrated alternatives. In addition, for cost estimates under this option, active capping is assumed to take place in SMAs 9U and 14. This is consistent with the findings of the capping screening in Section 6.2, which found that these areas are the most likely place where active capping might be necessary, although standard capping may be feasible in these areas, particularly when coupled with sufficient upland groundwater source controls.

The assumed process option for active capping is the addition of an organoclay mat under the sand chemical isolation layer of the above-mentioned engineered cap cross section. EPA requested unit costs for another potential active layer type, which are provided in Appendix K (Table 9).

7.3.7 Removal

The assumed process options for environmental removal are use of mechanical dredging, with either: 1) upland disposal, barge transport to a transload facility within Portland Harbor, dewatering in barges with diatomaceous earth, transloading to rail transportation, and rail transport to Columbia Ridge Landfill; or 2) barge transport to an in-water CDF. Additional specific assumptions are:

- Dredging under light (i.e., movable) structures is assumed to occur (as defined in Section 5.4) for the removal focused alternatives via temporary movement and replacement of the structure (e.g., a floating dock).
- Dredging under robust structures (fixed) or behind structures where dredging equipment cannot reach is assumed to not occur (as defined Section 5.4 and Table 7.2-1). Capping or in situ treatment is assumed for these areas.
  - Appendix K (Table 7) includes additional cost factors for removal and replacement of docks in order to dredge underneath the structures.
- Residuals management assumed to consist of one cleanup pass and 6-inch post-dredge sand cover (see Appendix Ib).

- Water quality BMPs are assumed to include operational BMPs discussed in Section 6.2 including a production rate that is consistent with such operational BMPs.
  - Barrier controls (e.g., silt curtains and rigid containment) are not included in BMPs for reasons discussed in Section 6.2.
  - Cost factors for the addition of silt curtains and sheetpile walls are included in Appendix K (Table 8).

7.3.8 Disposal

Per the general assumption of upland and/or CDF disposal noted under removal, specific assignments of volumes to disposal sites were made as described more in Section 7.4. In addition, Section 5.5 discusses two specific locations of potential listed hazardous waste materials at the Site. For draft FS alternative development purposes, material removed from these areas for any alternatives is assumed to be handled and transported as hazardous waste and disposed at a Subtitle C landfill for high range cost estimates. For low-range cost estimates, waste handling and disposal at a Subtitle D landfill is assumed for this material. The actual determination of whether the sediment removed from these areas contains listed hazardous wastes that require hazardous waste handling and Subtitle C disposal will be determined in the remedial designs for these specific areas.

Because of the uncertainty about the volume and extent of these potentially hazardous wastes, the volume was estimated by assuming that the disposal volumes (as determined by the full DOI discussed in Section 5.10) associated with currently identified surface area of these two areas would be disposed at a Subtitle C landfill. The surface area for the area in RM 6.7 within SMA 14 was assumed to be the area of complete groundwater flowpath immediately in the vicinity of RM 6.7 as shown in Figure 5.7-1a-d. The surface area for the area in SMA 9U was estimated from Gasco/Siltronic sediments investigation documents (Anchor QEA 2010b).

7.3.9 Ex-Situ Treatment

As described in Section 6.2, dewatering of removed sediments may be required under some circumstances. As discussed more below, the assumed process option for dewatering is addition of diatomaceous earth to the sediments. This process absorbs water in the sediment, reducing the amount of contaminants present in liquid form and is a type of ex situ treatment that decreases the mobility of contaminants. Further, another common dewatering method under an environmental mechanical dredging scenario is the use of Portland cement or similar pozzolanic materials that not only dewater the sediments but also reduce the leaching potential of metals and some organic compounds in the sediment. The costs of diatomaceous earth addition for dewatering are included in cost estimates for all alternatives. Thus, ex situ treatment is incorporated into the removal and disposal of all material in each alternative for the purposes of this draft FS.

7.3.10 Long Term Monitoring

Long-term monitoring is assumed to take place as part of the comprehensive alternatives made up of all the above technologies. Although monitoring is an important component of MNR, monitoring is also assumed to take place for the other technologies as well as detailed in Appendix T. For draft FS purposes, long-term monitoring costs are estimated over a 30-year period. Per Appendix T, monitoring is assumed to include Site-wide monitoring of the comprehensive remedy to assess the general status and recovery of the Site. SMA- and technology-specific monitoring is also assumed including SMA-specific monitoring of cap performance, EMNR/in situ treatment performance monitoring, environmental dredge residual recovery, and CDF performance. Additional cost factors for monitoring variations requested by EPA are included in Appendix K (Tables 4 and 5).

7.4 ASSIGNMENT OF EXAMPLE DISPOSAL OPTIONS TO ALTERNATIVES

In order to complete comparative evaluations of the different alternatives, certain assumptions were made regarding disposal of environmental dredge material. At this stage in the process, it is difficult to know exactly what combinations of disposal facilities will ultimately be used for the final remedy. However, given the limited number of in-water disposal options and their capacities, actual CDF/CAD combinations for the final remedy should not vary significantly from what is assumed here.

Selection of CDF/CAD and upland disposal option combinations for the different remedial alternatives followed these general guidelines:

- Total capacity of the in-water CDF/CAD(s) screened through for FS purposes were generally equal to or less than the anticipated dredge volume, avoiding any excess capacity.
- The total number of in-water CDFs/CAD was generally minimized, such that if a larger CDF/CAD could handle the capacity of multiple smaller ones, then the larger CDF/CAD was selected.
- CDFs/CADs that maximized coverage of impacted sediments were generally selected.
- Any excess sediment requiring disposal would be disposed at an upland landfill, which was assumed to be Columbia Ridge for costing purposes.

Table 7.4-1 presents the portion of the remediation dredge volume for each alternative that was assumed to go to the different CDFs/CADs and upland disposal.

It is important to note that other equally valid examples of disposal options could be devised.

Per the disposal screening discussion in Section 6.2, the actual selection of disposal options will involve many aspects that cannot be accurately predicted at this time. Thus, actual disposal options will be determined in remedial designs as various projects are implemented after the ROD.

Per the disposal screening discussion in Section 6.2, the actual selection of disposal options will involve many aspects that cannot be accurately predicted at this time (e.g., whether a party is able to construct such a facility). Thus, actual disposal options will be determined in remedial designs as various projects are implemented after the ROD.

7.5 CONSTRUCTION SEQUENCING AND DURATIONS

To enable the detailed evaluation of remedial alternatives, certain assumptions were made regarding production rates and sequencing of the remediation activities at each SMA. Sequencing is important to understanding construction timeframes, as well as the durations of the alternatives (which can affect costs), and can have an impact on the time to achieve RAOs. There will be a number of factors that affect the actual construction sequencing including regulatory orders, funding, disposal availability, contractor and equipment availability, weather and river conditions, duration of in-water work window, and many others.

To be consistent between alternatives, the following guidelines were used to develop sequencing and project durations:

- The construction window for the Lower Willamette River is between July 1 and October 31 each year as established by NMFS for the protection of listed fish species that occur at the Site at other times of year. Currently, there are 88 to 105 construction days per season assuming 5 to 6 construction days per week, respectively.
- Each remediation dredge plant will remove on average 700 cy per day during open water mechanical dredging. This assumes that no containment structure is installed, which would reduce the effective work window and reduce the overall production capacity per season. This removal rate is based on two analyses:
  - Theoretical Efficiency Analysis: Assuming cycle times of 3 to 3.5 minutes, 10-cy buckets, 50 to 75 percent full, operating 10 to 12 hours per day with an effective work time of 50 to 60 percent estimated daily production ranges from 500 to 1,100 cy per day.
  - Evaluating Similar Environmental Dredging Projects: Three recent environmental mechanical dredging projects have been completed in the Portland Harbor area: dredging at the NW Natural Gasco facility in October 2005, dredging at the Port of Portland Terminal 4 facility in summer 2008, and dredging at the Alcoa facility in Vancouver, Washington, in fall 2009. All three projects involved mechanical dredging with similar size dredge bucket and upland disposal. The daily dredging production rates ranged from 500 to 900 cy per day.
- A target of three independent remediation dredge plants would be operating at one time within the Portland Harbor Site on work associated with the project. This assumption is based on optimum likely contractor availability.

- Each SMA would only have one remediation dredge plant operating at a time within their boundaries except SMA 17S, which could handle up to three dredge plants. This is based on the limited size of each SMA compared to the dredge plant footprint.
- Using the assumptions bulleted above, the seasonal remediation dredge volumes range from 190,000 to 230,000 cy. For costing and schedule development, 230,000 cy is assumed.
- Non-dredging related remediation activities (e.g., capping) would occur after dredging activities in each SMA.
- Remediation of areas under separate orders (orders with the Port [Terminal 4], NW Natural and Siltronic, and Arkema) are assumed to occur first for each comprehensive alternative. This is an assumed sequence for draft FS purposes. CDFs would be constructed as late as practicable within the sequencing, without becoming a schedule driver or delay factor for the dredging work, in order to minimize the time the CDFs are left open.
- Remediation dredging would occur throughout each of the four Site segments each year to the extent practicable. For example, multiple dredge plants would be spread out over more than one segment.
- Once remediation dredging within a specific SMA begins, it would continue until dredging in that SMA is completed (except for any stops required due to in-water work windows).
- Remediation work will generally be sequenced from upstream to downstream within each segment working as much as possible within the guidelines presented above.

Appendix K details the sequencing and construction duration assumptions for each alternative. For the larger alternatives, the resulting durations are substantial (as high as 28 years). There are a number of reasons to believe that these durations not only represent a reasonable estimate, but may more likely represent a fairly optimistic view of the potential durations including:

- The sequence assumes seamless transitions between projects and that all disposal site issues and designs are worked out in time to receive material from various remediation dredging operations.
- Three projects together may still tax capacity of regionally available qualified equipment/contractors/disposal sites due to the following reasons:
  - There will be ongoing navigation dredging/construction within Portland Harbor each year that will also complete for equipment and labor resources
  - Multiple parties performing cleanups will be competing for the same resources

- Due to the limited in-water work window, it is unlikely that out-of-area dredging equipment would be mobilized for the project (equipment being idle for 8 months of each year makes this option unrealistic).

- Many environmental projects have experienced lower production rates, particularly in cases where extensive BMPs are required by regulatory agencies.
- The durations assume there will be no changes in construction windows in the future, whereas historically these windows have been shrinking over time.
- Volumes may go up in remedial design, which often happens when additional data are collected and dredge prisms are refined.
- The durations do not include time to install or remove sheetpile walls or silt curtains.
- The durations do not include multiple residual passes, removal/replacement of structures, or use of sheetpile containment structures, all of which would lengthen the time required for remedy implementation.
- Depending on the size and characteristics of the transload facilities the through-put capacity and availability of rail or truck transportation could vary from the assumptions used here.
- Work in different SMAs will most likely be performed as separate projects. Any unforeseen delay in a later stage of any of those projects will impact schedule of other projects, as it will not be possible to fast-forward any work on short notice.
- There are considerable regulatory process logistics with having three simultaneous active projects each year for every year until completion of the project.

Given the assumptions associated with production rates, conducting three projects at a time, and no schedule delays associated with contracting or regulatory approvals, the sequencing and durations presented in this draft FS represent a very optimistic scenario.

In some cases, particular factors may change in remedial design that could conceivably lead to faster construction rates than assumed above. An example might be that applicable agencies determine that certain in-water work outside the construction window is allowable. However, on balance, more optimistic assumptions about durations are generally fewer, of lower impact on the durations, and/or appear less likely to occur. Given the assumptions above including production rates, conducting three projects at a time, and no schedule delays associated with contracting or regulatory approvals, the sequencing and durations presented above represent a very optimistic scenario.

7.6 COMPREHENSIVE ALTERNATIVE COST ESTIMATES

Appendix K presents the tools and approaches that were used to develop sediment remediation cost estimates for the draft FS alternatives. The appendix discusses the following:

- Construction tasks used as the basis for developing costs
- Methods used for developing quantities for the different construction tasks
- Cost approach used for each construction task
- Cost factors to address EPA comments on the Cost Tool Memorandum (EPA 2011c and LWG 2011f and see Appendix O).

The costs were developed specific to the localized SMA or portion of SMA (i.e., subSMA) being evaluated. In addition, the specific unit costs or quantities include explicit ranges in some situations, where justified, due to relatively important and large uncertainties identified by various sensitivity analyses. The costs discussion in Section 9 provides a description of the different cost elements where ranges were used to account for cost uncertainties.

EPA guidance (EPA 2000b) was followed to develop the cost estimates. In addition, professional judgment was used where appropriate in estimating daily costs and production rates. Professional judgment drew on recently completed Portland area projects including the Gasco Early Action, Terminal 4 Phase I Removal Action, and the Alcoa Sediment Remediation in Vancouver, Washington.

The resulting range of costs for each alternative is shown in Table 7.0-1. Appendix K provides costs broken down by SMA and additional cost details.

7.7 CONCLUSIONS

The 11 alternatives described in this section and summarized in Table 7.0-1 provide a range of remedial approaches for addressing potentially unacceptable risks for the Site consistent with EPA guidance (1988 and 2005a). These alternatives span both a range of RALs and active remedy acreages (SMAs), costs, and durations, as well as a range of technology applications as represented by the removal focused and integrated options. Per guidance, the alternatives also include a no action Alternative A for comparative purposes. Based on the alternative screening analyses, there is a reasonable expectation that this range of alternatives can meet the NCP threshold criteria of protectiveness and compliance with ARARs, as will be evaluated in detail and comparatively in Sections 8 and 9.

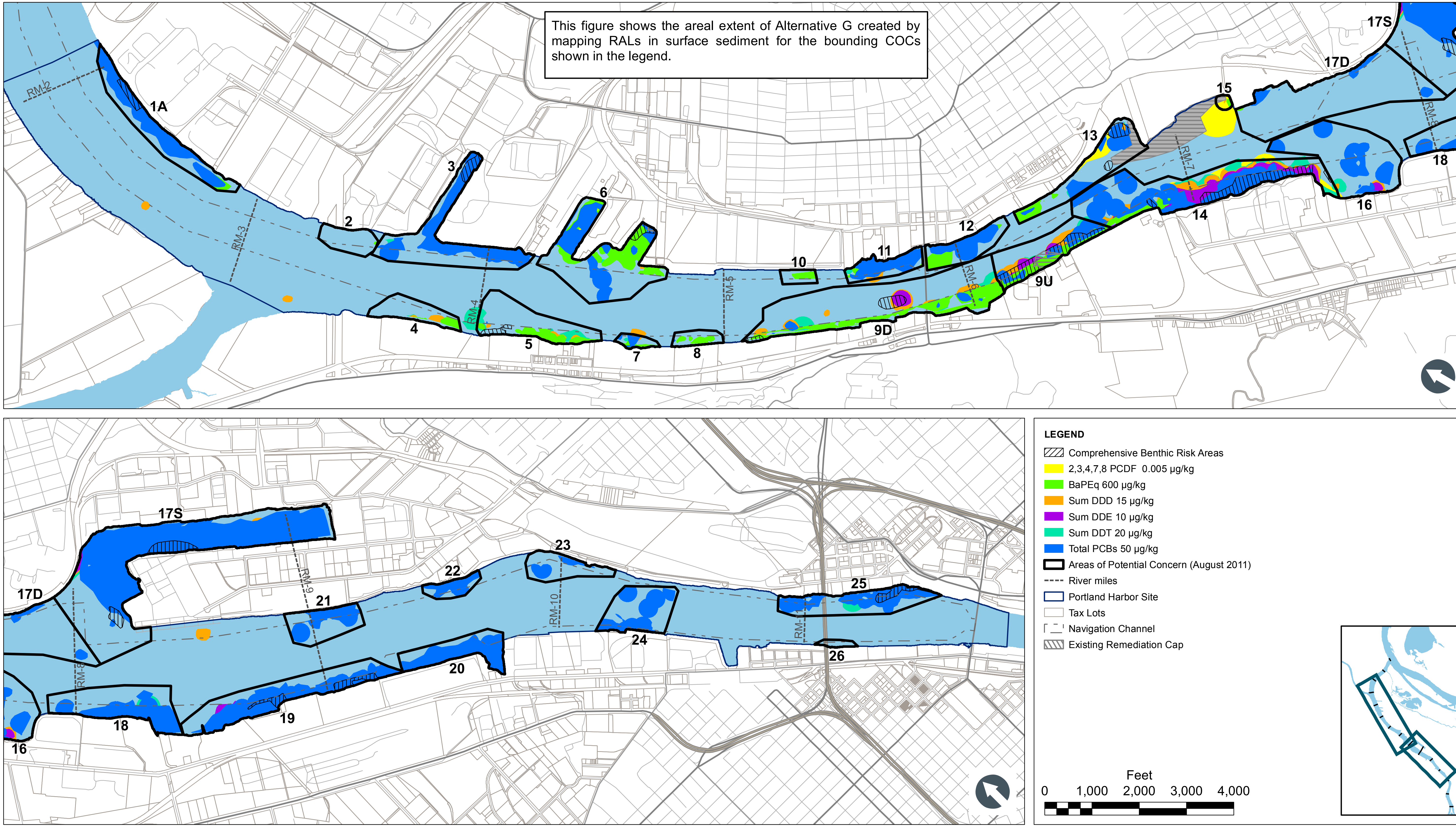

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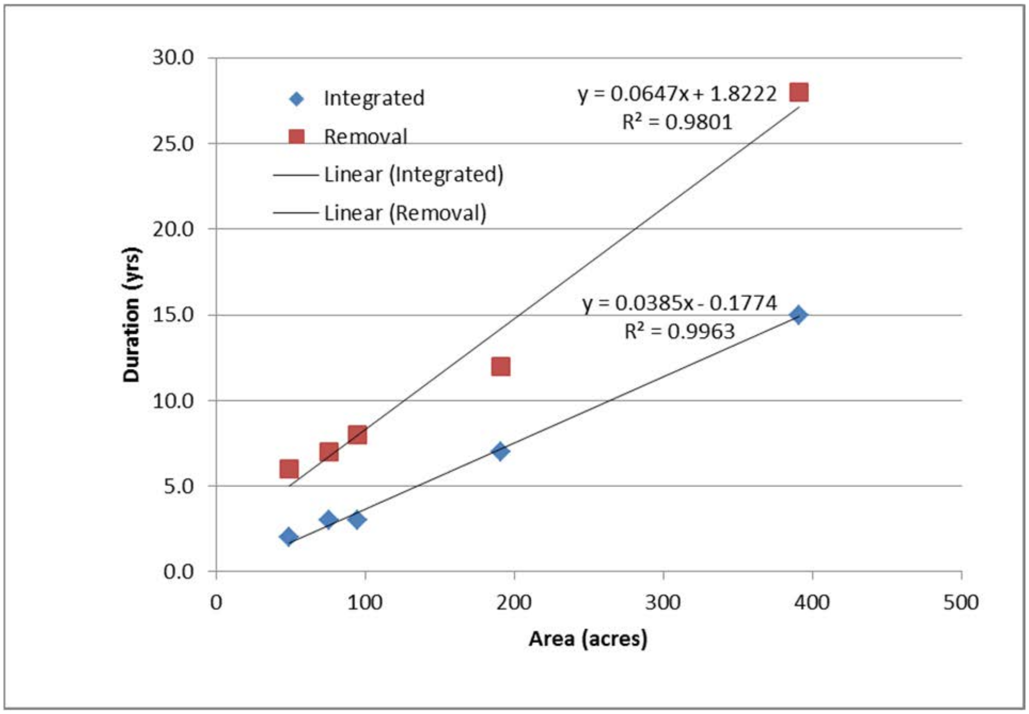
Figure 7.1-1
Portland Harbor RI/FS
Draft Feasibility Study
Summary of SMAs Designated by Alternative G

This figure shows that there is a predictable high correlation between the acreage of an alternative and its duration or cost.



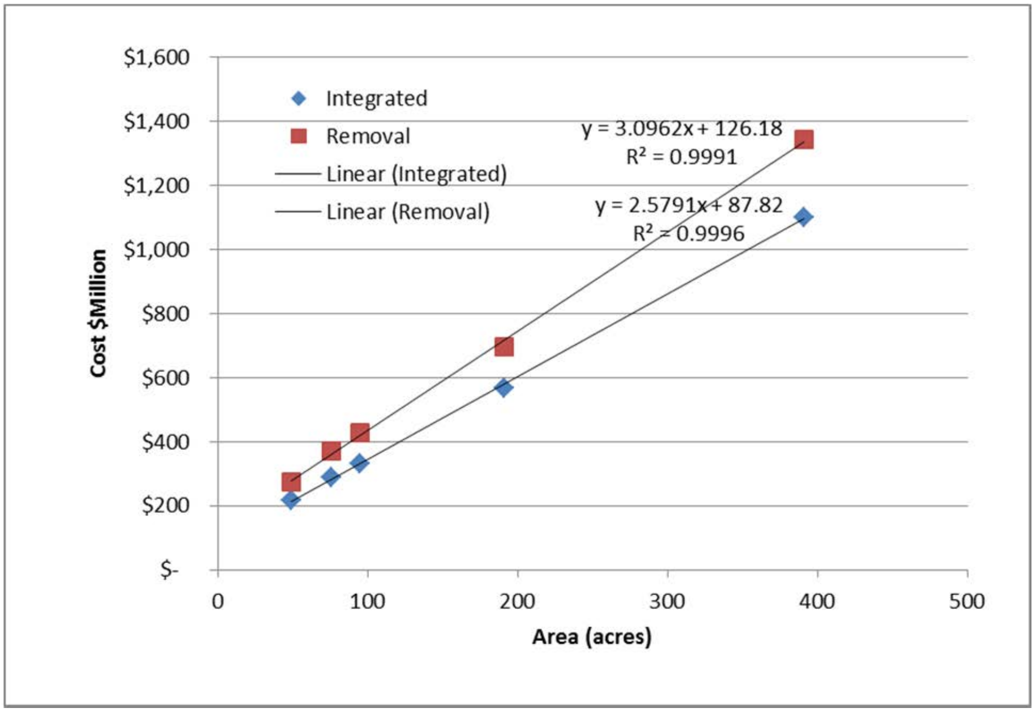
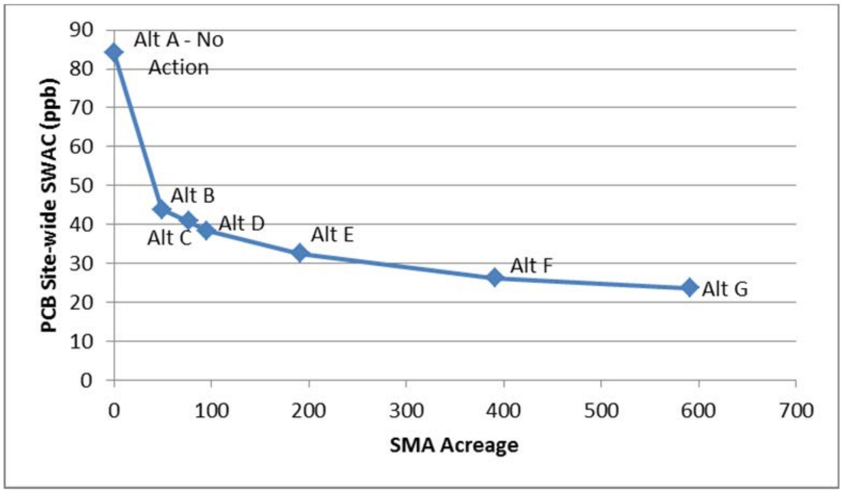
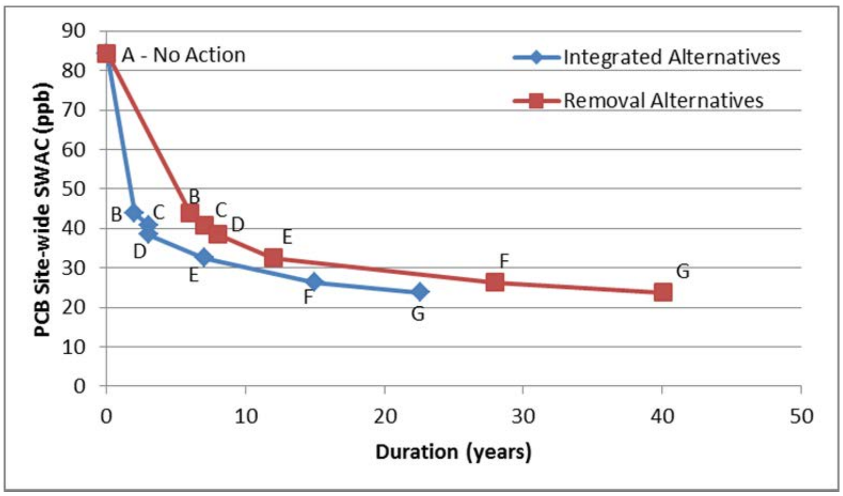


Figure 7.1-2
Portland Harbor RI/FS
Draft Feasibility Study
Correlation Between Alternative Acreage vs. Duration (years) and Cost ($million; Average of Low and High Estimates)

These figures compare PCB SWACs achieved by each alternative to the acreage of remediation, duration of the construction, and cost. As the acreage, duration, and cost of the remedy increase, the ability to reduce the SWAC decreases.





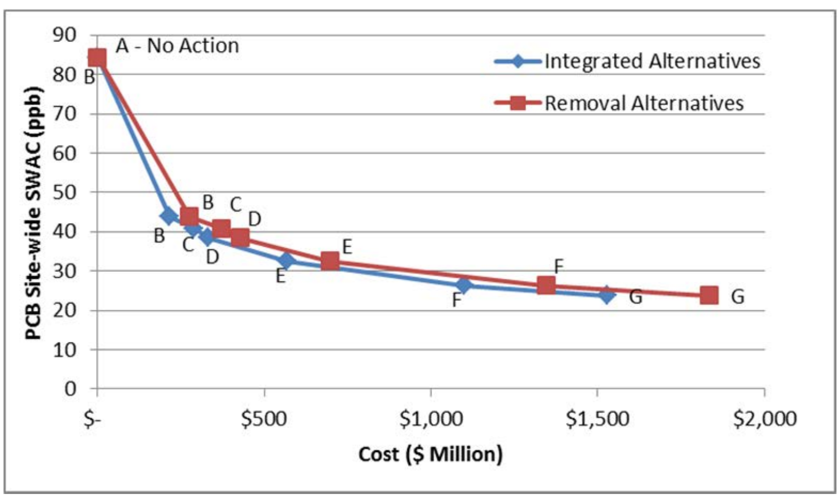


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Figure 7.1-3
Portland Harbor RI/FS
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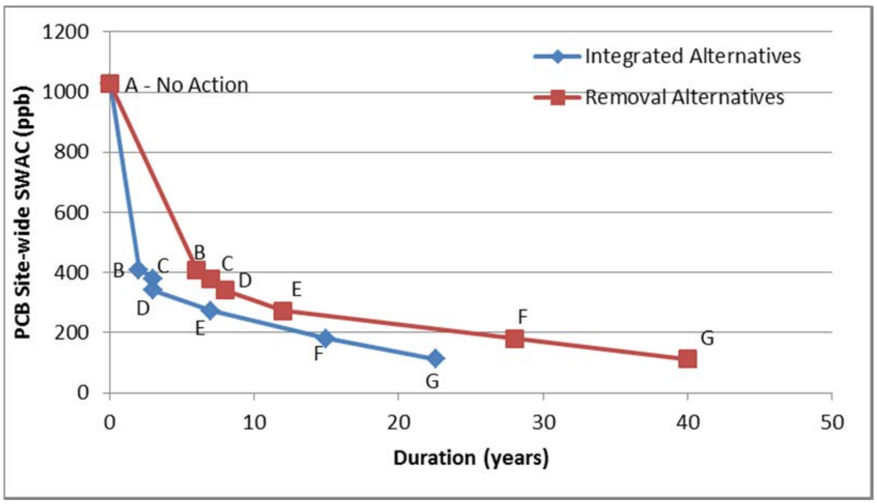
Time Zero PCB Site-wide SWACs Attained by Each Alternative as Compared to Estimated Acreages, Durations, and Costs

These figures compare BaPEq SWACs achieved by each alternative to the acreage of remediation, duration of the construction, and cost. As the acreage, duration, and cost of the remedy increase, the ability to reduce the SWAC decreases.



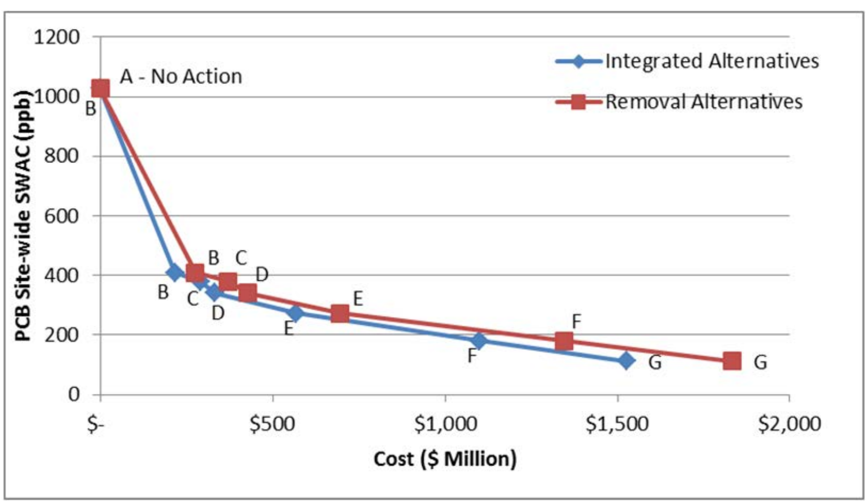


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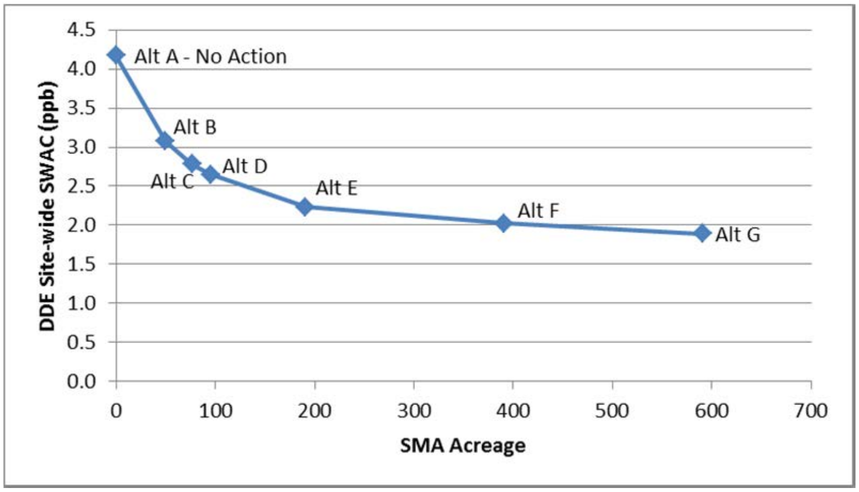
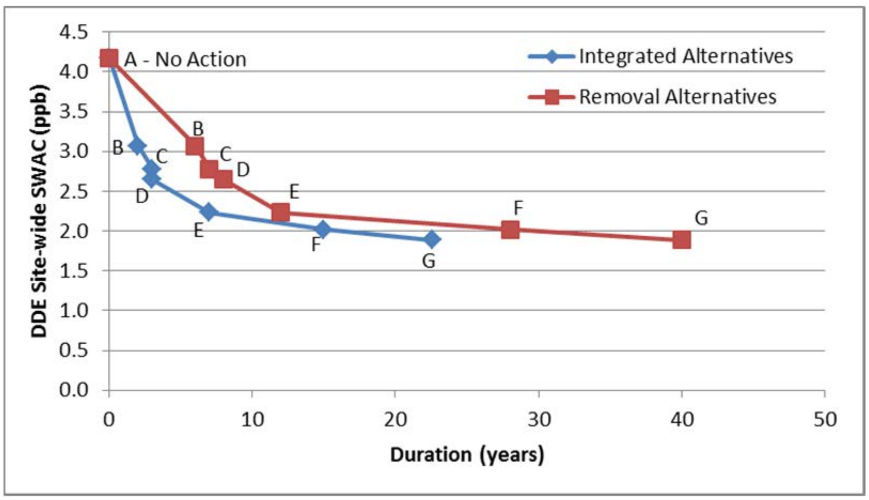
Figure 7.1-4
Portland Harbor RI/FS
Draft Feasibility Study
Time Zero BaPEq SWACs (Site-wide Shoreline Areas Outside the Navigation Channel) Attained by Each Alternative as Compared to Estimated Acreages, Durations, and Costs

These figures compare DDE SWACs achieved by each alternative to the acreage of remediation, duration of the construction, and cost. As the acreage, duration, and cost of the remedy increase, the ability to reduce the SWAC decreases.





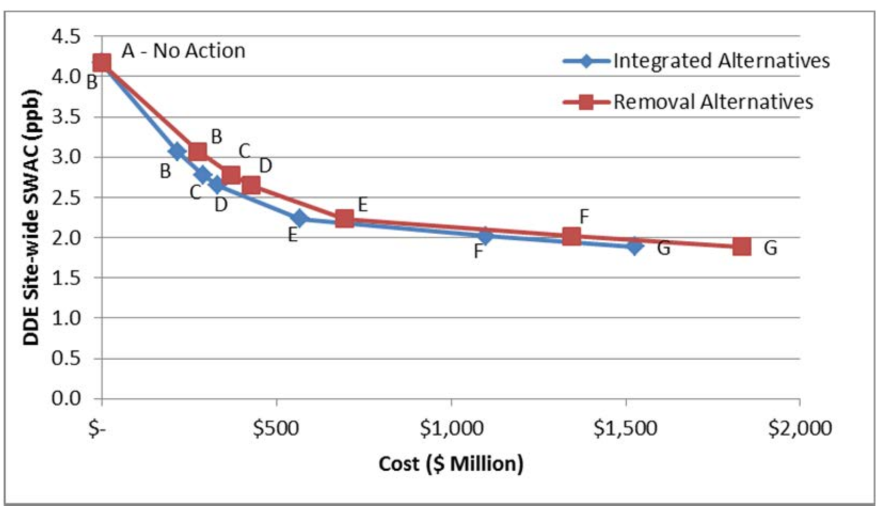


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Figure 7.1-5
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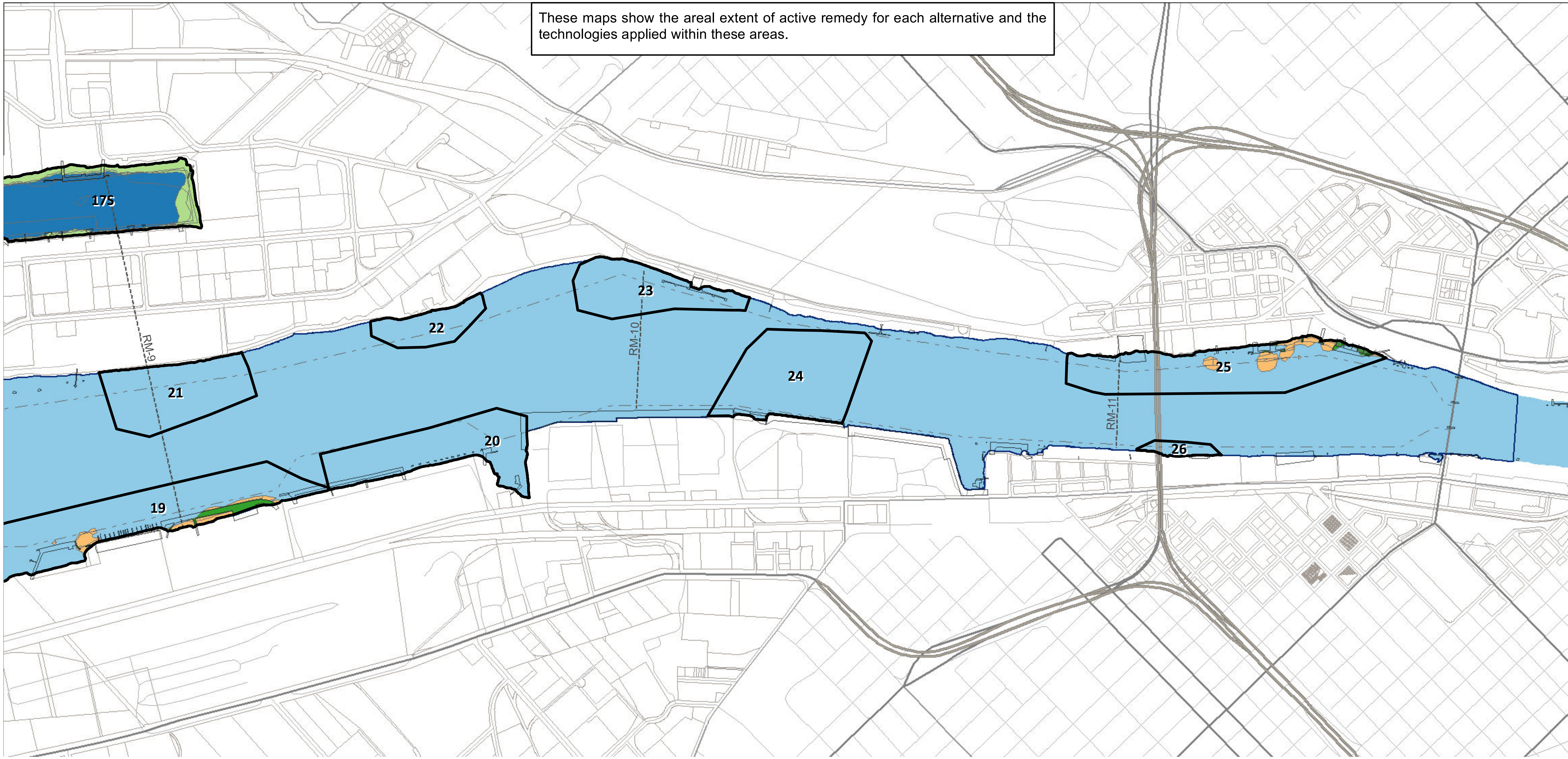
Time Zero DDE Site-wide SWACs Attained by Each Alternative as Compared to Estimated Acreages, Durations, and Costs

These maps show the areal extent of active remedy for each alternative and the technologies applied within these areas.



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 550 1,100 1,650 2,200

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Figure 7.2-1a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Removal Focused
Segment 1: AOPCs 20-26

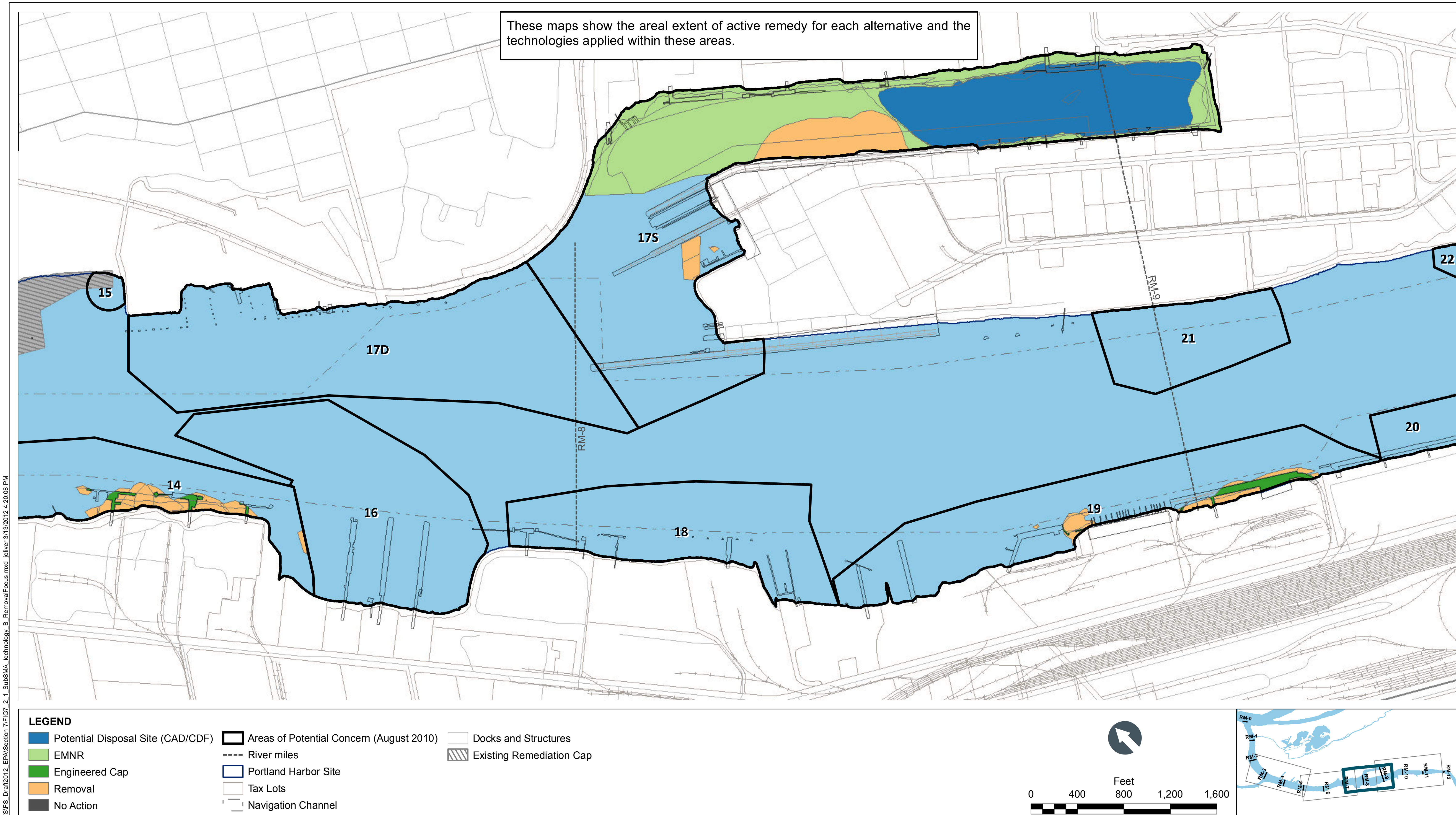

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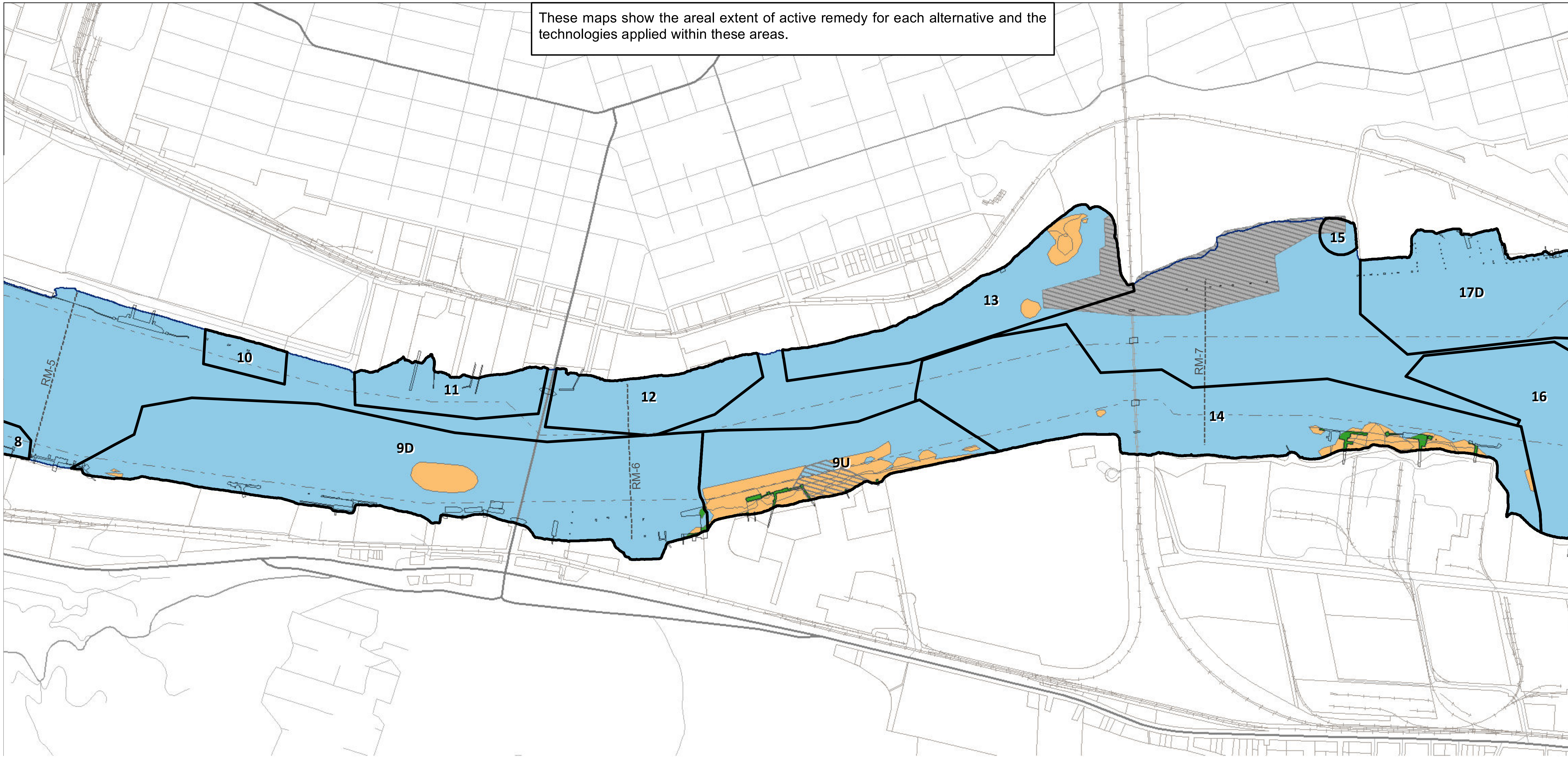
Figure 7.2-1b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Removal Focused
Segment 2: AOPCs 15-19

These maps show the areal extent of active remedy for each alternative and the technologies applied within these areas.



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet
0 450 900 1,350 1,800

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Figure 7.2-1c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Removal Focused
Segment 3: AOPCs 9D - 14

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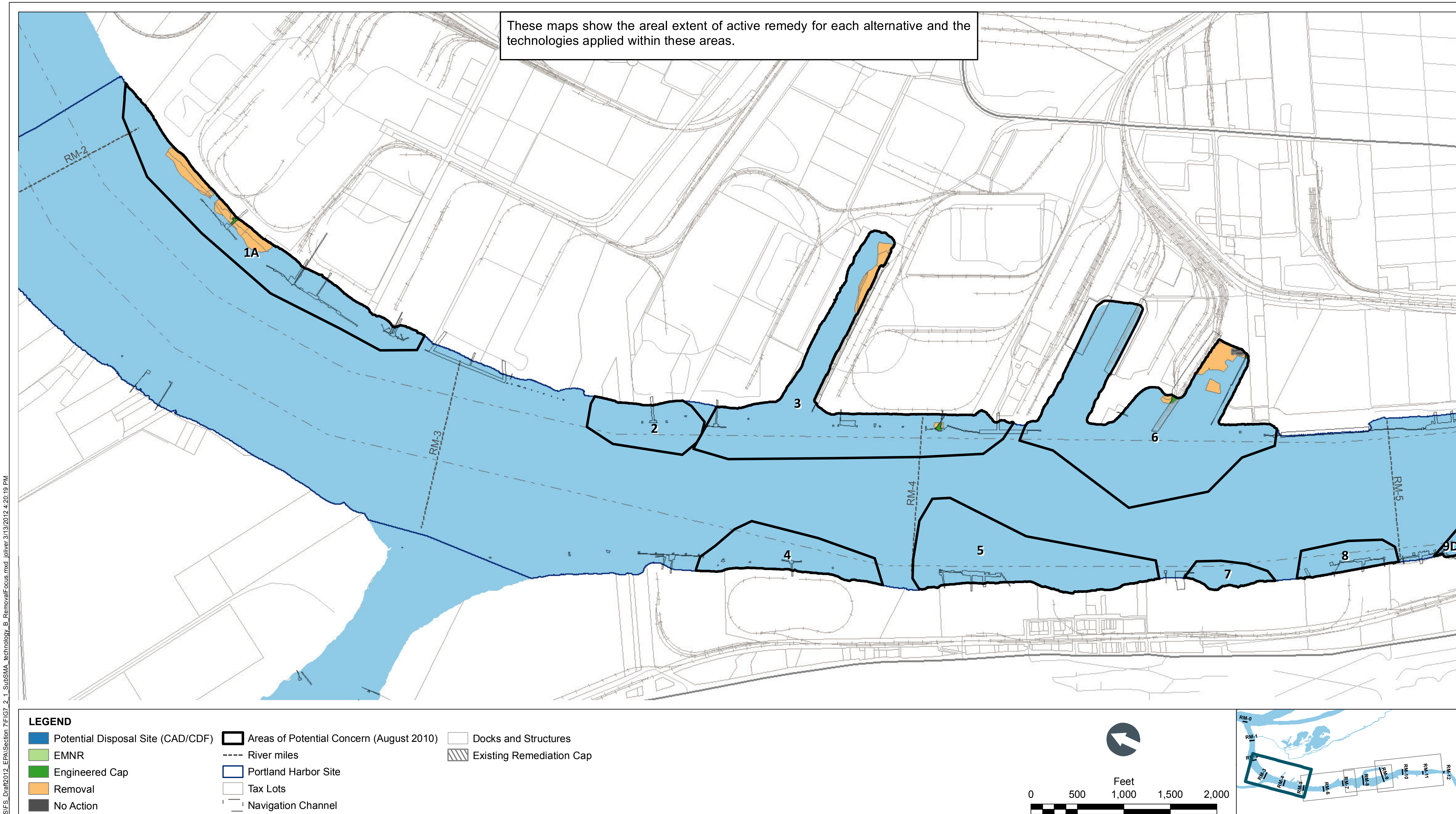

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Figure 7.2-1d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Removal Focused
Segment 4: AOPCs 1-8

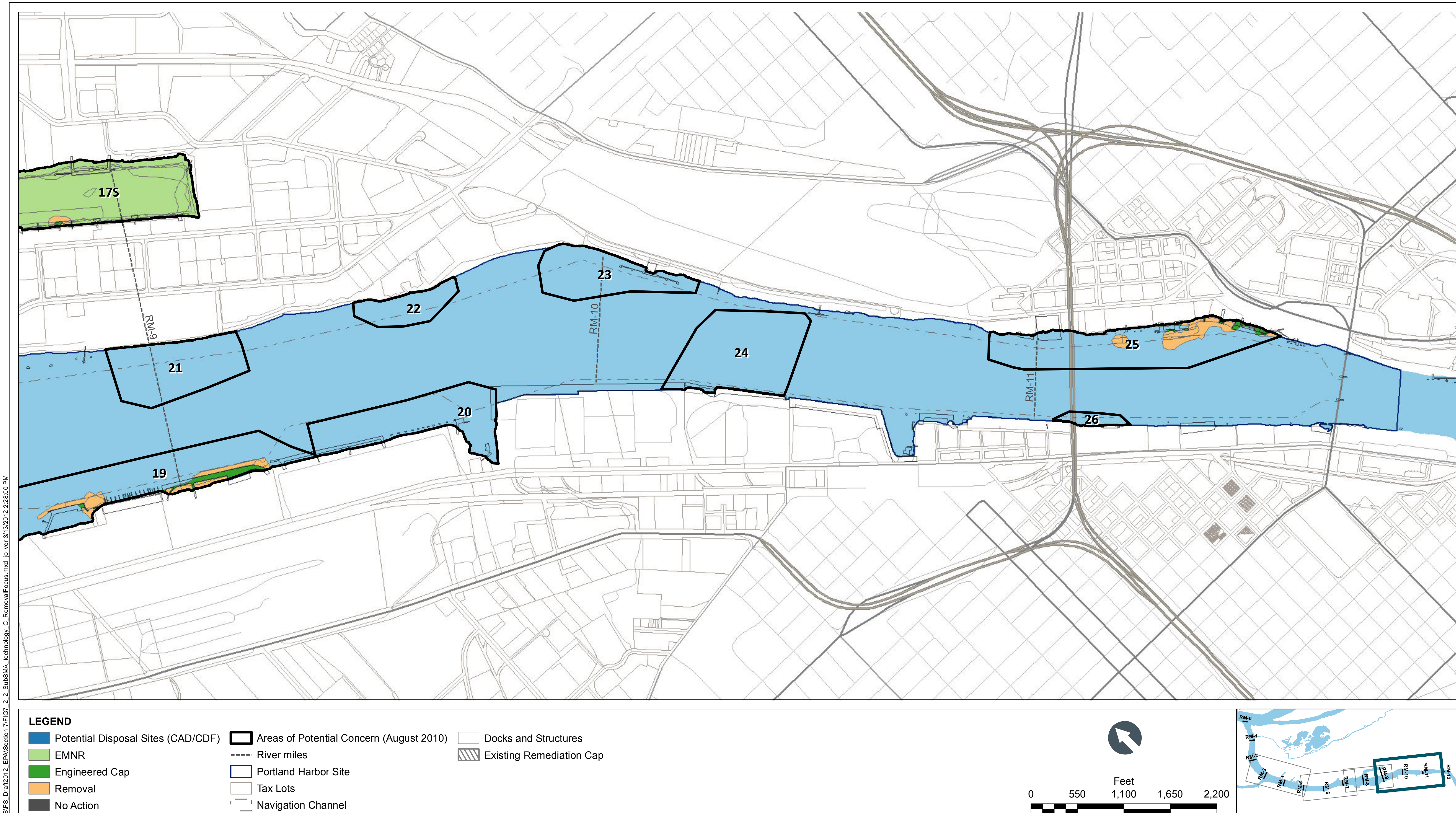

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Figure 7.2-2a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Removal Focused
Segment 1: AOPCs 20-26

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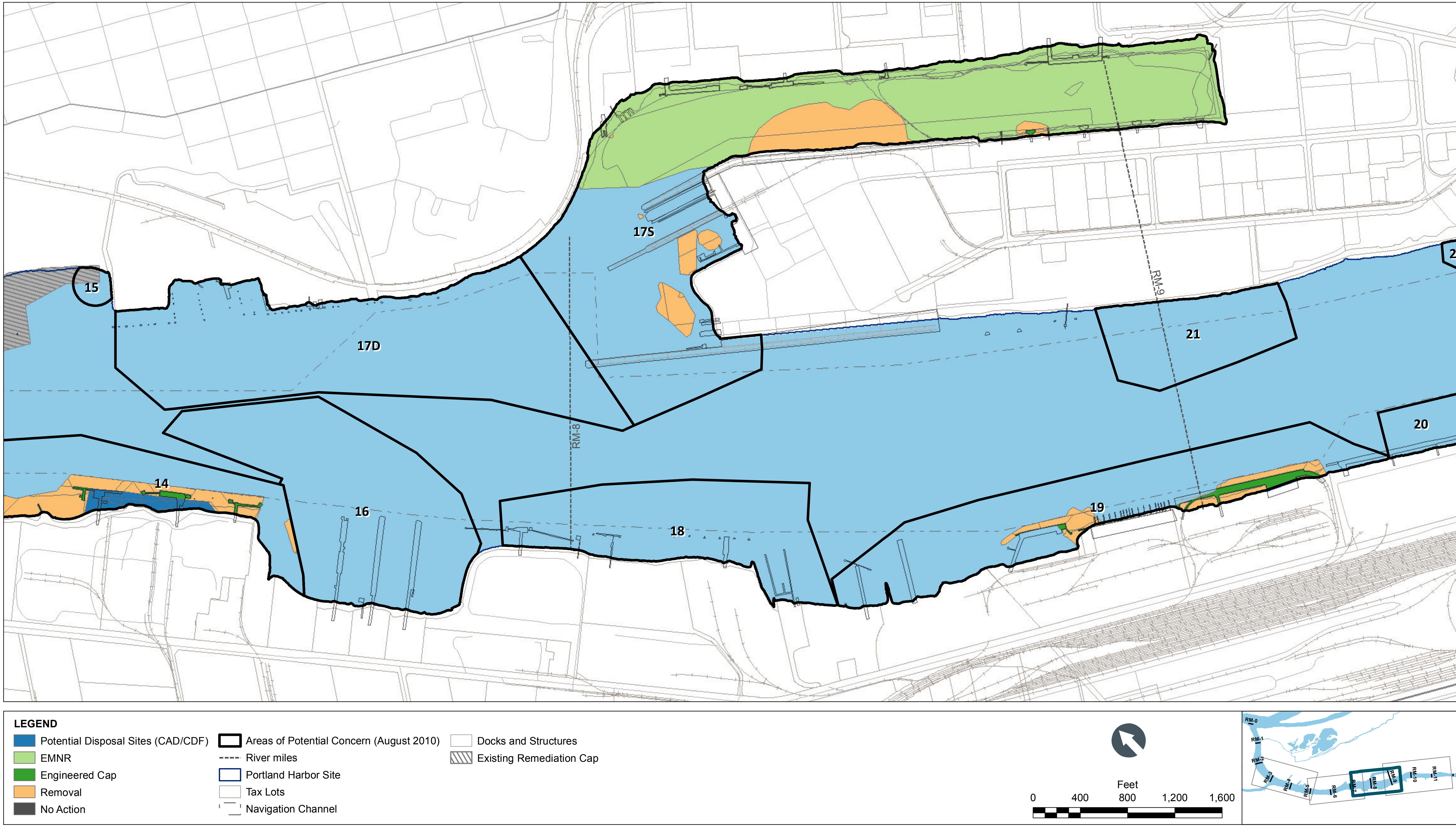

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Figure 7.2-2b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Removal Focused
Segment 2: AOPCs 15-19

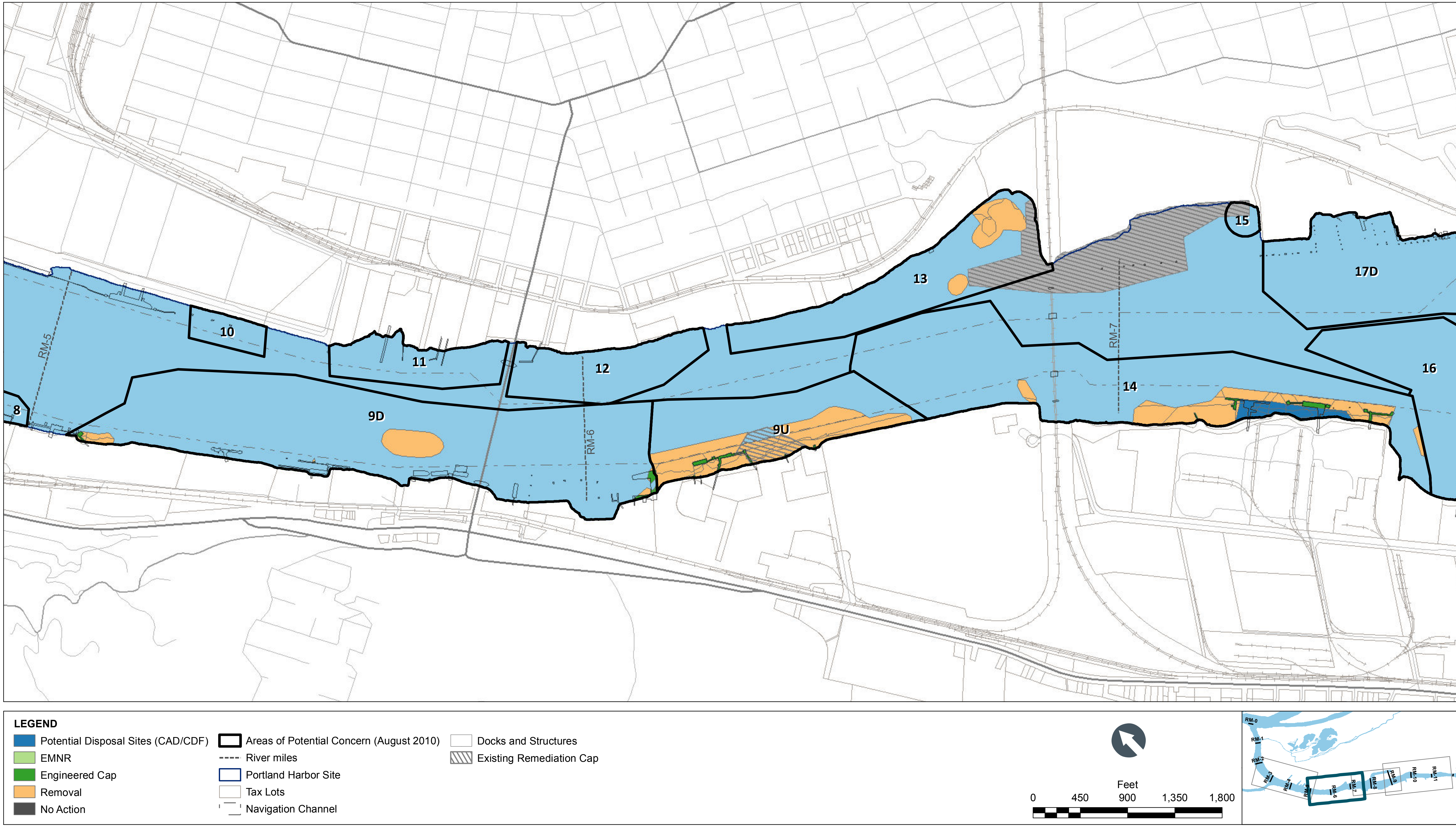

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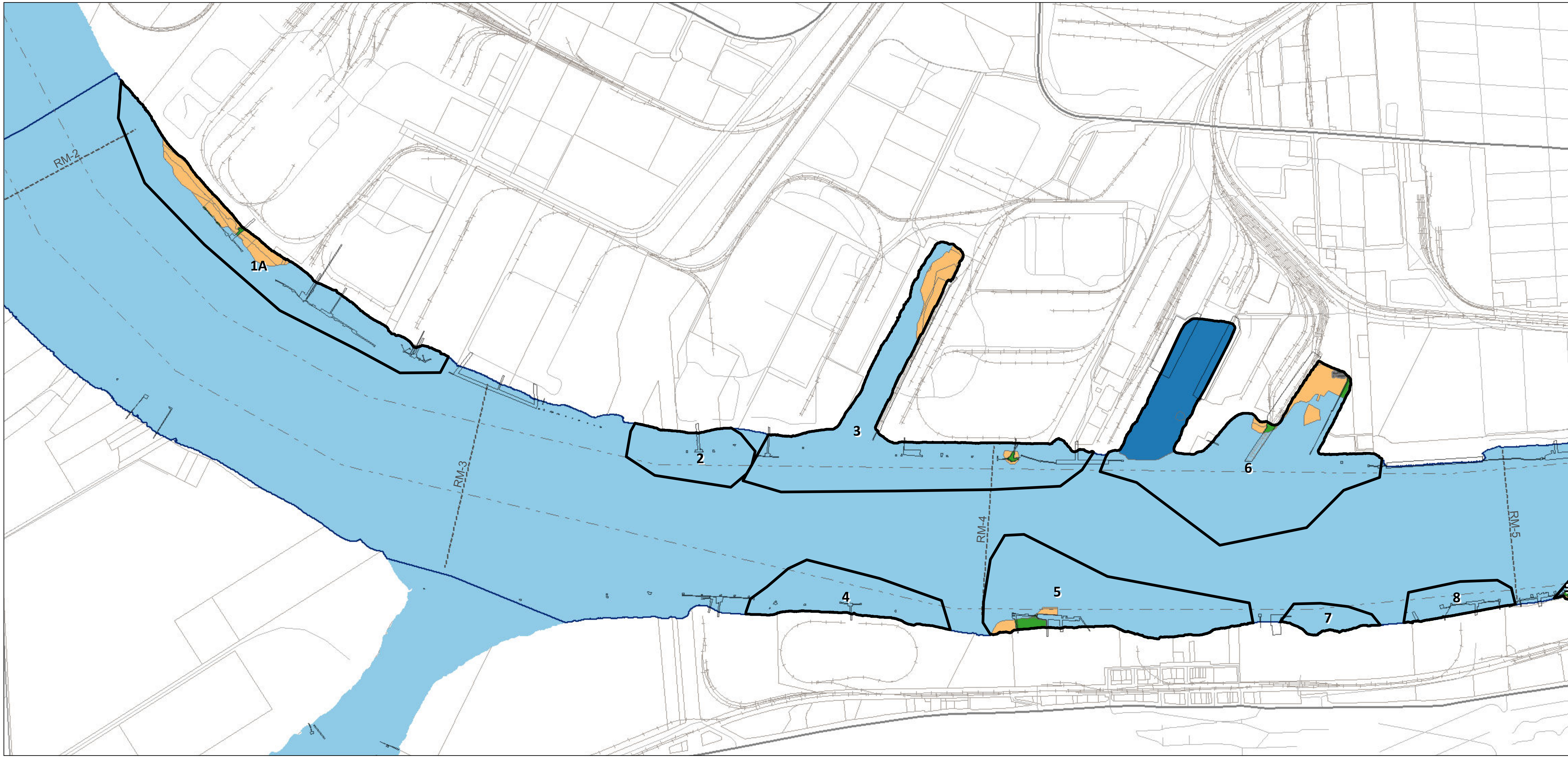
Figure 7.2-2c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Removal Focused
Segment 3: AOPCs 9D - 14



LEGEND

- Potential Disposal Sites (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 500 1,000 1,500 2,000

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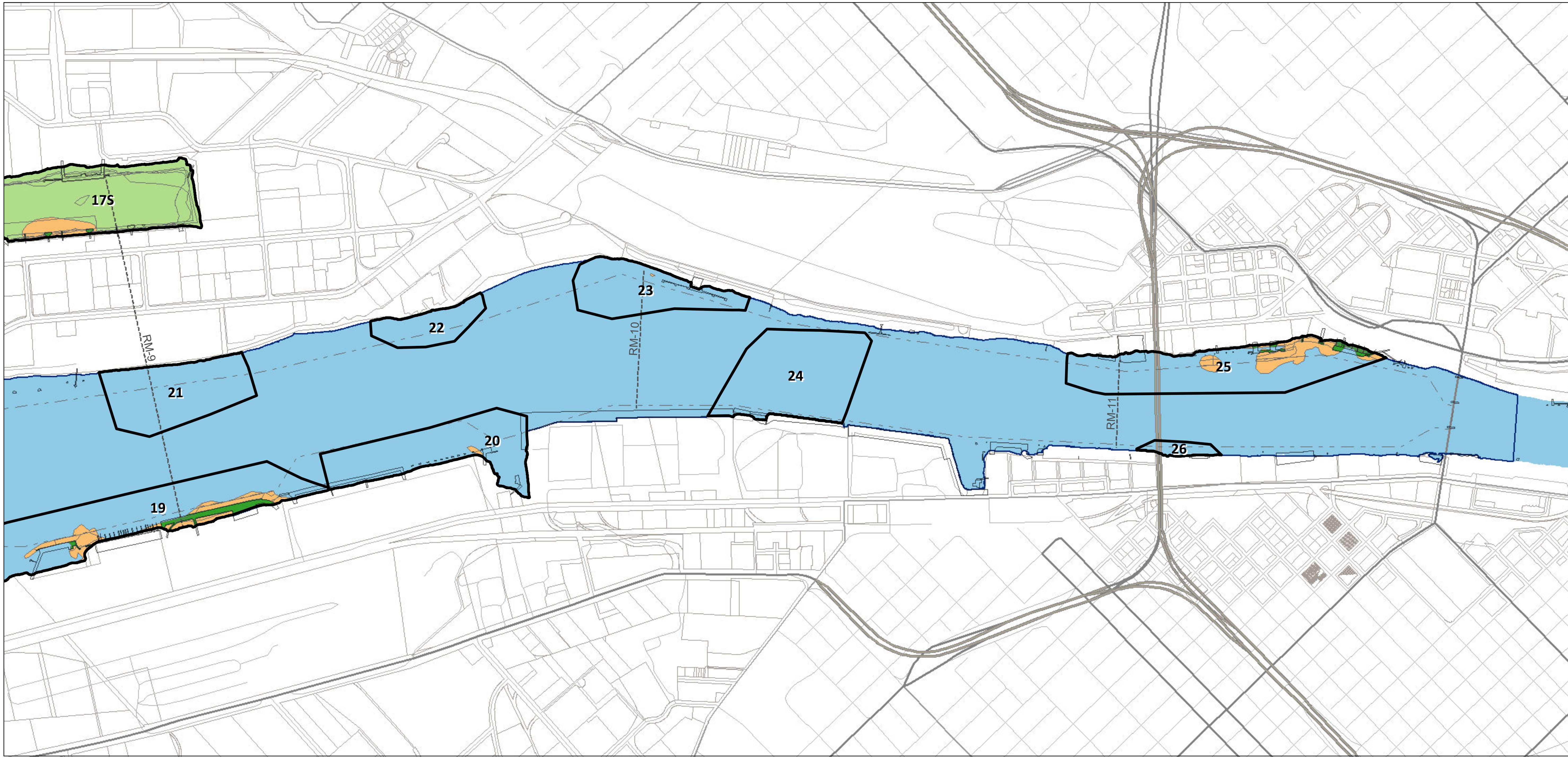
Figure 7.2-2d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Removal Focused
Segment 4: AOPCs 1-8



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 550 1,100 1,650 2,200

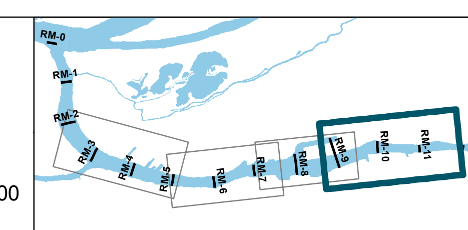


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Figure 7.2-3a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Removal Focused
Segment 1: AOPCs 20-26

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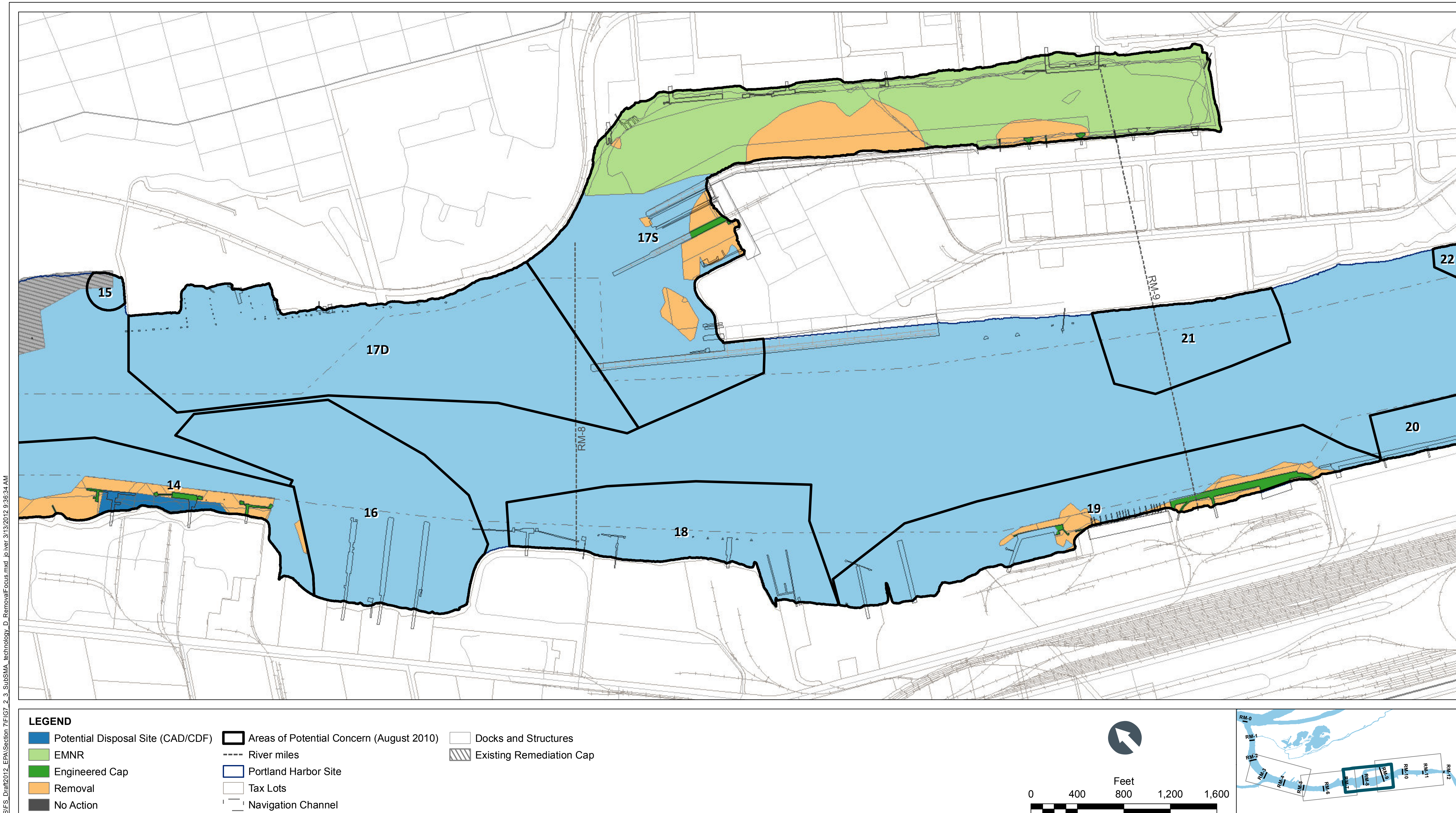

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Figure 7.2-3b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Removal Focused
Segment 2: AOPCs 15-19

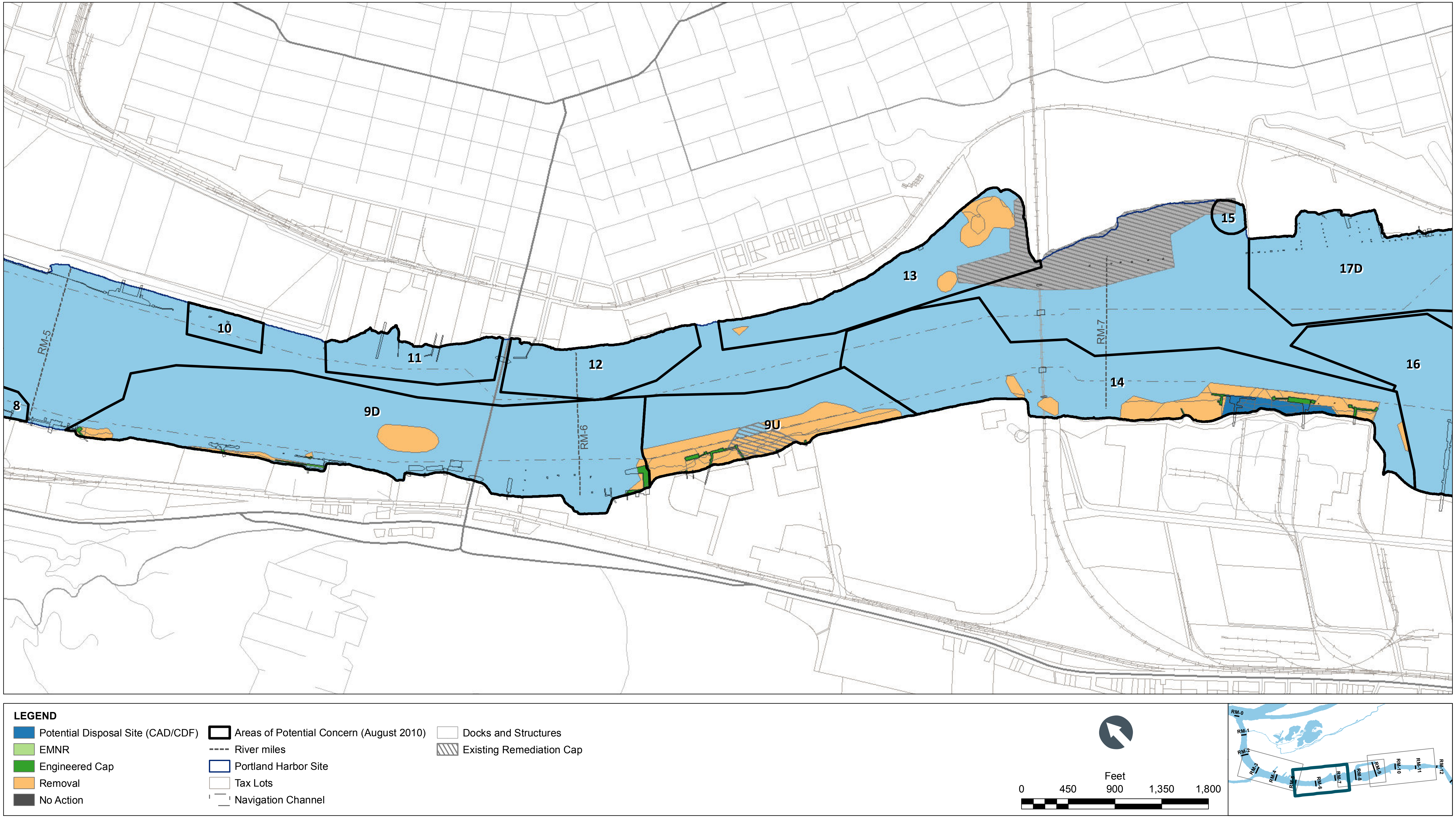

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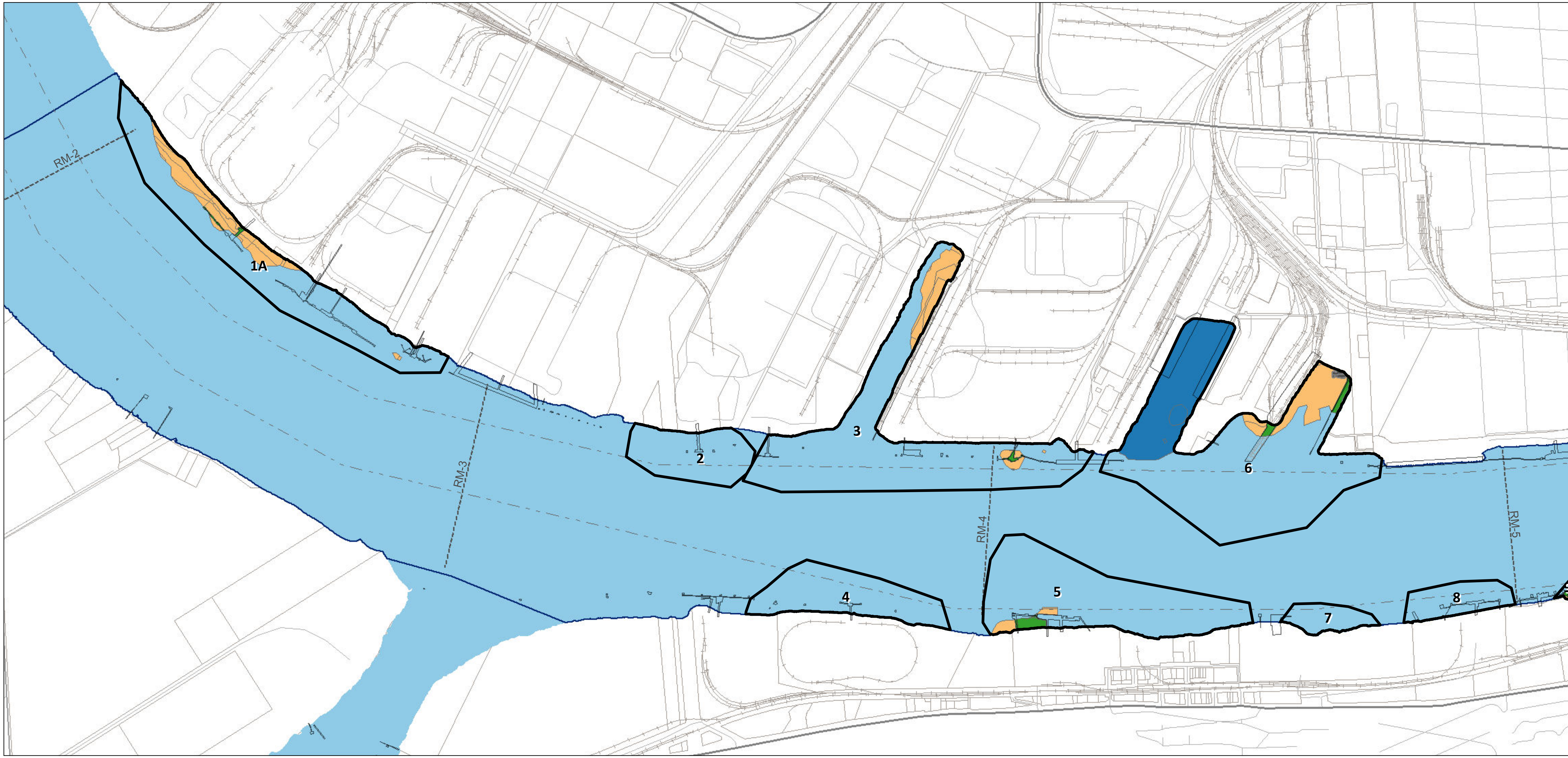
Figure 7.2-3c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Removal Focused
Segment 3: AOPCs 9D - 14



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet
0 500 1,000 1,500 2,000

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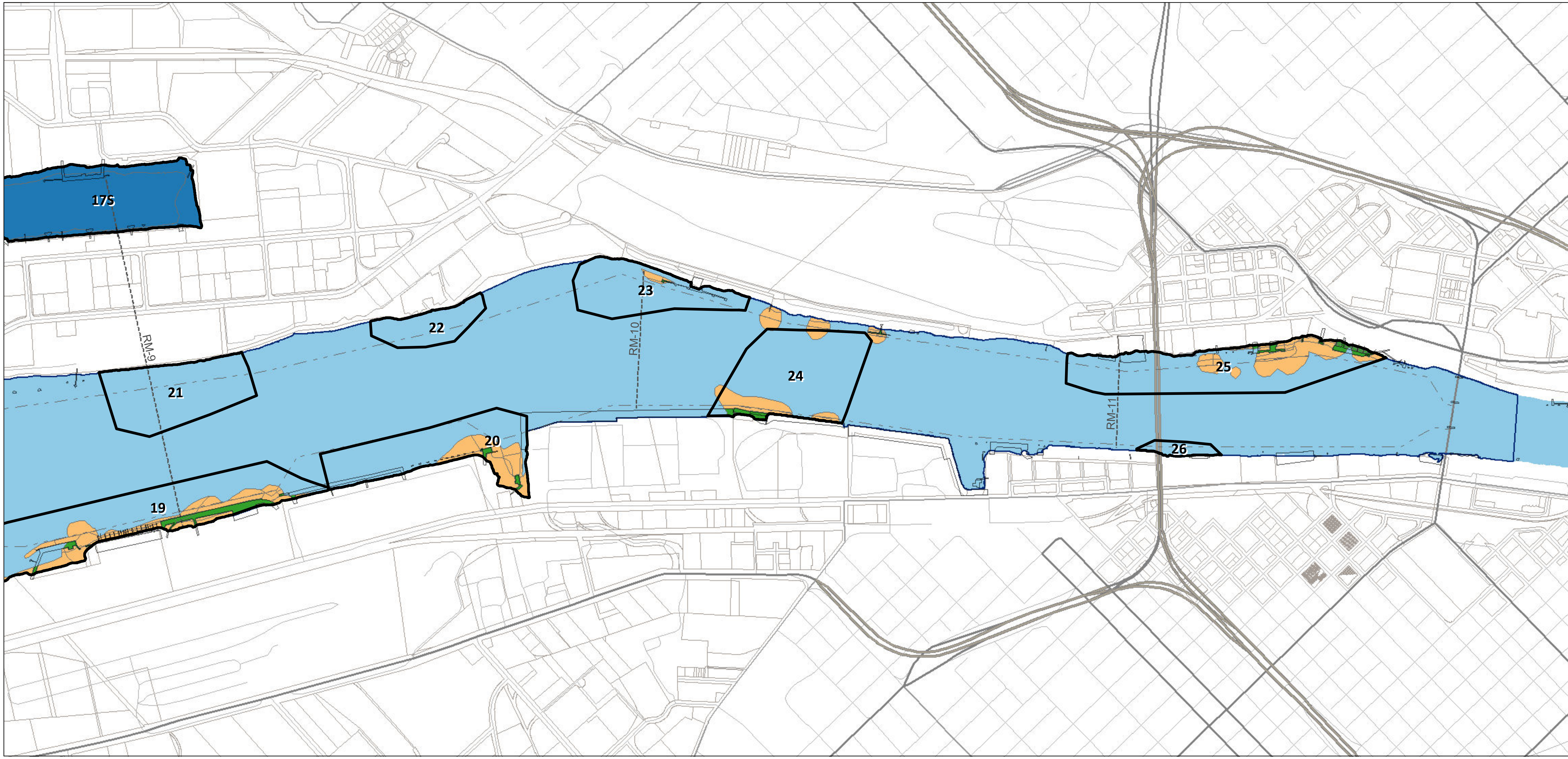
Figure 7.2-3d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Removal Focused
Segment 4: AOPCs 1-8



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 550 1,100 1,650 2,200

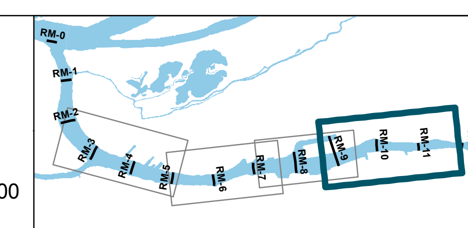


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Figure 7.2-4a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Removal Focused
Segment 1: AOPCs 20-26

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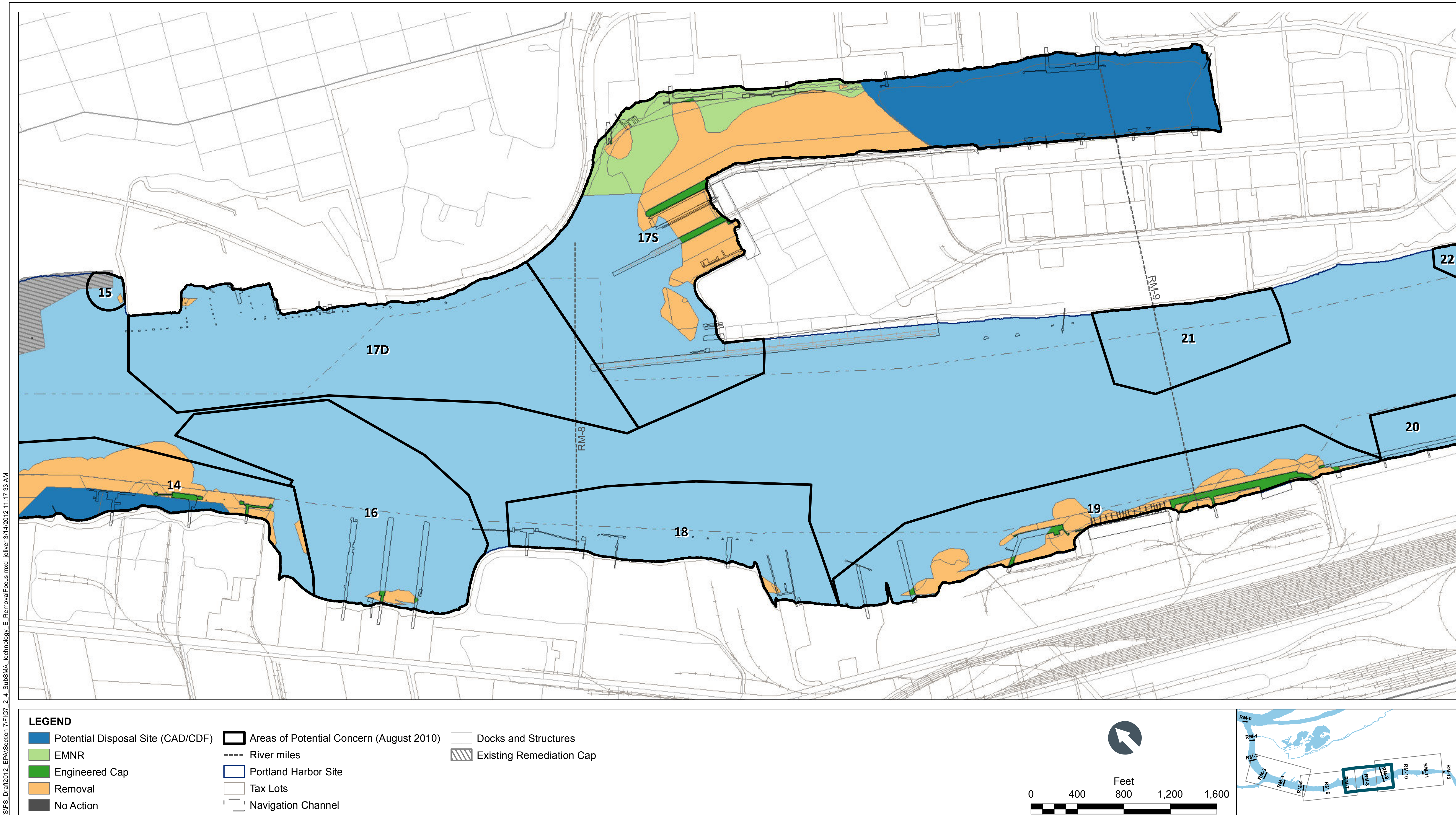

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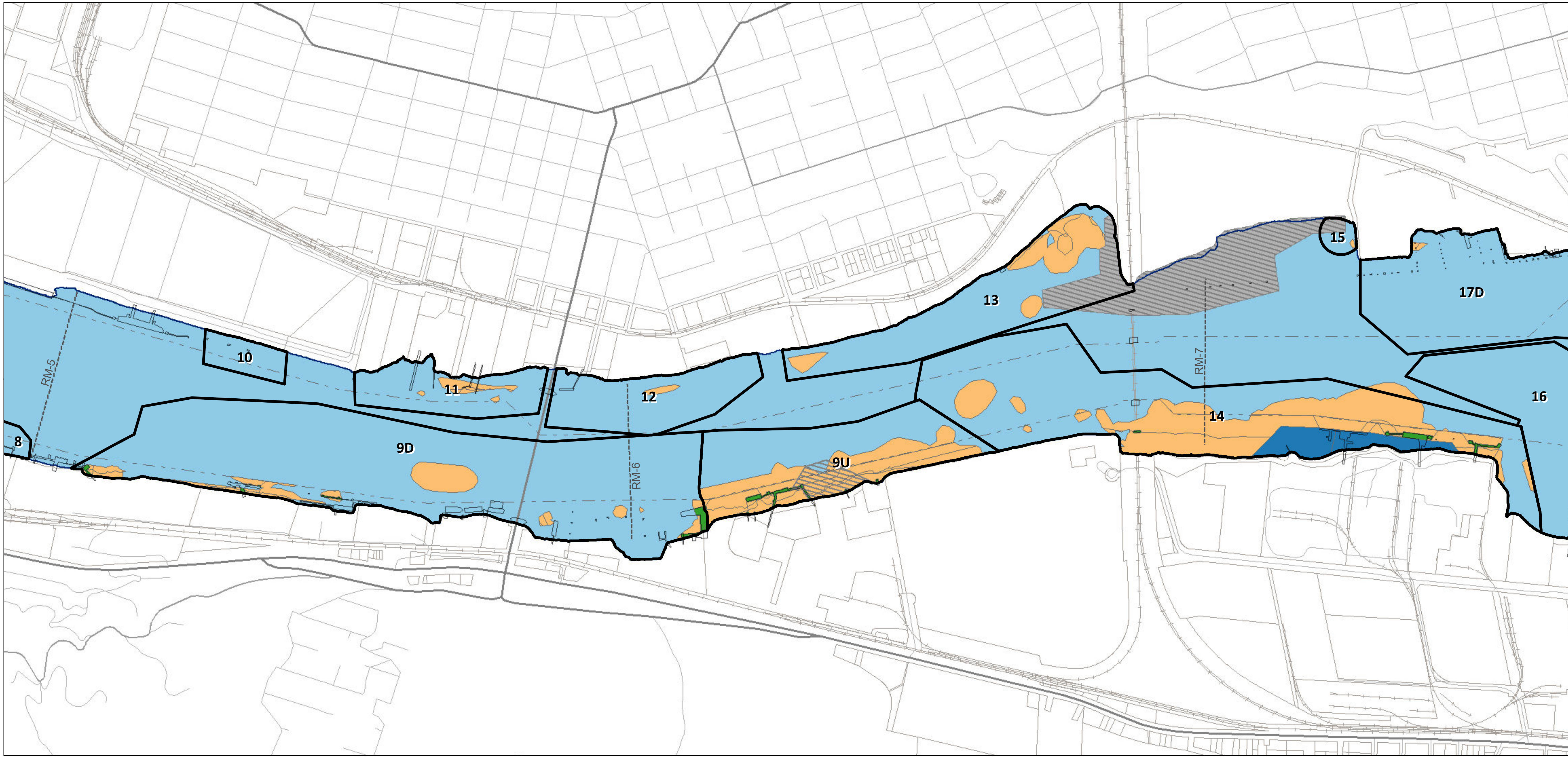
Figure 7.2-4b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Removal Focused
Segment 2: AOPCs 15-19



LEGEND
- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet
0 450 900 1,350 1,800

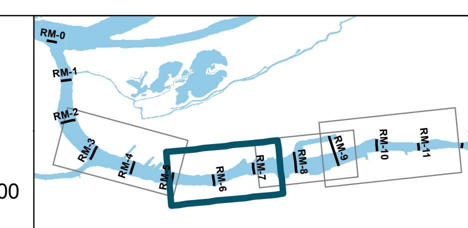


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Figure 7.2-4c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Removal Focused
Segment 3: AOPCs 9D - 14

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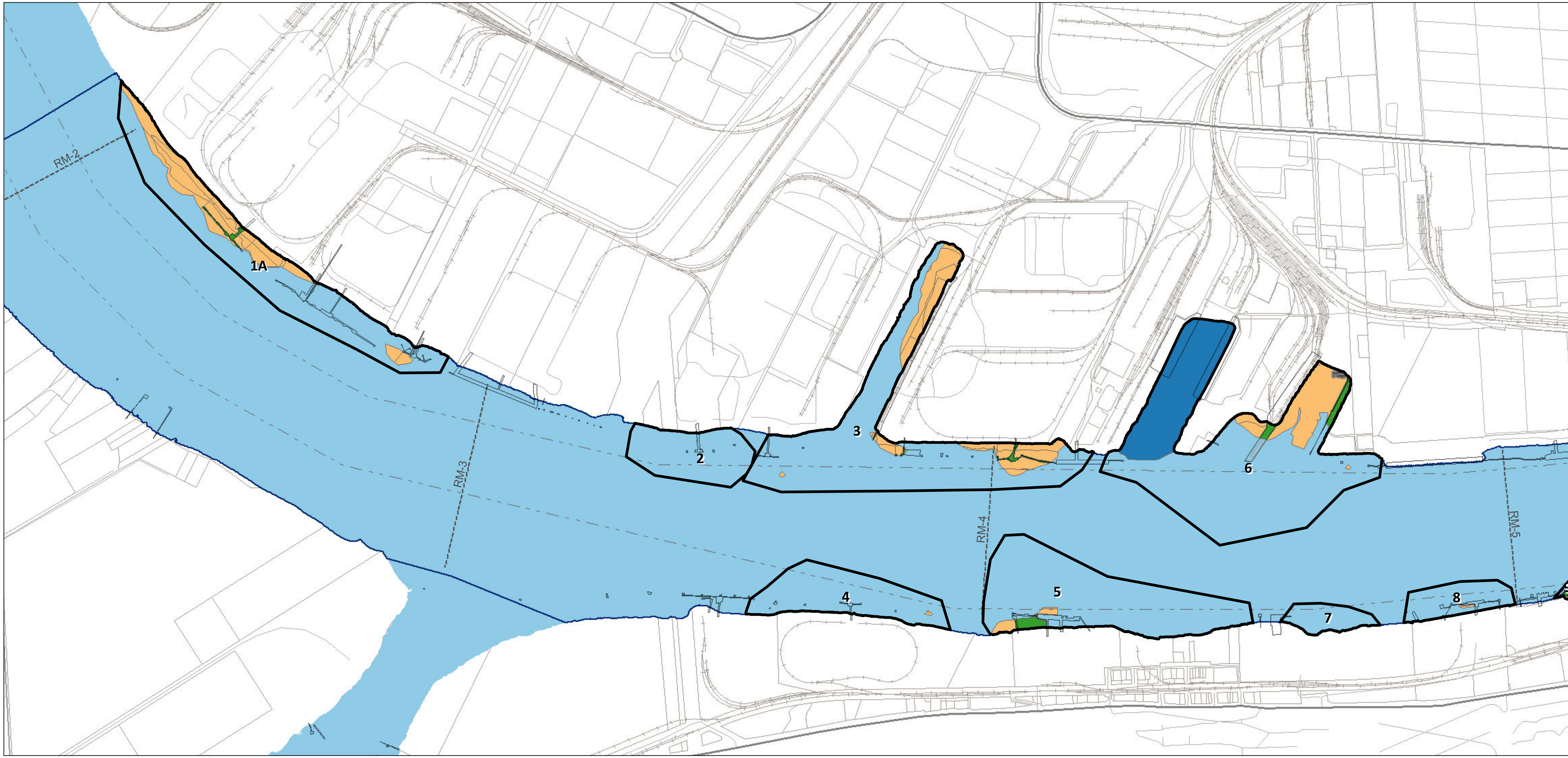

LEGEND
Potential Disposal Site (CAD/CDF)
EMNR
Engineered Cap
Removal
No Action
Areas of Potential Concern (August 2010)
River miles
Portland Harbor Site
Tax Lots
Navigation Channel
Docks and Structures
Existing Remediation Cap

Feet
0 500 1,000 1,500 2,000

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Figure 7.2-4d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Removal Focused
Segment 4: AOPCs 1-8

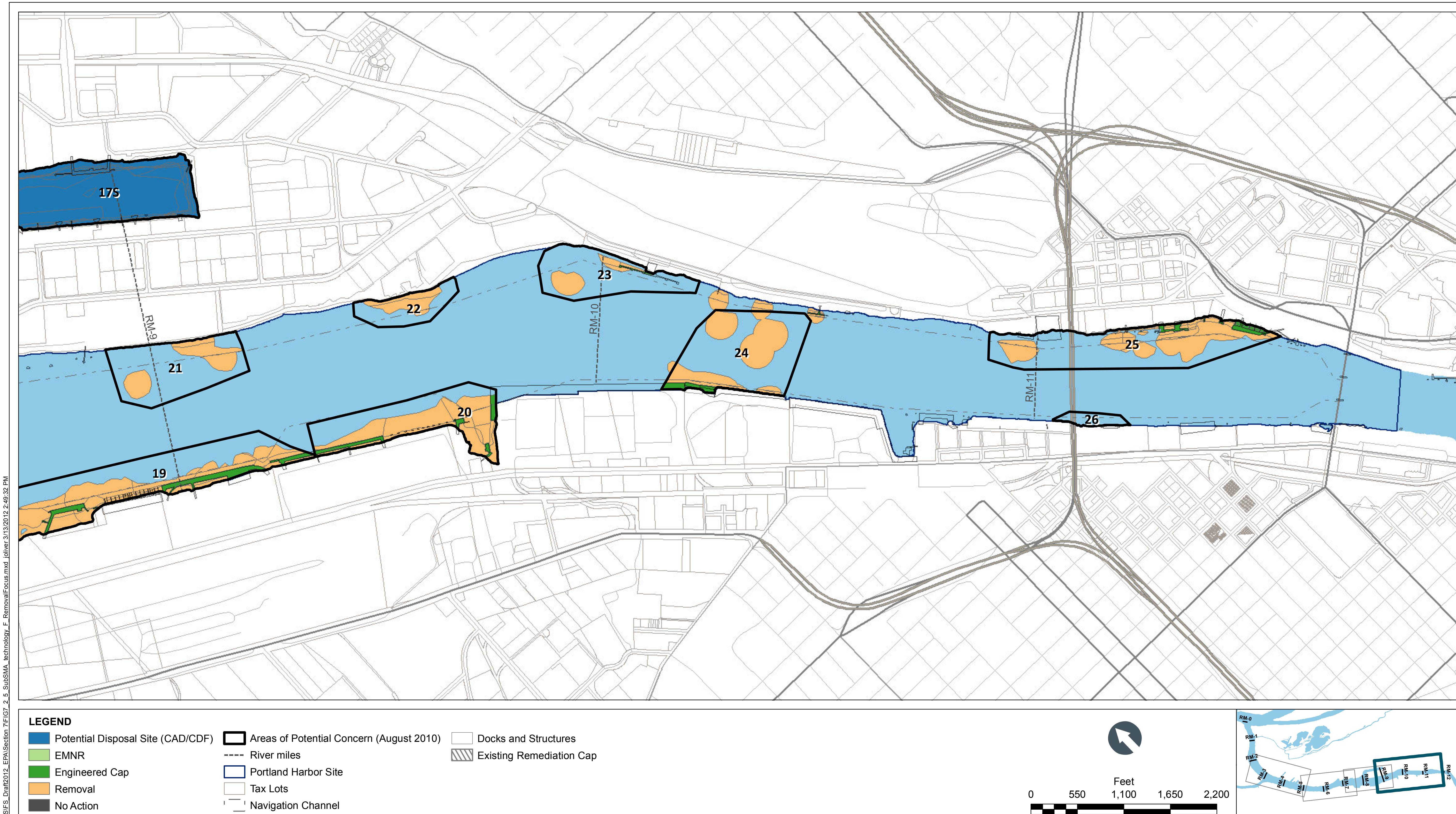

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Figure 7.2-5a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Removal Focused
Segment 1: AOPCs 20-26

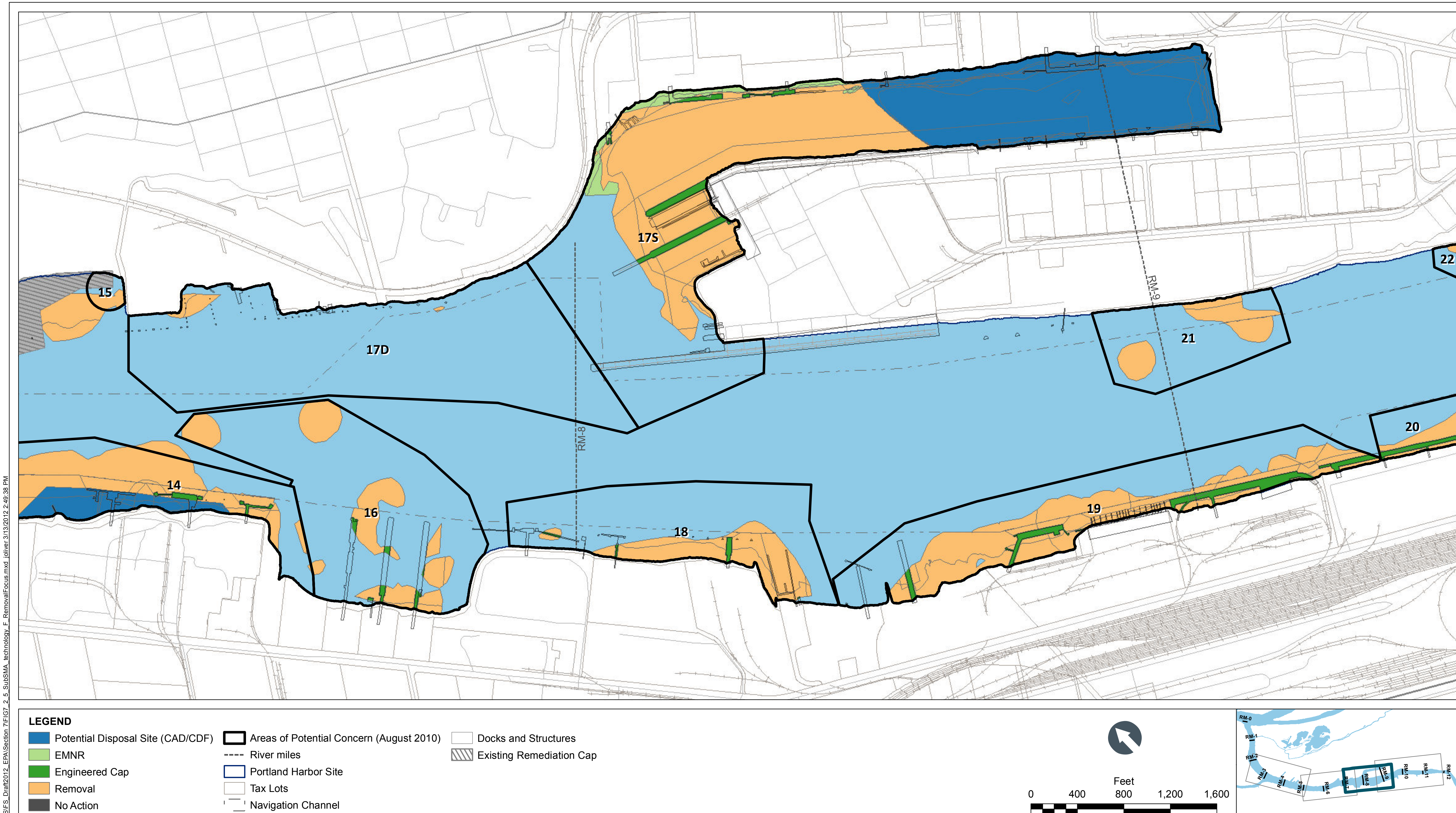

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Figure 7.2-5b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Removal Focused
Segment 2: AOPCs 15-19

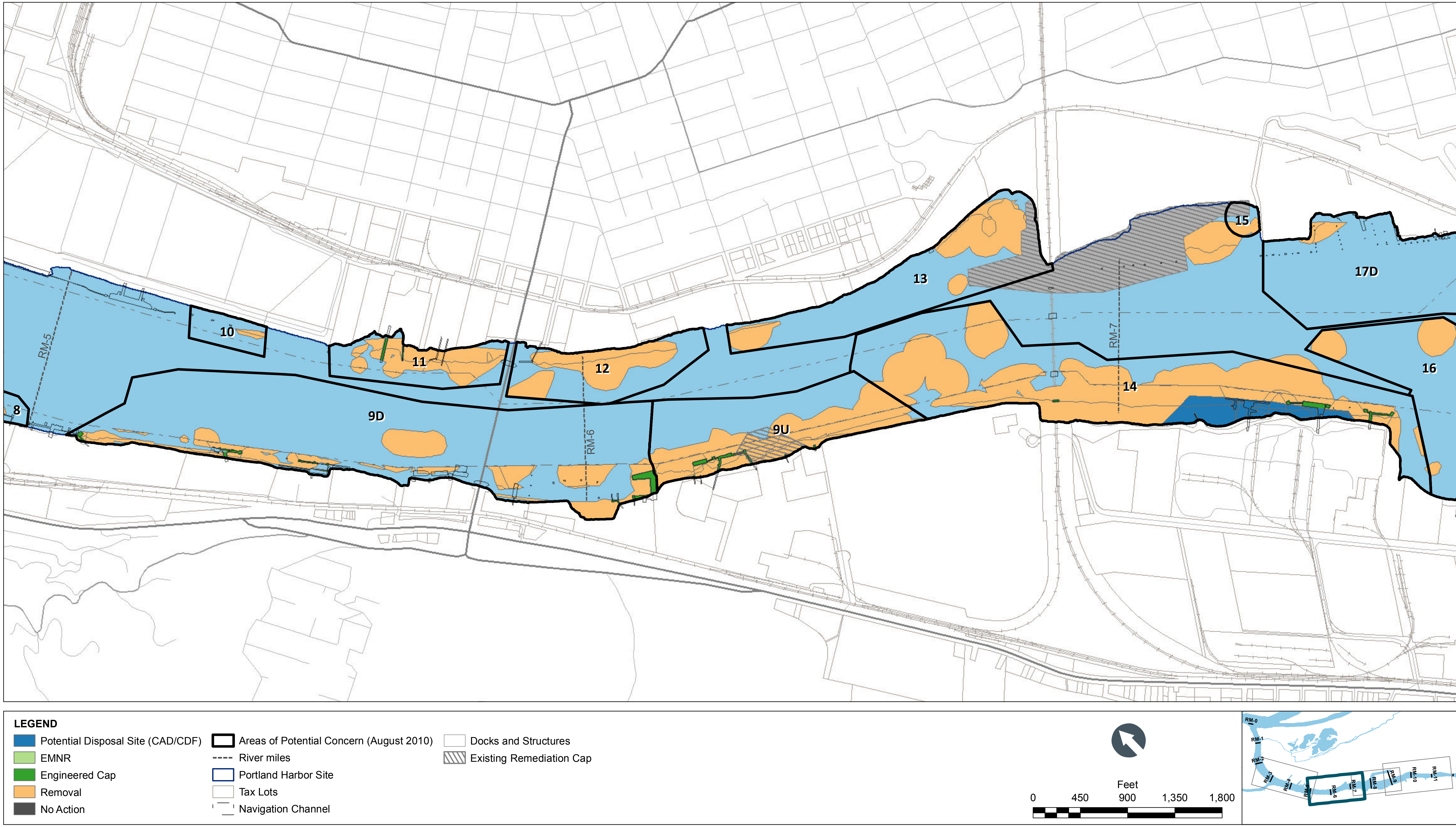

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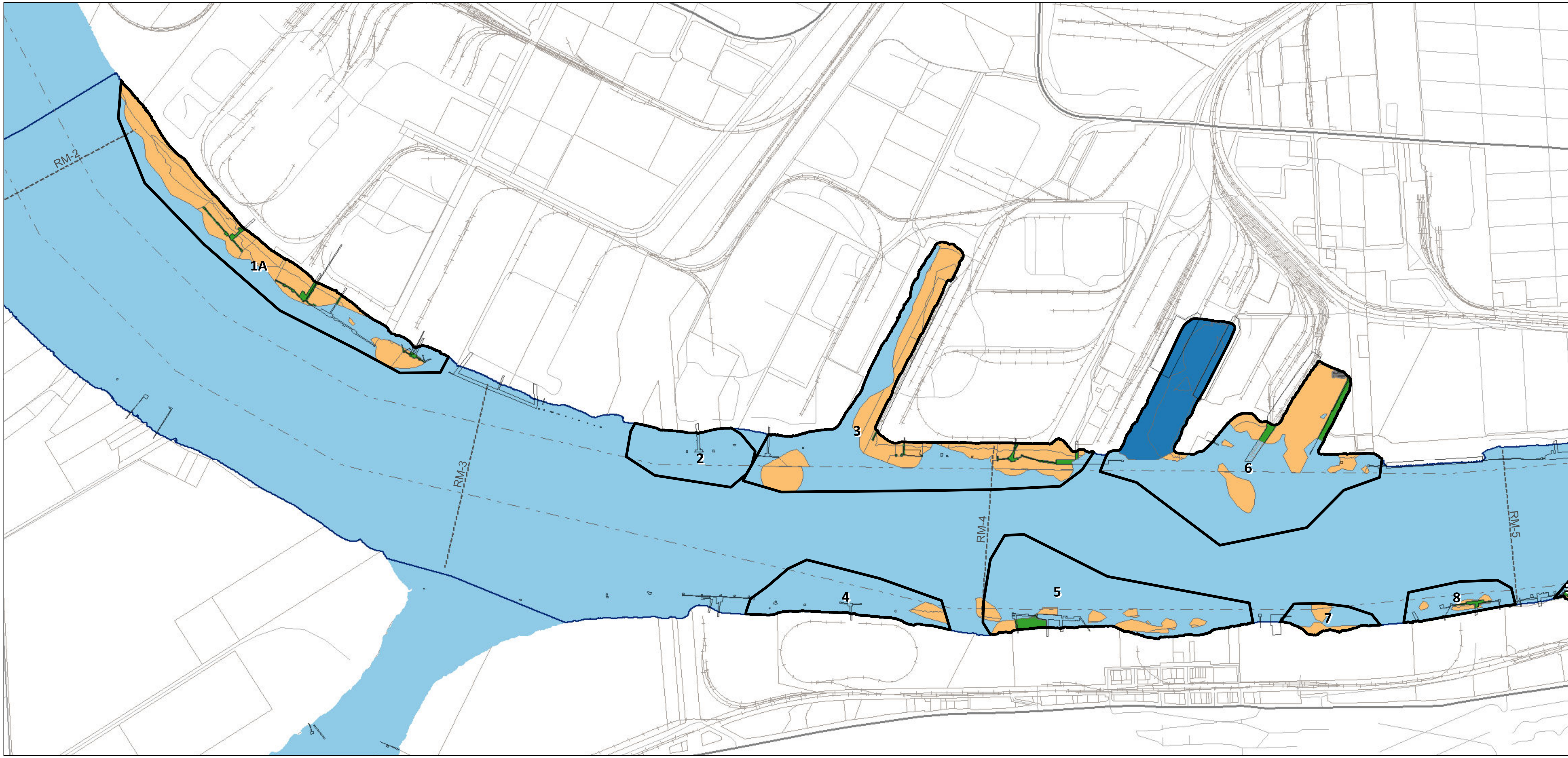
Figure 7.2-5c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Removal Focused
Segment 3: AOPCs 9D - 14



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 500 1,000 1,500 2,000

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Figure 7.2-5d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Removal Focused
Segment 4: AOPCs 1-8

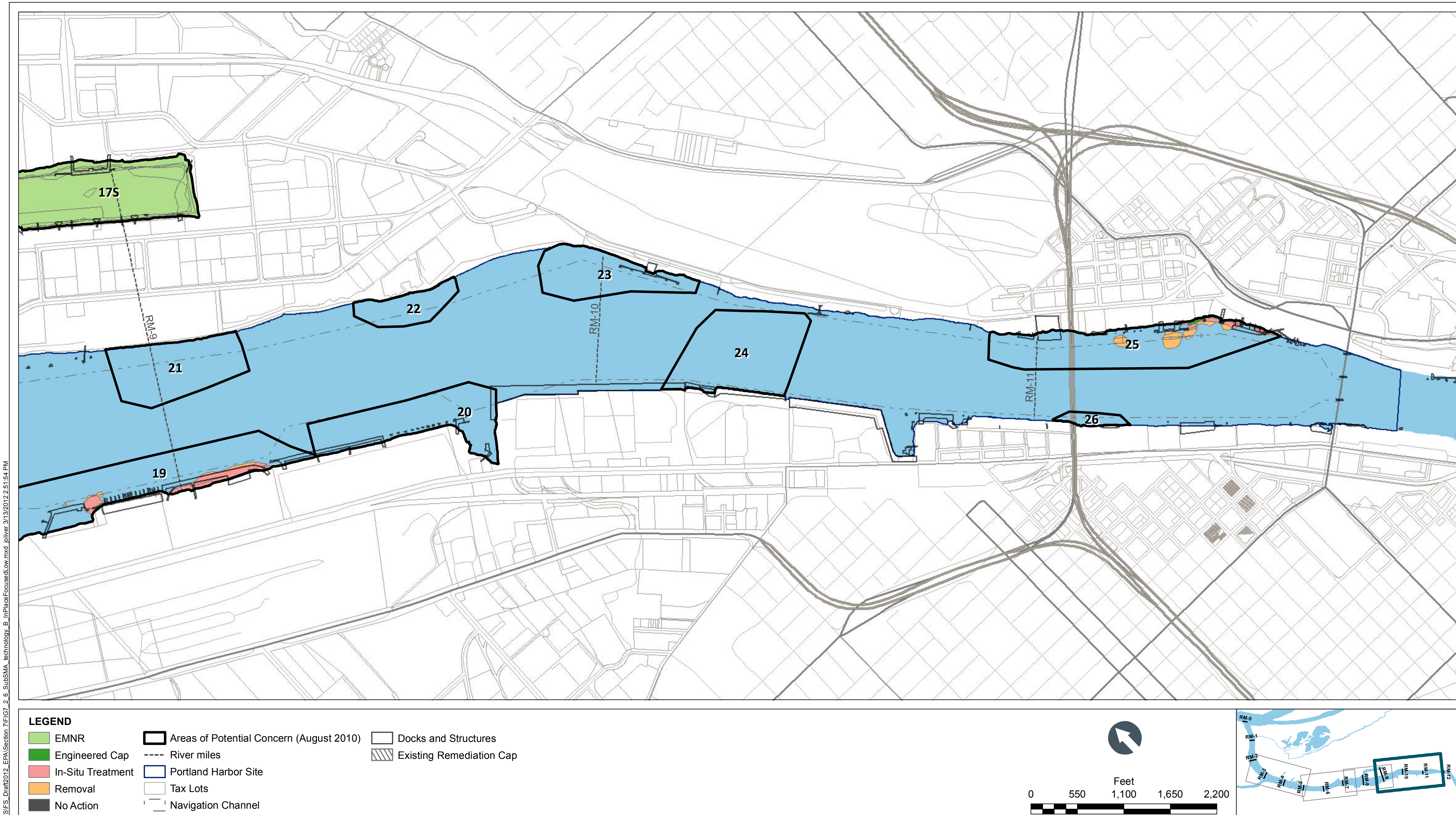

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Figure 7.2-6a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Integrated
Segment 1: AOPCs 20-26

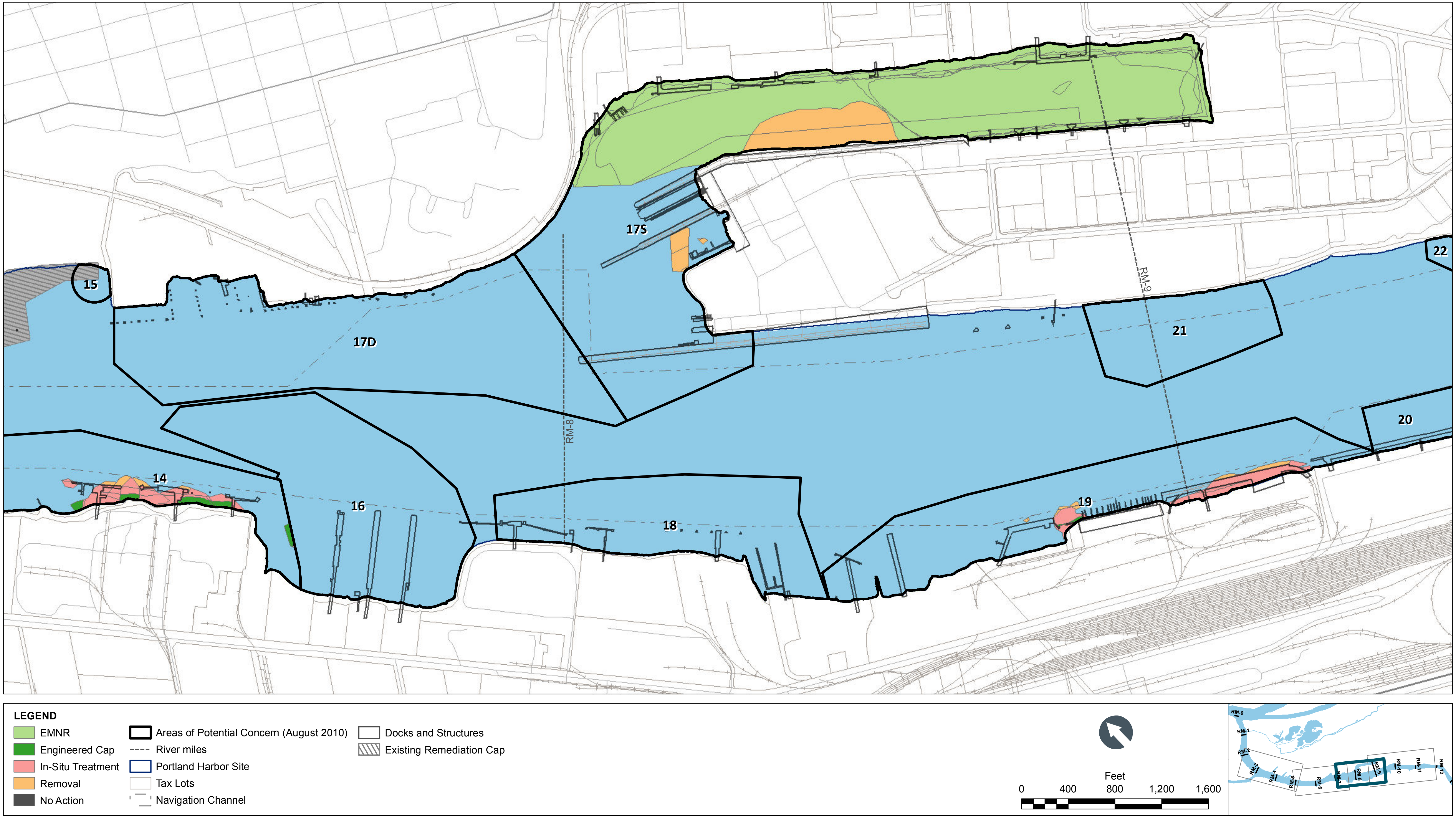

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Figure 7.2-6b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Integrated
Segment 2: AOPCs 15-19

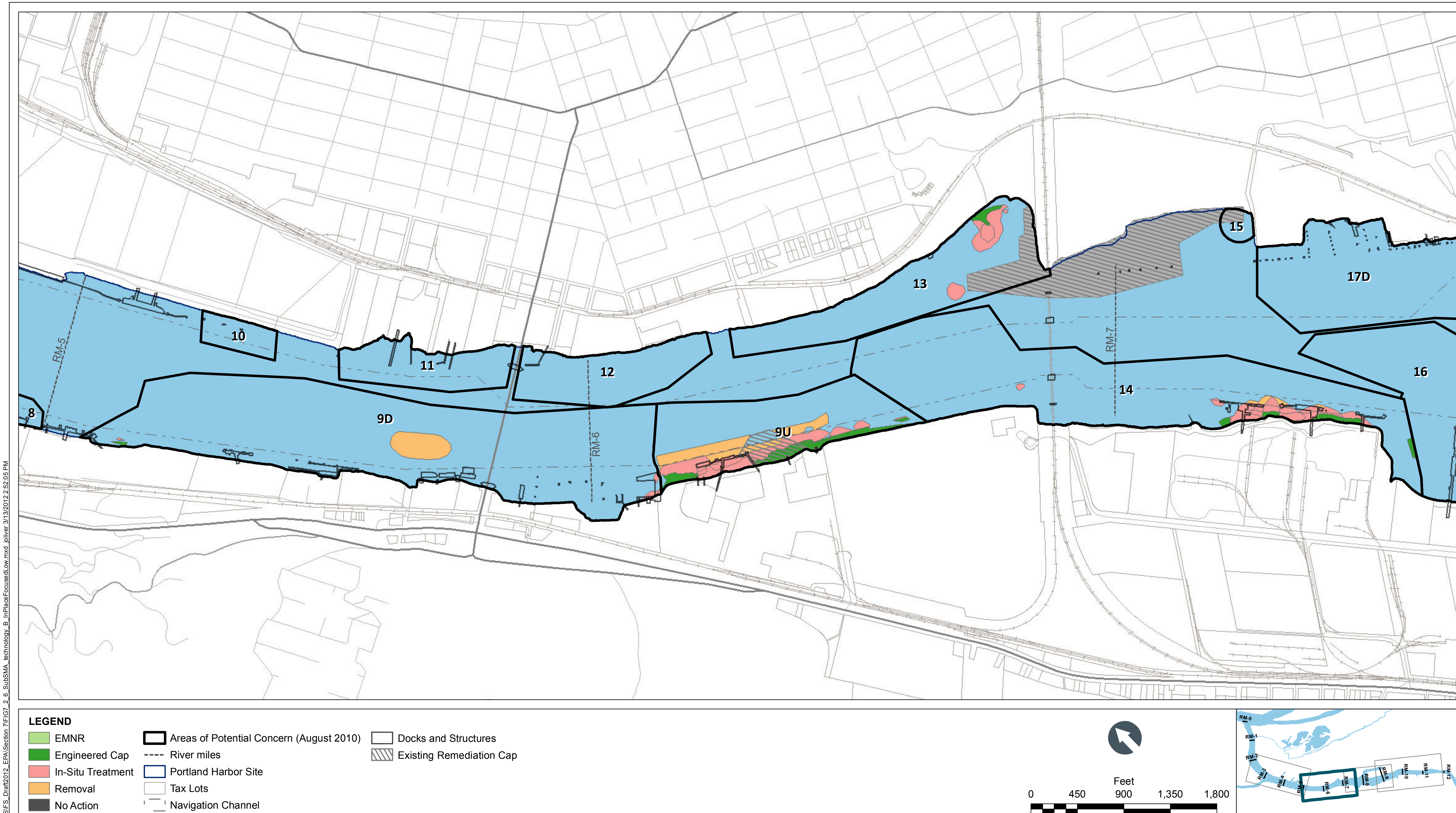

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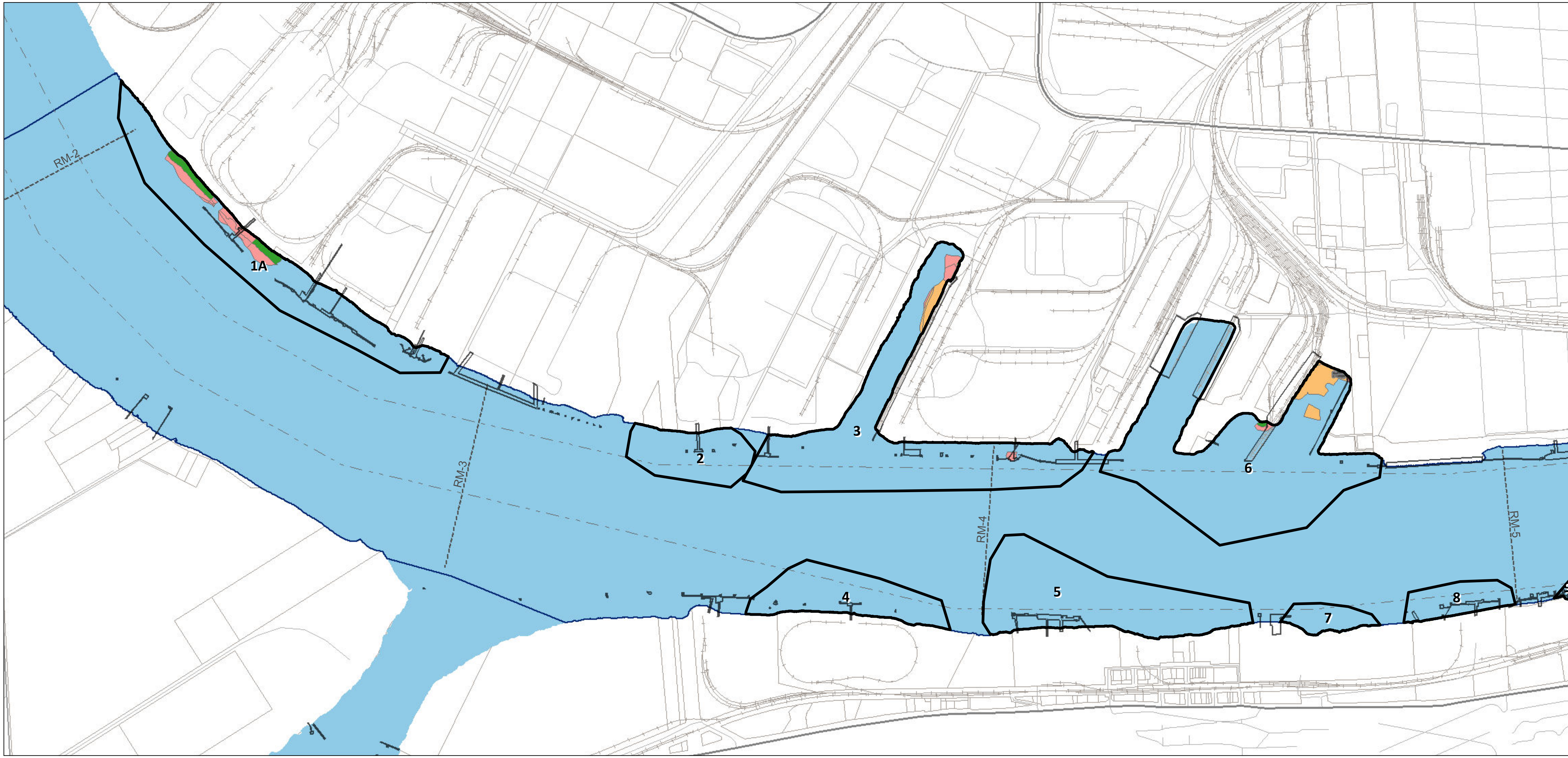
Figure 7.2-6c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Integrated
Segment 3: AOPCs 9D - 14



LEGEND

- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 500 1,000 1,500 2,000

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Figure 7.2-6d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative B - Integrated
Segment 4: AOPCs 1-8

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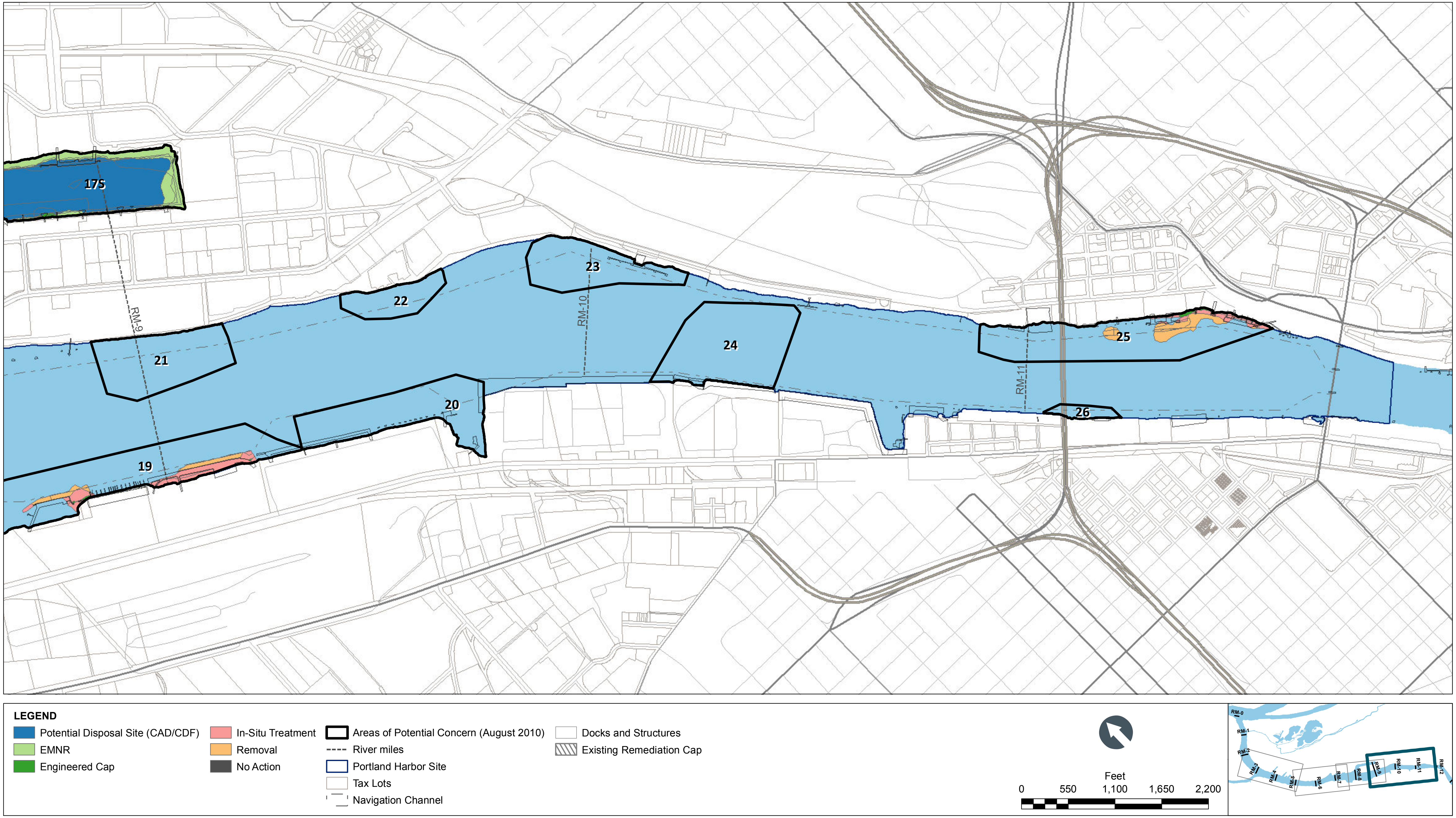

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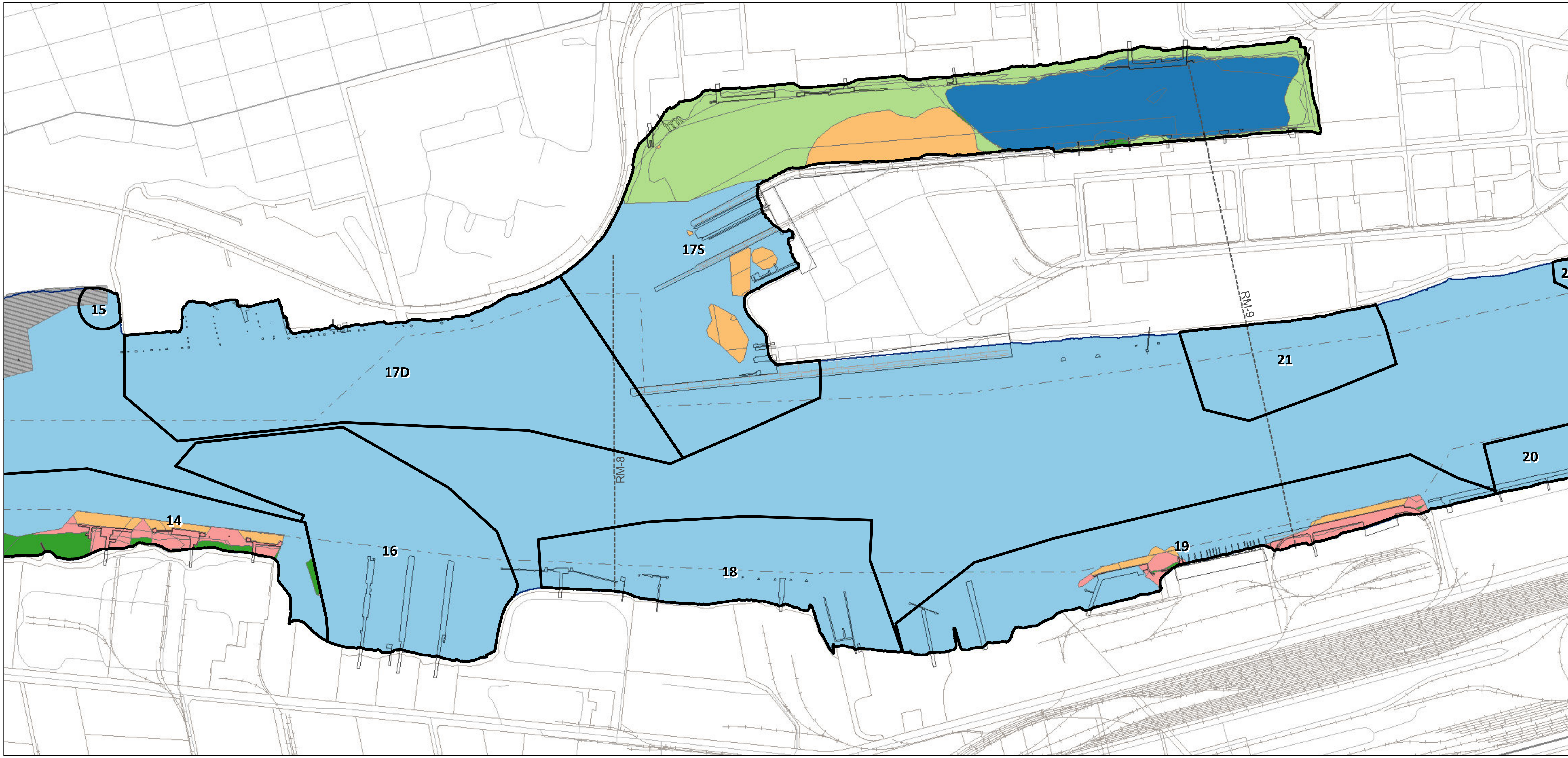
Figure 7.2-7a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Integrated
Segment 1: AOPCs 20-26



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 400 800 1,200 1,600

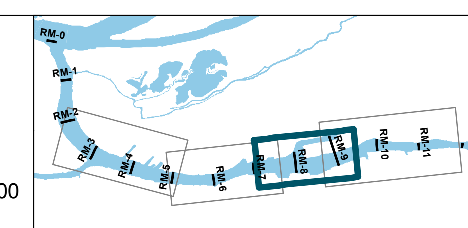


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Figure 7.2-7b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Integrated
Segment 2: AOPCs 15-19

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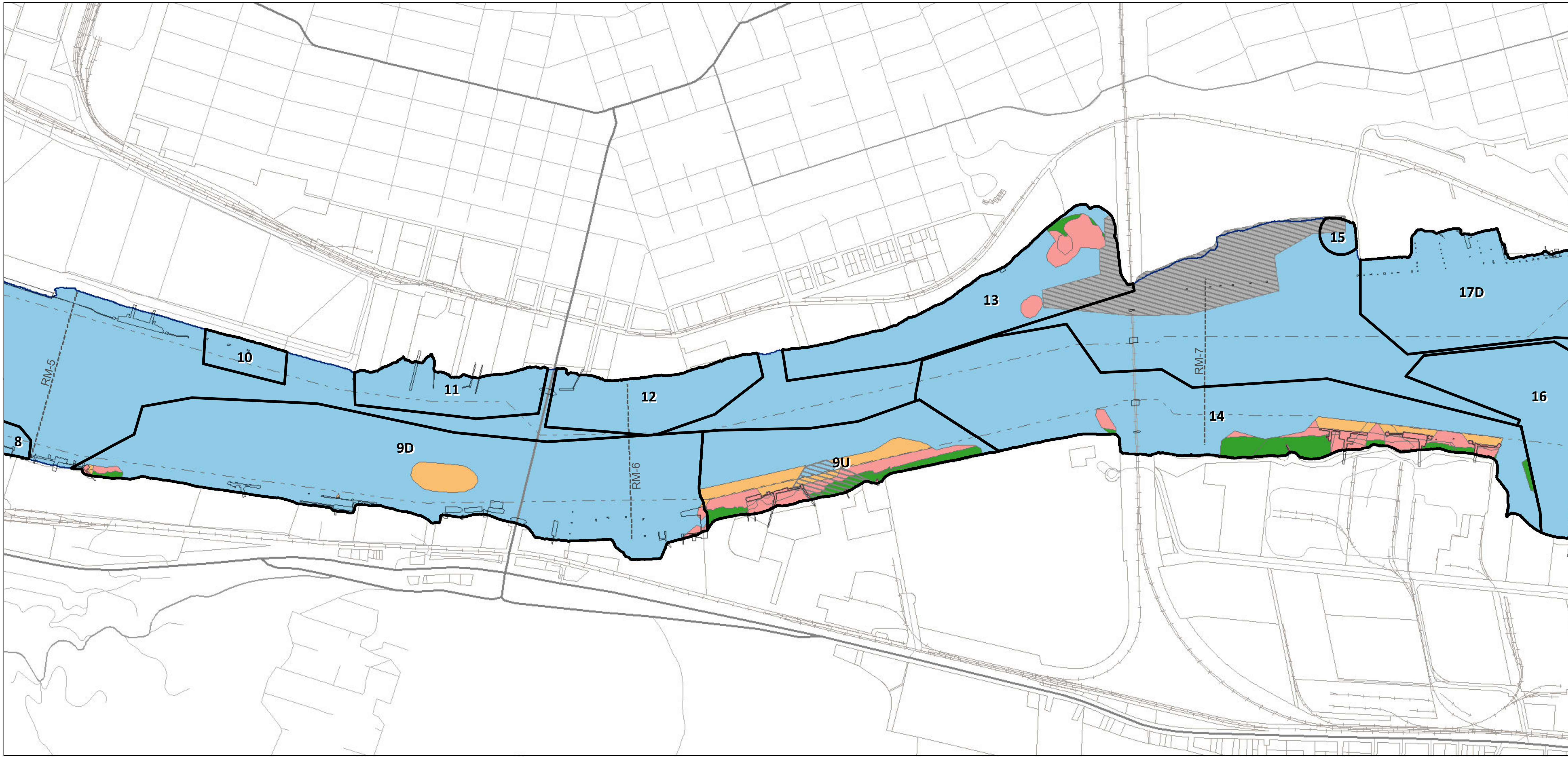

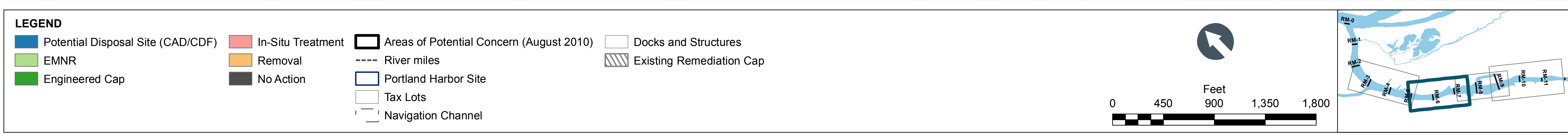

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Figure 7.2-7c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Integrated
Segment 3: AOPCs 9D - 14

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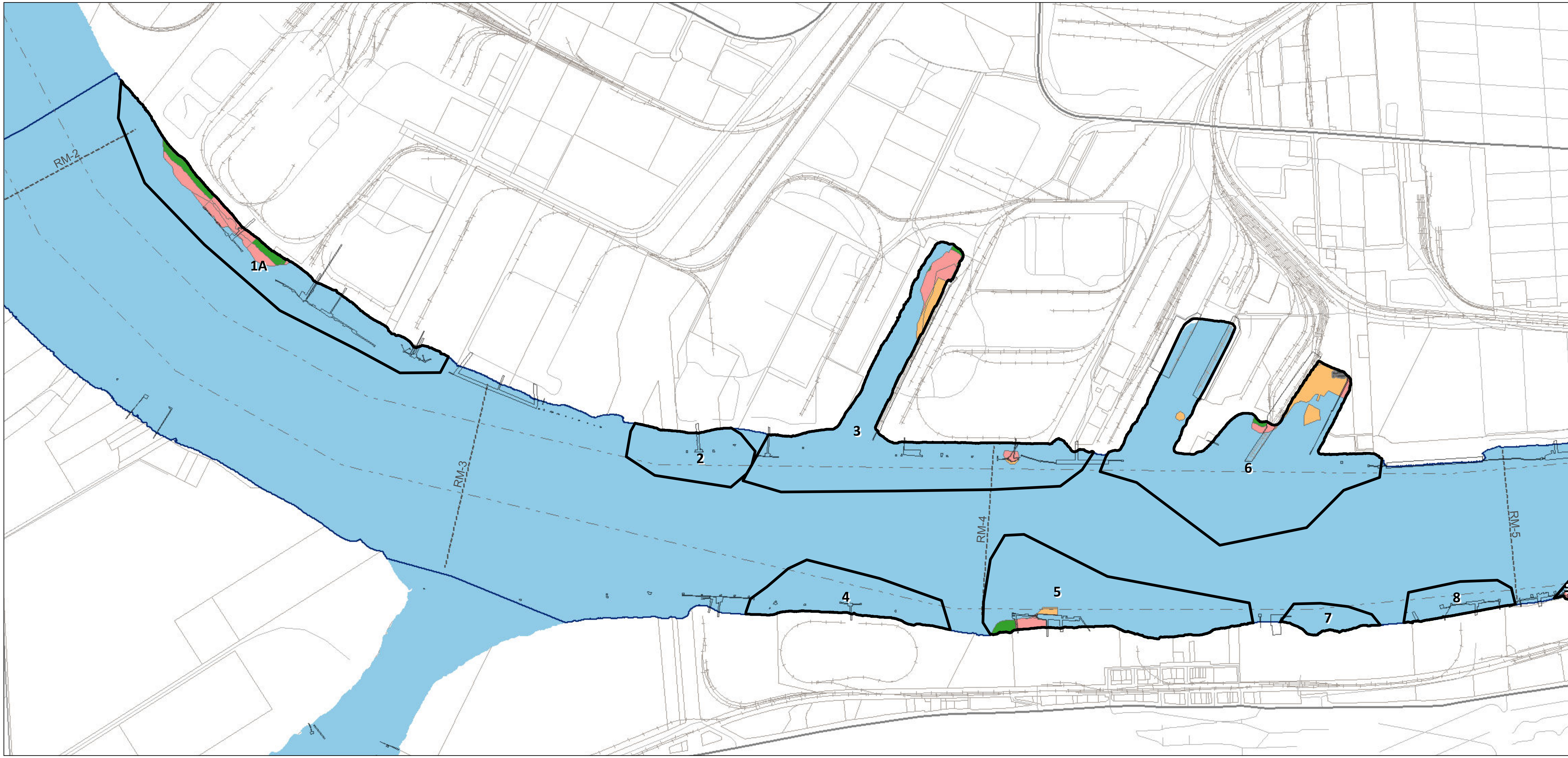

LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 500 1,000 1,500 2,000

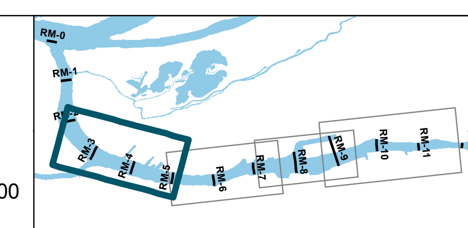

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Figure 7.2-7d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative C - Integrated
Segment 4: AOPCs 1-8

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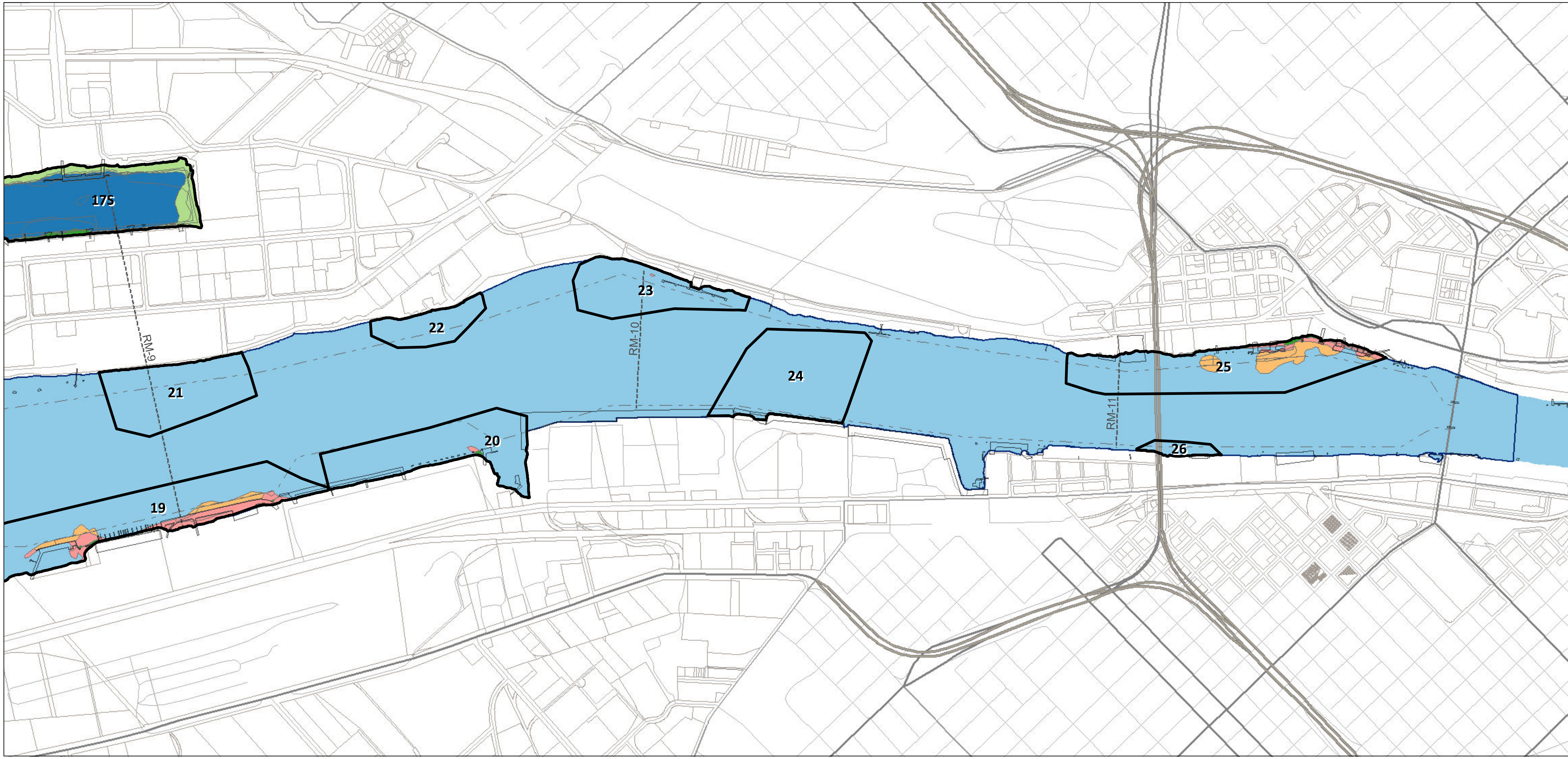

LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 550 1,100 1,650 2,200

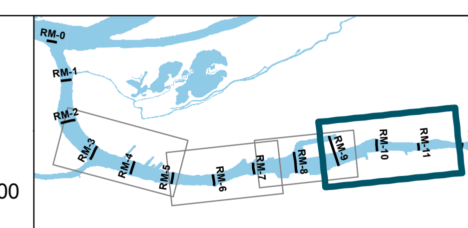

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Figure 7.2-8a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Integrated
Segment 1: AOPCs 20-26

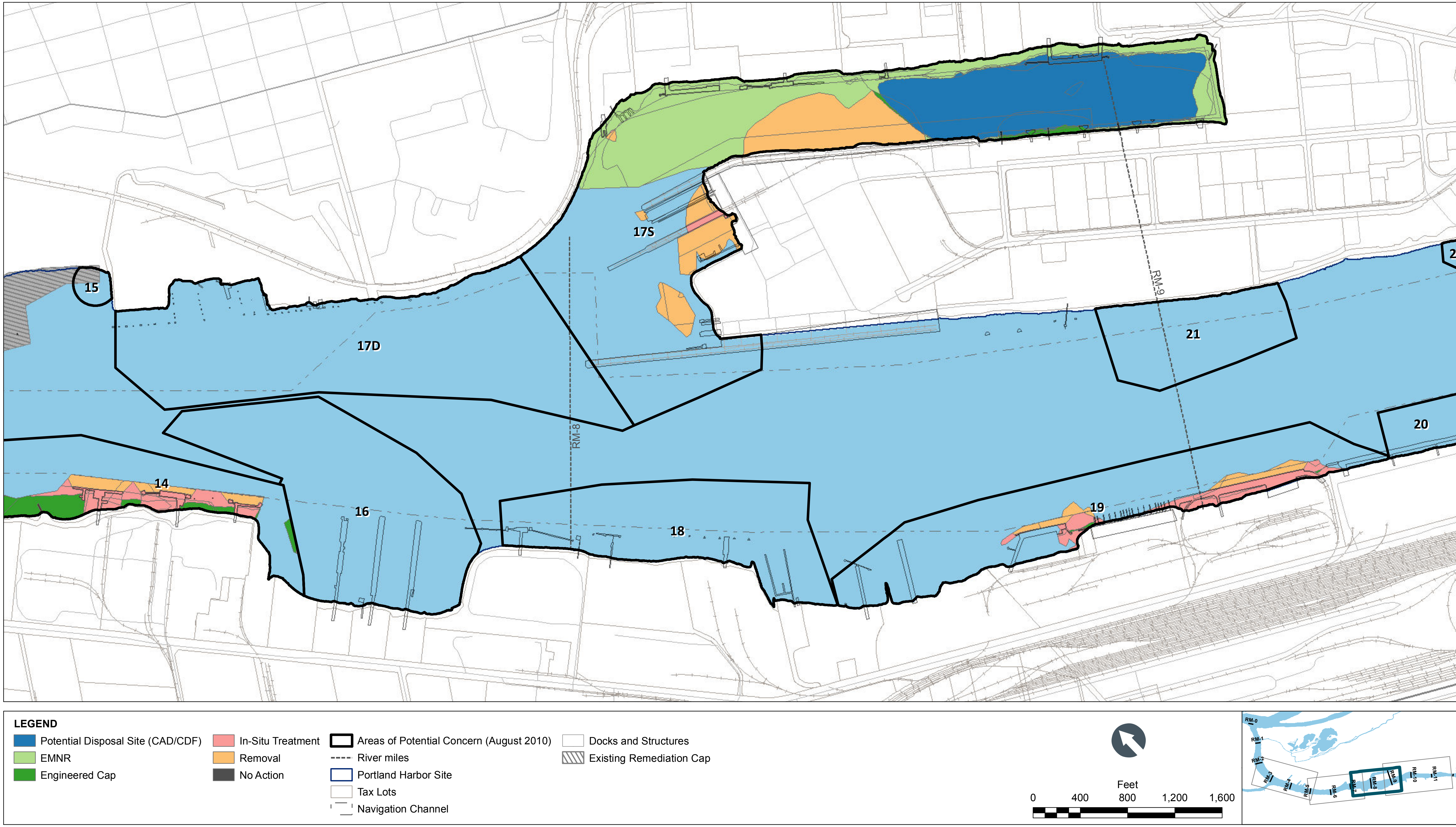

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Figure 7.2-8b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Integrated
Segment 2: AOPCs 15-19

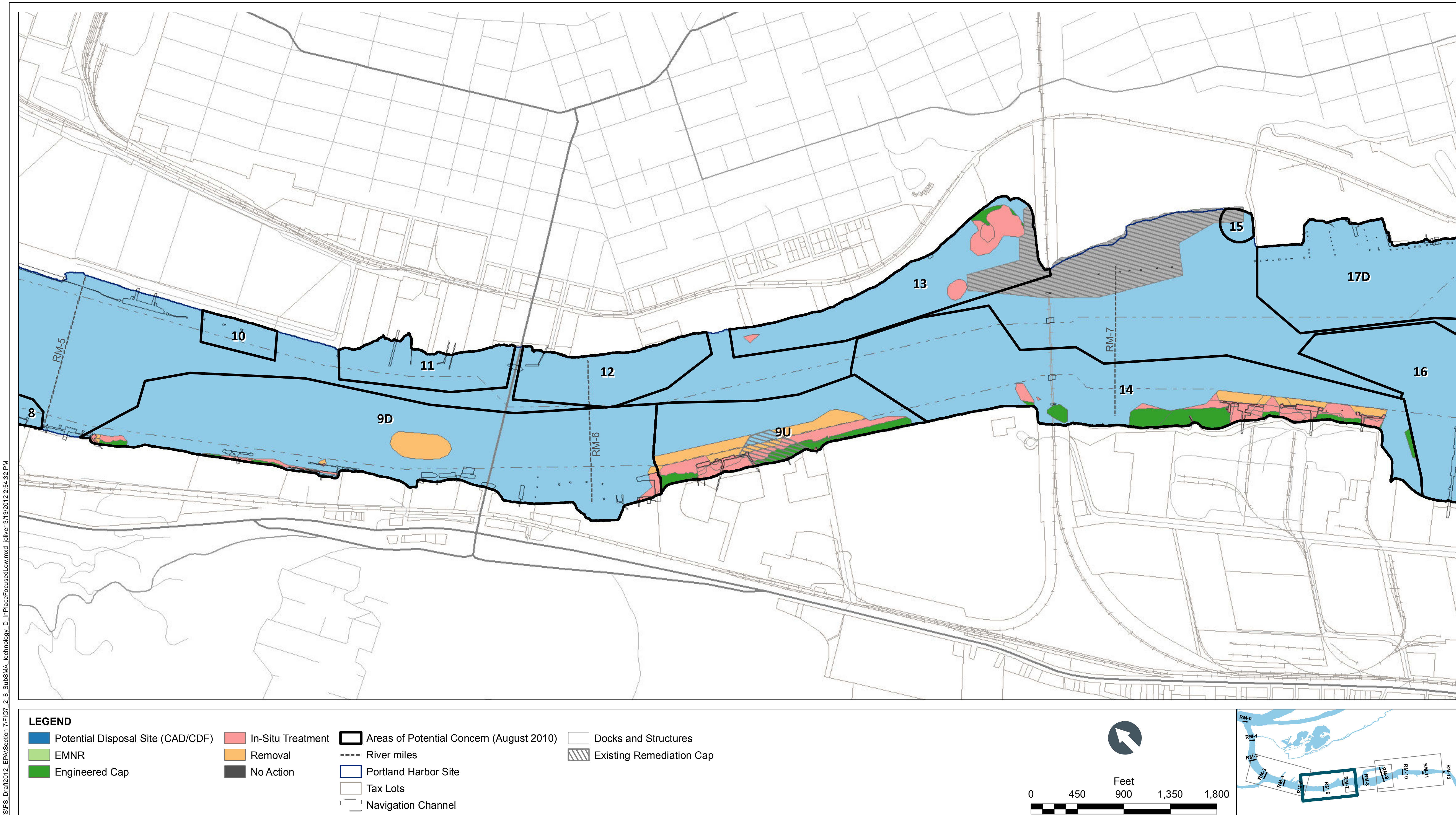

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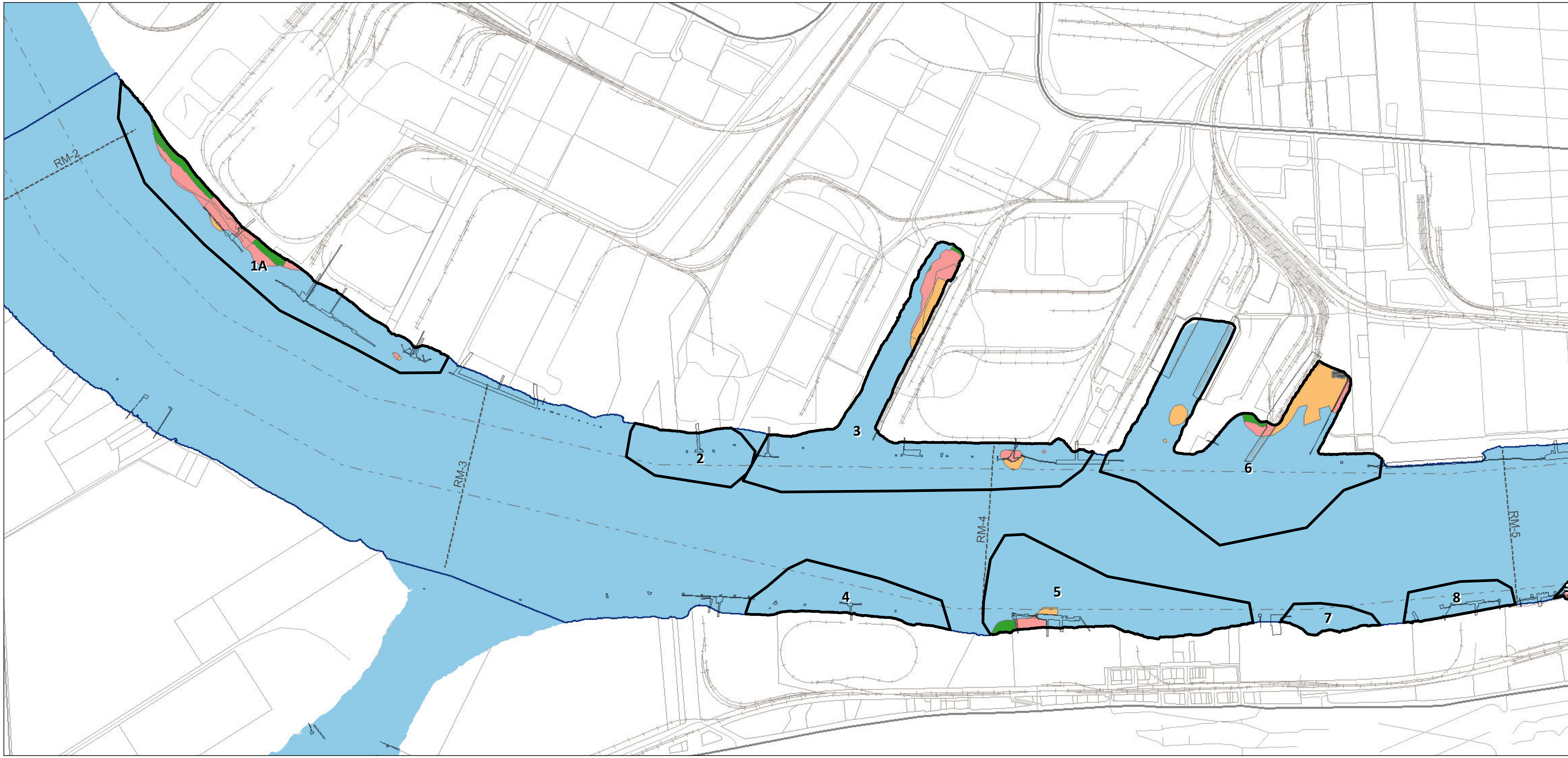
Figure 7.2-8c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Integrated
Segment 3: AOPCs 9D - 14



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet
0 500 1,000 1,500 2,000

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Figure 7.2-8d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative D - Integrated
Segment 4: AOPCs 1-8

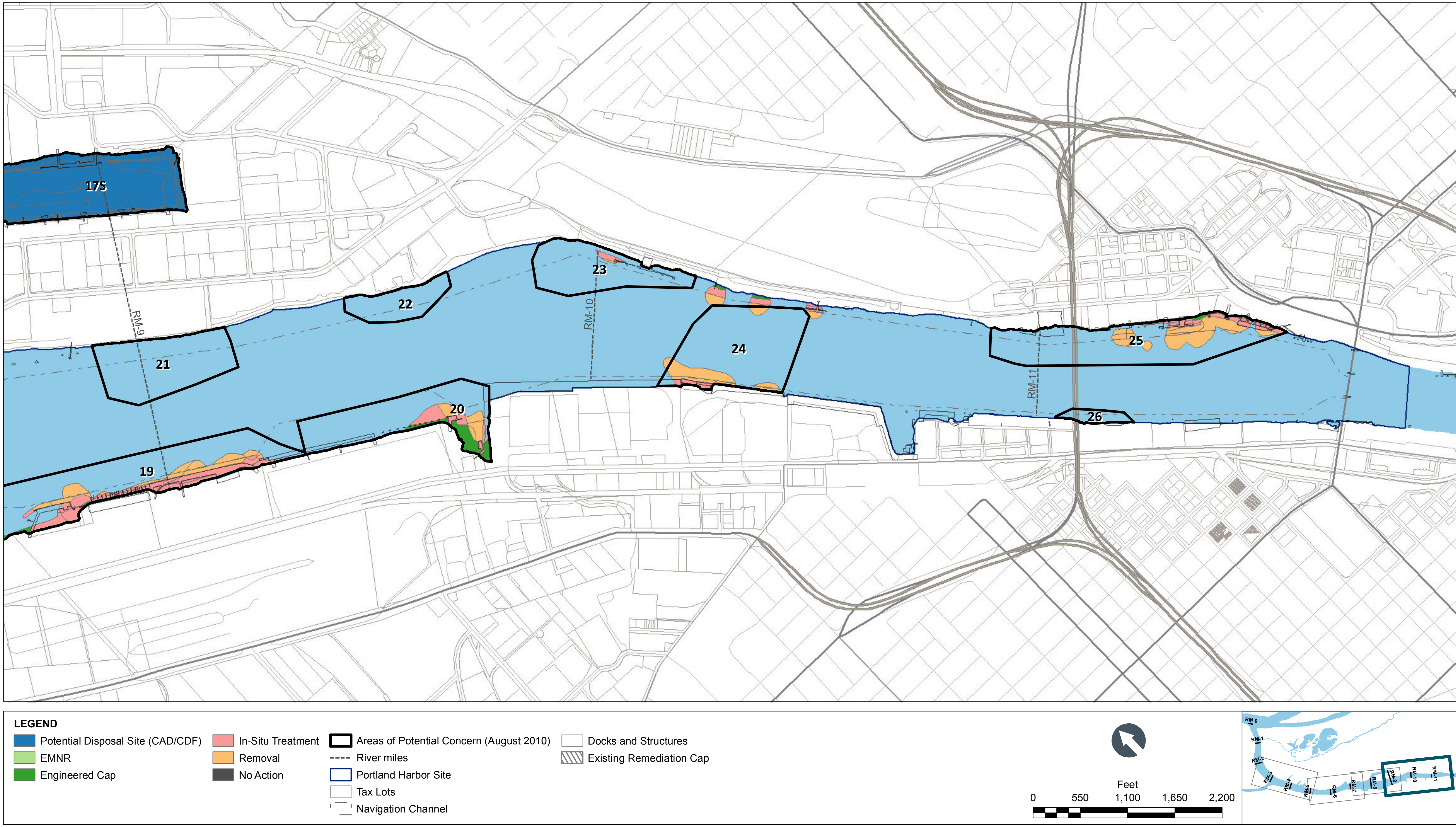

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Figure 7.2-9a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Integrated
Segment 1: AOPCs 20-26

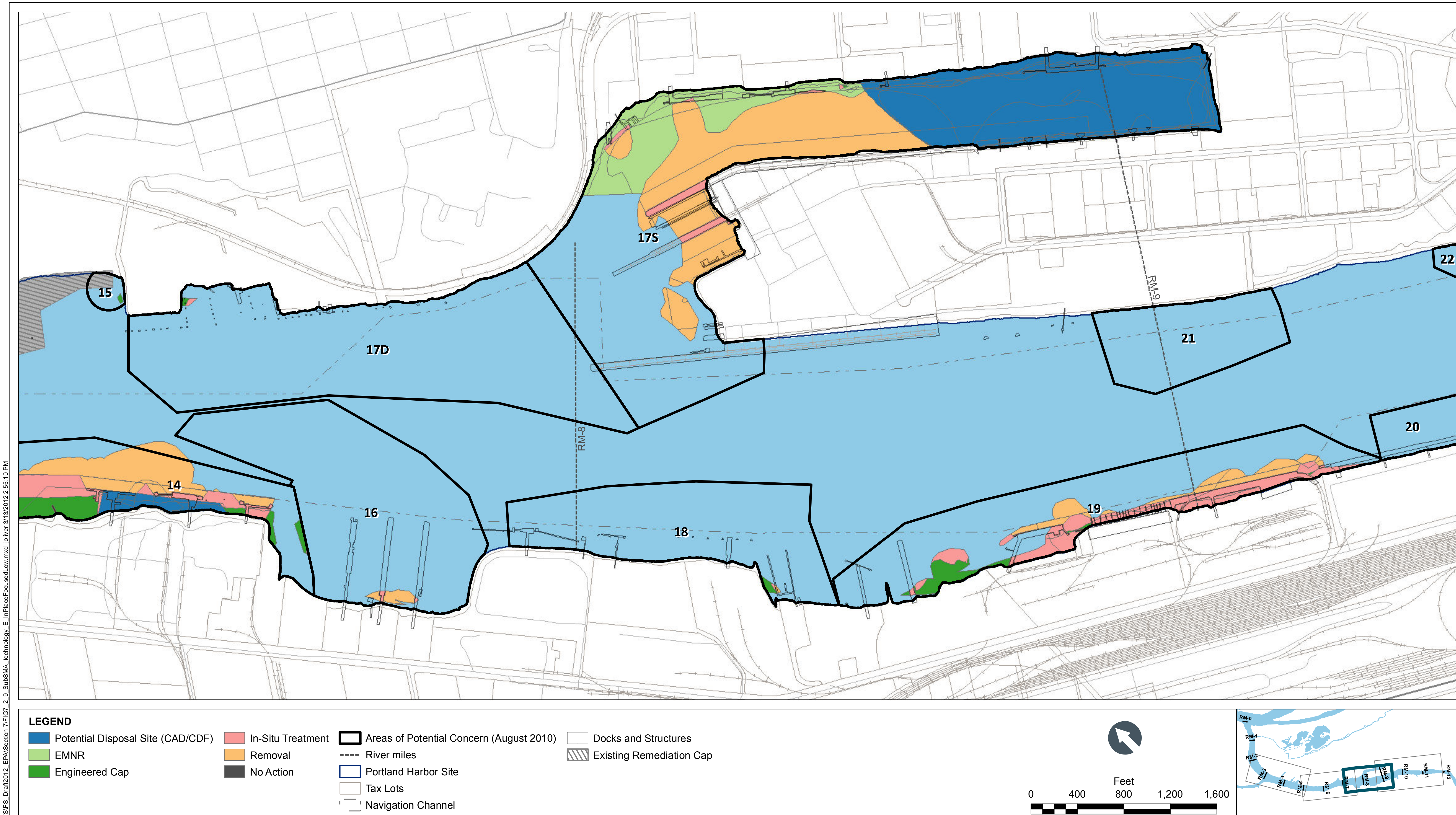

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Figure 7.2-9b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Integrated
Segment 2: AOPCs 15-19

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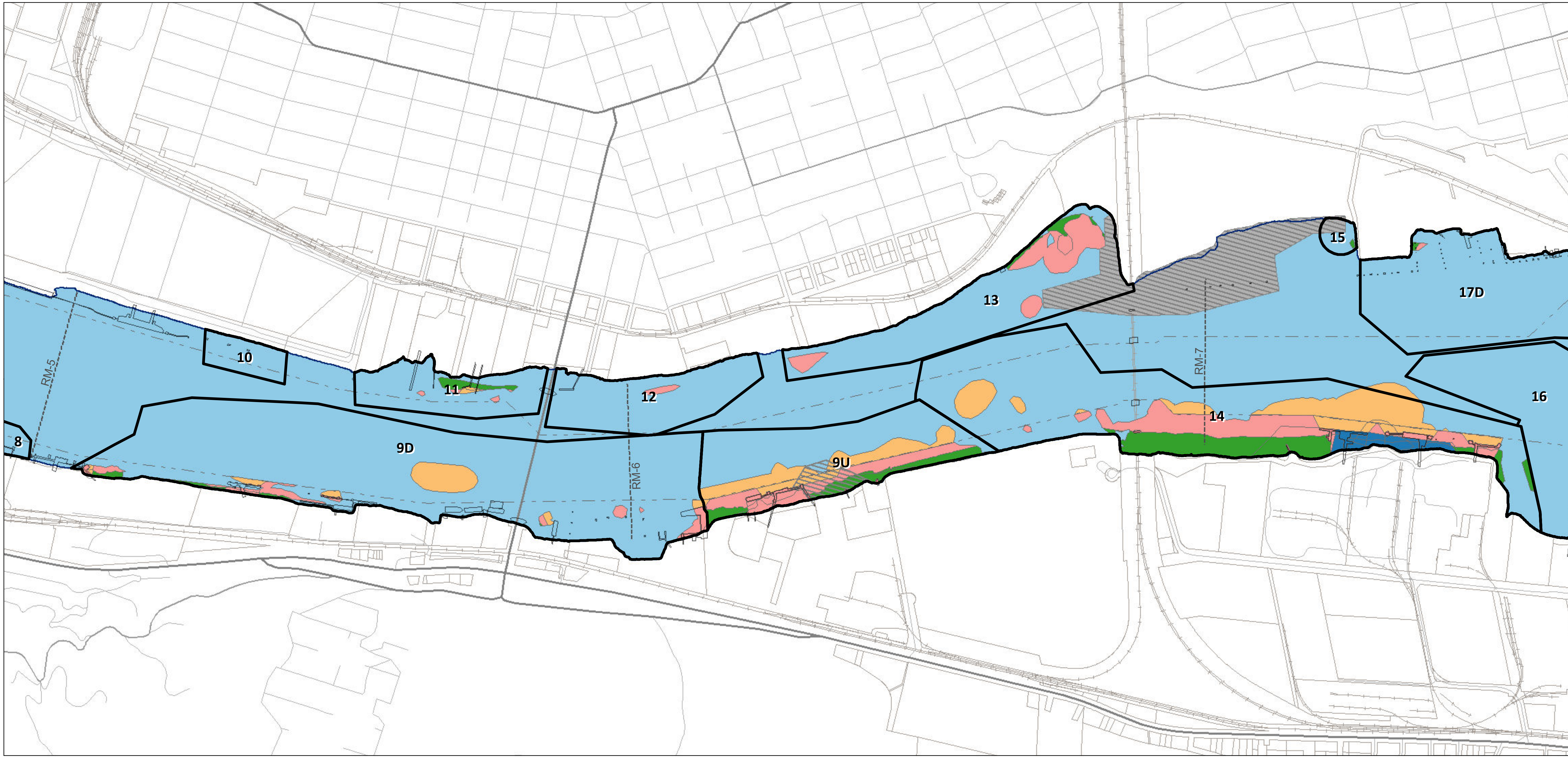

LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet
0 450 900 1,350 1,800

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Figure 7.2-9c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Integrated
Segment 3: AOPCs 9D - 14

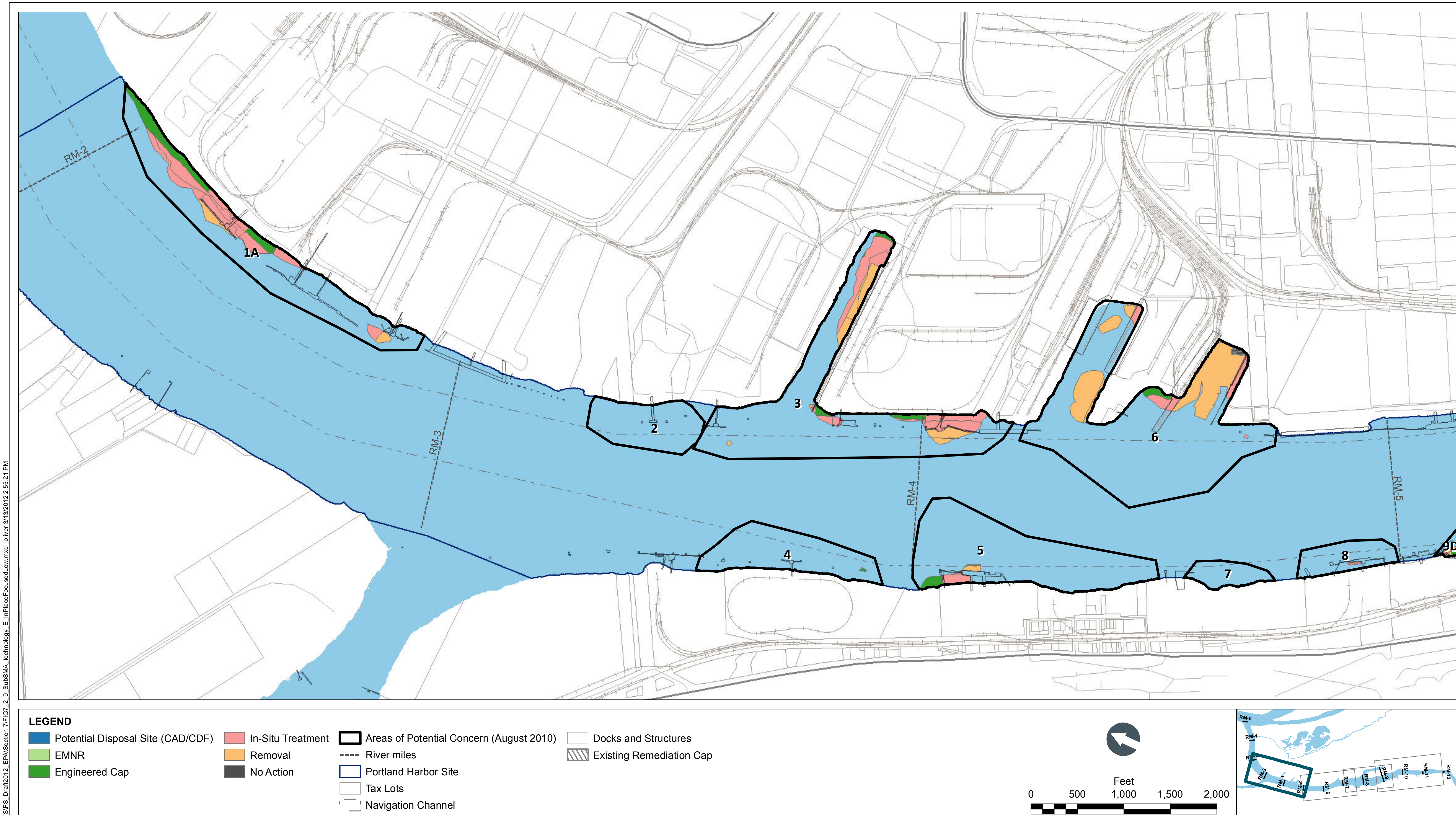

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Figure 7.2-9d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative E - Integrated
Segment 4: AOPCs 1-8

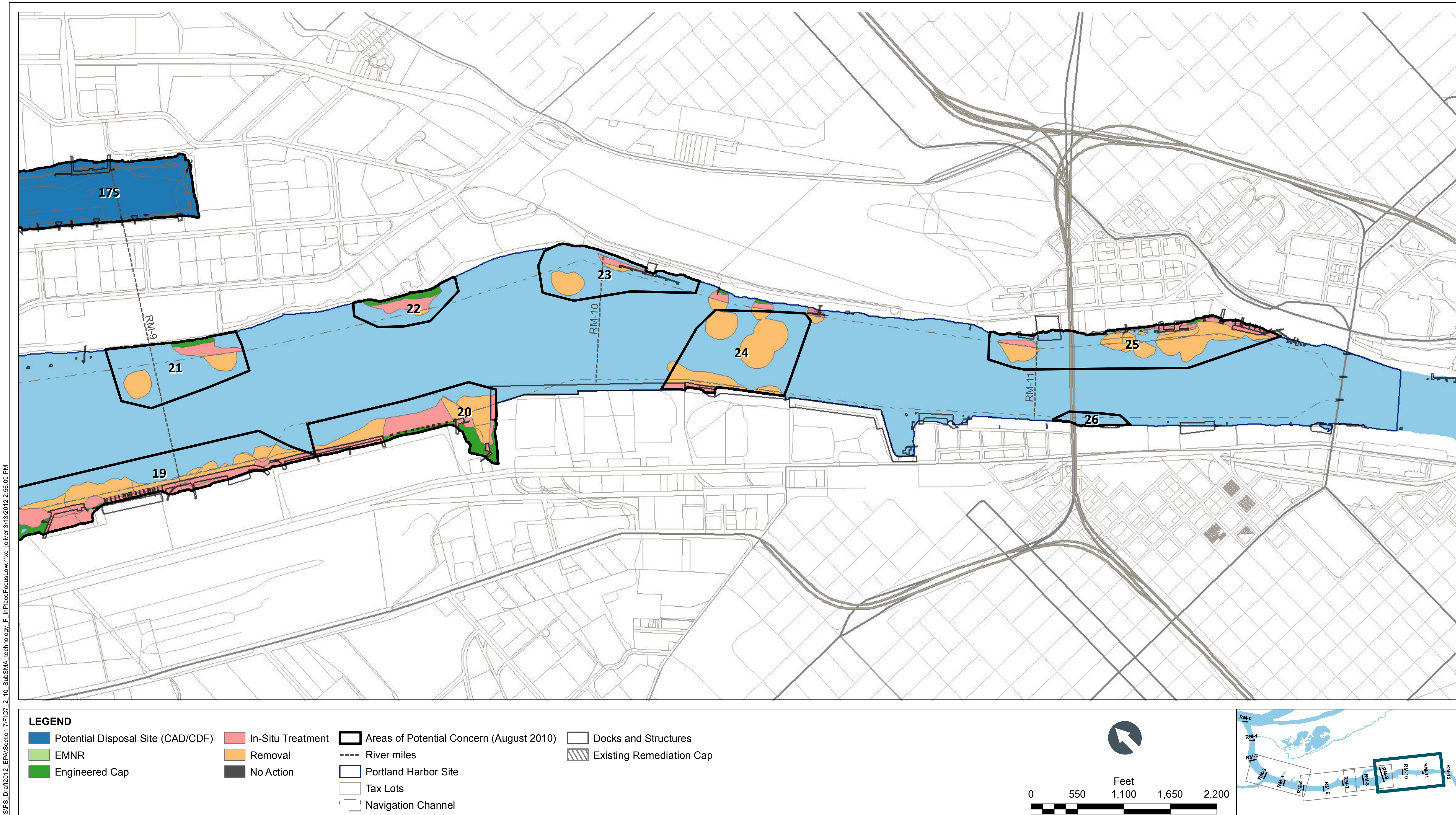

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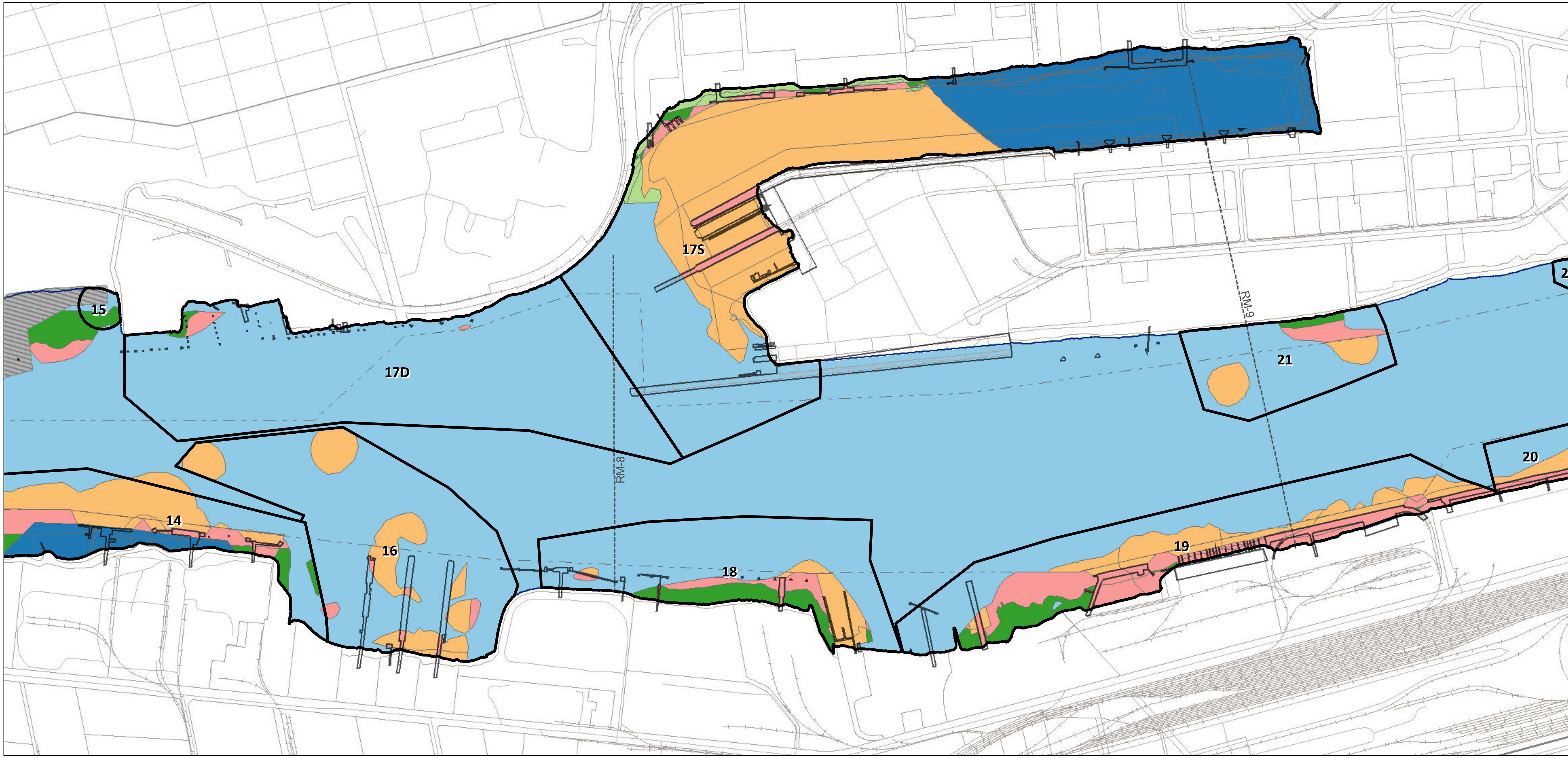
Figure 7.2-10a
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Integrated
Segment 1: AOPCs 20-26



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet
0 400 800 1,200 1,600

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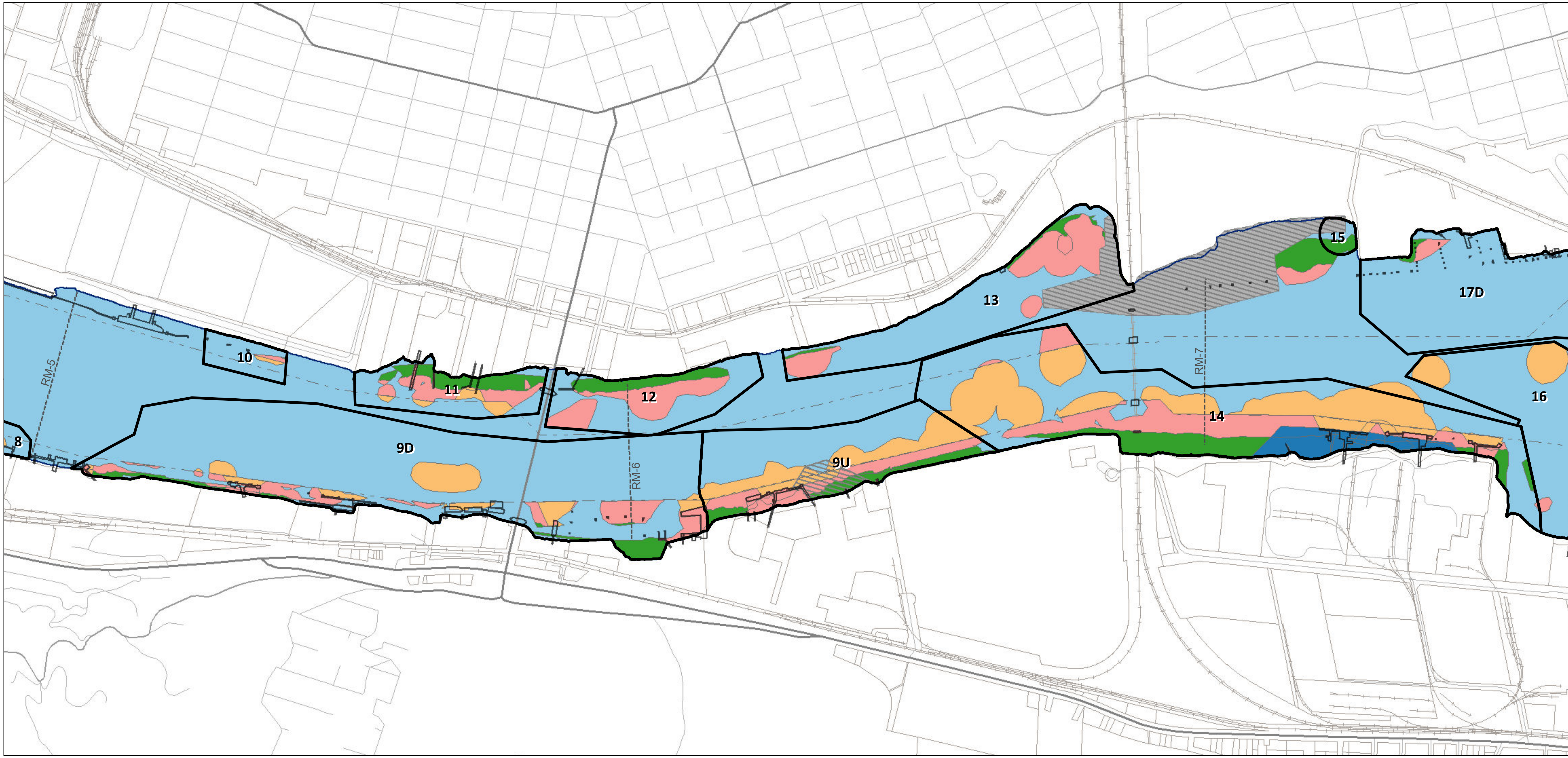
Figure 7.2-10b
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Integrated
Segment 2: AOPCs 15-19



LEGEND

Potential Disposal Site (CAD/CDF)	In-Situ Treatment	Areas of Potential Concern (August 2010)
EMNR	Removal	River miles
Engineered Cap	No Action	Portland Harbor Site
		Tax Lots
		Navigation Channel
Docks and Structures		
Existing Remediation Cap		

Feet

0 450 900 1,350 1,800

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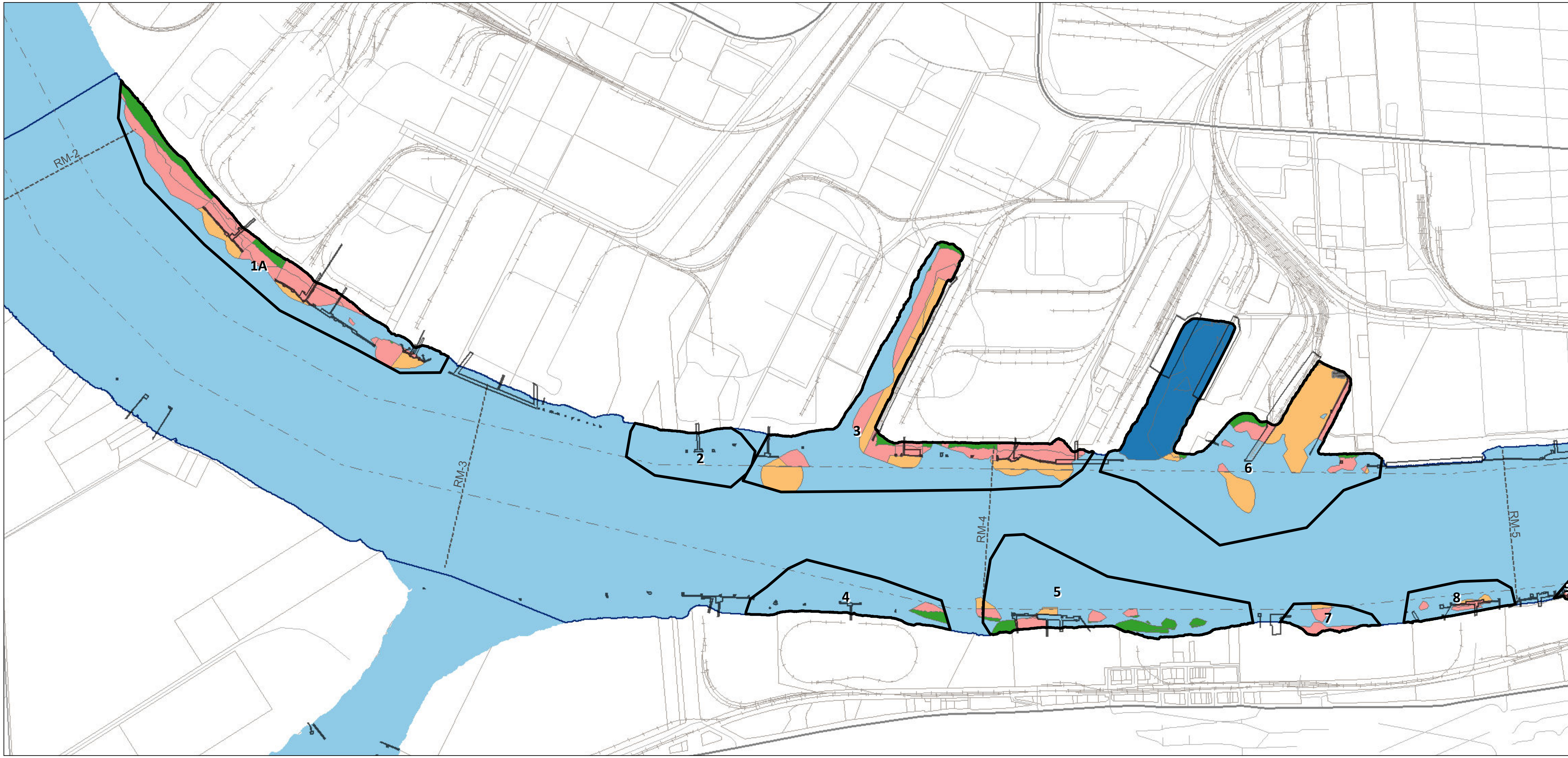
Figure 7.2-10c
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Integrated
Segment 3: AOPCs 9D - 14



LEGEND

- Potential Disposal Site (CAD/CDF)
- EMNR
- Engineered Cap
- In-Situ Treatment
- Removal
- No Action
- Areas of Potential Concern (August 2010)
- River miles
- Portland Harbor Site
- Tax Lots
- Navigation Channel
- Docks and Structures
- Existing Remediation Cap

Feet

0 500 1,000 1,500 2,000

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Figure 7.2-10d
Portland Harbor RI/FS
Draft Feasibility Study
Alternative F - Integrated
Segment 4: AOPCs 1-8

Table 7.0-1. Summary Description of Draft FS Comprehensive Alternatives for Portland Harbor

No.	Name	PCB RAL (ppb)	BaPEq RAL (ppb)	Sum DDE RAL (ppb)	Sum DDD RAL (ppb)	Sum DDT RAL (ppb)	2,3,4,7,8 PCDF RAL (ppb)	Benthic Toxicity	Technology Options	Total SMA Areas (acres)	Total SMA Volume Removed (cy)	Example Disposal Sites	In Place Remed-iation Area** (acres)	Dredge Area (acres)	Active Area Confined Beneath CAD or CDF (acres)	EMNR Area (acres)	Estimated Construction Duration (yr)	Estimated Net Present Value Cost ($M) Low	High
A	No action	None	None	None	None	None	None	None	None	NA	0	NA	NA	NA	NA	NA	NA	NA	NA
B-i	INTEGRATED – Active remediation of highest exposure areas (above maximum incremental reduction); MNR to achieve risk targets	1,000	20000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 10 (estimated) MQ > 0.7	In Place Technologies(a) above RAL where implementable (e.g., excluding future dredge areas)	49	198,000 to 293,000	Upland D	26	23	0	75	2	$ 169	$ 250
B-r	REMOVAL – Active remediation of highest exposure areas (above maximum incremental reduction); MNR to achieve risk targets	1,000	20000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 10 (estimated) MQ > 0.7	Dredging above RAL where implementable (e.g., with offsets from structures and slopes); otherwise in-place technologies** above RAL	49	541,000 to 783,000	Swan Island CAD, Upland D	7	42	0	41	6	$ 228	$ 330
C-i	INTEGRATED – Set RALs based on maximum incremental reduction; more reliance on active remediation (vs. MNR) to achieve risk targets	750	15000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	In Place Technologies(a) above RAL where implementable (e.g., excluding future dredge areas)	76	314,000 to 459,000	Swan Island CAD, Upland D	42	34	0	40	3	$ 231	$ 345
C-r	REMOVAL – Set RALs based on maximum incremental reduction; more reliance on active remediation (vs. MNR) to achieve risk targets	750	15000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	Dredging above RAL where implementable (e.g., with offsets from structures and slopes); otherwise in-place technologies** above RAL	76	776,000 to 1,127,000	T4, Arkema (1 Berth), Upland D	10	63	3	73	7	$ 304	$ 449
D-i	INTEGRATED – Set RALs to achieve majority of the more realistic risk targets through active remediation (i.e., at Year 0)	500	8000	200	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	In Place Technologies(a) above RAL where implementable (e.g., excluding future dredge areas)	95	387,000 to 565,000	Swan Island CAD, Upland D	49	43	3	37	3	$ 266	$ 398
D-r	REMOVAL – Set RALs to achieve majority of the more realistic risk targets through active remediation (i.e., at Year 0)	500	8000	200	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	Dredging above RAL where implementable (e.g., with offsets from structures and slopes); otherwise in-place technologies** above RAL	95	914,000 to 1,321,000	T4, Arkema (1 Berth), Upland D	13	78	4	68	8	$ 351	$ 520
E-i	INTEGRATED – Set RALs based on point of minimal change in concentration; achieve most risk targets through active remediation	200	4000[a]	50[b]	100*	150*	0.02*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	In Place Technologies(a) above RAL where implementable (e.g., excluding future dredge areas)	191	936,000 to 1,362,000	Arkema (1 Berth), Swan Island CDF, Upland D	83	91	17	15	7	$ 463	$ 709
E-r	REMOVAL – Set RALs based on point of minimal change in concentration; achieve most risk targets through active remediation	200	4000[a]	50[b]	100*	150*	0.02*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	Dredging above RAL where implementable (e.g., with offsets from structures and slopes); otherwise in-place technologies** above RAL	191	1,775,000 to 2,596,000	T4, Arkema (2 Berth), Swan Island (CDF), Upland D	21	146	25	15	12	$ 568	$ 884
F-i	INTEGRATED – Set RALs at level below point of minimal change and on the asymptote; achieve nearly all possible risk targets through active remediation	75	1500	20[c]	50*	60*	0.01*	Comp. Benthic Risk Areas achieved at Year 0 (MQ > 0.7)	In Place Technologies(a) above RAL where implementable (e.g., excluding future dredge areas)	391	2,129,000 to 3,151,000	T4, Arkema (2 Berths), Swan Island CDF, Upland D	166	176	49	3	15	$ 878	$ 1,389
F-r	REMOVAL – Set RALs at level below point of minimal change and on the asymptote; achieve nearly all possible risk targets through active remediation	75	1500	20[c]	50*	60*	0.01*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7	Dredging above RAL where implementable (e.g., with offsets from structures and slopes); otherwise in-place technologies** above RAL	391	4,195,000 to 6,182,000	T4, Arkema (2 Berths), Swan Island CDF, Upland D	38	304	49	3	28	$ 1,077	$ 1,762

Notes

*EPA directed RALs

** In-Place remedial technologies include a range of process options with similar effectiveness, implementability, and cost, including armored caps, sand caps/covers (EMNR), or in-situ treatment via activated carbon placement or similar, depending on SMA-specific characteristics

a - The LWG recommended a BaPEQ value of 8,000 ppb and EPA directed 4,000 ppb

b - The LWG recommended a sum DDE value of 200 ppb and EPA directed 50 ppb

c - The LWG recommended a sum DDE value of 100 ppb and EPA directed 20 ppb

$M	Million dollars
BaPEq	benzo(a)pyrene equivalent
CAD	confined aquatic disposal
CDF	confined disposal facility
cy	cubic yard
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
EMNR	Enhanced Monitored Natural Recovery
EPA	U S Environmental Protection Agency
FS	Feasibility Study
LWG	Lower Willamette Group
MNR	monitored natural recovery
MQ	Mean Quotient
PCB	polychlorinated biphenyl
PCDF	polychlorinated dibenzofuran
ppb	parts per billion
RAL	remedial action level
SMA	sediment management area
T4	Terminal 4
Upland D	Upland Subtitle D landfill
yr	year

Table 7.1-1. Summary of Alternative RALs for Portland Harbor Draft FS

No.	PCB RAL (ppb)	BaPEq RAL (ppb)	Sum DDE RAL (ppb)	Sum DDD RAL (ppb)	Sum DDT RAL (ppb)	2,3,4,7,8 PCDF RAL (ppb)	Benthic Toxicity
A	None	None	None	None	None	None	None
B	1,000	20000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 10 (estimated) MQ > 0.7
C	750	15000	1,000	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
D	500	8000	200	NA	NA	NA	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
E	200	4000[a]	50[b]	100*	150*	0.02*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
F	75	1500	20[c]	50*	60*	0.01*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7
G	50*	600*	10*	15*	20*	0.005*	Comp. Benthic Risk Areas achieved at Year 0 MQ > 0.7

Notes

*EPA directed RALs.

a - The LWG recommended a BaPEq value of 8,000 ppb and EPA directed 4,000 ppb.

b - The LWG recommended a sum DDE value of 200 ppb and EPA directed 50 ppb

c - The LWG recommended a sum DDE value of 100 ppb and EPA directed 20 ppb.

Acronyms

BaPEq	benzo(a)pyrene equivalent	LWG	Lower Willamette Group
DDD	dichloro-diphenyl-dichloroethane	MQ	Mean Quotient
DDE	dichloro-diphenyl-dichloroethene	PCB	polychlorinated biphenyl
DDT	dichloro-diphenyl-trichloroethane	PCDF	polychlorinated dibenzofuran
EPA	U.S. Environmental Protection Agency	ppb	parts per billion
FS	Feasibility Study	RAL	remedial action level

Table 7.1-2. Summary of Alternative Acreage and Estimated Site-wide Time-Zero SWACs Achieved for Alternatives A through G for Portland Harbor Draft FS

Alternative	Acres	Esimated Time-Zero SWACs (ppb)					
		Total PCBs	BaPEq*	Sum DDD	Sum DDE	Sum DDT	2,3,4,7,8-PCDF
Alt A - No Action	0	84	1026	8.8	4.2	20	0.0114
Alt B	49	44	410	5.7	3.1	7.9	0.0049
Alt C	76	41	380	5.0	2.8	6.0	0.0039
Alt D	95	38	340	4.9	2.7	5.9	0.0038
Alt E	191	33	274	3.5	2.2	3.8	0.0008
Alt F	391	26	180	3.0	2.0	3.0	0.0007
Alt G	591	24	112	2.5	1.9	2.2	0.0006

* SWACs for shoreline areas outside the navigation channel only.

Acronyms

BaPEq	benzo(a)pyrene equivalent
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
FS	Feasibility Study
PCB	polychlorinated biphenyl
PCDF	polychlorinated dibenzofuran
ppb	parts per billion
RAL	remedial action level
SMA	sediment management area
SWAC	Surface weighted average concentrations

Table 7.1-3. Summary of Alternative G Estimates of Duration and Costs as Compared to Alternatives B through F

Alternative	Area (acres)	Duration (years)	Cost ($ Millions)
No Action	0	0	$ -
B-i	49	2	$ 216
C-i	76	3	$ 290
D-i	95	3	$ 333
E-i	191	7	$ 569
F-i	391	15	$ 1,101
Alt G-i	591	23	$ 1,527
B-r	49	6	$ 276
C-r	76	7	$ 371
D-r	95	8	$ 428
E-r	191	12	$ 696
F-r	391	28	$ 1,344
Alt G-r	591	40	$ 1,833

Table 7.2-1. Application of Technologies by subSMA Type for Comprehensive Alternatives

SubSMA Type	SubSMA Label	SubSMA Description	Removal Focused	Integrated Cost Estimate A (1)	Integrated Cost Estimate B (2)
Channel	NC	Areas within the current federally authorized navigation channel.	Removal	Removal	Removal
	FMD	Approach areas located between the NC areas and docks where shipping access is needed now or in the future.	Removal	Removal	Removal
Structure	SS	Areas located beneath structures including a 5-foot offset from the structure face. The offset is based on the average DOI across the Study Area.	Cap	Cap	In situ Treatment
	SL	Areas where open water equipment is not accessible due to structures. Smaller water-based equipment would have to be used.	Removal	Cap	In situ Treatment
	SU	Areas where water-based equipment cannot reach but access from shore is feasible.	Removal	Cap	In situ Treatment
	SN	Areas where no water-based equipment can reach and upland structures, utilities, and/or topography prevent access from shore	Cap	Cap	In situ Treatment
Other	OW	Areas where there are no restrictions to dredging or capping equipment.	Removal	Cap	In situ Treatment
	-wz	Area above 0 NAVD88 subject to wind/wake waves.	Removal	Cap	Cap

Note:

FS costs will be developed as a range for in situ alternatives.

(1) This cost estimate will assume engineered caps in all applicable subSMAs.

(2) This cost estimate will assume various in-place technologies applied to applicable subSMAs as follows:

- Nearshore wave zones will likely require an armored cap to ensure effectiveness
- In situ treatment in and around structures and in open water areas.

SMA - Sediment Management Area

DOI - depth of impact

Table 7.4-1. Summary of Volumes of Sediment Assigned to Each Disposal Site for Each Alternative

Remedial Alternative	Disposal Options	Total Dredge Volume[1]		Volumes of Sediment by Disposal Method: Swan Island CAD[2]		Swan Island CDF[2]		Terminal 4 CDF[2]		Arkema CDF (1-Berth option)[3]		Arkema CDF (2-Berth option)[3]		Landfill[4]	
		Min (cy)	Max (cy)	Min (cy)	Max (cy)	Min (cy)	Max (cy)	Min (cy)	Max (cy)	Min (cy)	Max (cy)	Min (cy)	Max (cy)	Min (cy)	Max (cy)
B-i	Landfill	198,000	293,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	198,000	293,000
B-r	Swan Island CAD, Landfill	541,000	783,000	280,000	280,000	NA	NA	NA	NA	NA	NA	NA	NA	261,000	503,000
C-i	Swan Island CAD, Landfill	314,000	459,000	280,000	280,000	NA	NA	NA	NA	NA	NA	NA	NA	34,000	179,000
C-r	Terminal 4 CDF, Arkema (1 Berth), Landfill	776,000	1,127,000	NA	NA	NA	NA	670,000	670,000	55,000	55,000	NA	NA	51,000	402,000
D-i	Swan Island CAD, Landfill	387,000	565,000	280,000	280,000	NA	NA	NA	NA	NA	NA	NA	NA	107,000	285,000
D-r	Terminal 4 CDF, Arkema (1 Berth) CDF, Landfill	914,000	1,321,000	NA	NA	NA	NA	670,000	670,000	55,000	55,000	NA	NA	189,000	596,000
E-i	Swan Island CDF, Arkema (1 Berth) CDF, Landfill	936,000	1,362,000	NA	NA	815,600	1,179,200	NA	NA	55,000	55,000	NA	NA	65,400	127,800
E-r[5]	Terminal 4 CDF, Swan Island CDF, Arkema (2 Berth) CDF, Landfill	1,775,000	2,596,000	NA	NA	1,005,000	1,360,000	495,200	670,000	NA	NA	164,000	164,000	110,800	402,000
F-i[5]	Terminal 4 CDF, Swan Island CDF, Arkema (2 Berth) CDF, Landfill	2,129,000	3,151,000	NA	NA	1,232,000	1,360,000	607,200	670,000	NA	NA	164,000	164,000	125,800	957,000
F-r	Terminal 4 CDF, Swan Island CDF, Arkema (2 Berth) CDF, Landfill	4,195,000	6,182,000	NA	NA	1,360,000	1,360,000	670,000	670,000	NA	NA	164,000	164,000	2,001,000	3,988,000

Notes:

[1] Total estimated volume to be dredged from all SMAs. For purposes of this draft FS only, this estimate assumes that sediment from SMA 14 will be managed in the Arkema CDF or landfill. Sediment that does not meet acceptance criteria for in-water disposal sites will be landfilled regardless of available in-water capacity.

[2] Nominal capacities of the Disposal options (for sediment Sitewide except SMA 14 and sediment not meeting acceptance criteria):

Swan Island CAD	280,000 cy
Swan Island CDF	1,400,000 cy
Terminal 4 CDF	670,000 cy

[3] Disposal in the Arkema CDF is restricted to sediment dredged from SMA 14.

[4] Most volume designated "Landfill" will be sent to a Subtitle D landfill for disposal. A limited volume of sediment may not be accepted at a Subtitle D landfill. The Subtitle C landfill disposal option is retained for such material.

[5] The "minimum" estimated dredge volumes for SMAs excluding SMA 14 for remedial alternatives E-r and F-i are less than the total estimated capacities of the Terminal 4 and Swan Island CDFs. For this table, the volumes assigned to each disposal facility have been prorated. The volume shown in the landfill column is entirely the removal volume estimated for SMA 14 minus the capacity of the Arkema CDF associated with that remedial alternative.

CAD - Confined aquatic disposal

CDF - Confined disposal facility

cy - cubic yards

NA - Disposal Option Not Active

SMA - Sediment Management Area

CAD/CDF capacities do not account for settlement of the sediment bed underlying the facility.

This section presents the individual detailed analysis of the Site-wide comprehensive alternatives developed in Section 7. Each alternative is evaluated against seven of the nine NCP evaluation criteria on an individual basis. Changes in sediment, tissue, and water contaminant concentrations were projected over a period of 45 years to compare to specific RAOs for these same media. The primary finding is that all of the alternatives provide overall protection of human health and the environment over the long term, with the exception of Alternative A (No Action). However, the alternatives achieve these protective levels with a wide range of construction durations; short-term impacts to the environment, community, and workers; ease of implementation; and costs. The differences between the alternatives are further evaluated in the comparative evaluation in Section 9.

8.0 DETAILED ANALYSIS OF COMPREHENSIVE ALTERNATIVES

This section presents the individual detailed analysis of the Site-wide comprehensive alternatives developed in Section 7. See Table 7.0-1 for a summary of alternatives. The NCP evaluation criteria are summarized in Section 8.1, and the primary methods used to perform the evaluations relative to these criteria are described in Section 8.2. To avoid repetition in this draft FS, Section 8.2 also presents an analysis of common elements of remedial technologies and process options (e.g., dredging, capping, in situ treatment, EMNR, and MNR) with respect to the NCP evaluation criteria. Evaluation of the common elements is then incorporated by reference in the subsequent detailed analyses for each alternative (Sections 8.3 to 8.8) as well as the comparative analysis in Section 9. The results of this detailed analysis are used to perform the comparative analysis of the alternatives presented in Section 9, which in turn supports identification of the most appropriate remedial action for the Site.

The detailed analysis of comprehensive alternatives relative to NCP evaluation criteria relies on the significant body of Site-specific data and analyses that provide an effective tool for evaluating the relative performance of the comprehensive alternatives.

The detailed analysis of comprehensive alternatives relative to NCP evaluation criteria relies on the significant body of Site-specific data and analyses, Site-specific modeling, and Site-specific remedial activities that have been conducted over the past 10 years. Sections 2 and 6 of the draft FS summarize Site-specific data, analyses and recent remedial activities relevant to the evaluation of the comprehensive alternatives. Following EPA (2005a) guidance, these evaluations were supplemented with a well-developed, supported, and peer-reviewed predictive model to specifically address the spatial variability of Site conditions and estimate the timeframes for short-term construction impacts and long-term risk reductions resulting from implementation of each comprehensive alternative. Ultimately, the model provides an effective tool for evaluating the relative performance of the comprehensive alternatives. Projected changes in surface sediment (top 1 foot), fish tissue, and water column contaminant concentrations used in this detailed evaluation were derived from model simulations of each comprehensive alternative. Because the considerable body of Site-specific empirical data and analyses were used to develop and calibrate the detailed hydrodynamic, sediment transport, and contaminant fate/transport models of Portland Harbor (see Appendices La and Ha), the Site-specific modeling tools provide an objective quantitative framework to support the detailed evaluation of comprehensive alternatives. Moreover, a quantitative means of bounding model uncertainty was developed to assess the accuracy of these evaluations (see Appendices La and Ha). The findings of the combined Site-specific data and analyses, Site-specific modeling, and Site-specific remedial activities used to evaluate the comprehensive alternatives are presented in this section.

Representative technology process options are identified in the alternatives as described in Section 7. Process options are often appropriately modified during SMA-specific remedial design due to engineering considerations, local SMA conditions, and/or new information.

In many cases, details of the evaluations are more easily presented and understood in the context of the comparative analysis in Section 9. Therefore, in many cases within Section 8, the overall individual alternative results are highly summarized and the reader is referred to Section 9 for additional details and supporting information.

8.1 OVERVIEW OF NCP EVALUATION CRITERIA

Nine evaluation criteria (two threshold, five balancing, and two modifying criteria) have been established by EPA (1988, 2005a) to address the overall requirements of CERCLA and the NCP. Seven of the nine evaluation criteria serve as the basis for conducting the detailed analysis of the comprehensive alternatives in the draft FS (as noted below, the two Modifying Criteria will be evaluated by EPA at a later stage in the CERCLA process).

Threshold Criteria

1. **Overall Protection of Human Health and the Environment**: Addresses the overall ability of an alternative to eliminate, reduce, or control potential exposures to hazardous substances in both the short- and long-term and evaluates whether an alternative provides adequate overall protection to human health and the environment. This criterion is evaluated in the draft FS using RAOs for the following exposure pathways, as detailed in Section 3.2:

    1. Human health sediment direct contact
    2. Human health fish consumption (including shellfish)
    3. Human health surface water contact and drinking
    4. Human health groundwater direct contact and fish consumption
    5. Ecological sediment direct contact
    6. Ecological bioaccumulation/prey consumption
    7. Ecological surface water direct contact

8. Ecological groundwater direct contact and prey consumption

2. **Compliance with ARARs**: Assesses whether the alternative attains the identified chemical-specific, action-specific, and location-specific ARARs (see Section 3.4). CERCLA requires that remedial actions comply with the substantive provisions of federal and state promulgated ARARs, unless such standards are waived. Although compliance with all ARARs described in Section 3.4 was considered in the detailed evaluations of alternatives, the evaluations focused on five primary ARARs: Oregon State WQS and federal NRWQC, Oregon Environmental Cleanup Law, ESA, Section 404(b)(1) of the CWA, and FEMA Flood Rise Requirements.

Balancing Criteria

3. **Long-Term Effectiveness and Permanence**: Evaluates the alternative for the long-term effectiveness and permanence it provides. Factors considered under this criterion include:
   - Magnitude of residual risk remaining after implementation.
   - Adequacy and reliability of control measures (e.g., containment systems and institutional controls).

   In addition, the following considerations are part of the evaluation of the long-term effectiveness and permanence criterion of each alternative:

   - Ensure sediment cleanup activities consider, complement, and are compatible with already implemented and planned source controls.
   - Minimize downstream transport of contaminants.
   - Remedial approaches that do not prohibit the potential to re-establish ecological habitats.

   These additional considerations align with the Management Goals as described in Section 3.3.

4. **Reduction of Toxicity, Mobility, or Volume through Treatment**: Addresses the degree to which an alternative reduces the toxicity, mobility, or volume of chemical constituents through treatment. CERCLA has a statutory preference for selecting remedial actions that use treatment technologies to the maximum extent practicable. The evaluation focuses on the considerations defined in the NCP:

   - The treatment or recycling processes the alternatives employ and materials they will treat.
   - The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled.
   - The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of the reductions that are occurring.

- The degree to which the treatment is irreversible.
- The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity for bioaccumulation of residual hazardous substances and their constituents.
- The degree to which treatment reduces the inherent hazards posed by any principal threats at the site.

5. **Short-Term Effectiveness**: Assesses effects and potentially unacceptable risks to human health and the environment related to construction and implementation of each alternative. Per the NCP, the following factors are addressed:

   - Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigation measures during implementation.
   - Time until protection is achieved.
   - Short-term potentially unacceptable risks that might be posed to the community during implementation of an alternative.
   - Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures.

6. **Implementability**: Evaluates the ease or difficulty of implementing the alternative by considering technical feasibility, administrative feasibility, and availability of services and materials required for implementation. Per the NCP, this includes the evaluation of the following factors:

   - Technical feasibility
     - Technical difficulties and unknowns associated with the construction and operation of a technology (e.g., effects of navigation areas and structures on technology implementation)
     - The reliability of the technology
     - Ease of undertaking additional remedial actions
     - The ability to monitor the effectiveness of the remedy
   - Administrative feasibility
     - Activities needed to coordinate with other offices and agencies
     - The ability and time required to obtain any necessary approvals and permits from other agencies (for off-Site actions)
   - Availability of off-Site treatment, storage, and disposal services and capacity
     - Availability of adequate off-Site treatment, storage capacity, and disposal capacity and services

- Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources
- Availability of services and materials
- Availability of prospective technologies.

7. **Cost**: Evaluates present-worth (present value) direct and indirect capital, operating, and maintenance costs of implementing an alternative. The evaluation of this criterion was completed according to EPA 2000b guidance. Costs include capital costs (both direct and indirect), long-term monitoring and maintenance, and contingency in net present value dollars.

Modifying Criteria

8. **State (Support Agency) Acceptance**: Assesses the technical and administration issues raised by the supporting agencies about the alternatives.

9. **Community Acceptance**: Assesses issues and concerns raised by interested persons in the community about the potential remedial alternative.

Note that the modifying criteria (State [Support Agency] Acceptance and Community Acceptance) will be evaluated by EPA after compilation of public comments and input received on the Proposed Plan for the Site.

8.2 METHODOLOGIES TO EVALUATE NCP CRITERIA AND COMMON ELEMENTS OF THE EVALUATION

This section discusses the primary methods that were used in the detailed evaluation of Site-wide comprehensive alternatives, relative to the two threshold and five balancing NCP evaluation criteria summarized above. Also, for all of the criteria, elements common to the evaluation of all of the comprehensive remedial alternatives (including MNR, EMNR/in situ treatment, capping, and dredging/removal components) are described to avoid repetition in the individual analysis of each alternative, as well as in the comparative analysis in Section 9. This common elements evaluation focuses on those findings that are common to all the alternatives and component technologies, so that the differences between the alternatives can be more clearly highlighted in the later individual (Section 8) and comparative (Section 9) evaluations. The common elements discussion relies on Site-specific data that is presented in more detail later in Sections 8 and 9 as well as the screening of remedial technology effectiveness and implementability presented in Section 6.

8.2.1 Evaluation General Approach

Based on information presented in prior sections, this section describes the general approach and context for many of the more detailed evaluations discussed in Section 8 and 9. As discussed in Section 3.3, RAOs provide a general description of what the overall remedial action is expected to accomplish and help focus alternative development and evaluation (EPA 2005a). RGs are numeric expressions of the RAOs that achieve a range of protective levels or regional background concentrations (e.g., if protective RGs are below anthropogenic background). RGs have applicable exposure areas, which were set to be consistent with risk assessment methods used to date for the Site.

Using ranges (rather than single values) for RALs, RGs, and TTLs in the alternatives evaluation is consistent with guidance (EPA 2005a), and assists EPA in identifying sediment cleanup levels in the Proposed Plan and ROD from an appropriate range of RGs.

RALs define areas that are actively remediated (i.e., SMAs). With active remediation of the RAL-defined areas, each RG is expected to be met in time (i.e., following remedial action and natural recovery) over its applicable exposure area(s). The design of the range of RALs used in this draft FS addresses uncertainties in the calculation of the RALs, the RGs (as well as the target tissue levels [TTLs] associated with each RG), and the predictions of the long-term average concentration. Using ranges (rather than single values) for RALs, RGs, and TTLs in the alternatives evaluation is consistent with guidance (EPA 2005a), and assists EPA in identifying sediment cleanup in the Proposed Plan and ROD from an appropriate range of RGs.

Table 8.2.2-1 presents the ranges of RGs and TTLs from Section 3.6 and Appendix E used in Section 8 and 9 evaluations. Table 8.2.2-2 shows an additional comparative presentation of these values for PCBs as well as some additional PCB RGs and PRGs presented in Appendix E. As discussed in Section 3.6, the percentile estimates for PCB smallmouth bass whole body consumption are used as a general representation of RGs for other consumption scenarios (e.g., fillet with skin and fillet without skin). However, in some specific cases, the fillet RG ranges may be used to make additional comparisons to illustrate a particular point and are equally if not more valid in terms of potential exposures that occur at the Site. For BaP, the range of human health sediment direct contact percentile estimates shown in Table 8.2.2-1 is used.

The alternatives evaluation also considered a range of timeframes over which different RGs within these ranges are expected to be achieved, considering anticipated construction durations, natural recovery processes, and the potential effectiveness (and uncertainty) of source control actions within the basin. Thus, the comprehensive alternatives were modeled over a sufficiently long time period (30 to 45 years to project when the range of RGs would likely be achieved under each comprehensive alternative.

Most of the detailed alternative evaluations focused on the select RAL contaminants, including total PCBs, BaP, DDE, DDD, and DDT, and benthic toxicity as represented by MQ, which contribute the most widely distributed potentially unacceptable risks at the Site.

As detailed below, projected changes in surface sediment, fish tissue, and water column contaminant concentrations were used to inform evaluations of the comprehensive alternatives relative to several of the NCP criteria. These evaluations were conducted using select RAL contaminants that were included on various modeling lists determined using methods agreed to by EPA (see Section 4.1 and Appendix C). Thus, most of the detailed alternative evaluations focused on the select RAL contaminants, including total PCBs, BaP, DDE, DDD, and DDT, and benthic toxicity as represented by MQ which contribute the most widely distributed potentially unacceptable risks at the Site. As described in Section 4.1, these RAL contaminants are bounding COCs, which means they have contaminant distributions that overlap with other co-occurring contaminants potentially posing unacceptable risk. For some evaluations (e.g., cap long-term performance estimates), the full list of mobility evaluation contaminants (defined in Appendix C, Section 3) were evaluated, but the results of only some of these contaminants are summarized here in the main text.

As noted in Sections 2 through 4, projected changes in surface sediment, tissue, and surface water contaminant concentrations under the different alternatives are presented on a range of spatial scales relevant to various scenario/receptor exposure scales, as described in the draft final risk assessments. QEAFATE and linked Food Web Model projections described in Appendices Ha and Hb were also averaged across several river mile Segments (as described in Section 2.9) to help condense this information on an intermediate scale relevant to potentially unacceptable risks that occur over larger spatial scales (i.e., Site-wide) as well as smaller spatial scales (e.g., river mile or half river mile basis). As also noted previously, these comparisons are not intended to supplant specific comparisons to potentially appropriate spatial scales for some RGs (e.g., river mile scale), which are presented in Appendix U (Section 3) to provide additional detailed support to the overall evaluation.

The evaluations conducted using the select RAL contaminants are intended to be representative of the outcomes for the wider range of contaminants present at the Site.

The evaluations conducted using the select RAL contaminants are intended to be representative of the outcomes for the wider range of contaminants present at the Site. As discussed in Sections 2.6 and 6.2.2 and consistent with the RI, the primary mechanism of projected system recovery at the Site following sediment remediation is due to subsequent deposition and burial. This indicates that focusing evaluations on a few select COCs is reasonable, because variations in chemical-specific parameters across the range of Site contaminants are relatively less important as compared to the physical mechanism of burial of all contaminants. With regards to benthic toxicity, given that surface sediment concentrations of a large set of contaminants would all decline over time due to burial, the resultant calculation of the combined MQ would also decrease similarly over time. In addition to physical burial of contaminants, contaminant degradation over time is probably the most important chemical-specific mechanism contributing to natural recovery. Modeling of PCBs and DDx compounds conservatively assumed zero degradation, and BaP modeling

As discussed in Sections 2.6 and 6.2.2 and consistent with the RI, the primary mechanism of projected system recovery at the Site following sediment remediation is due to subsequent deposition and burial.

conservatively assumed limited degradation over time. Thus, modeling of these select COCs using a range of conservative degradation assumptions also provides a good representation of the range of potential outcomes for the entire list of contaminants presenting potentially unacceptable risk. The COC 2,3,4,7,8-PCDF, which has RALs for some alternatives, is a surrogate for overall dioxin/furan potentially unacceptable risks and is not specifically modeled. Consistent with the above approach, sediment burial is expected to have the same general impact on PCDF concentrations as for other COCs. Similarly, PCDF has similar general chemical and bioaccumulative properties as PCBs and DDx, which are modeled using the conservative zero degradation rate assumption. Thus, PCB and DDx modeling of alternatives is expected to be representative of outcomes for PCDF as well.

It is understood that representing many contaminants with projections for select COCs involves some level of uncertainty, but this uncertainty is nevertheless acceptable for an FS-level evaluation of such a large and complex site. To further assist EPA in making risk-management decisions, sediment concentrations achieved at time zero (i.e., not using modeling projections) for each comprehensive alternative were calculated for every Site contaminant posing potentially unacceptable risk with a PRG above background and consistent with the risk assessments; these calculations are presented in Section 5.9. These more simple time zero estimates provide EPA with the information needed to understand how each alternative will address the broadest possible list of contaminants posing potentially unacceptable risk.

The following sections describe the more specific methods used to assess the comprehensive alternatives relative to the two threshold and five balancing NCP evaluation criteria. Also, within each section, the common elements of the detailed evaluation for the alternatives and their component technologies of MNR, EMNR/in situ treatment, capping, and environmental dredging/removal are discussed for each criterion. As noted above, the common elements discussion helps avoid repetition of the similarities between the alternatives throughout the remainder of Section 8 and 9 evaluations.

8.2.2 Overall Protection of Human Health and the Environment

This criterion addresses the overall ability to eliminate, reduce, or control potential exposures to hazardous substances in both the short and long term. As discussed in EPA (2005a), the NCP evaluation of overall protectiveness is highly location-specific.

8.2.2.1 Methods

As noted above, the ability of an alternative to provide overall protection to human health and the environment is determined based on the extent to which it achieves RAOs. The primary information used to make this determination are projected changes in surface sediment, fish tissue, and water column COC concentrations derived from model simulations of each comprehensive alternative both during and after construction, and comparison of these projections with the range of sediment RGs, TTLs, and water quality criteria, respectively, as well as the timeframes to achieve such levels. The range of sediment RGs and TTLs used in these evaluations are summarized in Table 8.2.2-1. These evaluations also considered the results from model uncertainty analyses that quantified upper/lower uncertainty bounds on the predictions from the QEAFATE and Food Web Models (see Appendices Ha and Hb, respectively).

Determination of RAO attainment was performed by comparing projected short- and long-term changes in COC concentrations in surface sediment, surface water, and tissue resulting from implementation of the alternatives with the range of sediment RGs, water quality standards/criteria, and TTLs, respectively, as well as the time to achieve such levels. The evaluation of alternatives focused on the following RAOs:

- Short- and long-term changes in surface sediment contaminant concentrations, which are directly relevant to RAO 1 (human health sediment direct contact) and RAO 5 (ecological sediment direct contact).
- Short- and long-term changes in tissue contaminant concentrations, which are directly relevant to RAO 2 (human health fish consumption) and RAO 6 (ecological bioaccumulation/prey consumption).
- Short- and long-term changes in surface water concentrations, which are directly relevant to RAO 3 (human health surface water contact and drinking water) and RAO 7 (ecological surface water direct contact).
- Protectiveness for under river groundwater plumes after known plume sources are controlled through upland source controls, which is directly relevant to RAO 4 (human health groundwater direct contact and fish consumption) and RAO 8 (ecological groundwater direct contact and prey consumption).

Due to the uncertainty/sensitivity around these RGs (as expressed by the representative RG and TTL ranges used in this draft FS), differences between points in these representative RG ranges may not be highly relevant to risk reduction achieved at the Site.

It is important to note that, although reductions in sediment or tissue concentrations are often noted in Section 8 and 9, these concentration reductions do not necessarily equate to meaningful reductions of potentially unacceptable risk. Thus, the comparison to the RGs and TTLs is used to help determine whether risk reduction has been achieved in a way that is meaningful to the RAOs. Further, as discussed in Section 3.6 and Appendix E, due to the uncertainty/sensitivity around these RGs (as expressed by the representative RG and TTL ranges used in this draft FS), differences between points in these representative RG ranges may not be highly relevant to risk reduction achieved at the Site. For example, the differences in estimates of potentially unacceptable risks achieved can range between 10^{-6} and 10^{-4} cancer risk level based only on the exposure scenario assumed (e.g., whole body versus fillet without skin consumption). Therefore, the risk reduction achieved between, for example, attainment of a 95th percentile versus a 99th percentile whole body RG estimate is small in comparison (see Appendix E for more details).

In addition, compliance with surface water RAOs 3 and 7 is evaluated and discussed for each alternative throughout Sections 8 and 9. However, as noted in Section 3.2, based on the findings of the risk assessments, there are no potentially unacceptable risks in surface water at the Site relevant to RAOs 3 and 7, and the Site already achieves these surface water RAOs. Therefore, evaluations against surface water RAOs are only conducted to assess whether any of the alternatives might cause short-term or long-term changes in surface water concentrations that would increase from current conditions and potentially not meet the surface water RAOs. As discussed more throughout Sections 8 and 9, all the alternatives were found to create long-term surface water concentrations that are not substantially different from existing surface water concentrations at the Site, and there is no substantial difference between the alternatives in this regard.

Projected Site-wide changes in surface sediment concentrations of bounding COCs including total PCBs, BaP, and DDE during and following implementation of each comprehensive alternative are presented in Figures 8.2.2-1, 8.2.2-2, and 8.2.2-3, respectively. Similar projections by river Segment are presented in Figures 8.2.2-4, 8.2.2-5, and 8.2.2-6, respectively. Additional projections for DDD and DDT, as well as other spatial scales, are provided in Appendix U (Section 3). Figures 8.2.2-1 through 8.2.2-6 show the uncertainty associated with the conservative case or lower bound estimate for these projections. Projected changes in whole body smallmouth bass tissue total PCB concentrations by river Segment during and following implementation of each comprehensive alternative are presented in Figure 8.2.2-7. Additional projections on other spatial scales are provided in Appendix Hb (Attachment 1).

Projected changes in surface water (water column average) concentrations of bounding COCs including total PCBs, BaP, and DDE during and following implementation of each comprehensive alternative are presented by river Segment in Figures 8.2.2-8, 8.2.2-9, and 8.2.2-10, respectively. Additional projections for DDD and DDT are provided in Appendix U (Section 3).

8.2.2.2 Common Elements – Overall Protection Evaluation

> *Ongoing upstream contaminant levels and other known sources likely contribute to potentially unacceptable risks in sediment, water, and tissue at the Site.*

For all the alternatives, overall protection of human health and the environment is achieved by reducing contaminant concentrations and or reducing exposures to surface sediment, tissue, and the water column. To accomplish reductions in surface water and tissue concentrations, the comprehensive alternatives reduce concentrations of or exposure to contaminants in surface sediments, which reduces the flux of contaminants into these other media. Based on evaluations presented in this draft FS, ongoing upstream contaminant levels and other known sources likely contribute to potentially unacceptable risks in sediment, water, and tissue at the Site. Coordinated source control efforts being directed by DEQ at more than 80 upland sites are anticipated to assist in the sediment remediation achieving long-term reductions in Site potentially unacceptable risks, but contributions from upstream surface water concentrations will likely prevent the Site from achieving the risk level represented by the ranges of available RGs.[1]

> *Reduced contaminant concentrations/exposures in the various media are achieved over time under all comprehensive alternatives through a combination of capping (with or without armoring, as necessary), dredging/removal with post-dredge residual covers (where needed), EMNR/in situ treatment, and ongoing natural recovery.*

Reduced contaminant concentrations/exposures in the various media are achieved over time under all comprehensive alternatives through a combination of capping (with or without armoring, as necessary), dredging/removal with post-dredge residual covers (where needed), EMNR/in situ treatment, and ongoing natural recovery. All of the alternatives integrate to varying degrees ongoing Site-wide natural recovery processes with more active technologies. As discussed in Section 6.2.2 and consistent with the draft final RI and the CSM presented in Section 2.6, Site-specific data have demonstrated that these processes are effective and are likely supported by reduction of discharges to the river through previous land-based source control efforts and ongoing natural sedimentation of relatively low concentration materials from upstream of the Site. The natural recovery processes have and will continue to reduce surface sediment, tissue, and water column concentrations of all of the contaminants posing potentially unacceptable risk at the Site. Per Section 5.6.6, capping or removal with residuals management (where needed) is expected to directly address (contain in place or remove) the vast majority of buried contamination above the RALs present at the Site for all active alternatives (Alternatives B through F).

Further, the projections of future media concentrations indicate that all the alternatives will be achieving concentrations that are within the range of available background estimates on a Site-wide basis, which is the most appropriate spatial scale for background comparisons. The range of background estimates reflects uncertainty in the eventual background level for the Site and similarly, the modeling projections have uncertainty in terms of the equilibrium conditions eventually achieved for the Site. Thus, alternatives should always be evaluated in the context that certain low RG ranges may be eventually found to be below background and/or Site equilibrium levels and cannot be achieved by even the most aggressive remedial alternatives. In fact, differences between point estimates of the low RGs and background may not be functionally significant, given the small numerical differences.

[1] For example, using the FWM, if the within Site sediment concentrations are set to zero, the projected fish tissue concentrations would equate to an approximate 10^{-5} cancer risk level for human health whole body smallmouth fish consumption, low ingestion (i.e., Focused PRG scenario).

Uncertainty results show that the model projection uncertainties do not change conclusions regarding the overall effectiveness of the alternatives given that the action alternatives are all still projected to reach relatively similar protective sediment concentrations in the long term.

Figures 8.2.2-1 through 8.2.2-6 show the uncertainty associated with the conservative case or lower bound estimate for the modeling projections. This uncertainty analysis shows that the model projections do not change conclusions regarding the overall effectiveness of the alternatives given that the action alternatives are all still projected to reach relatively similar protective sediment concentrations in the long term. These concentration results are very similar in comparison to the range of RGs and background estimates. In some specific cases, PCB or DDE EPA point estimates are not achieved for some alternatives under the "upper bound" modeling assessment. However, these differences in concentrations are extremely small as compared to the sensitivity/uncertainties associated with the RGs themselves and the range of background levels for the Site, as discussed above. Appendix U (Section 5) presents additional evaluations of uncertainty associated with other MNR LOEs (beyond modeling uncertainty), which also do not substantially alter these conclusions.

Capping or removal with residuals management (where needed) is expected to directly address (the vast majority of buried contamination above the RALs present at the Site for all active alternatives (Alternatives B through F).

All of the comprehensive alternatives evaluated in this draft FS are projected to reduce COC levels in surface sediment, tissue, and the water column over time. The combination of more active technologies and MNR is expected to minimize the potential remobilization of buried COCs, which could potentially be subject to erosion or disturbance in the future. Projections for all alternatives indicate that large scale erosion events, such as the one simulated in Year 17 of the projections, would result in some temporary increase in sediment concentrations that would return to the pre-event trajectory within a few years (Figures 8.2.2-1 through 8.2.2-3). As discussed in Section 5.6, capping or removal with residuals management (where needed) is expected to directly address (i.e., contain in place or remove) the vast majority of buried contamination above the RALs present at the Site for all the alternatives with more active technologies (Alternatives B through F).

The common elements of the alternatives evaluation associated with MNR, EMNR/in situ treatment, capping, and dredging/removal are discussed below.

8.2.2.2.1 MNR

MNR generally relies upon natural processes to provide for relatively lower levels of short-term (during recovery) protection, but may provide long-term protection. As described in Section 6.2.2, the average Site-wide net sedimentation rate is approximately 2.6 cm/yr, providing a natural source of low contaminant concentration material that progressively covers sediments and reduces surface sediment concentrations over time.

> *A range of independent empirical datasets along with detailed Site-specific modeling all confirm that MNR will effectively reduce potentially unacceptable risks over time, though to varying degrees depending on the specific location within the Site.*

Further, empirical bathymetry data show 88 percent of the Site is depositional or shows no substantial change. A range of independent empirical datasets along with detailed Site-specific modeling all confirm that MNR will effectively reduce potentially unacceptable risks over time, though to varying degrees depending on the specific location within the Site. These LOEs are summarized below and are consistent with the detailed reviews of empirical data from the draft final RI, Section 2.2, the CSM in presented Section 2.6, and empirical data evaluations in Sections 6.2.2:

- DEQ is currently investigating or directing source control work at more than 80 upland sites, which will continue to contribute to MNR.
- Most of the Site is net depositional and is characterized by stable sediment deposits, although sedimentation rates and recovery half-lives vary both laterally and longitudinally, with localized areas of sediments that are in dynamic equilibrium (alternating erosion and deposition, with relatively long recovery half-lives).
- Concentrations of sediment particles entering the Site from upstream and depositing within the Site are lower than in bedded surface sediments in SMAs, accelerating MNR even in areas that are in dynamic equilibrium.
- More recently deposited sediments (i.e., surface 0 to 30 cm) in most of the Site have lower concentrations than the underlying deeper sediments, providing corroborating evidence of recent MNR at the Site.
- Time series analyses of surface sediment concentrations provide further documentation of MNR, with observed decreases in concentrations, consistent with MNR modeling projections.

The overall weight-of-evidence analysis summarized in Section 6.2.2 indicates that MNR will protect human health and the environment across the majority of the Site, though there are localized areas where MNR would be less effective. As detailed in Appendices La and Ha, detailed modeling was performed to project future reductions in water column, sediment, and fish tissue concentrations attributable to MNR. The model results, which are presented in detail throughout Section 9, provide a particularly useful tool for evaluating the protectiveness of MNR on relatively small spatial scales and over long timeframes.

8.2.2.2.2 EMNR/In Situ Treatment

As described in Sections 6.2.3 and 6.2.4, EMNR can be used to effectively accelerate the natural recovery process by placing a thin layer of suitable sand or sediment, while in situ treatment can effectively reduce the bioavailability of certain contaminants by placing an even thinner layer of AC or other amendments. Both technologies would protect human health and the environment across the Site. Potential in situ treatment options included in the remedial alternatives for this draft FS build on promising results from pilot projects recently completed in the United States and Europe, demonstrating significant reductions in the bioavailability of PCBs, PAHs, dioxins/furans, DDx, and mercury (Ghosh et al 2011). Based on these data, application of in situ treatment technologies is currently being planned at other similar Superfund sediment sites (e.g., Lower Duwamish River). Direct broadcasting of AC was identified as a representative process option for EMNR/in situ treatment, and was used to develop alternatives for the draft FS. This is a draft FS determination only, and other process options and reagents could be retained for further evaluation and use in remedial design of specific SMAs, particularly because this technology is rapidly evolving.

Direct broadcasting of activated carbon is a draft FS determination only; other process options and reagents could be retained for further evaluation and use in remedial design of specific SMAs, particularly because this technology is rapidly evolving.

8.2.2.2.3 Capping

Placement of caps would provide for protection of human health and the environment by reducing COC concentrations on the sediment surface and reducing flux to the water column, which in turn would reduce levels in water, fish, and other biota. Caps included in the remedial alternatives for this draft FS would be designed in accordance with EPA and USACE guidance (Palermo et al. 1998; USACE 1998) to provide long-term chemical isolation and ensure the stability, integrity, and protectiveness of the caps under the range of potential erosional forces. The preliminary cap designs at the Site were determined through an evaluation of Site-specific information so that the cap would meet the following objectives:

- Physical isolation of COCs in the sediment from the benthic environment
- Erosion protection (i.e., to mitigate resuspension and transport of sediments to downstream areas) to maintain cap stability against forces resulting from open water river flows, propeller, and other forces
- Chemical isolation (i.e., reduce the flux of COCs to the water column).

In accordance with EPA (Palermo et al. 1998) and USACE (1998) design guidance, the total thickness of a protective cap was specified as the sum of the thicknesses required to achieve each of the design objectives listed above.

8.2.2.2.4 Dredging/Removal

As discussed in Section 6.2.7, unless otherwise noted, all dredging discussed in Sections 8 and 9 refers to remediation or environmental dredging (as opposed to navigation or maintenance dredging). Statements with regards to the effectiveness or impacts of environmental dredging in most cases do not apply to navigation and maintenance dredging.

While alternatives including removal would reduce the volume of contaminated sediments in the river and can achieve overall protection of human health and the environment, short-term water quality impacts and elevated post-dredging residuals reduce the protectiveness of this remedial technology, particularly when trying to achieve low concentrations relative to target material concentrations. These expectations are based on detailed evaluations of dredging effectiveness, including the recent evaluation by the National Research Council (NRC 2007) in *Sediment Dredging at Superfund Megasites: Assessing the Effectiveness*. The NRC noted that,

> "*Dredging effectiveness is limited by resuspension and release of contaminants during dredging and the generation and exposure of residual contamination by dredging*" (NRC 2007 – p. 163) and "*Dredging alone is unlikely to be effective in meeting short-term and long-term goals if a site has one or more unfavorable conditions*" (NRC 2007 – p. 5).

EPA's (2005a) guidance likewise notes that,

> "*the level of uncertainty associated with estimating residual contamination [after dredging] can be high at some sites*," and that "*[a]nother limitation [of dredging] may include the potential for contaminant losses during dredging through resuspension*" (EPA 2005a – p. iv-v).

More recent publications have continued to document similar dredging-related residuals and corresponding increases in fish tissue concentrations at sediment cleanup sites (EPA 2005a; NRC 2007; Patmont and Palermo 2007; USACE 2008a; Bridges et al. 2010). Dredging may have particularly limited effectiveness as a means to provide overall protection of human health and the environment when applied to the following situations:

- In areas where rocks/cobbles or other debris is present on the river bottom, because they increase resuspension and residuals generation.
- In areas where the highest sediment concentrations are located at the base of the dredge prism. In these cases, post-dredge cover may be essential (or the most appropriate approach might be partial removal followed by capping or even capping only).
- In areas where substantially contaminated sediments immediately overlie hard bottom, resulting in relatively high post-dredge residual concentrations due to the inability of the dredge equipment to remove all sediment above the hard bottom surface.

Because of the protectiveness limitations posed by dredging residuals, the representative set of removal process options used in the draft FS incorporated specific actions to manage residuals. The effectiveness of potential residuals management strategies was evaluated according to the methods described in Appendix Ib, using Site-specific sediment data and assumptions about the likely range of process options that would be used to implement removal at the Site.

Based on this evaluation, a single cleanup pass and suitable sand cover (similar to EMNR) was considered an appropriate strategy to carry forward for residuals management under the removal alternatives for draft FS purposes, consistent with recent strategies used successfully at other sediment cleanup sites (e.g., Gasco Early Action; Fox River, Wisconsin; Hudson River, New York; etc.), and in recognition of the limitations associated with attempting to manage residuals through multiple cleanup passes. Using this approach, the calculations conducted in Appendix Ib indicate that the RALs defined by the alternatives can be achieved, but with progressively more difficulty for the lower RALs. Also, for the lower RALs, the post-dredge cover plays a greater role in achieving the RALs as compared to dredging itself. This indicates that process options that have a higher RAL as the target for dredging and lower RALs achieved by post-dredge covers, as necessary, may be a more reasonable approach for remedial designs.

Thus, it is important to note that the draft FS residuals management strategy is only an FS-level assumption. However, given experience at other sites, this FS assumption appears to be one reasonable approach to pursue in remedial design, as do options that instead dredge to higher RALs and use cover to achieve lower RALs as necessary. Remedial implementation strategies that rely solely upon additional dredge passes to achieve RALs will create sediment volumes far in excess of those estimated for this draft FS, and therefore will increase the durations, short-term water quality impacts, and costs of such dredging.

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8.2.3 Compliance with ARARs

This criterion assesses whether the alternative attains the identified chemical-specific, action-specific, and location-specific ARARs (see Section 3.4). As noted above, five select ARARs were the focus of the draft FS evaluation, although compliance with all ARARs was considered in the detailed evaluations of alternatives.

8.2.3.1 Methods

The methods used to evaluate compliance with the five primary ARARs are summarized below.

State and Federal Surface Water Quality Standards/Criteria (WQS/NRWQC). Short- and long-term surface water quality projections for each alternative were compared with state and federal surface water quality standards and criteria. As discussed in Section 3.4, each alternative is evaluated relative to achievement of WQS and NRWQC in Site surface waters to aid EPA in its ARAR analysis. As a starting point, the detailed evaluation assesses whether the WQS or NRWQC is expected to be achieved in the water column at the Site post-remedy. To the extent the numeric criteria are projected to be achieved, the ARAR has been met. For those contaminants where the potential surface water criteria is not expected to be achieved, the alternatives evaluation assesses to the extent practicable, whether that exceedance is impacted by the hazardous substances that will remain in sediments at the Site or is attributable to the upstream load. To the extent WQS and NRWQC exceedances are driven by upstream loads and not Site sediments, EPA may find compliance with these surface water ARARs “with respect to…contaminants that will remain onsite.” The alternatives evaluation also compares across alternatives to assess whether any alternative is projected to contribute more than another to reduction in surface water concentrations post-remedy. To the extent EPA determines that an ARAR waiver is necessary with respect to any surface water criteria, as discussed in Section 3.4, the alternatives evaluation will assist in making that assessment.

It should be noted that instances of exceedances of specific values are noted in Section 8 discussions, but in many cases such exceedances may occur over very small areas and durations of time. Given it is unwieldy to show a spatial and temporal figure for every instance of an exceedance, the spatial and temporal extent of the exceedances is expressed as a percent of the entire simulation period throughout the entire Site. Thus, an exceedance that occurs over the entire Site for the entire simulation would be noted as an exceedance over 100 percent of the simulation. More information on exceedances is provided in Section 9.2.1.

Also, comparisons are made to drinking water MCLs. The LWG disagrees that MCLs are ARARs against which the surface water itself should be measured because under OAR 340-041-0340 Table 340A, the beneficial use designation of the Willamette River for domestic water supply assumes adequate pre-treatment will be applied. Therefore, the LWG believes that direct application of MCLs to individual, untreated surface water samples at the Site is inappropriate. This analysis was, nonetheless, carried through as directed by EPA.

Oregon Environmental Cleanup Law. Long-term sediment concentration projections for each alternative were compared to potential cleanup value requirements included in this ARAR. Also, as described in Section 5.5, no Oregon hot spots were identified; however, this draft FS evaluates treatment and removal of areas of higher concentrations consistent with the intent of the Oregon Environmental Cleanup Law.

Section 404(b)(1) of the CWA. The 404(b)(1) analysis presented in Appendix M provides an assessment of how each alternative would comply with this ARAR.

FEMA Flood Rise Requirements. For all communities participating in the National Flood Insurance Program, any action that encroaches on the floodway cannot cause a significant increase in water surface elevation in the river during a 100-year flood event. An increase is defined as more than 0.00 feet (FEMA 2011). The City of Portland is the implementing community in this case and, in coordination with FEMA, interprets the threshold as "less than 0.005 feet" based on the assumption that hydraulic model results less than 0.005 feet would be rounded to 0.00 feet and therefore meet the criterion (D. Morgan, personal communication). A one-dimensional hydrodynamic model (HEC-RAS) of the Lower Willamette River and Multnomah Channel was used to evaluate compliance of each of the comprehensive alternatives with this ARAR (Appendix Lb).

ESA. The Preliminary Draft BA (Anchor QEA 2012), which is submitted concurrently with but is not a part of this draft FS, provides an assessment of the range of potential effects to ESA-listed species that may result from implementation of each alternative. The Preliminary Draft BA is intended to inform and assist EPA in developing its own Site-wide BA to initiate formal consultation with the Services.

As further detailed in the BA, the ESA consultation will likely continue through development of EPA's Proposed Plan and the associated public comment process, so that ESA resources are adequately analyzed and addressed prior to selection of the preferred alternative and issuance of the ROD. Consultation will likely be iterative and evolve over time as EPA moves toward selection of its preferred alternative. Early engagement is encouraged by the Services' joint ESA regulations 50 CFR 402.14 (a), which state that each federal agency shall review its actions at the earliest possible time to determine whether any action may affect listed species or critical habitat. The consultation process will provide the Services a timely opportunity to evaluate EPA's package initiating consultation and to determine if all of the information has been provided per the ESA Section 7 Consultation Handbook (USFWS and NMFS 1998). The handbook also acknowledges that, although formal consultation must result in a biological opinion, the process is flexible and can be adapted at any point to respond to project modifications agreed to by the action agency (USFWS and NMFS 1998). Importantly, EPA will also be able to use this process to assist in engaging NMFS and USFWS to accurately reflect ESA terms and conditions and the costs of such measures in the Proposed Plan at a Site-wide scale (50 CFR §402.12(k)). This approach will ensure that the Proposed Plan both meets requirements of the ESA as an ARAR, and that EPA considers and accounts for the costs of the ESA compliance by considering potential ESA impact avoidance and minimization measures while applying the nine NCP criteria to identify the recommended remedial action. This approach will allow EPA to complete its consultation with the Services before it issues the ROD.

It is further anticipated that the Services' Site-wide biological opinion would be sufficiently comprehensive to lay the framework for individual consultations, as necessary, such that it would streamline the implementation and completion of individual projects. Individual remedial actions may have SMA-specific impacts that are not addressed with sufficient specificity in the Site-wide consultation and therefore consultation would need to occur to the extent those proposed actions have impacts that are not evaluated under the Site-wide biological opinion. However, the subsequent individual Section 7(a)(2) consultations, if necessary, could be tiered to the Site-wide consultation on the ROD, thus allowing for more timely and efficient remedy implementation.

Thus, the Preliminary Draft BA evaluates proposed actions as consisting of the remedial activities or technologies that could occur as part of the selected alternative. The activities are described generally to include a range of methods that can be refined by EPA in its final Site-wide BA as more information becomes available on the proposed action.

The evaluation of potential impacts to listed species from the sediment remedial technologies described in the Preliminary Draft BA also includes impact avoidance or minimization measures and conservation measures, including Section 404(b)(1) CWA compensatory mitigation, that may be required for aquatic functions unavoidably lost as a result of the remedial activities. The compensatory mitigation would be performed under Section 404 of the CWA but would also provide conservation benefits under the ESA to listed species and critical habitat. As such, mitigation activities are included as part of the proposed action, and the ESA review will be completed and reach conclusions based on the entire proposed action, which includes mitigation.

The Preliminary Draft BA identifies long-term and short-term minimization and avoidance elements that are deemed adequate to avoid jeopardy to the species with respect to the remedial technologies that are a part of the alternatives being evaluated in this document. These impact avoidance and minimization measures and conservation measures are described in the Preliminary Draft BA by remedial technology. If a remedial technology is applied to a critical habitat area, the impact avoidance and minimization measures and conservation measures listed in the Preliminary Draft BA are also likely to be applied.

Also, the Preliminary Draft BA does not specifically consider each alternative; rather, the document considers the remedial technologies that make up the alternatives and evaluates potential impacts to listed species of implementing those technologies. Therefore, this draft FS uses the information from the evaluation of technologies in the Preliminary Draft BA to evaluate the remedial alternatives that are made up of various combinations of those technologies.

8.2.3.2 Common Elements – Compliance with ARARs

All of the alternatives are expected to comply with the five primary ARARs evaluated in detail, with the possible exceptions of certain WQS/NRWQC and FEMA flood regulations.

WQS/NRWQC. Based on Site-specific modeling and as described in the sections below, none of the comprehensive alternatives are capable of achieving all potential chemical-specific state and federal surface water WQS/NRWQC. This is largely due to Site background loading conditions (i.e., upstream river contaminants entering the Site), which have been accounted for in model projections. Exceedances of WQS/NRWQC are projected by the model to occur over the entire Site for some very low criteria (e.g., based on human health fish consumption) and occur in localized areas for most other criteria. These localized areas are in embayments and slips where quiescent conditions create less movement and mixing of water.

Per the draft final RI, the 95th percentile UPL of upstream background surface water concentrations of arsenic, dieldrin, total PCBs, total PAHs, 4’4-DDT, sum DDT, and 2,3,7,8-TCDD exceeded the federal or state fish consumption values for these contaminants.[2] Upstream surface water background levels of mercury also exceed Oregon chronic aquatic life WQS, although not the federal NRWQC. Per Table 3.1-1, arsenic, dieldrin, and mercury are not COCs for the Site.

Of the surface water COCs listed above, two were directly modeled—total PCBs and 4’4-DDT. For total PCBs, the Oregon WQS is not expected to be achieved in the water column post-remedy (see long-term concentrations in Figure 8.2.2-8). Figure 8.2.2-8 also illustrates that for total PCBs, no alternative is projected to contribute more than any other alternative to reduction in surface water concentrations post-remedy, because total PCB concentrations projected in the water column post-remedy will be primarily attributable to upstream background. For 4’4-DDT, this contaminant is expected to meet the NRWQC (see long-term concentrations in Appendix U, Figure 3.2-5). The result for 4’4-DDT is expected to be generally representative of this class of contaminants (i.e., DDx).

Of the other COCs listed above, although total PAHs were not modeled, BaP was modeled. Based on the RI data, concentrations of BaP do not currently exceed the applicable Oregon WQS or NRWQC, and they are not projected to exceed the standards post-remedy (Appendix U, Figure 3.2-2). The only remaining surface water COC for the Site is 2,3,7,8-TCDD, which was not modeled. However, given that this COC has similar bioaccumulation properties to PCBs and DDT and is largely co-located in sediments with those COCs, no alternative is projected to contribute more than any other to reduction of this COC’s concentrations in surface water post-remedy and concentrations in the water column post-remedy are expected to be primarily attributable to upstream background.

For the environmental dredging/removal portion of the alternatives, exceedances of various criteria during construction are projected (Figures 8.2.2-8 through 10). Compliance with WQS/NRWQC would be achieved through management (through operational BMPs; see Section 6.2.7.3) of water quality impacts at the point of dredging. Short-term (during construction) increases in water column concentrations exceeding both existing concentrations and certain WQS/NRWQC are anticipated during some dredging operations as detailed below.

FEMA Flood Rise Requirements. All of the alternatives except Alternative A (No Action) had maximum projected increases in water surface elevation (during an

[2] As discussed in Section 3.1.3, the FS generally has not been updated to incorporate the Oregon Human Health Water Quality Criteria for Toxic Pollutants that became effective October 17, 2011 due to insufficient time to integrate these criteria in the developing draft FS. The Oregon WQS for fish consumption used in this evaluation were the Effective Oregon Water Quality Criteria for Human Health, Effective June 1, 2010. However, as discussed in Sections 3.1.3 existing data have been rescreened with the updated criteria to assist in comparisons to the older criteria used in the draft FS evaluations. In particular, comparison of potential ARAR values (including the pre- and post-October 2011 Oregon Human Health Water Quality Criteria for fish consumption) to Site surface water and to 95th percentile upper prediction limit (UPL) background concentration values is provided in Tables 5.5-2 and 5.5-3.

estimated[3] "100-year" flood event) of more than 0.005 feet. However, the HEC-RAS model's precision is estimated to be no less than 0.25 feet. The predicted increases in water surface elevations for all action alternatives during an estimated "100-year" flood are considered to be negligible and not significantly different between alternatives based on the model precision; therefore, compliance of the alternatives with this ARAR cannot be confirmed. To demonstrate compliance with the ARAR in remedial design one or more of the following actions would need to be taken for any alternative selected by EPA: 1) additional modeling with a higher precision; 2) revisions to effective Flood Insurance Studies, Flood Insurance Rate Maps, or Flood Boundary Floodway Maps following FEMA regulations (FEMA 2011); or 3) mitigation for any unacceptable flood rise that can be confirmed in remedial design.

8.2.4 Long-Term Effectiveness and Permanence

This criterion assesses the alternative for magnitude of residual risk remaining after implementation and the adequacy and reliability of control measures (e.g., containment systems and institutional controls).

8.2.4.1 Methods

The long-term effectiveness and permanence of the comprehensive alternatives was evaluated for each of the NCP factors of magnitude of residual risk and adequacy and reliability of controls. Several methods were used for magnitude of residual risk, each of which relates to determining attainment of specific RAOs. Attainment of the RAOs indicates that the magnitude of residual risk is within the RAO definition. The methods used for these evaluations are described below.

8.2.4.1.1 Magnitude of Residual Risk – Long-Term Sediment, Biota Tissue, and Surface Water COC Concentration Projections

The QEAFATE model was used to project the following long-term contaminant concentrations resulting from implementation of each alternative:

- Sediment quality projections were compared with a range of RGs in Table 8.2.2-1. This metric is most relevant to RAOs 1, 2, 4, and 5.
- Biota tissue projections from the QEAFATE model and linked Food Web Model were compared to a range of TTLs, consistent with the sediment RG ranges (Table 8.2.2-1). This metric is most relevant to RAOs 2 and 5. Biota projections were limited to total PCBs, the primary contributor to calculated and fish consumption potentially unacceptable risks at the Site.
- Surface water quality projections were compared with state WQS and federal NRWQC. This metric is most relevant to RAOs 3 and 7.

[3] Per Appendix Lb, the results of the flood frequency analysis are uncertain due to the relatively short period of record of flow rate data that could be used in the analysis. Therefore, the flow rate used to represent the 100-year flood should only be considered an estimate and not as a formal or regulatory definition of such an event.

While sediment projections were primarily compared with ranges of RGs, in some cases comparisons were made to EPA's point estimates of specific RGs. As discussed in Sections 3 and 4 and Appendix E, such point RG estimates are conservative because the exposure assumptions and scenarios defined in the risk assessments are conservative. For DDx contaminants, comparisons to point estimate PRGs or RGs were performed due to the lack of RG range estimates similar to PCBs and BaP. As discussed in Section 3.6, the RG sensitivity analysis reveals considerable variability in the protectiveness associated with RG point estimates. For example, different types of human health consumption scenarios (e.g., fillet or fillet with skin consumption) or endpoints (e.g., noncancer) result in widely varying RGs. TTLs used for biota tissue contaminant comparisons are analogous to the RG estimate ranges used (Table 8.2.2-1), and the same general approach as described for sediment comparisons also applies to tissue comparisons to TTLs.

Long-term sediment quality projections were developed and presented on a range of spatial scales including Site-wide and by Segment. Projections were also developed by river mile for PCBs, DDD, DDE, and DDT and by shoreline half river mile for BaP, as presented in Appendices Ha and U. As discussed in Section 2.9, the Segment approach summarizes the alternative evaluation at an overall spatial scale relevant to draft FS engineering decisions and provides a reasonable intermediate spatial scale for comparison to RGs that range between smaller scales (e.g., river mile or half river mile shoreline) and larger scales (e.g., Site-wide) that are most relevant to the various RGs. For this reason, both Site-wide, 1 river mile-based, and shoreline half river mile-based RG ranges are shown on figures presenting sediment quality projections by Segment.

8.2.4.1.2 Magnitude of Residual Risk – Potential for Recontamination

Each alternative was also evaluated using the QEAFATE model to assess the potential for long-term sediment recontamination, which is relevant to RAOs 1, 2, 5, and 6. This evaluation included examination of recontamination potential at smaller spatial scales and assessed recontamination potential from ongoing known sources (e.g., stormwater, permitted industrial discharges, groundwater, and upstream inputs), along with localized recontamination due to dredging-related resuspension in adjacent areas. This was primarily accomplished by reviewing projected sediment concentrations after remediation both Site-wide and locally.

8.2.4.1.3 Magnitude of Residual Risk – Minimization of Potential for Groundwater Impacts

Each alternative was also evaluated relative to the potential for human health and ecological potentially unacceptable risks resulting from exposures to contaminated groundwater, which is relevant to RAOs 4 and 8. These evaluations used QEAFATE model projections, which incorporated identified groundwater plumes (Appendix Ha, Section 3.2), to assess long-term surface water and sediment quality changes in groundwater discharge areas. Additionally, modeling was performed for a range of COCs to evaluate the effectiveness of capping technologies in groundwater discharge areas. Surface water quality projections for both QEAFATE and cap modeling were compared to state WQS, federal NRWQC, and drinking water MCLs.

As discussed in Section 3.2, identified upland groundwater plumes will be primarily controlled through upland source control actions administered under DEQ's oversight of work performed by individual upland parties. Thus, RAOs 4 and 8 only apply to that portion of each groundwater plume that is downgradient of its respective upland groundwater source control boundary (i.e., riverward of the riverbank and out under the riverbed). These downgradient detached plumes would be expected to remain after upland source controls are in place but dissipate or naturally attenuate over time once the source has been controlled.

As described in Section 2.5.2, an analysis of groundwater flows into the river near known or suspected upland contaminated groundwater plumes was conducted during the RI to identify where such upland groundwater plumes might be discharging to the river at measurable levels. Where discharges to the river that had the potential to impact TZW were characterized, they were identified as "complete" upland contaminated plume pathways in the draft final RI. Contaminated groundwater discharge areas with complete flowpaths were identified on the west bank of the Study Area between RM 6 to 8. It is possible that other complete groundwater flowpaths could be identified in the future at in other Site areas, including during SMA-specific remedial designs.

It is important to note that from a human health perspective, the BHHRA did not identify human health potentially unacceptable risks to people who may contact or ingest water from nearshore groundwater seeps. Relative to potentially unacceptable ecological risks, a number of COCs in TZW were identified that are potentially or partially attributable to upgradient groundwater plumes.

Sediment alternatives were evaluated relative to potential chemical-specific water quality standards and criteria[4] that EPA indicated are relevant to groundwater including Oregon WQS for human health fish consumption and freshwater chronic aquatic life as well as federal NRWQC for human health consumption of aquatic organisms, drinking water MCLs, and NRWQC freshwater chronic aquatic life values. The ability of sediment remedies to help meet these standards and criteria in surface water is evaluated in the long-term effectiveness sections below for the primary contributors to potentially unacceptable risks. The modeling approaches used in the above evaluations of surface water quality conditions, as well as for sediment and biota tissue quality evaluations, integrated groundwater loadings from known or suspected upland sources in complete groundwater plume areas. These modeling projections conservatively assumed no reductions over time in the groundwater source loads relative to current conditions (Appendix Ha, Section 3.2).

As noted in Sections 3.1, 6.2, and Appendix C, the list of COCs included in the Site fate and transport modeling did not include all contaminants potentially associated with complete upland contaminated plume pathways. As a result, additional evaluations were conducted for relatively mobile and high concentration contaminants in these areas using a representative set of three contaminants (i.e., benzene, chlorobenzene, and vinyl

[4] As noted in Section 3.2, the LWG does not agree that these are ARARs when applied to TZW evaluations.

chloride). Appendix C (Section 3) contains more information regarding these contaminants; a summary of this evaluation is provided below:

- SMA 9U contains groundwater plumes from some PAHs, benzene, and TCE including mobile breakdown products such as vinyl chloride.
- SMA 14 contains groundwater plumes for DDx, chlorobenzene, perchlorate, and VOCs (e.g., chloroform), of which chlorobenzene is mobile and present at high concentrations.

For the purposes of this draft FS, the ability of in-place capping technologies to effectively reduce the flux of these contaminants was evaluated, focusing on the bioactive zone in river sediments, TZW, and surface water. Capping could potentially be included as the primary remedy in combination with groundwater source controls within these complete groundwater plume areas (see more below about remedial options for groundwater plume areas).

As discussed in Section 6.2.6, active capping was modeled in these complete plume areas, and modeled concentrations at the bottom of the cap bioactive zone were compared to available water quality benchmarks for these contaminants. The modeling assumed that upland source controls were in place that would reduce the velocity of groundwater. This is consistent with the types of groundwater source control actions currently under design for upland areas adjacent to SMAs 9U and 14 (Anchor QEA 2011d and ERM 2011).

8.2.4.1.4 Magnitude of Residual Risk – Minimization of Downstream Transport

Management Goal 2 calls for minimization of potential downstream transport of contaminants, which is generally relevant to the NCP factor of magnitude of residual risk. This goal was evaluated using long-term QEAFATE model projections, which quantified the mass of contaminants leaving the downstream boundaries of the Site under each alternative.

8.2.4.1.5 Adequacy of Controls

The ability of institutional controls and containments (e.g., capping) to reliably control residual risks was evaluated using general information on institutional control program assumed for each alternative as well as evaluations of capping, EMNR/in situ treatment, and stability from Section 6.2.

8.2.4.1.6 Other Factors – Habitat Enhancement Potential Integration

Habitat enhancement potential integration into the sediment remedy (Management Goal 3) was evaluated using the findings of the 404(b)(1) analysis in Appendix M and Preliminary Draft BA (Anchor QEA 2012). The preliminary restoration concepts often indicate excavation in the nearshore area for the purposes of creating a shallower slope in the ACM, removing riprap and upland fill, creating new off-channel habitat through reconnection of the historic floodplain, and/or improved riparian zone vegetation. Some action alternatives may require placement of engineered caps or similar containment technologies for certain nearshore areas to address wave/wake erosion issues and protect the stability of the cap (Appendix Hc, Section 4) that would result in different slopes, substrates, and elevations than desired for some restoration efforts. Similarly, removal technologies may create greater water depth conditions, slopes, or substrates (e.g., changing ACM and shallow water habitat to deep water) than desired for some restoration efforts.

The potential overlap between preliminary potential habitat restoration concept areas (Table 2.4-3)[5] and sediment remediation alternatives was examined to determine if sediment remediation would preclude habitat restoration (e.g., relevant to Management Goal 3 in Section 3.3). The potential overlap between possible restoration sites and alternative areas was mapped and assessed to determine whether each remedial alternative might prohibit or limit use of these overlapping areas as restoration projects.

8.2.4.1.7 Disposal Options Long-Term Effectiveness

The long-term effectiveness of on-Site disposal options included in each alternative was evaluated against the FS CDF Performance Standards (EPA 2010e and LWG 2010a and b; Appendix O) as defined in Section 6.2.9. The evaluations against the performance standards include modeling projections of CDF long-term contaminant isolation effectiveness presented in Appendix Jb.

The FS CDF Performance Standards do not apply to the upland disposal options. The commercial landfills considered all operate under permits issued by the states of Oregon or Washington. Prior to transporting dredged material from the Site to one of these landfills, the compliance of the facility will be confirmed with the Region 10 Regional Off-Site Contact in accordance with the Off-Site Rule (40 CFR 300.440). The landfill cells have been designed and built to meet regulatory requirements, and they are operated, maintained, and inspected to maintain compliance with applicable requirements. Waste profiles will be completed and approved by the landfills prior to transporting sediment to confirm that the sediment meets the waste acceptance criteria for the landfill. Disposal of sediment from the Site at landfills operating in compliance with the conditions of their permits and other applicable requirements will provide effective containment of hazardous substances in the long term.

Appendix U (Section 6) contains tables with the full FS CDF Performance Standards and summarizing the results of this evaluation for each on-Site CDF or CAD for each performance standard. Some performance standards address similar issues and are therefore grouped relevant to the magnitude of risk and adequacy of controls.

[5] The areas used in this evaluation are from preliminary information on potential restoration concepts identified by third parties. There are no definitive design plans available for these potential restoration sites beyond preliminary conceptual designs, and there are no concrete restoration plans moving forward for most of these sites. Further, the preliminary restoration concepts may not be consistent with current or future site uses or may have other logistical issues that would need to be addressed before they could become actual restoration projects.

While the FS CDF Performance Standards were evaluated for the purpose of this draft FS, alternative performance standards that are equally protective of human health and the environment may be appropriate to consider during remedial design. Such alternative performance standards may include, but are not limited to, the following: 1) evaluation of fish consumption and drinking water criteria in the receiving water column of the Willamette River rather than in the porewater of the CDF berm: 2) spatial averaging of fish consumption exposure concentrations over representative home ranges and harvesting areas in the river, rather than the limited area of the berm interface; 3) evaluation of chronic criteria at the interface of the riprap armor and the berm material, rather than 1 foot inside the berm material where benthic organisms are not likely to be present; and 4) incorporation of different less conservative biodegradation rates for organic constituents than those assumed in Appendix Jb (Section 3.5.2).

For the Terminal 4 CDF and Swan Island Lagoon CDF options, contaminant transport modeling was performed to determine whether the CDFs would effectively contain bounding COCs evaluated (Appendix Jb, Section 3). The modeling for the Terminal 4 CDF reflects the advanced status of the design, whereas the modeling for the Swan Island Lagoon CDF is preliminary based on the initial conceptual design for this CDF developed for this draft FS. If the selected remedy includes the use of the Swan Island Lagoon CDF, the design would include additional modeling to further document achievement of appropriate performance standards developed during remedial design. Similarly, final design and construction of Terminal 4 CDF could include additional modeling refinements or different performance standards than the FS-level standards that currently exist.

Sediment leaching data within one or two locations within select SMAs were collected for FS purposes for use in the CDF modeling in Appendix Jb (Section 3). Although this is more data than is normally available for an FS-level analysis of CDF performance, these data are not necessarily representative of the entire range of conditions in every SMA. Data from SMAs 9U and 14 were not included in the long-term groundwater modeling in Appendix Jb (Section 3) for draft FS purposes. Due to the wide range of chemical conditions within these SMAs, it is fully expected that much of the sediments in these locations may be acceptable for placement in a CDF or CAD. This acceptability may be further expanded if stabilization or other treatment methods prior to disposal are found to be cost effective in remedial design. The details of which sediments within these two SMAs can be disposed in CDF/CADs could be evaluated in remedial design based on additional sediment leaching data, other relevant data, and design level modeling, as necessary to determine compliance with CDF performances standards existing at that time.

8.2.4.2 Common Elements – Long-Term Effectiveness and Permanence

Similar to the discussion for overall protectiveness, all the alternatives are effective at reducing COC concentrations in or reducing exposures to surface sediment, tissue, and the water column.

8.2.4.2.1 MNR

With respect to the magnitude of residual risk, MNR may provide low to high level of risk reduction depending on processes being relied upon and Site-specific characteristics that might enhance the long-term isolation or destruction of contaminants. With respect to the adequacy and reliability of controls for residual risk, MNR may provide low control but is potentially acceptable, depending on the processes being relied upon and Site-specific conditions.

Natural recovery processes are expected to continue to cause long-term reductions in water column, sediment, and tissue contaminant levels at the Site, and reductions in potentially unacceptable risks related to these contaminants. These natural recovery processes are expected to continue over the long term.

Natural recovery processes are expected to continue to cause long-term reductions in water column, sediment, and tissue contaminant levels at the Site, and reductions in potentially unacceptable risks related to these contaminants. Empirical data from the RI, as summarized in Section 2.6, pertaining to the long-term effectiveness and permanence of source control and natural recovery processes are reviewed in Section 6.2.2 and have been incorporated into detailed Site-specific fate and transport modeling. These natural recovery processes are expected to continue over the long term.

Because sediment exceeding RGs would remain in the river under all alternatives for a period of time until RG ranges are met, the potential for sediment erosion during the recovery period(s) is relevant in the evaluation of long-term effectiveness and permanence as it relates to adequacy and reliability of controls. Detailed fate and transport modeling revealed that extreme flood events, modeled in year 17 of the HST and QEAFATE projections, would result in a transient increase in surface sediment concentrations over most spatial scales and areas assessed. As discussed in Appendix Ha, Section 5.3, during such an extreme flood event, some sediment bed erosion is projected to occur. However, in this situation, such transient erosion events are followed by continued or increased deposition as flows return to normal conditions, which cause the sediments to recover to pre-flood equilibrium conditions usually within a few years (Figures 8.2.2-1 through 8.2.2-6).

8.2.4.2.2 EMNR/In Situ Treatment

With respect to the magnitude of residual risk, EMNR/in situ treatment may provide moderate to high level of risk reduction depending on specific treatment designs for location-specific contaminants. With respect to the adequacy and reliability of controls for residual risk, these technologies may provide moderate to high control, depending on location-specific sediment stability considerations.

As described in Sections 6.2.3 and 6.2.4, EMNR can be used to effectively accelerate the natural recovery process by placing a thin layer of suitable sand or sediment, while in situ treatment can effectively reduce the bioavailability of certain contaminants by placing an even thinner layer of AC or other amendments. Both technologies would achieve long-term protection and permanence across areas where they were found to be implementable in Section 6.2 (e.g., outside of areas that would be expected to be prone to consistent erosional forces).

8.2.4.2.3 Capping

With respect to the magnitude of residual risk, capping may provide moderate to high level of risk reduction and low to moderate residual risk, depending on cap design, placement, construction, and maintenance to address Site characteristics that might otherwise prevent long-term isolation of contaminants. With respect to the adequacy and reliability of controls for residual risk, capping may provide moderate to high control, depending on cap stability and contaminant migration through cap.

Caps included in the remedial alternatives for the draft FS were based on preliminary designs following EPA and USACE guidance. Caps designed and constructed in accordance with this guidance provide long-term chemical isolation and stability (EPA 2005a). Different cap designs have been developed to address the range of potential erosional forces anticipated within different areas of the Site (see Section 6.2.5). The results of these analyses support that these mechanisms would not impact the long-term stability of the caps. Placement of boat anchors on the caps is also expected to have minimal impact, primarily due to the relatively small surface area potentially affected by this activity (Palermo et al. 1998; USACE 1998). Note that large ships are not expected to anchor in areas that are capped, given that per Section 6.2, caps are not generally expected to be placed in the navigation channel and future maintenance dredge areas associated with large ship traffic.

Based on the extensive Site-specific data collection directed towards evaluation of cap stability, coupled with Site-specific evaluations of each of the forces (extreme currents, propwash, waves, etc.) that might impact cap stability, all caps included in alternatives evaluated in the draft FS are expected to be stable over the long term. Similarly, contaminant flux evaluations using conservative assumptions indicate that caps can be designed to minimize contaminant flux to the river that will meet WQS/NRWQC over the long term.

It is also assumed for the draft FS that habitat features will be incorporated into many of the caps eventually designed at the Site. Although specific habitat designs are not developed for the draft FS, the mitigation analysis in Appendix M, Attachment 1 defines the level of habitat impact associated with each cap in each alternative and defines the level of mitigation necessary to achieve no long-term net impact to the habitats at the Site. Also, in many cases, the substrate and elevation changes assumed for effective cap design were found in Appendix M to already create habitat improvements without any additional habitat features being added.

Long-term monitoring and maintenance of the caps is included as an element of all capping alternatives to further ensure their long-term effectiveness and permanence, consistent with EPA and USACE guidance. Proper design and installation would reduce future maintenance requirements. In the event that damage to the caps occurs, affected areas would be identified during post-construction monitoring and subsequently addressed (which is included in cost estimates for caps).

8.2.4.2.4 Dredging/Removal

With respect to the magnitude of residual risk, environmental dredging/removal may provide moderate to high level of risk reduction and low to moderate residual risk, depending on the effectiveness of dredging and use of backfill material. With respect to the adequacy and reliability of controls for residual risk, this technology may provide high control due to removal of contaminants, if residual contamination is below cleanup levels or addressed through post-dredge covers or capping (if needed).

While environmental dredging/removal would reduce the volume of contaminated sediments in the river and contribute to long-term effectiveness and permanence, post-dredge surface concentrations are anticipated to be elevated above RGs due to unavoidable residuals. Dredging residuals have routinely been observed during other environmental dredging projects, particularly when rocks/cobbles or other debris are present on the river bottom, which increases resuspension and residuals generation (Patmont and Palermo 2007). These considerations are built into the remedial alternatives included in the draft FS, where all dredging alternatives include a post-dredge cover. The long-term effectiveness and permanence of alternatives that include dredging is driven primarily by the post-dredge cover component, particularly for lower RALs, because the ability of the covers to provide long-term containment of the post-dredging residuals controls potential future exposures to human health and the environment. As discussed under overall protection, there are a range of process options, some involving greater use of covers, which are appropriate for further consideration in remedial design.

Sediments removed as part of each alternative would be disposed of at protective CDFs and/or off-Site landfills. These disposal facilities would provide effective long-term management of the dredged materials, controlling potential future exposure to human and environmental receptors to within acceptable levels.

8.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion assesses the degree to which an alternative reduces the toxicity, mobility, or volume of COCs through treatment. CERCLA has a statutory preference for selecting remedial actions that use treatment technologies to the maximum extent practicable.

8.2.5.1 Methods

This criterion was assessed by calculating the acreage of contaminated sediments addressed by treatment for each alternative. Also, the volumes of sediment that were removed and treated via dewatering and/or stabilization were also qualitatively considered.

8.2.5.2 Common Elements – Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction in toxicity through treatment would mostly occur for those alternatives that include in-situ treatment or dredging followed by ex-situ treatment (i.e. dewatering) of the dredge spoils. MNR and EMNR do not include a treatment component, and capping generally does not include treatment under the alternatives except through the use of active capping in certain areas as discussed below. The treatment provided by the other technologies is noted in the following subsections.

8.2.5.2.1 EMNR/In Situ Treatment

In situ treatment can effectively reduce the toxicity and mobility of sediment contaminants by controlling their bioavailability. Placement of AC has proven effective in reducing the bioavailability of a range of sediment contaminants at other sites, including the bounding COCs for the Site for a variety of pathways and receptors including the benthic community (Ghosh et al. 2011; Cornelissen et al. 2011).

8.2.5.2.2 Active Capping

Active capping is included in the draft FS in certain areas, and this is one form of in situ treatment. Further active capping is a retained technology providing treatment that could be added to standard capping as judged necessary in SMA-specific remedial designs.

8.2.5.2.3 Dredging/Removal

Dewatering using diatomaceous earth (the assumed process option for draft FS purposes) and/or addition of other materials that also reduce contaminant leaching (e.g., Portland cement) are forms of ex situ treatment that reduce the mobility of contaminants in sediment and dewater.

8.2.6 Short-Term Effectiveness

This criterion assesses impacts related to construction and implementation of each alternative.

8.2.6.1 Methods

Short-term impacts were evaluated following the NCP short-term factors of environmental impacts, time until protection, community risks, and potential impacts on workers.

Potential Environmental Impacts. Water quality, sediment recontamination, potential downstream and off Site transport of contaminants, and air pollutant and greenhouse gas (GHG) emissions were evaluated for the construction phase of each alternative.

Water quality, recontamination, and downstream transport during construction were evaluated using QEAFATE model projections throughout the Site. Model-projected water column concentrations were compared to water quality criteria and benchmarks, while sediment quality projections were compared to RGs and RALs. For the evaluation of potential sediment recontamination from short-term construction activities, time-series plots of projected increases in average surface sediment total PCB and DDE concentrations were developed for 1-mile SWAC areas downstream of (and including) each SMA. The same approach was used for BaP but using a half mile SWAC for that COC.[6]

The potential impacts of GHG and air pollutant emissions during construction of each alternative were estimated using standard air inventory calculation methods as described in Appendix Ic. The GHG component was based on projected emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), with emissions reported in metric tons (tonnes) of carbon dioxide equivalents (CO_2-eq).[7] The air pollutant component was focused on seven select pollutants (NOx, SO_2, CO, HC, VOCs, PM_{10}, and $PM_{2.5}$).[8] Projected emissions were categorized into the following five primary emissions-generating activities: 1) Site preparation; 2) dredging; 3) placement of remedial materials (e.g., capping, EMNR, and post-dredge residual cover sand); 4) in situ treatment; and 5) transportation of materials/waste (including transportation of capping and similar materials via tug/barge, transportation of diatomaceous earth via truck, and transportation of dredged sediments for upland disposal via rail). Emissions were estimated for these activities based on the anticipated type of equipment, duration of use, and fuel consumption rates, consistent with the draft FS cost estimates (Appendix K).

The potential short-term impacts to water quality from on-Site disposal facility construction and filling for disposal options associated with each alternative were evaluated through review of the FS CDF Performance Standards (EPA 2010e and LWG 2010a and b; Appendix O). This included evaluation of the potential for surface water quality impacts during CDF construction and filling with contaminated sediments (Appendix Jb, Section 2). While the FS CDF Performance Standards were evaluated for the purpose of this draft FS, alternative short-term performance standards that are equally protective of human health and the environment may be appropriate to consider during remedial design.

Time Until Protection is Achieved. The approximate timeframes required to achieve RAOs were evaluated by comparing projected changes over time in sediment and tissue COC concentrations projected using the QEAFATE and Food Web Models to the ranges of sediment RGs and TTLs.

Potentially Unacceptable Community Risks and Quality of Life. The primary community risk during construction would occur through the short-term water quality, downstream transport, recontamination, and air pollutant impacts discussed above. In

[6] A complete description of the method used to estimate short-term recontamination concentrations using the fate and transport model is provided in Section 6 of Appendix Ha.
[7] In accordance with the Climate Leaders Greenhouse Gas Inventory Protocol, Design Principles, published by EPA (2005). CO_2-eq is calculated by multiplying the mass of individual GHGs times their associated global warming potential (GWP).
[8] Nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), hydrocarbons (HC), VOCs, particulate matter less than 10 and 2.5 microns in diameter (PM_{10} and $PM_{2.5}$)

addition, “quality of life” during the short-term construction phase of the alternatives was evaluated through a qualitative assessments of the human use environment and the potential for alternatives to affect issues of aesthetics, odor and dust, traffic, noise, commercial navigation, and recreation.

Potential Impacts to Workers. Protection of workers during construction of each alternative was assessed using calculated estimates of non-fatal and fatal injuries using incident occurrence rate data in conjunction with the anticipated construction operations associated with each alternative. Data were reviewed from the U.S. Department of Labor, Bureau of Labor Statistics database (USDL 2011) and used to obtain injury and fatality occurrence rates by occupation for the 2009 calendar year (the most recent year for which data were available). The non-fatal injury occurrence rate was estimated by determining the number of anticipated non-fatal injuries to occur annually per 200,000 work hours. The non-fatal incident occurrence rates for labor classifications anticipated to be involved with construction for this project were as follows: 4.3 for general construction workers (Other Heavy and Civil Engineering Construction, NAICS Code – 2379) and 2.2 for railway workers (Rail Transportation, NAICS Code 482). These labor classifications are the best near-matches for the work to be conducted under the remedial action construction tasks.

The fatal injury occurrence rate was calculated by determining the number of anticipated fatal injuries to occur annually per 200,000,000 work hours. The fatal incident occurrence rates for labor classifications anticipated to be involved with construction for this project were as follows: 11.0 for equipment operators, 18.8 for construction laborers, 13.3 for railway workers, and 15.3 for construction supervisors. These labor classifications are the best near-matches for the work to be conducted under the remedial action construction tasks. Projection estimates of non-fatal and fatal incidents were based on all construction activity investigated by the U.S. Department of Labor in 2009. There is no information available regarding the health and safety plans and/or procedures that were in place at the time the injuries/fatalities occurred.

8.2.6.2 Common Elements – Short-Term Effectiveness

Short-term impacts common to all of the alternatives include temporary water quality impacts, localized low-level recontamination of nearby downstream sediments, some downstream transport of contaminants, air pollutant and GHG, community quality of life impacts, and worker incidents. These impacts are evaluated in greater detail in the alternative-specific evaluations (Sections 8.3 to 8.8), and in the comparative analysis of alternatives presented in Section 9. With regards to time until protection is achieved, the individual components cannot be readily differentiated relative to this factor outside the context of a comprehensive alternative. One exception is that MNR may have somewhat longer time to achieve RAOs (see below).

An evaluation of the Site-specific application of MNR, EMNR/in situ treatment, capping, and dredging/removal in consideration of this criterion follows.

8.2.6.2.1 MNR

Generally, this technology is associated with effectively reducing risks over time, though to varying degrees depending on the specific location within the Site. Considering the uncertainties of other factors, such as the range of RG estimates and modeling uncertainty, these factors are much larger than the differences in time to achieve RAOs for MNR as compared to using more active technologies. With MNR, there are no additional impacts to the environment, public/worker protection, or existing habitats from the remedy itself.

8.2.6.2.2 EMNR/In Situ Treatment

Under the assumed representative process option of direct broadcasting AC, there are some short-term impacts associated with EMNR/in situ treatment construction including minor water quality impacts, air and GHG emissions, and worker accidents during the construction. These are evaluated in greater detail in the sections below. Targeted AC dosage rates for in situ treatment are below those that would result in benthic impacts (Ghosh et al. 2011), and if there are minor unexpected impacts, rapid recolonization of the EMNR/in situ treatment surface by the benthic invertebrate community is expected as described more for capping below.

8.2.6.2.3 Capping

Short-term impacts associated with cap placement would include possible minor effects on water quality (primarily turbidity and surface foam from the capping materials themselves, which will be chemically suitable for this use). Consequently, silt curtains and similar barriers are not commonly used for capping operations. For example, EPA (2005a) notes operational controls that are typically applied to limit water quality impacts during capping operations. Further, monitoring data collected at other capping sites similar to the conditions of the Lower Willamette indicates that silt curtains are likely ineffective in controlling downstream water quality, and in such situations their use is not recommended (EPA 2005a). If determined to be necessary during remedial design or construction, turbidity and surface foam impacts potentially associated with placement of suitable capping materials could be controlled through operational BMPs.

Placement of cap material would in some cases provide desirable habitat substrates (e.g., gravel) and in many other cases the larger cap armor types are expected to fill in with deposition of sand and silt-sized materials similar to those currently present at these same locations across the Site. These new surfaces are expected to provide suitable substrate for the benthic invertebrate community (i.e., the mixtures that often mimic existing Site sediments). Studies completed in the Columbia River estuary indicate that recolonization after sediment disturbance (e.g., initial placement of the cap) through construction usually occurs within several months when suitable substrate is present (McCabe et al. 1998).

8.2.6.2.4 Dredging/Removal

With environmental dredging/removal, the time to achieve protection varies depending on the size (volume and duration) and complexity of the project and is generally more uncertain than for EMNR/in situ treatment or capping due to dredging-induced resuspension, release, and residuals. Table 6.2-11 provides a summary of case studies regarding documented releases related to contaminated sediment dredging projects, mostly focused on PCBs. The release rates observed across these studies are generally in the range of 2 to 4 percent, with most of the release being in the bioavailable dissolved form. As demonstrated by these case studies, there are no documented differences in these release rates between projects that use barrier controls and those that do not. Although all of the studies involved silt curtains or similar technologies, it is not expected that the predominantly dissolved phase release can be effectively contained by any technology, including sheetpile walls, because neither technology can provide a watertight barrier (see Section 6.2.7).

Unavoidable resuspension and release of COCs during sediment removal would result in significant short-term increases in water and fish tissue COC concentrations (Bridges et al. 2010), as presented in more detail in Section 9.3.2.

As noted in Section 6.2.7, based on the documented issues with effectiveness and implementability of rigid containment, and the limited documented benefit associated with such controls, consideration of rigid containment as a removal BMP is generally not warranted for remedial design. Consideration of silt curtains during remedial design may be appropriate in limited application; however, any potential advantage needs to be considered in light of the increased potential for impacts related to floodplains impacts, scour, and other unintended consequences discussed in Section 6.2.7.

In areas of the river where dredging occurs, the fish habitat and benthic community will be significantly altered and/or eliminated in the short term. However, where acceptable concentrations can be achieved in dredge areas (e.g., through placement of post-dredge covers) recolonization would be expected within several months (McCabe et al. 1998).

8.2.7 Implementability

This criterion assesses the ease or difficulty of implementing the remedial technology/ process option by considering technical feasibility, administrative feasibility, and availability of services and materials required for implementation as well as the additional factors for each of these noted in Section 8.1.

8.2.7.1 Methods

The technical feasibility evaluation included reviews of the implementability issues described for each component technology in Section 6.2 as well as the combined implementability issues associated with each alternative. Section 9.6 contains a comparative detailed evaluation of all of the implementability factors for the alternatives as noted in Section 8.1. As discussed in Section 9.6, most of the implementability issues associated with alternatives are directly related to the duration of the alternatives, and these durations are a good overall metric for levels of implementability issues. Therefore, for Section 8 evaluations (e.g., Section 8.4.6), the durations of the alternatives are briefly discussed as a general indicator of implementability.

8.2.7.2 Common Elements – Implementability

All of the alternatives have some implementability issues, with greater implementability challenges occurring for the alternatives that actively remediate larger areas and volumes of sediment. Larger areas and volumes are directly correlated to longer construction durations. Thus, construction duration is a good overall metric regarding the relative implementability of the alternatives and is used throughout Section 8 to summarize implementability issues. Section 9.6 contains additional details of how different aspects of implementability factors noted in Section 8.1 compare across alternatives.

In addition, an important implementability issue that applies to all alternatives is integration with ongoing Site navigation and other uses. As detailed in Section 6.2, the implementability of the technologies making up the alternatives is often mostly determined by compatibility with ongoing Site navigation and shoreline uses. Therefore, all of the remedial technologies in each alternative are applied only in areas that are expected to be compatible with these existing uses. The application of technologies to specific areas in these alternatives represent draft FS assumptions only, and as noted in Section 6, flexibility is expected for remedial design to further refine or change these technology applications as remedial design data and analyses indicate. Therefore, remedial design efforts will also have to fully consider Site navigation and other uses, both current and potential future, in any refinement of technology applications of the alternative eventually selected by EPA.

The application of technologies to specific areas in these alternatives represent draft FS assumptions only, and as noted in Section 6, flexibility is expected for remedial design to further refine or change these technology applications as remedial design data and analyses indicate. Therefore, remedial design efforts will also have to fully consider Site navigation and other uses, both current and potential future, in any refinement of technology applications of the alternative eventually selected by EPA.

8.2.7.2.1 MNR

There are no implementability issues associated with MNR because it does not require any Site construction activities and monitoring is relatively easy to implement.

8.2.7.2.2 EMNR/In Situ Treatment

Construction of EMNR and/or in situ treatment at the Site is both administratively and technically implementable. These materials have been successfully applied at other similar sites using one of five process options, including:

- Mechanical mixing of amendments into shallow sediment using injection tines or rotary tilling equipment
- Slurry placement of the amendments onto the sediment surface (e.g., in a clay mixture), potentially including injection or mixing into near-surface sediments

- Mixing amendments with sand and placing the blended materials using methods similar to the EMNR technology discussed above
- Sequentially placing amendments under a thin sand cover
- Broadcast application of amendments in a pelletized form to improve settling characteristics (e.g., SediMite^{TM}; the pellet matrix subsequently degrades, allowing the AC to slowly mix into surface sediments through bioturbation)

Specific EMNR/in situ treatment placement methods would be determined during the design phase.

Because this technology changes the sediment bed elevation only slightly, it would have little to no impact on existing navigation. However, as described in Section 6.2, for draft FS purposes, placement of EMNR/in situ treatment was generally not assumed for navigation channel or future maintenance dredge areas with specific exceptions (i.e., SMA 17S). Where new future uses are possible, EMNR/in situ treatment would need to be integrated with a series of institutional controls in the event that the EMNR/in-situ layer is removed or significantly disturbed.

8.2.7.2.3 Capping

Construction of caps at the Site is both administratively and technically implementable over much of the Site, except for navigation channel and future maintenance dredge areas described in Sections 5.4 and 6.2. In addition, a range of regional capping projects have confirmed the implementability of operations such as onshore preparation of the cap materials and transportation of the cap materials from the staging area to the placement area. Necessary personnel for the various tasks (i.e., crane and loader operators, global positioning system [GPS] engineer, and monitoring crew) are typically readily available. Capping projects throughout the northwest United States have also demonstrated that an armored cap can be successfully placed across the conditions at the Site (e.g., McCormick and Baxter, Gasco Early Action, and Terminal 4 Removal Action Phase 1); specific cap placement methods to achieve target cap thickness would be determined during the design phase. Based on recent capping project experiences and a preliminary review of local borrow pits, it is likely that suitable materials for all of the different cap specifications can be obtained from local sources.

8.2.7.2.4 Dredging/Removal

Environmental dredging/removal at the Site is both administratively and technically implementable, although there are some limitations. Dredging of sediment could be accomplished using construction equipment available from a number of marine contractors. Although not without limits, necessary equipment, personnel, and services are expected to be available in sufficient supply to implement the dredging components of the remedial alternatives and as demonstrated through recent environmental dredging operations in the Site area. However, as discussed in Section 6.2, Site-specific conditions such as the presence of structures and steep slopes would affect the implementability of dredging/removal, and for reasons stated in Section 6.2 dredging in these areas is generally not assumed for the draft FS.

8.2.8 Cost

Cost ranges were estimated and presented for each alternative consistent with EPA (2000) guidance and as detailed in Section 7 and Appendix K. Costs were estimated for the different alternatives following methods described in Section 7.5 and Appendix K. Per the NCP, capital costs, including both direct and indirect costs, annual operation and maintenance costs, and net present value of capital and operations/maintenance costs are included in the estimates.

8.3 ALTERNATIVE A DETAILED ANALYSIS – NO ACTION

8.3.1 Overall Protection of Human Health and the Environment

As discussed above, overall protection is evaluated for each alternative by the extent to which it achieves RAOs. This determination was performed by comparing projected short- and long-term changes in COC concentrations in surface sediment, tissue, and surface water resulting from implementation of the alternatives with the range of sediment RGs (compared to projected SWACs over various spatial scales), TTLs, and water quality standards/criteria as well as the time to achieve such levels.

Sediment. Alternative A is projected to approach the high-end range of PCB background estimates over most of the Site and achieve surface sediment concentrations (SWACs over various spatial scales) that are below EPA's conservative point estimate RGs and PRGs for bounding COCs BaP, DDD, DDE, and DDT. Alternative A is not projected to achieve long-term surface sediment PCB concentrations that are at or below the most conservative estimates of risks (i.e., ranges of RGs) for PCBs, and thus this alternative is not expected to meet sediment RAOs 1 and 5 (Figures 8.2.2-1, to 8.2.2-6). The most conservative RGs are within the estimated range of background and may not be effectively different from background based on sediment concentrations, tissue concentrations, or risk. This alternative has no short-term impacts to sediment due to construction. Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and sediment core profiles reviewed in Section 6.2.2 indicate deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports that the no action alternative would result in reduced long-term sediment concentrations as indicated by the modeling.

Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and sediment core profiles reviewed in Section 6.2.2 indicate deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports that the No Action alternative would result in reduced long-term sediment concentrations as indicated by the modeling.

Tissue. River Segments 1, 3, and 4 are projected to achieve smallmouth bass whole body tissue PCB concentrations at or near EPA's point estimate TTL under Alternative A**.**

This alternative is not projected to achieve long-term PCB tissue COC concentrations that are at or below the most conservative estimates of risk levels (i.e., ranges of TTLs), and thus this alternative is not expected to achieve tissue RAOs 2 and 6 (Figure 8.2.2-7).

Surface Water. Alternative A is projected to achieve long-term surface water concentrations post-remedy that are the same as all the other alternatives (Figures 8.2.2-8 through 8.2.2-10). However, Alternative A is not projected to achieve levels associated with certain risk -based water quality criteria and standards, particularly those based on fish consumption, primarily because upstream concentrations entering the Site already exceed some of these criteria, as discussed above.

Groundwater. Upland source control actions by themselves may be able to address groundwater RAOs 4 and 8, and thus, Alternative A may meet these RAOs. However, given that this alternative allows no provision for additional in-water remedies (e.g., capping) to assist in attainment of the groundwater RAOs in the river, Alternative A is least likely to meet those RAOs.

8.3.2 Compliance with ARARs

Chemical-Specific ARARs. As discussed in Section 3, there are no chemical-specific ARARs for sediment quality at the Site. Detailed evaluations relative to Alternative A are summarized below to provide comparisons to each chemical-specific water quality criteria (Section 9.2.1 contains additional details):

- MCLs – None of the depth-integrated water column samples collected from the Study Area during the RI exceeded drinking water MCLs. However, fate and transport modeling for total PCBs and BaP indicates that concentrations of these contaminants could nevertheless exceed drinking water MCLs in very small areas and periods (i.e., 0.01 percent or less of the simulation [one one-hundredth of a percent]). The small difference between the RI and model results may be due the fact that RI samples do not cover all the Site conditions and locations simulated in the model.
- Fish consumption WQS/NRWQC – None of the depth-integrated water column samples for DDx collected from the Study Area during the RI exceeded human health fish consumption values. However, the model projects some exceedances of the WQS/NRWQC values for these contaminants for Alternative A for reasons noted above. Model projections also suggest exceedances of WQS/NRWQC for PCBs found in the RI would continue under Alternative A, though in some cases the criteria are below background, and in these situations the background value provides a more relevant comparison. In these cases, the exceedances of the criteria/background represent 12, 0.6, and 0.07 percent of the simulation, for PCBs, BaP and DDx, respectively. Thus, BaP and DDx exceedances are projected for very small areas and periods.

- Chronic and Acute WQS – Of the contaminants evaluated, WQS have only been promulgated for acute and chronic toxicity effects from PCBs[9]. Although RI sampling revealed minimal exceedances of the PCB chronic criteria, model projections suggest existing exceedances of the chronic standard noted in the RI would continue under Alternative A (representing 1.8 percent of the simulation).

Location-Specific ARARs. Alternative A is expected to meet several applicable location-specific ARARs as summarized below (Section 9.2.2 contains additional details):

- Oregon Environmental Cleanup Law – Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at 1×10^{-6} for individual carcinogens and 1×10^{-5} for multiple carcinogens. (Other aspects of this rule [i.e., human health noncancer endpoints and ecological risk levels] are similar to CERCLA criteria and are discussed under long-term effectiveness.) Total PCB concentrations representing a 10^{-5} cancer risk level, calculated using the range of sediment RGs representing smallmouth bass whole body consumption that overlaps with or below the estimated background range, is not projected to be achieved by Alternative A. However, the alternative does achieve the 10^{-5} cancer risk level if consumption of smallmouth bass fillets with skin on is assumed. Also, this alternative is projected to achieve the respective long-term sediment BaP, DDD, DDE, and DDT[10] concentrations in the 10^{-6} cancer risk range. Alternative A does not treat or remove any potential Oregon hot spots at the Site.[11]
- ESA – Alternative A would comply with ESA because it causes no construction impacts or other changes to the baseline condition that might affect listed species.
- CWA Section 404(b)(1) and FEMA Flood Rise Requirements – Similarly, no actions triggering the CWA Section 404(b)(1) or FEMA ARARs would occur under Alternative A.

8.3.3 Long-Term Effectiveness and Permanence

Evaluation of the long-term effectiveness and permanence criterion is summarized below. Section 9.3 contains additional details.

Magnitude of Residual Risk - Surface Sediment COC Projections. Alternative A is projected to achieve surface sediment concentrations that are below EPA's conservative point estimate RGs and PRGs for BaP, DDD, DDE, and DDT, and these RGs are projected to be achieved over time Site-wide and within each river Segment (Figures

[9] WQS acute and chronic criteria exist for the sum of DDT and its metabolites, and therefore are not compared here to individual projections for DDD, DDE, and DDT.
[10] Note that these RG ranges are expressed in terms of BaPEq or sum DDD, DDE, and DDT, which represents a form of summation across several compounds. However, the modeling is conducted on just the individual compounds of BaP, DDD, DDE, and DDT, and results presented are for those single contaminants only. Thus, it is appropriate to compare these model results to the individual contaminant Oregon risk level standard.
[11] Per Section 5.5, no Oregon hot spots were identified at the Site.

8.2.2-1 to 8.2.2-6). Under Alternative A, on a Site-wide basis, the projected PCB levels are within the high end of the estimated background range. However, PCBs are not projected to achieve the lowest RGs either Site-wide or within Segment 2. Looking at a river mile spatial scale (see graphs in Appendix U, Section 3.1), DDD, DDE, and DDT are all projected to be below their respective EPA point estimate RG/PRGs over the long term under Alternative A. For PCBs, Alternative A is projected to achieve levels below the lowest PCB RG in all RMs except 3 to 4, 6 to 7 (where Alternative A is projected to achieve EPA's point estimate RG), and Swan Island Lagoon. For RMs 3 to 4, additional modeling accounting for ongoing stormwater source controls in this area suggests that Alternative A may achieve the lowest PCB RG over the long term (Appendix Ha, Section 6). For Swan Island Lagoon, Alternative A is projected to result in long-term PCB sediment concentrations above the 90th percentile PCB RG.

Magnitude of Residual Risk - Biota Tissue Concentration Projections. As discussed above, tissue modeling projections were primarily assessed at the river Segment spatial scale, although river mile scale results are also provided in Appendix Hb, Attachment 1. The Segment scale is most representative of the overall scales of potential PCB bioaccumulation exposures and associated RGs/PRGs, which range from 1 river mile to Site-wide. Alternative A is projected to achieve smallmouth whole body levels that are below the range of TTLs in river Segments 1 and 3 (Figure 8.2.2-7). In Segment 2, this alternative is projected to achieve levels just above the 95th percentile estimate of the PCB TTLs, but not the lower ranges of TTLs. In Segment 4, Alternative A is projected to achieve levels just above EPA's point estimate of the TTL.

Other Projections and Assessments. The long-term effectiveness of all alternatives was also evaluated for surface water concentration projections, minimization of the potential for long-term sediment recontamination, minimization of potential groundwater impacts, minimization of downstream transport, integration with habitat enhancement, and disposal site long-term effectiveness. Alternative A generally has no effect on any of these measures beyond or substantially different from existing conditions within the Site or is not applicable to these measures (e.g., integration with habitat enhancement and disposal site effectiveness).

8.3.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Because Alternative A includes no active technologies, there is no reduction of toxicity, mobility, and volume through treatment provided by this alternative.

8.3.5 Short-Term Effectiveness

A number of short-term effectiveness measures were evaluated for all alternatives as introduced in Section 8.2. There are no short-term construction-related impacts associated with Alternative A**.** Section 9.5 contains additional details about time until protection, which is summarized below.

Time Until Protection is Achieved - Projected Timeframes to Achieve RAOs. As discussed in Section 3.6, this draft FS uses a range of RGs that may eventually be judged by EPA to meet the RAOs within the acceptable risk ranges noted in the guidance. Figures 8.2.2-1 to 8.2.2-7 generally summarize the projected sediment and tissue concentration reductions over time. This information was further examined, as detailed in Section 9.5.5). In summary, under Alternative A, Segment 1 already meets the lowest BaP and DDE RGs and is projected to achieve the range of relevant PCB RGs in 0 (i.e., currently achieves the RGs) to 5 years. Segment 2 is projected to achieve the DDE RG in about 3 years, already achieves the lowest BaP RGs, and would likely not achieve the lowest PCB RGs (EPA point estimate and 99th percentile) in 45 years. Segment 3 is projected to achieve the various RGs in anywhere from 0 to greater than 45 years, given the overall ranges of RGs and uncertainties of the assessment. Segment 4 is projected to achieve the various PCB RGs in anywhere from 0 to more than 45 years, while DDE and BaP already achieve the lowest RGs, or nearly so.

8.3.6 Implementability

There are no direct implementability issues associated with Alternative A because it does not require any Site construction or monitoring activities.

8.3.7 Cost

There are no costs associated with the baseline Alternative A.

8.4 ALTERNATIVE B DETAILED ANALYSIS

8.4.1 Overall Protection of Human Health and the Environment

Sediment. Alternatives B-i and B-r are both projected to achieve long-term surface sediment COC concentrations (SWACs over various spatial scales) that are at or below conservative estimates of acceptable risk levels (i.e., ranges of RGs), and these alternatives are expected to meet sediment RAOs 1 and 5 at all spatial scales for all COCs except PCBs (Figures 8.2.2-1, to 8.2.2-6). At the river mile spatial scale (see figures in Appendix U, Section 3.1), Alternatives B-i and B-r are projected to achieve the lower PCB RG ranges (EPA point estimate and/or 99th percentile) except in RMs 3 to 4 and Swan Island Lagoon. For RM 3 to 4, both alternatives are projected to achieve the 99th percentile RG range if ongoing stormwater source controls in this area are completed (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 90 to 110 ppb (Appendix U, Figure 3.1-3), which represents a risk level near or below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is projected to be achieved (into the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1 and Appendix E, Table 5.6-1). The most conservative RGs are within the estimated range of background and may not be effectively different from background based on sediment concentrations, tissue concentrations, or risk. Alternative B-r, which involves more dredging of contaminated sediments as compared to Alternative B-i, is projected to have greater short-term (during construction phase) sediment concentrations due to dredging-induced releases and residuals (Figures 8.2.2-1 to 8.2.2-6). Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and core profiles reviewed in Section 6.2.2 indicate overall deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports the concept that a combination of active remedies and MNR would result in substantially reduced long-term sediment concentrations as indicated by the modeling.

Tissue. Alternatives B-i and B-r are both projected to achieve long-term PCB smallmouth bass whole body tissue contaminant concentrations that are at or below the most conservative estimates of acceptable risk levels (i.e., ranges of TTLs), and thus both alternatives are expected to meet tissue RAOs 2 and 6 (Figure 8.2.2-7). Under both alternatives, Segments 1 and 3 are projected to reach levels below the lowest end of the TTL range, while Segments 2 and 4 are projected to achieve levels that are at or near EPA's point estimate TTL. Implementation of either alternative is projected to result in short-term increases in tissue PCB concentrations (during the construction phase and a few years afterwards) due to dissolved PCB dredging releases to the water column, particularly in Segment 2 due to dredging in SMA 17S (Swan Island Lagoon) and SMA 19 and Segment 4 due to dredging in SMA 3. These projected short-term increases are greater under Alternative B-r (Figure 8.2.2-7).

Surface Water. Alternatives B-i and B-r are projected to achieve long-term surface water concentrations post-remedy that are the same as all the other alternatives (Figures 8.2.2-8 through 8.2.2-10). However, these alternatives are not projected to achieve risk levels associated with certain risk-based water quality criteria and standards, particularly those based on fish consumption, primarily because upstream concentrations entering the Site already exceed some of these criteria. These alternatives are also projected to have short-term impacts to surface water due to dredging releases, particularly Alternative B-r, similar to those described above for tissue.

Groundwater. Upland source control actions by themselves may be able to address groundwater RAOs 4 and 8, but implementation of Alternative B-i would likely further assist in achieving these RAOs. Relative to Alternative B-r, Alternative B-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide opportunities for in-water remedies (e.g., capping) to assist in attainment of the groundwater RAOs in the river, if appropriate. Alternative B-r has relatively limited amounts of in-place remediation, and thus, provides more limited opportunity to assist in achieving these RAOs.

8.4.2 Compliance with ARARs

Chemical-Specific ARARs. Similar to Alternative A, Alternatives B-i and B-r are not expected to meet every potential WQS/NRWQC and MCL, primarily because upstream concentrations entering the Site already exceed one or more of these values. Detailed evaluations relative to Alternatives B-i and B-r are summarized below for each chemical-specific water quality criteria (Section 9.2.1 contains additional details):

- MCLs – Fate and transport modeling for total PCBs and BaP indicates that concentrations of these contaminants could exceed drinking water MCLs in very small areas and periods (i.e., 0.05 percent or less of the simulation [five one-hundredths of a percent]). Although MCL exceedances were not observed in existing data in the RI, the modeling projections include a construction period for these alternatives that is different from any condition measured by RI data.
- Fish consumption WQS/NRWQC – Model projections suggest exceedances of WQS/NRWQC for PCBs, BaP, and DDx under Alternatives B-i and B-r, though in some cases the criteria are below background. In these cases, the exceedances of the criteria/background represent approximately 12, 1, and 0.5 percent of the simulation for these contaminants, respectively. Alternative B-i is projected to have fewer exceedances than Alternative B-r (e.g., BaP exceedances represent 0.6 percent of the simulation for B-i, but 0.9 percent for B-r).
- Chronic and Acute WQS – Model projections suggest exceedances of the chronic WQS for PCBs (representing about 0.5 percent of the simulation) under Alternatives B-i and B-r primarily due to dredging-related releases. These alternatives are also projected to have some exceedances of the acute PCB criterion in very limited areas and periods (less than 0.01 percent of the simulation) due to dredging-related releases.

Location-Specific ARARs. Alternatives B-i and B-r are generally expected to meet the location-specific ARARs as summarized below (Section 9.2.2 contains additional details):

- Oregon Environmental Cleanup Law – Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at $1x10^{-6}$ for individual carcinogens and $1x10^{-5}$ for multiple carcinogens. (Other aspects of this rule are similar to CERCLA criteria and are discussed under long-term effectiveness.) Both Alternatives B-i and B-r are projected to achieve total PCB concentrations representing a 10^{-5} cancer risk level, using the overall range of sediment RGs and tissue TTLs representing smallmouth bass whole body consumption, which is highly overlapping with or below the estimated background range. These alternatives are also projected to achieve the respective long-term sediment BaP, DDD, DDE, and DDT concentrations in the 10^{-6} cancer risk range. Alternatives B-i and B-r identify relatively high concentration areas (above the RALs for these alternatives) and targets some of those areas for in situ treatment (B-i) or removal and off-Site disposal (B-i and B-r) consistent with the intent of Oregon hot spot requirements. These alternatives treat or remove sediment in those areas. See Section 9.2.2 for additional information.
- ESA – Alternatives B-i and B-r would comply with ESA with the implementation of potential impact avoidance and minimization measures and conservation measures included in the alternatives.

- CWA Section 404(b)(1) – Alternatives B-i and B-r meet the substantive requirements of this ARAR (Appendix M).
- FEMA Flood Rise Requirements – The predicted increases in water surface elevations for Alternative B-i and B-r during an estimated "100-year" flood are considered to be negligible and not significantly different between alternatives based on the model precision, and therefore compliance with this ARAR cannot be confirmed (see Section 8.2.3 for further discussion).

8.4.3 Long-Term Effectiveness and Permanence

Evaluation of the long-term effectiveness and permanence criterion is summarized below. Section 9.3 contains additional details.

Magnitude of Residual Risk - Surface Sediment COC Projections. Alternatives B-i and B-r are both projected to achieve surface sediment COC concentrations below EPA's conservative point estimate RGs and PRGs for PCBs, BaP, DDD, DDE, and DDT both Site-wide and in each river Segment (Figures 8.2.2-1 to 8.2.2-6). Looking at a river mile spatial scale (see river mile graphs Appendix U, Section 3.1), DDD, DDE, and DDT are all projected to be reduced over the long term under Alternatives B-i and B-r to below their respective EPA point estimate RG/PRGs. Similar long-term effectiveness was projected for BaP on a shoreline half-river mile basis. For PCBs, Alternatives B-i and B-r are both projected to achieve levels below the 99th percentile RG in all river miles except in RMs 3 to 4 and Swan Island Lagoon. For RMs 3 to 4, additional projections, assuming ongoing stormwater source controls are completed, indicate these alternatives may achieve levels below the RG range over the long term (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 90 to 110 ppb (Appendix U, Figure 3.1-3), which represents a risk level near or below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is achieved (in the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1).

Magnitude of Residual Risk - Biota Tissue Concentration Projections. Alternatives B-i and B-r are projected to achieve smallmouth bass whole body tissue PCB levels that are below the range of TTLs in Site Segments 1 and 3 (Figure 8.2.2-7). In Segments 2 and 4, these alternatives are projected to achieve levels just below or near EPA's point estimate of the PCB TTL.

Minimization of Potential Long-Term Sediment Recontamination. As discussed above, long-term surface sediment COC concentrations under Alternatives B-i and B-r are projected to be at or below the lowest RGs for all river miles, except for the PCB point estimate RG in Swan Island Lagoon. Thus, on a Site-wide basis long-term sediment recontamination is generally not expected even using the conservative assumption that current upland loadings continue (i.e., no further source controls). An additional evaluation of the potential for long-term recontamination at smaller spatial scales indicated that following initial reductions in surface sediment COC concentrations, these concentrations are projected to increase in response to continuing contaminant inputs. However, these projected increases are generally lower than current COC concentrations and no areas are projected to exceed the EPA point estimate RG (as generally shown Figures 8.2.2-1 to 8.2.2-6 and see Section 9.3.4 for additional information).

Magnitude of Residual Risk - Minimization of Potential Groundwater Impacts. As noted above, relative to Alternative B-r, Alternative B-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide greater opportunities for in-water remedies (e.g., capping) to assist in minimizing potential groundwater impacts. Alternative B-r has relatively limited amounts of in-place remediation and thus provides more limited opportunities to assist in minimizing potential groundwater impacts.

Magnitude of Residual Risk - Minimization of Potential Long-Term Downstream Contaminant Transport. Figures 8.2.2-8 to 8.2.2-10 show surface water concentrations projected through 45 years. The projected transport of these contaminant concentrations off Site throughout the simulation period was examined (as discussed more in Section 9.3.6). Alternative B-r is projected to result in additional downstream transport of contaminants beyond the No Action condition. Alternative B-i results in less downstream transport than would otherwise take place without the remedy, primarily due to reductions in PCB flux from areas of sediment that are capped or treated in place under this alternative. Although Alternative B-i also includes environmental dredging, these construction phase releases are balanced by reduced flux in capped or treated areas during the remainder of the 45-year period simulated.

Adequacy of Controls. Alternatives B-i and B-r result in some residual concentrations of contaminants at the Site. Physical/chemical barriers (e.g., dredge residual cover or cap), long-term monitoring, operations/maintenance, and institutional controls included in the alternatives are expected to adequately control these residual concentrations and maintain them at the sediment, tissue, and water concentrations discussed above. As noted in Section 5.6.6, very little subsurface contamination above the RALs is left in place outside areas of active remediation that could be subject to potential future release. See Section 9.3.7 for additional discussion.

Other Factors – Habitat Restoration Potential Integration. Implementation of either Alternative B-i or B-r would not prevent integration of remediation with potential habitat restoration actions. More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.3.8).

Disposal Site Long-Term Effectiveness. Alternative B-i includes disposal only within upland commercial landfills, which are designed and permitted to provide effective long-term isolation of contaminants within the landfills. Alternative B-r also includes a CAD option in Swan Island Lagoon. The long-term effectiveness of this CAD option was evaluated using the FS CDF Performance Standards (EPA 2010e; LWG 2010a and b;

Appendix O). Based on this evaluation, the Swan Island CAD can be designed and built in a manner that meets all of the long-term FS CDF Performance Standards (Appendix U, Section 6) as discussed further in Section 9.3.9.

8.4.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Under Alternative B-i, in situ treatment (e.g., using direct broadcast placement of AC) would be used to remediate approximately 19 acres of sediment. In situ treatment can effectively reduce the toxicity and mobility of the Site contaminants by controlling their bioavailability (Ghosh et al. 2011; Cornelissen et al. 2011). Alternative B-r would provide a smaller degree of reduction in contaminant mobility, primarily through ex situ treatment of removed sediments via dewatering.

8.4.5 Short-Term Effectiveness

Evaluation of the short-term effectiveness criterion is summarized below. Section 9.5 contains additional details.

Environmental Impacts - Construction Water Quality Impacts. Projected changes in water column contaminant concentrations during in-water construction operations under Alternatives B-i and B-r are discussed above in Section 8.4.2 including the spatial and temporal extent of potential MCL and WQS/NRWQC exceedances. Dredging-related resuspension and unavoidable releases to the water column are projected to result in short-term exceedances of these criteria over small areas and periods. Alternative B-i is projected to have fewer short-term construction water quality impacts than Alternative B-r.

Environmental Impacts - Potential Sediment Recontamination During Construction. Under both Alternatives B-i and B-r, modeling projections and comparisons with case study results from other environmental dredging sites (Bridges et al. 2010) suggest that potential sediment recontamination of adjacent areas resulting from dredging resuspension and residuals would generally be limited to within approximately 500 to 1,000 feet of the dredging activity. Alternative B-r has a higher potential for adjacent recontamination because of the greater amount of dredging included in this alternative and could require additional residual management to control short-term risks (see Section 6.2.7). More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.5.2).

Environmental Impacts - Construction Potential Downstream Transport. Figures 8.2.2-8 to 8.2.2-10 show the elevated surface water concentrations projected early in the simulation period due to environmental dredging releases during construction. The projected transport of these released contaminants off the Site throughout the simulation period was examined further (as discussed more in Section 9.5.3). Alternative B-r construction is projected to result in measurable additional downstream transport of contaminants beyond the no action condition for this period, particularly DDD and DDT due to potential release/downstream transport associated with dredging of a localized area having relatively higher concentration sediment deposits. Alternative B-i results in relatively little additional downstream transport in this period.

Environmental Impacts - Air Pollutant and Greenhouse Gas Emissions. Detailed evaluations of air emissions resulting from implementation of the alternatives are summarized in Appendix Ic. Construction of Alternatives B-i or B-r is projected to result in approximately 4,000 to 6,000 and 6,000 to 10,000 tonnes, respectively, of increased CO_2 equivalent air emissions. This total range is equivalent to the annual emissions from 780 to 1,900 cars. Alternative B-r has larger projected impacts due to the larger volumes and durations of work involved.

Time Until Protection is Achieved - Projected Timeframes to Achieve RAOs. Figures 8.2.2-1 to 8.2.2-7 generally summarize the projected sediment and tissue concentration reductions over time. This information was further examined, as detailed in Section 9.5.5. In summary, under Alternatives B-i and B-r, Segment 1 already meets the lowest BaP and DDE RGs and is projected to achieve the ranges of relevant PCB RGs in 0 (i.e., currently achieves the lowest RGs) to 5 years. Segment 2 is projected to achieve the DDE RG in about 2 to 4 years, already achieves lowest BaP RGs, and would achieve PCB RGs in 0 to greater than 45 years, given the overall ranges of RGs and the uncertainties of the assessment. For both alternatives, Segment 3 is projected to achieve the RGs in anywhere from 0 to 36 years, again given the overall ranges of RGs and uncertainties of the assessment, while Segment 4 is projected to achieve the PCB RGs in anywhere from 0 to more than 45 years (DDE and BaP already achieve the lowest ranges of RGs, or nearly so, in Segment 4).

Community Risks and Quality of Life. Implementation of these alternatives would also result in some impacts to quality of life measures both within and around the harbor during construction (Appendix U, Section 4.4). Alternative B-r has generally higher impacts than Alternative B-i, due to the larger volumes and durations of work involved.

Potential Impacts to Workers. As discussed in more detail in the comparative analysis of alternatives (Section 9.5.7), construction of Alternatives B-i and B-r is projected to result in approximately three and eight non-fatal worker injuries (incidents), respectively, and a 1 and 3 percent chance of a fatal worker incident, respectively. Alternative B-r has larger projected impacts due to the larger volumes and durations of work involved.

Disposal Site Short-Term Effectiveness. Alternative B-i includes disposal only within upland commercial landfills. With appropriate operational BMPs, environmental risks related to spills or releases of contaminated sediments or water during transport operations are anticipated to be small. Alternative B-r also includes upland disposal and would have similar potential impacts. Alternative B-r includes a CAD option in Swan Island Lagoon. Because filling of the CAD would result in some unavoidable direct exposure to water column (given that it is assumed for draft FS purposes that there would not be a berm isolating the CAD from the surrounding water column), there is a potential for minimal short-term, localized water quality impacts during these filling operations, which can be further minimized through use of appropriate BMPs. The Swan Island CAD can be designed and built in a manner that meets all of the short-term FS CDF Performance Standards (Appendix U, Section 6).

8.4.6 Implementability

As discussed in Section 8.2.7, duration is used as a general metric for the level of implementability issues associated with alternatives. Section 9.6 contains more detailed discussions of the various implementability factors for all alternatives. Both Alternatives B-i and B-r are readily implementable. Alternatives B-i and B-r have projected construction durations of approximately 2 years and 6 years, respectively.

8.4.7 Cost

Alternatives B-i and B-r have estimated costs in the $169 million to $250 million and $228 million to $330 million range, respectively.

8.5 ALTERNATIVE C DETAILED ANALYSIS

8.5.1 Overall Protection of Human Health and the Environment

Sediment. Alternatives C-i and C-r are both projected to achieve long-term sediment contaminant concentrations (SWACs over various spatial scales) that are at or below conservative estimates of acceptable risk levels (i.e., ranges of RGs), and these alternatives are expected to meet sediment RAOs (1 and 5) at all spatial scales for all COCs except for PCBs (Figures 8.2.2-1 to 8.2.2-6). For PCBs, at the river mile spatial scale (see figures in Appendix U, Section 3.1), Alternatives C-i and C-r are both projected to achieve levels below the PCB RG ranges in all river miles except for the most conservative PCB RGs (EPA point estimate and 99th percentile) in RMs 3 to 4 and Swan Island Lagoon. Further, RM 3 to 4 achieves the EPA point estimate RG for Alternative C-i and is projected to achieve the lowest RGs for both alternatives if ongoing stormwater source controls in this area are completed (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 90 to 110 ppb (Appendix U, Figure 3.1-3), which represents a risk level near or below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is projected to be achieved (into the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1 and Appendix E, Table 5.6-1). The most conservative RGs are within the estimated range of background and may not be effectively different from background based on sediment concentrations, tissue concentrations, or risk. Alternative C-r, which involves more dredging of contaminated sediments as compared to Alternative C-i, results in greater short-term (during construction) sediment concentrations due to dredging-induced releases and residuals (Figures 8.2.2-1 to 8.2.2-6). For PCBs, at the river mile spatial scale (see figures in Appendix U, Section 3.1), Alternatives C-i and C-r are both projected to achieve levels below the PCB RG ranges in all river miles except for the most conservative PCB (EPA point estimate and 99th percentile) in RMs 3 to 4 and Swan

Island Lagoon. Further, RM 3 to 4 achieves the EPA point estimate RG for Alternative C-i, and is projected to achieve the lowest RGs for both alternatives if ongoing stormwater source controls in this area are completed (Appendix Ha, Section 6). Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and core profiles reviewed in Section 6.2.2 indicate overall deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports the concept that a combination of active remedies and MNR would result in substantially reduced long-term sediment concentrations.

Tissue. Alternatives C-i and C-r are both projected to achieve long-term smallmouth bass whole body PCB tissue contaminant concentrations that are at or below the most conservative estimates of acceptable risk levels (i.e., ranges of TTLs), and thus both alternatives are expected to meet tissue RAOs (2 and 6) (Figure 8.2.2-7). Under both alternatives, Segments 1 and 3 are projected to reach levels below the lowest end of the TTL range, while Segments 2 and 4 are projected to achieve levels that are at or near EPA's point estimate TTL. Implementation of Alternative C-r is projected to result in short-term increases (during construction and a few years afterwards) in tissue PCB concentrations due to dissolved PCB dredging releases to the water column, particularly in Segment 2 due to dredging in SMA 17S (Swan Island Lagoon) and SMA 19, and in Segment 4 due to dredging in SMA 3 (Figure 8.2.2-7).

Surface Water. Alternative C-i and C-r are projected to achieve long-term surface water concentrations post-remedy that are the same as all the other alternatives (Figures 8.2.2-8 through 8.2.2-10). However, these alternatives are not projected to achieve risk levels associated with certain of the chemical-specific water quality criteria and standards, particularly those based on fish consumption, because upstream concentrations entering the Site already exceed some of these criteria. These alternatives are projected to have short-term impacts to surface water due to dredging releases, particularly Alternative C-r, similar to those described for tissue.

Groundwater. Upland source control actions by themselves may be able to address the groundwater RAOs 4 and 8, but implementation of Alternative C-i would likely further assist achieving these RAOs. Relative to Alternative C-r, Alternative C-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide opportunities for in-water remedies (e.g., capping) to assist in attainment of the groundwater RAOs in the river, if appropriate. Alternative C-r has relatively limited amounts of in-place remediation and thus provides more limited opportunity to assist in achieving these RAOs.

8.5.2 Compliance with ARARs

Chemical-Specific ARARs. Similar to the previous alternatives, Alternatives C-i and C-r are not expected to meet every potential WQS/NRWQC and MCL, primarily because upstream concentrations entering the Site already exceed one or more of these values. Detailed evaluations relative to Alternatives C-i and C-r are summarized below for each chemical-specific water quality criteria (Section 9.2.2 contains additional details):

- MCLs – Fate and transport modeling for total PCBs and BaP indicates that concentrations of these contaminants could exceed drinking water MCLs in very small areas and periods (i.e., 0.04 percent or less of the simulation [four one-hundredths of a percent]). Although MCL exceedances were not observed in existing data in the RI, the modeling projections include a construction period for these alternatives that is different from any condition measured by RI data.
- Fish consumption WQS/NRWQC – Model projections suggest exceedances of WQS/NRWQC for PCBs, BaP, and DDx under Alternatives B-i and B-r, though in some cases the criteria are below background. In these cases, the exceedances of the criteria/background represent approximately 12, 1, and 0.4 percent of the simulation for these contaminants, respectively. Alternative C-i is projected to have fewer exceedances than Alternative C-r (e.g., DDD exceedances represent 0.2 percent of the simulation for C-i, but 0.6 percent for C-r).
- Chronic and Acute WQS – Model projections suggest exceedances of the chronic WQS for PCBs (representing about 0.5 percent of the simulation) under Alternatives C-i and C-r primarily due to dredging-related releases. These alternatives are also projected to have some exceedances of the acute PCB criterion in very limited areas and periods (less than 0.01 percent of the simulation) due to dredging-related releases.

Location-Specific ARARs. Alternatives C-i and C-r are generally expected to meet the location-specific ARARs as summarized below (Section 9.2.1 contains additional details):

- Oregon Environmental Cleanup Law – Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at $1x10^{-6}$ for individual carcinogens and $1x10^{-5}$ for multiple carcinogens. (Other aspects of this rule are similar to CERCLA criteria and are discussed under long-term effectiveness.) Both Alternatives C-i and C-r are projected to achieve total PCB concentrations representing a 10^{-5} cancer risk level, using the overall range of sediment RGs and tissue TTLs representing smallmouth bass whole body consumption, which is highly overlapping with or below the estimated background range. These alternatives are also projected to achieve the respective long-term sediment BaP, DDD, DDE, and DDT concentrations in the 10^{-6} cancer risk range. Alternatives C-i and C-r identify relatively high concentration areas (above the RALs for these alternatives) and targets some of those areas for in situ treatment (C-i) or removal and off-Site disposal (C-i and C-r) consistent with the intent of Oregon hot spot requirements. These alternatives treat or remove sediment in those areas. See Section 9.2.2 for additional information.
- ESA – Alternatives C-i and C-r would comply with ESA with the implementation of potential impact avoidance and minimization measures and conservation measures included in the alternatives.

- CWA Section 404(b)(1) – Alternatives C-i and C-r meet the substantive requirements of this ARAR (Appendix M).
- FEMA Flood Rise Requirements – The predicted increases in water surface elevations for Alternative C-i and C-r during an estimated "100-year" flood are considered to be negligible and not significantly different between alternatives based on the model precision, and therefore compliance of the alternatives with this ARAR cannot be confirmed (see Section 8.2.3 for further discussion).

8.5.3 Long-Term Effectiveness and Permanence

Evaluation of the long-term effectiveness and permanence criterion is summarized below. Section 9.3 contains additional details.

Magnitude of Residual Risk - Surface Sediment COC Projections. Alternatives C-i and C-r are both projected to achieve surface sediment COC concentrations below EPA's conservative point estimate RGs and PRGs for PCBs, BaP, DDD, DDE, and DDT Site-wide and in each river Segment (Figures 8.2.2-1 to 8.2.2-6). Looking at a river mile spatial scale (see graphs Appendix U, Section 3.1), DDD, DDE, and DDT are all projected to be reduced over the long term under Alternatives C-i and C-r to below their respective EPA point estimate RG/PRGs. Similar long-term effectiveness was projected for BaP on a shoreline half-river mile basis. For PCBs, Alternatives C-i and C-r are both projected to achieve levels below the 99th percentile RG in all river miles except in RMs 3 to 4 and Swan Island Lagoon. For RMs 3 to 4, additional model projections, assuming that ongoing stormwater source controls are completed, suggest that these alternatives may achieve levels below the RG range over the long term (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the 90 to 110 ppb range (Appendix U, Figure 3.1-3), which represents a risk level near or below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is achieved (in the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1).

Magnitude of Residual Risk - Biota Tissue Concentration Projections. Alternatives C-i and C-r are projected to achieve smallmouth bass whole body tissue PCB levels that are below the range of TTLs in Site Segments 1 and 3 (Figure 8.2.2-7).

In Segments 2 and 4, Alternatives C-i and C-r are projected to achieve levels just below or near EPA's point estimate of the PCB TTL.

Magnitude of Residual Risk - Minimization of Potential Long-Term Sediment Recontamination. As discussed above, long-term surface sediment COC concentrations under Alternatives C-i and C-r are projected to be at or below the lowest RGs, except for the PCB point estimate RG in Swan Island Lagoon. Thus, long-term sediment recontamination is generally not expected even using the conservative assumption that current upland loadings continue (i.e., with no further source controls. An additional evaluation of the potential for long-term recontamination at smaller spatial scales indicated that following initial reductions in surface sediment COC concentrations, these concentrations are projected to increase in response to continuing contaminant inputs. However, these projected increases are generally lower than current COC concentrations and no areas are projected to exceed the EPA point estimate RG (as generally shown Figures 8.2.2-1 to 8.2.2-6; see Section 9.3.4 for additional information).

Magnitude of Residual Risk - Minimization of Potential Groundwater Impacts. As noted above, relative to Alternative C-r, Alternative C-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide greater opportunities for in-water remedies (e.g., capping) to assist in minimizing potential groundwater impacts. Alternative C-r has relatively limited amounts of in-place remediation and thus provides more limited opportunities to assist in minimizing potential groundwater impacts.

Magnitude of Residual Risk - Minimization of Potential Long-Term Downstream Contaminant Transport. Figures 8.2.2-8 to 8.2.2-10 show surface water concentrations projected through 45 years. The projected transport of these contaminant concentrations off Site throughout the simulation period was examined (as discussed more in Section 9.3.6). Alternative C-r is projected to result in additional downstream transport of contaminants beyond the no action condition. Alternative C-i results in less downstream transport than would otherwise take place without the remedy, primarily due to reductions in PCB flux from areas of sediment that are capped or treated in place under this alternative. Although Alternative C-i also includes environmental dredging, these construction phase releases are balanced by reduced flux in capped or treated areas during the remainder of the 45-year period simulated.

Adequacy of Controls. Alternatives C-i and C-r result in some residual concentrations of contaminants at the Site. Physical/chemical barriers (e.g., dredge residual cover or cap), long-term monitoring, operations/maintenance, and institutional controls included in the alternatives are expected to adequately control these residual concentrations and maintain them at the sediment, tissue, and water concentrations discussed above. As noted in Section 5.6.6, very little contamination above the RALs is left in place outside areas of active remediation that could be subject to potential future release. See Section 9.3.7 for additional discussion.

Other Factors - Habitat Restoration Potential Integration. Implementation of either Alternative C-i or C-r would not prohibit potential integration with potential habitat restoration actions. More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.3.8).

Disposal Site Long-Term Effectiveness. Alternative C-i involves disposal only within upland commercial landfills and the Swan Island CAD. Alternative C-r includes CDFs at Terminal 4 and Arkema's preliminary design (1-Berth) as well as upland disposal. The long-term effectiveness of each on-Site CDF or CAD was evaluated using the FS CDF Performance Standards (EPA 2010e; LWG 2010a and b; Appendix O). Based on this evaluation, the CAD and CDFs can be designed and built in a manner that meets all of long-term FS CDF Performance Standards (Appendix U, Section 6) as discussed further in Section 9.3.9.

8.5.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Under Alternative C-i, in situ treatment (e.g., using direct broadcast placement of AC) would be used to remediate approximately 29 acres of sediment. In situ treatment can effectively reduce the toxicity and mobility of the Site contaminants by controlling their bioavailability (Ghosh et al. 2011; Cornelissen et al. 2011). Alternative C-r would provide a smaller degree of reduction in contaminant mobility, primarily through ex situ treatment of removed sediments via dewatering.

8.5.5 Short-Term Effectiveness

Section 9.5 contains additional details.

Environmental Impacts - Construction Water Quality Impacts. Projected changes in water column contaminant concentrations during in-water construction operations under Alternatives C-i and C-r are discussed in Section 8.5.2, including the spatial and temporal extent of potential MCL and WQS/NRWQC exceedances. Dredging-related resuspension and unavoidable releases to the water column are projected to result in short-term exceedances of these criteria over small areas and periods. Alternative C-i is projected to have fewer short-term construction water quality impacts than Alternative C-r.

Environmental Impacts - Potential Sediment Recontamination During Construction. Under both Alternatives C-i and C-r, modeling projections and comparisons with case study results from other environmental dredging sites (Bridges et al. 2010) suggest that potential sediment recontamination of adjacent areas resulting from dredging resuspension and residuals would generally be limited to within approximately 500 to 1,000 feet of the dredging activity. Alternative C-r has a higher potential for adjacent recontamination because of the greater amount of dredging included in this alternative and could require additional residual management to control short-term risks (see Section 6.2.7). More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9).

Environmental Impacts - Construction Potential Downstream Transport. Figures 8.2.2-8 to 8.2.2-10 show the elevated surface water concentrations projected early in the simulation period due to environmental dredging releases during construction. The projected transport of these released contaminants off the Site throughout the simulation period was examined further (as discussed more in Section 9.5.3). Alternative C-r construction is projected to result in measurable additional downstream transport of contaminants beyond the no action condition for this period. Alternative C-i results in relatively little additional projected downstream transport in this period.

Environmental Impacts – Air Pollutant and Greenhouse Gas Emissions. Detailed evaluations of air emissions resulting from implementation of the alternatives are summarized in Appendix Ic. Construction of Alternatives C-i or C-r are projected to result in approximately 2,000 to 5,000 and 4,000 to 7,000 tonnes, respectively, of increased CO_2 equivalent air emissions. This total range is equivalent to the annual emissions from 450 to 1,400 cars. Alternative C-r has larger projected impacts due to the larger volumes and durations of work involved.

Time Until Protection is Achieved – Projected Timeframes to Achieve RAOs. Figures 8.2.2-1 to 8.2.2-7 generally summarize the projected sediment and tissue concentration reductions over time. This information was further examined, as detailed in Section 9.5.5. In summary, under Alternatives C-i and C-r, Segment 1 already meets the lowest BaP and DDE RGs and is projected to achieve the ranges of relevant PCB RGs in 0 (i.e., currently achieves the lowest RGs) to 5 years. Segment 2 is projected to achieve the DDE RG in about 2 to 4 years, already achieves lowest BaP RGs, and would achieve PCB RGs in 0 to greater than 45 years, given the overall ranges of RGs and the uncertainties of the assessment. For both alternatives, Segment 3 is projected to achieve the RGs in anywhere from 0 to 38 years, again given the overall ranges of RGs and uncertainties of the assessment, while Segment 4 is projected to achieve the PCB RGs in anywhere from 0 to more than 45 years (DDE and BaP already achieve the lowest RGs, or nearly so).

Community Risks and Quality of Life. Implementation of these alternatives would also result in some impacts to quality of life measures both within and around the harbor during construction (Appendix U, Section 4.4). Alternative C-r has larger projected impacts due to the larger volumes and durations of work involved.

Potential Impacts to Workers. Finally, as discussed in more detail in the comparative analysis of alternatives (Section 9.5.7), construction of Alternatives C-i and C-r are projected to result in approximately 4 and 10 non-fatal worker injuries (incidents), respectively, and a 2 and 4 percent chance of a fatal worker incident, respectively. Alternative C-r has larger projected impacts due to the larger volumes and durations of work involved.

Disposal Site Short-Term Effectiveness. Alternatives C-i and C-r involve disposal within upland commercial landfills as well as on-Site CDFs/CADs. With appropriate operational BMPs, environmental risks related to spills or releases of contaminated sediments or water during transport operations are anticipated to be small. Evaluation of Site CDFs and CADs using the FS CDF Performance Standards indicates these facilities can be designed and built in a manner that meets all of these standards (Appendix U, Section 6). Alternative C-i includes a CAD option in Swan Island Lagoon. Because filling of the CAD would result in some unavoidable direct exposure to water column (given that it is assumed for draft FS purposes that there would not be a berm isolating the CAD from the surrounding water column), there is a potential for minimal short-term, localized water quality impacts during these filling operations, which can be further minimized through use of appropriate BMPs. The Swan Island CAD can be designed and built in a manner that meets all of the short-term FS CDF Performance Standards (Appendix U, Section 6).

8.5.6 Implementability

As discussed in Section 8.2.7, duration is used as a general metric for the level of implementability issues associated with alternatives. Section 9.6 contains more detailed discussions of the various implementability factors for all alternatives. Both Alternatives C-i and C-r are readily implementable. Alternatives C-i and C-r have projected construction durations of approximately 3 years and 7 years, respectively.

8.5.7 Cost

Alternatives C-i and C-r have estimated costs in the \$231 million to \$345 million and \$304 million to \$449 million range, respectively.

8.6 ALTERNATIVE D DETAILED ANALYSIS

8.6.1 Overall Protection of Human Health and the Environment

Sediment. Alternatives D-i and D-r are both projected to achieve long-term sediment contaminant concentrations (SWACs over various spatial scales) that are at or below conservative estimates of acceptable risk levels (i.e., ranges of RGs), and these alternatives are expected to meet sediment RAOs (1 and 5) at all spatial scales for all COCs except for PCBs (Figures 8.2.2-1 to 8.2.2-6). For PCBs, at the river mile spatial scale (see figures in Appendix U, Section 3.1), Alternatives D-i and D-r are both projected to achieve levels below the PCB RG ranges in all river miles except for the most conservative PCB RGs (EPA point estimate and 99th percentile) in RMs 3 to 4 and Swan Island Lagoon. Further, RM 3 to 4 achieves the EPA point estimate RG for Alternative D-i, and is projected to achieve the lowest RGs for both alternatives if ongoing stormwater source controls in this area are completed (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 90 to 110 ppb (Appendix U, Figure 3.1-3), which represents a risk level near or below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is projected to be achieved (into the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1 and Appendix E, Table 5.6-1). The most conservative RGs are within the estimated range of background and may not be effectively different from background based on sediment concentrations, tissue concentrations, or risk. Alternative D-r, which involves more dredging of contaminated sediments as compared to Alternative D-i, is projected to result in greater short-term sediment concentrations due to dredging-induced releases and residuals (Figures 8.2.2-1 to 8.2.2-6). Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and core profiles reviewed in Section 6.2.2 indicate overall deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports the concept that a combination of active remedies and MNR would result in substantially reduced long-term sediment concentrations.

Tissue. Alternatives D-i and D-r are both projected to achieve long-term PCB smallmouth bass whole body tissue contaminant concentrations that are at or below the most conservative estimates of acceptable risk levels (i.e., ranges of TTLs), and thus both alternatives are expected to meet tissue RAOs (2 and 6) (Figure 8.2.2-7). Under both alternatives, Segments 1 and 3 are projected to reach levels below the lowest end of the TTL range, while Segments 2 and 4 are projected to achieve levels that are at or near EPA's point estimate TTL. Implementation of Alternative D-r is projected to result in increases (during construction and a few years afterwards) in tissue PCB concentrations due to dissolved PCB dredging releases to the water column, particularly in Segments 2 due to dredging in SMAs 17S (Swan Island Lagoon) and 19 and Segment 4 due to dredging in SMA 3.

Surface Water. Alternative D-i and D-r are projected to achieve long-term surface water concentrations post-remedy that are the same as all the other alternatives (Figures 8.2.2-8 through 8.2.2-10). However, these alternatives are not projected to achieve risk levels associated with certain of the chemical-specific water quality criteria and standards, particularly those based on fish consumption, because upstream concentrations entering the Site already exceed some of these criteria. These alternatives are projected to have short-term impacts to surface water due to dredging releases, particularly Alternative D-r, similar to that described for tissue.

Groundwater. Upland source control actions by themselves may be able to address the groundwater RAOs 4 and 8, but implementation of Alternative D-i would likely further assist achieving these RAOs. Relative to Alternative D-r, Alternative D-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide opportunities for in-water remedies (e.g., capping) to assist in attainment of the groundwater RAOs in the river, if appropriate. Alternative D-r has relatively limited amounts of in-place remediation and thus provides more limited opportunity to assist in achieving these RAOs.

8.6.2 Compliance with ARARs

Chemical-Specific ARARs. Similar to the previous alternatives, Alternatives D-i and D-r are not expected to meet every potential WQS/NRWQC and MCL, primarily because upstream concentrations entering the Site already exceed one or more of these values. Detailed evaluations relative to Alternatives D-i and D-r are summarized below for each chemical-specific water quality criteria (Section 9.2.1 contains additional details):

- MCLs – Fate and transport modeling for total PCBs and BaP indicates that concentrations of these contaminants could exceed drinking water MCLs in very small areas and periods (i.e., 0.04 percent or less of the simulation [four one-hundredths of a percent]). Although MCL exceedances were not observed in existing data in the RI, the modeling projections include a construction period for these alternatives that is different from any condition measured by RI data.

- Fish consumption WQS/NRWQC – Model projections suggest exceedances of WQS/NRWQC for PCBs, BaP, and DDx under Alternatives D-i and D-r, though in some cases the criteria are below background. In these cases, the exceedances of the criteria/background represent approximately 12, 0.7, and 0.4 percent of the simulation for these contaminants, respectively. Alternative D-i is projected to have fewer exceedances than Alternative D-r (e.g., BaP exceedances represent 0.5 percent of the simulation for D-i, but 0.9 percent for D-r).
- Chronic and Acute WQS – Model projections suggest exceedances of the chronic WQS for PCBs (representing about 0.5 percent of the simulation) under Alternatives D-i and D-r primarily due to dredging-related releases. These alternatives are also projected to have some exceedances of the acute PCB criterion in very limited areas and periods (less than 0.01 percent of the simulation) due to dredging-related releases.

Location-Specific ARARs. Alternatives D-i and D-r are generally expected to meet the location-specific ARARs as summarized below (Section 9.2.2 contains additional details):

- Oregon Environmental Cleanup Law – Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at $1x10^{-6}$ for individual carcinogens and $1x10^{-5}$ for multiple carcinogens. (Other aspects of this rule are similar to CERCLA criteria and are discussed under long-term effectiveness.) Both Alternatives D-i and D-r are projected to achieve total PCB concentrations representing a 10^{-5} cancer risk level, using the overall range of sediment RGs and tissue TTLs representing smallmouth bass whole body consumption, which is highly overlapping with or below the estimated background range. These alternatives are also projected to achieve the respective long-term sediment BaP, DDD, DDE, and DDT concentrations in the 10^{-6} cancer risk range. Alternatives D-i and D-r identify relatively high concentration areas (above the RALs for these alternatives) and targets some of those areas for in situ treatment (D-i) or removal and off-Site disposal (D-i and D-r) consistent with the intent of Oregon hot spot requirements. These alternatives treat or remove sediment in those areas. See Section 9.2.2 for additional information.
- ESA – Alternatives D-i and D-r would comply with ESA with the implementation of potential impact avoidance and minimization measures and conservation measures included in the alternatives.
- CWA Section 404(b)(1) – Alternatives D-i and D-r meet the substantive requirements of this ARAR (Appendix M).
- FEMA Flood Rise Requirements – The predicted increases in water surface elevations for Alternatives D-i and D-r during an estimated “100-year” flood are considered to be negligible and not significantly different between alternatives

based on the model precision, and therefore compliance with this ARAR cannot be confirmed (see Section 8.2.3 for further discussion).

8.6.3 Long-Term Effectiveness and Permanence

Evaluation of the long-term effectiveness and permanence criterion is summarized below. Section 9.3 contains additional details.

Magnitude of Residual Risk - Surface Sediment COC Projections. Alternatives D-i and D-r are both projected to achieve surface sediment COC concentrations below EPA's conservative point estimate RGs and PRGs for PCBs, BaP, DDD, DDE, and DDT both Site-wide and in each river Segment (Figures 8.2.2-1 to 8.2.2-6). Looking at a river mile spatial scale (see graphs Appendix U, Section 3.1), DDD, DDE, and DDT are all projected to be reduced over the long term under Alternatives D-i and D-r to below their respective EPA point estimate RG/PRGs. Similar long-term effectiveness was projected for BaP on a shoreline half-river mile basis. For PCBs, Alternatives D-i and D-r are both projected to achieve levels below the 99^{th} percentile RG in all river miles except in RMs 3 to 4 and Swan Island Lagoon. For RMs 3 to 4, additional projections, assuming ongoing stormwater source controls are completed, suggest that these alternatives may achieve levels below the RG range over the long term (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 90 to 110 ppb (Appendix U, Figure 3.1-3), which represents a risk level near or below a 95^{th} percentile estimate of the 10^{-4} cancer risk (95 ppb; Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is achieved (in the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1).

Magnitude of Residual Risk - Biota Tissue Concentration Projections. Alternatives D-i and D-r are projected to achieve smallmouth bass whole body tissue PCB levels that are below the range of TTLs in Site Segments 1 and 3 (Figure 8.2.2-7). In Segments 2 and 4, these alternatives are projected to achieve levels just below or near EPA's point estimate of the PCB TTL.

Magnitude of Residual Risk - Minimization of Potential Long-Term Sediment Recontamination. As discussed above, long-term surface sediment COC concentrations under Alternatives D-i and D-r are projected to be within ranges that are generally at or below the lowest RGs, except for the PCB point estimate RG in Swan Island Lagoon. Thus, long-term sediment recontamination is generally not expected even using the conservative assumption that current upland loadings continue (i.e., with no further source controls. An additional evaluation of the potential for long-term recontamination at smaller spatial scales indicated that following initial reductions in surface sediment COC concentrations, these concentrations are projected to increase in response to continuing contaminant inputs. However, these projected increases are generally lower than current COC concentrations and no areas are projected to exceed the EPA point estimate RG (as generally shown Figures 8.2.2-1 to 8.2.2-6 and see Section 9.3.4 for additional information).

Magnitude of Residual Risk - Minimization of Potential Groundwater Impacts. As noted above, relative to Alternative D-r, Alternative D-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide greater opportunities for in-water remedies (e.g., capping) to assist in minimizing potential groundwater impacts. Alternative D-r has relatively limited amounts of in-place remediation and thus provides more limited opportunities to assist in minimizing potential groundwater impacts.

Magnitude of Residual Risk - Minimization of Potential Long-Term Downstream Contaminant Transport. Figures 8.2.2-8 to 8.2.2-10 show surface water concentrations projected through 45 years. The projected transport of these contaminant concentrations off Site throughout the simulation period was examined (as discussed more in Section 9.3.6). Alternative D-r is projected to result in additional downstream transport of contaminants beyond the no action condition. Alternative D-i results in less downstream transport than would otherwise take place without the remedy, primarily due to reductions in PCB flux from areas of sediment that are capped or treated in place under this alternative. Although Alternative D-i also includes environmental dredging, these construction phase releases are balanced by reduced flux in capped or treated areas during the remainder of the 45-year period simulated.

Adequacy of Controls. Alternatives D-i and D-r result in some residual concentrations of contaminants at the Site. Physical/chemical barriers (e.g., dredge residual cover or cap), long-term monitoring, operations/maintenance, and institutional controls included in the alternatives are expected to adequately control these residual concentrations and maintain them at the sediment, tissue, and water concentrations discussed above. As noted in Section 5.6.6, very little contamination above the RALs is left in place outside areas of active remediation that could be subject to potential future release. See Section 9.3.7 for additional discussion.

Other Factors – Habitation Restoration Potential Integration. Implementation of either Alternative D-i or D-r would not prohibit integration with potential habitat restoration actions. More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.3.8).

Disposal Site Long-Term Effectiveness. Alternative D-i involves disposal only within upland commercial landfills and the Swan Island CAD. Alternative D-r includes CDFs at Terminal 4 and Arkema's preliminary design (1-Berth) as well as upland disposal. The long-term effectiveness of each on-Site CDF or CAD was evaluated using the FS CDF Performance Standards (EPA 2010e; LWG 2010a and b; Appendix O). Based on this evaluation, the CAD and CDFs can be designed and built in a manner that meets all of the long-term FS CDF Performance Standards (Appendix U, Section 6) as discussed further in Section 9.3.9.

8.6.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Under Alternative D-i, in situ treatment (e.g., using direct broadcast placement of AC) would be used to remediate approximately 34 acres of sediment. In situ treatment can effectively reduce the toxicity and mobility of the Site contaminants by controlling their bioavailability (Ghosh et al. 2011; Cornelissen et al. 2011). Alternative D-r would provide a smaller degree of reduction in contaminant mobility, primarily through ex situ treatment of removed sediments via dewatering.

8.6.5 Short-Term Effectiveness

Evaluation of the short-term effectiveness criterion is summarized below. Section 9.5 contains additional details.

Environmental Impacts - Construction Water Quality Impacts. Projected changes in water column contaminant concentrations during in-water construction operations under Alternatives D-i and D-r are discussed above in Section 8.6.2 including the spatial and temporal extent of potential MCL and WQS/NRWQC exceedances. Dredging-related resuspension and unavoidable releases to the water column are projected to result in short-term exceedances of these criteria over small areas and periods. Alternative D-i is projected to have fewer short-term construction water quality impacts than Alternative D-r.

Environmental Impacts - Potential Sediment Recontamination During Construction. Under both Alternatives D-i and D-r, modeling projections and comparisons with case study results from other environmental dredging sites (Bridges et al. 2010) suggest that potential sediment recontamination of adjacent areas resulting from dredging resuspension and residuals would generally be limited to within approximately 500 to 1,000 feet of the dredging activity. Alternative D-r has a higher potential for adjacent recontamination because of the greater amount of dredging included in this alternative and could require additional residual management to control short-term risks (see Section 6.2.7). More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.5.2).

Environmental Impacts - Construction Potential Downstream Transport. Figures 8.2.2-8 to 8.2.2-10 show the elevated surface water concentrations projected early in the simulation period due to environmental dredging releases during construction. The projected transport of these released contaminants off the Site throughout the simulation period was examined further (as discussed more in Section 9.5.3). Alternative D-r construction is projected to result in measurable additional downstream transport of contaminants beyond the no action condition for this period. Alternative D-i results in relatively little additional downstream transport in the construction period.

Environmental Impacts – Air Pollutant and Greenhouse Gas Emissions. Detailed evaluations of air emissions resulting from implementation of the alternatives are summarized in Appendix Ic. Construction of Alternatives D-i or D-r is projected to result in approximately 4,000 to 7,000 and 4,000 to 10,000 tonnes, respectively, of increased

CO_2 equivalent air emissions. This total range is equivalent to the annual emissions from 730 to 2,000 cars. Alternative D-r has larger projected impacts due to the larger volumes and durations of work involved.

Time Until Protection is Achieved - Projected Timeframes to Achieve RAOs. Figures 8.2.2-1 to 8.2.2-7 generally summarize the projected sediment and tissue concentration reductions over time. This information was further examined, as detailed in Section 9.5.5. In summary, under Alternatives D-i and D-r, Segment 1 already meets the lowest BaP and DDE RGs and is projected to achieve the ranges of relevant PCB RGs in 0 (i.e., currently achieves the lowest RG) to 5 years. Segment 2 is projected to achieve the DDE RG in about 2 to 3 years, already achieves the lowest BaP RG, and would achieve PCB RGs in 0 to greater than 45 years, given the overall ranges of RGs and the uncertainties of the assessment. For both alternatives, Segment 3 is projected to achieve the RGs in anywhere from 0 to 36 years, again given the overall ranges of RGs and uncertainties of the assessment, while Segment 4 is projected to achieve the PCB RGs in anywhere from 0 to more than 45 years (DDE and BaP already achieve the lowest RGs, or nearly so).

Community Risks and Quality of Life. Implementation of these alternatives would also result in some impacts to quality of life measures both within and around the harbor during construction (Appendix U, Section 4.4). Alternative D-r has larger projected impacts due to the larger volumes and durations of work involved.

Potential Impacts to Workers. As discussed in more detail in the comparative analysis of alternatives (Section 9.5.7), construction of Alternatives D-i and D-r is projected to result in approximately 5 and 12 non-fatal worker injuries (incidents), respectively, and a 2 and 5 percent chance of a fatal worker incident, respectively. Alternative D-r has larger projected impacts due to the larger volumes and durations of work involved.

Disposal Site Short-Term Effectiveness. Alternatives D-i and D-r involve disposal within upland commercial landfills as well as on-Site CDFs/CADs. With appropriate operational BMPs, environmental risks related to spills or releases of contaminated sediments or water during transport operations are anticipated to be small. Evaluation of Site CDFs and CADs using the short-term FS CDF Performance Standards indicates these facilities can be designed and built in a manner that meets all of these standards (Appendix U, Section 6). Alternative D-i includes a CAD option in Swan Island Lagoon. Because filling of the CAD would result in some unavoidable direct exposure to the water column (given that it is assumed for draft FS purposes that there would not be a berm isolating the CAD from the surrounding water column), there is a potential for minimal short-term, localized water quality impacts during these filling operations, which can be further minimized through use of appropriate BMPs. The Swan Island CAD can be designed and built in a manner that meets all of the short-term FS CDF Performance Standards (Appendix U, Section 6).

8.6.6 Implementability

As discussed in Section 8.2.7, duration is used as a general metric for the level of implementability issues associated with alternatives. Section 9.6 contains more detailed discussions of the various implementability factors for all alternatives. Both Alternatives D-i and D-r are readily implementable. Alternatives D-i and D-r have projected construction durations of approximately 3 years and 8 years, respectively.

8.6.7 Cost

Alternatives D-i and D-r have estimated costs in the \$266 million to \$398 million and \$351 million to \$520 million range, respectively.

8.7 ALTERNATIVE E DETAILED ANALYSIS

8.7.1 Overall Protection of Human Health and the Environment

Sediment. Alternatives E-i and E-r are both projected to achieve long-term sediment contaminant concentrations (SWACs over various spatial scales) that are at or below conservative estimates of acceptable risk levels (i.e., ranges of RGs), and these alternatives are anticipated to achieve sediment RAOs (1 and 5) at all spatial scales for all COCs except for PCBs (Figures 8.2.2-1 to 8.2.2-6). At the river mile spatial scale (see figures in Appendix U, Section 3.1), Alternatives E-i and E-r are both projected to achieve levels below the PCB RG ranges in all river miles except for the most conservative PCB RGs (EPA point estimate and 99th percentile) in RMs 3 to 4 and Swan Island Lagoon. Further, RM 3 to 4 achieves the EPA point estimate RG for Alternative E-i and is projected to achieve the lowest RGs for both alternatives if ongoing stormwater source controls in this area are completed (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 75 to 80 ppb (Appendix U, Figure 3.1-3), which represents a risk level below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is projected to be achieved (into the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1 and Appendix E, Table 5.6-1). The most conservative RGs are within the estimated range of background and may not be effectively different from background based on sediment concentrations, tissue concentrations or risk. Alternative E-r, which involves more dredging of contaminated sediments as compared to Alternative E-i, is projected to result in greater sediment concentrations during construction over a long period (i.e., 12 years) due to dredging-induced releases and residuals (Figures 8.2.2-1 to 8.2.2-6). Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and core profiles reviewed in Section 6.2.2 indicate overall deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports the concept that extensive active remedies combined with MNR would result in substantially reduced long-term sediment concentrations.

Tissue. Alternatives E-i and E-r are both projected to achieve long-term PCB smallmouth bass whole body tissue contaminant concentrations that are at or below the most conservative estimates of acceptable risk levels (i.e., ranges of TTLs), and thus both alternatives are expected to meet tissue RAOs (2 and 6) (Figure 8.2.2-7). Under both alternatives, Segments 1 and 3 are projected to reach levels below the lowest end of the TTL range, while Segments 2 and 4 are projected to achieve levels that are at or near EPA's point estimate TTL. Implementation of Alternative E-r is projected to result in increases (during construction and a few years afterwards) in tissue PCB concentrations due to dissolved PCB dredging releases to the water column, particularly in Segment 2 due to dredging in SMA 17S (Swan Island Lagoon) and SMA 19, and in Segment 4 due to dredging in SMA 3.

Surface Water. Alternatives E-i and E-r are projected to achieve long-term surface water concentrations post-remedy that are the same as all the other alternatives (Figures 8.2.2-8 through 8.2.2-10). However, these alternatives are not projected to meet risk levels associated with certain of the chemical-specific water quality criteria and standards, particularly those based on fish consumption, because upstream concentrations entering the Site already exceed some of these criteria. These alternatives have short-term impacts to surface water due to dredging releases, particularly Alternative E-r, similar to that described for tissue.

Groundwater. Upland source control actions by themselves may be able to address the groundwater RAOs 4 and 8, but implementation of Alternative E-i would likely further assist in achieving these RAOs. Relative to Alternative E-r, Alternative E-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide opportunities for in-water remedies (e.g., capping) to assist in attainment of the groundwater RAOs in the river, if appropriate. Alternative E-r has relatively limited amounts of in-place remediation and thus provides more limited opportunity to assist in achieving these RAOs.

8.7.2 Compliance with ARARs

Chemical-Specific ARARs. Similar to the previous alternatives, Alternatives E-i and E-r are not expected to meet every potential WQS/NRWQC and MCL, primarily because upstream concentrations entering the Site already exceed one or more of these values. Detailed evaluations relative to Alternatives E-i and E-r are summarized below for each chemical-specific water quality criteria (Section 9.2.1 contains additional details):

- MCLs – Fate and transport modeling for total PCBs and BaP indicates that concentrations of these contaminants could exceed drinking water MCLs in very small areas and periods (i.e., 0.06 percent or less of the simulation [six one-hundredths of a percent]). Although MCL exceedances were not observed in existing data in the RI, the modeling projections include a construction period for these alternatives that is different from any condition measured by RI data.

- Fish consumption WQS/NRWQC – Model projections suggest exceedances of WQS/NRWQC for PCBs, BaP, and DDx under Alternatives E-i and E-r, though in some cases the criteria are below background. In these cases, the exceedances of the criteria/background represent approximately 13, 1, and 0.5 percent of the simulation for these contaminants, respectively. Alternative E-i is projected to have fewer exceedances than Alternative E-r (e.g., DDE exceedances represent 0.3 percent of the simulation for Alternative E-i, but 0.6 percent for Alternative E-r).
- Chronic and Acute WQS – Model projections suggest exceedances of the chronic WQS for PCBs (representing about 0.8 percent of the simulation) under Alternatives E-i and E-r primarily due to dredging-related releases. These alternatives are also projected to have some exceedances of the acute PCB criterion in very limited areas and periods (less than 0.01 percent of the simulation) due to dredging-related releases.

Location-Specific ARARs. Alternatives E-i and E-r are generally expected to meet the location-specific ARARs as summarized below (Section 9.2.2 contains additional details):

- Oregon Environmental Cleanup Law – Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at $1x10^{-6}$ for individual carcinogens and $1x10^{-5}$ for multiple carcinogens. (Other aspects of this rule are similar to CERCLA criteria and are discussed under long-term effectiveness.) (Other aspects of this rule [i.e., human health noncancer endpoints and ecological risk levels] are similar to CERCLA criteria and are discussed under long-term effectiveness.) Both Alternatives E-i and E-r are projected to achieve total PCB concentrations representing a 10^{-5} cancer risk level, using the overall range of sediment RGs and tissue TTLs representing smallmouth bass whole body consumption, which is highly overlapping with or below the estimated background range. These alternatives are also projected to achieve the respective long-term sediment BaP, DDD, DDE, and DDT concentrations in the 10^{-6} cancer risk range. Alternatives E-i and E-r identify relatively high concentration areas (above the RALs for these alternatives) and targets some of those areas for in situ treatment (E-i) or removal and off-Site disposal (E-i and E-r) consistent with the intent of Oregon hot spot requirements. These alternatives treat or remove sediment in those areas. See Section 9.2.2 for additional information.
- ESA – Alternatives E-i and E-r would comply with ESA with the implementation of potential impact avoidance and minimization measures and conservation measures included in the alternatives.
- CWA Section 404(b)(1) – Alternatives E-i and E-r meet the substantive requirements of this ARAR (Appendix M).

- FEMA Flood Rise Requirements – The predicted increases in water surface elevations for Alternative E-i and E-r during an estimated "100-year" flood are considered to be negligible and not significantly different between alternatives based on the model precision, and therefore compliance with this ARAR cannot be confirmed (see Section 8.2.3 for further discussion).

8.7.3 Long-Term Effectiveness and Permanence

Evaluation of the long-term effectiveness and permanence criterion is summarized below. Section 9.3 contains additional details.

Magnitude of Residual Risk - Surface Sediment COC Projections. Alternatives E-i and E-r are both projected to achieve surface sediment COC concentrations below EPA's conservative point estimate RGs and PRGs for PCBs, BaP, DDD, DDE, and DDT both Site-wide and in each river Segment (Figures 8.2.2-1 to 8.2.2-6). Looking at a river mile spatial scale (see graphs Appendix U, Section 3.1), DDD, DDE, and DDT are all projected to be reduced over the long term under Alternatives E-i and E-r to below their respective EPA point estimate RG/PRGs. Similar long-term effectiveness was projected for BaP on a shoreline half-river mile basis. For PCBs, Alternatives E-i and E-r are both projected to achieve levels below the 99th percentile RG in all river miles except in RMs 3 to 4 and Swan Island Lagoon. For RMs 3 to 4, additional projections, assuming ongoing stormwater source controls are completed, suggest that these alternatives may achieve levels below the RG range over the long term (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 75 to 80 ppb (Appendix U, Figure 3.1-3), which represents a risk level below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is achieved (in the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1 and Appendix E, Table 5.6-1). Alternative E-r, which involves more dredging of contaminated sediments as compared to Alternative E-i, is projected to result in greater sediment concentrations over a long period (i.e., 12 years) due to dredging-induced releases and residuals (Figures 8.2.2-1 to 8.2.2-6).

Magnitude of Residual Risk - Biota Tissue Concentration Projections. Alternatives E-i and E-r are projected to achieve smallmouth bass whole body tissue PCB levels that are below the range of TTLs in Site Segments 1 and 3 (Figure 8.2.2-7). In Segments 2 and 4, these alternatives are projected to achieve levels just below or near EPA's point estimate of the PCB TTL.

Magnitude of Residual Risk - Minimization of Potential Long-Term Sediment Recontamination. As discussed above, long-term surface sediment COC concentrations under Alternatives E-i and E-r are projected to be at or below the lowest RGs, except for the PCB point estimate RG in Swan Island Lagoon. Thus, long-term sediment recontamination is generally not expected even using the conservative assumption that current upland loadings continue (i.e., no further source controls. An additional evaluation of the potential for long-term recontamination at smaller spatial scales indicated that, following initial reductions in surface sediment COC concentrations, these concentrations are projected to increase in response to continuing contaminant inputs. However, these projected increases are generally lower than current COC concentrations and no areas are projected to exceed the EPA point estimate RG (as generally shown Figures 8.2.2-1 to 8.2.2-6; see Section 9.3.4 for additional information).

Magnitude of Residual Risk - Minimization of Potential Groundwater Impacts. As noted above, relative to Alternative E-r, Alternative E-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide greater opportunities for in-water remedies (e.g., capping) to assist in minimizing potential groundwater impacts. Alternative E-r has relatively limited amounts of in-place remediation and thus provides more limited opportunities to assist in minimizing potential groundwater impacts.

Magnitude of Residual Risk - Minimization of Potential Long-Term Downstream Contaminant Transport. Figures 8.2.2-8 to 8.2.2-10 show surface water concentrations projected through 45 years. The projected transport of these contaminant concentrations off Site throughout the simulation period was examined (as discussed more in Section 9.3.6). Alternative E-r is projected to result in additional downstream transport of contaminants beyond the no action condition. Alternative E-i is projected to have no substantial change in downstream transport that would otherwise take place without the remedy, primarily due to reductions in PCB flux from areas of sediment that are capped or treated in place under this alternative. Although Alternative E-i also includes environmental dredging, these construction phase releases are balanced by reduced flux in capped or treated areas during the remainder of the 45-year period simulated.

Adequacy of Controls. Alternatives E-i and E-r result in some residual concentrations of contaminants at the Site. Physical/chemical barriers (e.g., dredge residual cover or cap), long-term monitoring, operations/maintenance, and institutional controls included in the alternatives are expected to adequately control these residual concentrations and maintain them at the sediment, tissue, and water concentrations discussed above. As noted in Section 5.6.6, very little contamination above the RALs is left in place outside areas of active remediation that could be subject to potential future release. See Section 9.3.7 for additional discussion.

Other Factors – Habitat Restoration Potential Integration. Implementation of either Alternative E-i or E-r would not prohibit integration with potential habitat restoration actions. More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.3.8).

Disposal Site Long-Term Effectiveness. Alternative E-i involves disposal within upland commercial landfills, Swan Island CDF, and Arkema's preliminary design (1-Berth) CDF. Alternative E-r includes disposal within upland landfills, the Terminal 4 CDF, Arkema's preliminary design (2-Berth) CDF, and Swan Island CDF. The long-term effectiveness of each on-Site CDF was evaluated using the FS CDF Performance Standards (EPA 2010e; LWG 2010a and b; Appendix O). Based on this evaluation, the CDFs can be designed and built in a manner that meets all of the long-term FS CDF Performance Standards (Appendix U, Section 6) as discussed further in Section 9.3.9.

8.7.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Under Alternative E-i, in situ treatment (e.g., using direct broadcast placement of AC) would be used to remediate approximately 58 acres of sediment. In situ treatment can effectively reduce the toxicity and mobility of the Site contaminants by controlling their bioavailability (Ghosh et al. 2011; Cornelissen et al. 2011). Alternative E-r would provide a smaller degree of reduction in contaminant mobility, primarily through ex situ treatment of removed sediments via dewatering.

8.7.5 Short-Term Effectiveness

Evaluation of the short-term effectiveness criterion is summarized below. Section 9.5 contains additional details.

Environmental Impacts - Construction Water Quality Impacts. Projected changes in water column contaminant concentrations during in-water construction operations under Alternatives E-i and E-r are discussed above in Section 8.7.2 including the spatial and temporal extent of potential MCL and WQS/NRWQC exceedances. Dredging-related resuspension and unavoidable releases to the water column are projected to result in short-term exceedances of these criteria over small areas and periods. Alternative E-i is projected to have fewer short-term construction water quality impacts than Alternative E-r.

Environmental Impacts - Construction Potential Sediment Recontamination During Construction. Under both Alternatives E-i and E-r, modeling projections and comparisons with case study results from other environmental dredging sites (Bridges et al. 2010) suggest that potential sediment recontamination of adjacent areas resulting from dredging resuspension and residuals would generally be limited to within approximately 500 to 1,000 feet of the dredging activity. Alternative E-r has a higher potential for adjacent recontamination because of the greater amount of dredging included in this alternative and could require additional residual management to control short-term risks (see Section 6.2.7). More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.5.2).

Environmental Impacts - Construction Potential Downstream Transport. Figures 8.2.2-8 to 8.2.2-10 show the elevated surface water concentrations projected early in the simulation period due to environmental dredging releases during construction. The projected transport of these released contaminants off the Site throughout the simulation period was examined further (as discussed more in Section 9.5.3). Alternative E-r construction is projected to result in measurable additional downstream transport of contaminants beyond the no action condition for this period. Alternative E-i results in some additional downstream transport in this period, but less than Alternative E-r.

Environmental Impacts – Air Pollutant and Greenhouse Gas Emissions. Detailed evaluations of air emissions resulting from implementation of the alternatives are summarized in Appendix Ic. Construction of Alternatives E-i or E-r is projected to result in approximately 5,000 to 6,000 and 7,000 to 12,000 tonnes, respectively, of increased CO_2 equivalent air emissions. This total range is equivalent to the annual emissions from 880 to 2,400 cars. Alternative E-r has larger projected impacts due to the larger volumes and durations of work involved.

Projected Timeframes to Achieve RAOs. Figures 8.2.2-1 to 8.2.2-7 generally summarize the projected sediment and tissue concentration reductions over time. This information was further examined, as detailed in Section 9.5.5. In summary, under Alternatives E-i and E-r, Segment 1 already meets the BaP and DDE RGs and is projected to achieve the ranges of relevant PCB RGs in 0 (i.e., currently meets the lowest RG) to 5 years. Segment 2 is projected to achieve the DDE RG in about 2 to 3 years, already achieves the lowest BaP RG, and would achieve PCB RGs in 0 to greater than 45 years, given the overall ranges of RGs and the uncertainties of the assessment. Segment 3 is projected to achieve the RGs in anywhere from 0 to 35 years, again given the overall ranges of RGs and uncertainties of the assessment, while Segment 4 is projected to achieve the PCB RGs in anywhere from 0 to more than 45 years (DDE and BaP already achieve the lowest RGs, or nearly so).

Community Risks and Quality of Life. Implementation of these alternatives would also result in some impacts to quality of life measures both within and around the harbor during construction (Appendix U, Section 4.4). Alternative E-r has larger projected impacts due to the larger volumes and durations of work involved.

Potential Impacts to Workers. As discussed in more detail in the comparative analysis of alternatives (Section 9.5.7), construction of Alternatives E-i and E-r is projected to result in approximately 12 and 22 non-fatal worker injuries (incidents), respectively, and a 5 and 9 percent chance of a fatal worker incident, respectively. Alternative E-r has larger projected impacts due to the larger volumes and durations of work involved.

Disposal Site Short-Term Effectiveness. Alternatives E-i and E-r involve disposal within upland commercial landfills as well as on-Site CDFs. With appropriate operational BMPs, environmental risks related to spills or releases of contaminated sediments or water during transport operations are anticipated to be small. Evaluation of on-Site CDFs using the short-term CDF Performance Standards indicates these facilities can be designed and built in a manner that meets all of these standards (Appendix U, Section 6).

8.7.6 Implementability

As discussed in Section 8.2.7, duration is used as a general metric for the level of implementability issues associated with alternatives. Section 9.6 contains more detailed discussions of the various implementability factors for all alternatives. Both Alternatives

E-i and E-r are implementable. Alternatives E-i and E-r have projected construction durations of approximately 7 years and 12 years, respectively.

8.7.7 Cost

Alternatives E-i and E-r have estimated costs in the $463 million to $709 million and $568 million to $884 million range, respectively.

8.8 ALTERNATIVE F DETAILED ANALYSIS

8.8.1 Overall Protection of Human Health and the Environment

Sediment. Alternatives F-i and F-r are both projected to achieve long-term sediment contaminant concentrations (SWACs over various spatial scales) that are at or below conservative estimates of acceptable risk levels (i.e., ranges of RGs) and are expected to meet sediment RAOs (1 and 5) at all spatial scales for all COCs except for PCBs (Figures 8.2.2-1, to 8.2.2-6). At the river mile spatial scale (see figures in Appendix U, Section 3.1), Alternatives F-i and F-r are both projected to achieve levels below the PCB RG ranges in all river miles except for the most conservative PCB RGs (EPA point estimate and 99th percentile) in RMs 3 to 4 and Swan Island Lagoon. Further, RM 3 to 4 achieves the EPA point estimate RG for Alternative F-i and is projected to achieve the lowest RGs for both alternatives if ongoing stormwater source controls in this area are completed (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 60 to 75 ppb (Appendix U, Figure 3.1-3), which represents a risk level below a 95^{th} percentile estimate of the 10^{-4} cancer risk (95 ppb; Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is projected to be achieved (into the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1 and Appendix E, Table 5.6-1). The most conservative RGs are within the estimated range of background and may not be effectively different from background based on sediment concentrations, tissue concentrations or risk. Alternative F-r, which involves much more dredging of contaminated sediments as compared to Alternative F-i, is projected to result in greater sediment concentrations during construction over a long period (nearly 30 years) due to dredging-induced releases and residuals and the longer time it takes to complete the alternative (Figures 8.2.2-1, to 8.2.2-6). Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and core profiles reviewed in Section 6.2.2 indicate overall deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports the concept that extensive active remedies combined with MNR would result in substantially reduced long-term sediment concentrations.

Tissue. Alternatives F-i and F-r are both projected to achieve long-term PCB smallmouth bass whole body tissue contaminant concentrations that are at or below the most conservative estimates of acceptable risk levels (i.e., ranges of TTLs) and thus both alternatives are expected to meet tissue RAOs (2 and 6) (Figure 8.2.2-7). Under both alternatives, Segments 1 and 3 are projected to reach levels below the lowest end of the TTL range, while Segments 2 and 4 are projected to achieve levels that are below EPA's point estimate TTL. Implementation of Alternative F-r is projected to result in increases (during construction and for a few years afterwards) in tissue PCB concentrations due to dissolved PCB dredging releases to the water column, particularly in Segment 2 due to dredging in SMAs 17S (Swan Island Lagoon) and 19, and Segment 4 due to dredging in SMA 3.

Surface Water. Alternatives F-i and F-r are projected to achieve long-term surface water concentrations post-remedy that are the same as all the other alternatives (Figures 8.2.2-8 through 8.2.2-10). However, these alternatives are not projected to meet risk levels associated certain many of the chemical-specific water quality criteria and standards, particularly those based on fish consumption, because upstream concentrations entering the Site already exceed some of these criteria. These alternatives have considerable short-term impacts to surface water due to dredging releases, particularly Alternative F-r, similar to that described for tissue.

Groundwater. Upland source control actions by themselves may be able to address the groundwater RAOs 4 and 8, but implementation of Alternative F-i would likely further assist in achieving these RAOs. Relative to Alternative F-r, Alternative F-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide opportunities for in-water remedies (e.g., capping) to assist in attainment of the groundwater RAOs in the river, if appropriate. Alternative F-r has relatively limited amounts of in-place remediation and thus provides more limited opportunity to assist in achieving these RAOs.

8.8.2 Compliance with ARARs

Chemical-Specific ARARs. Similar to the previous alternatives, Alternatives F-i and F-r are not expected to meet every potential WQS/NRWQC and MCL, primarily because upstream concentrations entering the Site already exceed one or more of these values. Detailed evaluations relative to Alternatives F-i and F-r are summarized below for each chemical-specific water quality criteria (Section 9.2.1 contains additional details):

- MCLs – Fate and transport modeling for total PCBs and BaP indicates that concentrations of these contaminants could exceed drinking water MCLs in very small areas and periods (i.e., 0.05 percent or less of the simulation [five one-hundredths of a percent]). Although MCL exceedances were not observed in existing data in the RI, the modeling projections include a construction period for these alternatives that is different from any condition measured by RI data.
- Fish consumption WQS/NRWQC – Model projections suggest exceedances of WQS/NRWQC for PCBs, BaP, and DDx under Alternatives F-i and F-r, though in some cases the criteria are below background. In these cases, the exceedances of the criteria/background represent approximately 16, 1, and 0.6 percent of the simulation for these contaminants, respectively. Alternative F-i is projected to have fewer exceedances than Alternative F-r (e.g., PCB exceedances represent

14.3 percent of the simulation for Alternative F-i, but 17.5 percent for Alternative F-r).

- Chronic and Acute WQS – Model projections suggest exceedances of the chronic WQS for PCBs (representing about 1.2 percent of the simulation) under Alternatives F-i and F-r primarily due to dredging-related releases. These alternatives are also projected to have some exceedances of the acute PCB criterion in very limited areas and periods (less than 0.01 percent of the simulation) due to dredging-related releases.

Location-Specific ARARs. Alternatives F-i and F-r are generally expected to meet the location-specific ARARs as summarized below (Section 9.2.2 contains additional details):

- Oregon Environmental Cleanup Law – Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at $1x10^{-6}$ for individual carcinogens and $1x10^{-5}$ for multiple carcinogens. (Other aspects of this rule are similar to CERCLA criteria and are discussed under long-term effectiveness.) Both Alternatives F-i and F-r are projected to achieve total PCB concentrations representing a 10^{-5} cancer risk level, using the overall range of sediment RGs and tissue TTLs representing smallmouth bass whole body consumption, which is highly overlapping with or below the estimated background range. These alternatives are also projected to achieve the respective long-term sediment BaP, DDD, DDE, and DDT concentrations in the 10^{-6} cancer risk range. Alternatives F-i and F-r identify relatively high concentration areas (above the RALs for these alternatives) and targets some of those areas for in situ treatment (F-i) or removal and off-Site disposal (F-i and F-r) consistent with the intent of Oregon hot spot requirements. These alternatives treat or remove sediment in those areas. See Section 9.2.2 for additional information.
- ESA – Alternatives F-i and F-r would comply with ESA with the implementation of potential impact avoidance and minimization measures and conservation measures included in the alternatives.
- CWA Section 404(b)(1) – Alternatives F-i and F-r meet the substantive requirements of this ARAR (Appendix M).
- FEMA Flood Rise Requirements – The predicted increases in water surface elevations for Alternative F-i and F-r during an estimated "100-year" flood are considered to be negligible and not significantly different between alternatives based on the model precision, and therefore compliance with this ARAR cannot be confirmed (see Section 8.2.3 for further discussion).

8.8.3 Long-Term Effectiveness and Permanence

Evaluation of the long-term effectiveness and permanence criterion is summarized below. Section 9.3 contains additional details.

Magnitude of Residual Risk - Surface Sediment COC Projections. Alternatives F-i and F-r are both projected to achieve surface sediment COC concentrations below EPA's conservative point estimate RGs and PRGs for PCBs, BaP, DDD, DDE, and DDT both Site-wide and in each river Segment (Figures 8.2.2-1 to 8.2.2-6). Looking at a river mile spatial scale (see graphs Appendix U, Section 3.1), DDD, DDE, and DDT are all projected to be reduced over the long term under Alternatives F-i and F-r to below their respective EPA point estimate RG/PRGs. Similar long-term effectiveness was projected for BaP on a shoreline half-river mile basis. For PCBs, Alternatives F-i and F-r are both projected to achieve levels below the 99th percentile RG in all river miles except in RMs 3 to 4 and Swan Island Lagoon. For RMs 3 to 4, additional projections, assuming ongoing stormwater source controls are completed, suggest that these alternatives may achieve levels below the RG range over the long term (Appendix Ha, Section 6). In Swan Island Lagoon, both alternatives are projected to achieve long-term surface sediment PCB concentrations in the range of 60 to 75 ppb (Appendix U, Figure 3.1-3), which represents a risk level below a 95th percentile estimate of the 10^{-4} cancer risk (95 ppb; see Table 8.2.2-1 and Appendix E, Table 5.6-1), assuming whole body consumption of smallmouth bass. A lower risk level is achieved (in the 10^{-5} cancer risk range) if fillet consumption scenarios are considered (Table 8.2.2-1). Alternative F-r, which involves much more dredging of contaminated sediments as compared to Alternative F-i, is projected to result in greater sediment concentrations during construction over a long period (nearly 30 years) due to dredging-induced releases and residuals and the longer time it takes to complete the alternative (Figures 8.2.2-1 to 8.2.2-6).

Magnitude of Residual Risk - Biota Tissue Concentration Projections. Alternatives F-i and F-r are projected to achieve smallmouth bass whole body PCB levels that are below the range of TTLs in Site Segments 1 and 3 (Figure 8.2.2-7). In Segments 2 and 4, these alternatives are projected to achieve levels below EPA's point estimate of the PCB TTL.

Magnitude of Residual Risk - Minimization of Potential Long-Term Sediment Recontamination. As discussed above, long-term surface sediment COC concentrations under Alternatives F-i and F-r are projected to be within ranges that are generally at or below the most conservative estimates of protectiveness except for PCBs in Swan Island Lagoon. Thus, long-term sediment recontamination is generally not expected even using the conservative assumption that current upland loadings continue (i.e., with no further source controls. An additional evaluation of the potential for long-term recontamination at smaller spatial scales indicated that following initial reductions in surface sediment COC concentrations, these concentrations are projected to increase in response to continuing contaminant inputs. However, these projected increases are generally lower than current COC concentrations and no areas are projected to exceed the EPA point estimate RG (as generally shown Figures 8.2.2-1 to 8.2.2-6; see Section 9.3.4 for additional information).

Magnitude of Residual Risk - Minimization of Potential Groundwater Impacts. As noted above, relative to Alternative F-r, Alternative F-i has a greater emphasis on in-place remediation, so implementation of this alternative would provide greater opportunities for in-water remedies (e.g., capping) to assist in minimizing potential groundwater impacts. Alternative F-r has relatively limited amounts of in-place remediation and thus provides more limited opportunities to assist in minimizing potential groundwater impacts.

Magnitude of Residual Risk - Minimization of Potential Long-Term Downstream Contaminant Transport. Figures 8.2.2-8 to 8.2.2-10 show surface water concentrations projected through 45 years. The projected transport of these contaminant concentrations off Site throughout the simulation period was examined (as discussed more in Section 9.3.6). Alternative F-r is projected to result in substantial additional downstream transport of contaminants beyond the no action condition. Alternative F-i is projected to result in no substantial change in downstream transport that would otherwise take place without the remedy, primarily due to reductions in PCB flux from areas of sediment that are capped or treated in place under this alternative. Although Alternative F-i also includes environmental dredging, these construction phase releases are balanced by reduced flux in capped or treated areas during the remainder of the 45-year period simulated.

Adequacy of Controls. Alternatives F-i and F-r result in some residual concentrations of contaminants at the Site. Physical/chemical barriers (e.g., dredge residual cover or cap), long-term monitoring, operations/maintenance, and institutional controls included in the alternatives are expected to adequately control these residual concentrations and maintain them at the sediment, tissue, and water concentrations discussed above. As noted in Section 5.6.6, very little contamination above the RALs is left in place outside areas of active remediation that could be subject to potential future release. See Section 9.3.7 for additional discussion.

Other Factors – Habitat Restoration Potential Integration. Implementation of either Alternative F-i or F-r would not prohibit potential integration with potential habitat restoration actions. More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.3.8).

Disposal Site Long-Term Effectiveness. Both Alternatives F-i and F-r involve disposal within upland commercial landfills as well as in the Terminal 4 CDF, Arkema's preliminary design (2-Berth) CDF, and Swan Island CDF. The long-term effectiveness of each on-Site CDF was evaluated using the FS CDF Performance Standards (EPA 2010e; LWG 2010a and b; Appendix O). Based on this evaluation, the CDFs can be designed and built in a manner that meets all of the long-term FS CDF Performance Standards (Appendix U, Section 6) as discussed further in Section 9.3.9.

8.8.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Under Alternative F-i, in situ treatment (e.g., using direct broadcast placement of AC) would be used to remediate approximately 117 acres of sediment. In situ treatment can effectively reduce the toxicity and mobility of the Site contaminants by controlling their bioavailability (Ghosh et al. 2011; Cornelissen et al. 2011). Alternative F-r would provide a smaller degree of reduction in contaminant mobility, primarily through ex situ treatment of removed sediments via dewatering.

8.8.5 Short-Term Effectiveness

Evaluation of the short-term effectiveness criterion is summarized below. Section 9.5 contains additional details.

Environmental Impacts - Construction Water Quality Impacts. Projected changes in water column contaminant concentrations during in-water construction operations under Alternatives F-i and F-r are discussed above in Section 8.8.2 including the spatial and temporal extent of potential MCL and WQS/NRWQC exceedances. Dredging-related resuspension and unavoidable releases to the water column are projected to result in short-term exceedances of these criteria over small areas and periods. Alternative F-i is projected to have fewer short-term construction water quality impacts than Alternative F-r.

Environmental Impacts - Construction Potential Sediment Recontamination During Construction. Under both Alternatives F-i and F-r, modeling projections and comparisons with case study results from other environmental dredging sites (Bridges et al. 2010) suggest that potential sediment recontamination of adjacent areas resulting from dredging resuspension and residuals would generally be limited to within approximately 500 to 1,000 feet of the dredging activity. Alternative F-r has a higher potential for adjacent recontamination because of the greater amount of dredging included in this alternative, and could require additional residual management to control short-term risks (see Section 6.2.7). More detailed evaluations of this criterion are provided in the comparative analysis of alternatives (Section 9.5.2).

Environmental Impacts - Construction Potential Downstream Transport. Figures 8.2.2-8 to 8.2.2-10 show the elevated surface water concentrations projected early in the simulation period due to environmental dredging releases during construction. The projected transport of these released contaminants off the Site throughout the simulation period was examined further (as discussed more in Section 9.5.3). Alternative F-r construction is projected to result in substantial additional downstream transport of contaminants beyond the no action condition for this period. Alternative F-i results in some additional downstream transport in this period, but less than Alternative F-r.

Environmental Impacts – Air Pollutant and Greenhouse Gas Emissions. Detailed evaluations of air emissions resulting from implementation of the alternatives are summarized in Appendix Ic. Construction of Alternatives F-i or F-r is projected to result in approximately 10,000 to 23,000 and 39,000 to 71,000 tonnes, respectively, of increased CO_2 equivalent air emissions. This total range is equivalent to the annual emissions from 1,900 to 14,000 cars. Alternative F-r has larger projected impacts due to the larger volumes and durations of work involved.

Time Until Protection is Achieved - Projected Timeframe to Achieve RAOs. Figures 8.2.2-1 to 8.2.2-7 generally summarize the projected sediment and tissue concentration reductions over time. This information was further examined, as detailed in Section 9.5.5. In summary, under Alternatives F-i and F-r, Segment 1 already meets the BaP and DDE RGs and is projected to achieve the ranges of relevant PCB RGs in 0 (i.e., currently meets the lowest RG) to 11 years. Segment 2 is projected to achieve the DDE RG in about 2 to 3 years, already achieves lowest BaP RG, and would achieve PCB RGs in 0 to greater than 45 years, given the overall ranges of RGs and the uncertainties of the assessment. Segment 3 is projected to achieve the RGs in anywhere from 0 to 31 years, again given the overall ranges of RGs and uncertainties of the assessment, while Segment 4 is projected to achieve the PCB RGs in anywhere from 0 to more than 45 years (DDE and BaP already meet the lowest RGs, or nearly so).

Community Risks and Quality of Life. Implementation of these alternatives would also result in some impacts to quality of life measures both within and around the harbor during construction (Appendix U, Section 4.4). Alternative F-r has larger projected impacts due to the larger volumes and durations of work involved.

Potential Impacts to Workers. As discussed in more detail in the comparative analysis of alternatives (Section 9.5.7), construction of Alternatives F-i and F-r is projected to result in approximately 27 and 51 non-fatal worker injuries (incidents), respectively, and 11 and 21 percent chance of a fatal worker incident, respectively. Alternative F-r has larger projected impacts due to the larger volumes and durations of work involved.

Disposal Site Short-Term Effectiveness. Alternatives F-i and F-r involve disposal within upland commercial landfills as well as on-Site CDFs. With appropriate operational BMPs, environmental risks related to spills or releases of contaminated sediments or water during transport operations are anticipated to be small. Evaluation of Site CDFs using the short-term FS CDF Performance Standards indicates these facilities can be designed and built in a manner that meets all of these standards (Appendix U, Section 6).

8.8.6 Implementability

As discussed in Section 8.2.7, duration is used as a general metric for the level of implementability issues associated with alternatives. Section 9.6 contains more detailed discussions of the various implementability factors for all alternatives. Both Alternatives F-i and F-r would be difficult to implement. Alternatives F-i and F-r have projected construction durations of approximately 15 years and 28 years, respectively.

8.8.7 Cost

Alternatives F-i and F-r have estimated costs in the $878 million to $1,389 million ($1.4 billion) to $1,077 million to $1,762 million ($1.1 billion to $1.8 billion) range, respectively.

8.9 CONCLUSIONS

This section presented the individual detailed analyses of the Site-wide comprehensive alternatives developed in Section 7. The primary findings are that all of the alternatives provide overall protection of human health and the environment over the long term, with the exception of Alternative A (No Action). However, the alternatives achieve these protective levels with a wide range of construction durations; short-term impacts to the environment, community, and workers; ease of implementation; and costs. The differences between the alternatives are further evaluated with additional supporting documentation in the comparative evaluation in Section 9.

This figure, and those like it, show sediment concentrations over time projected for each remedial alternative. The upper panel shows the model best estimate or "base case", and the lower panel shows the most conservative (high concentration) "lower bound" estimate within the model calibration.

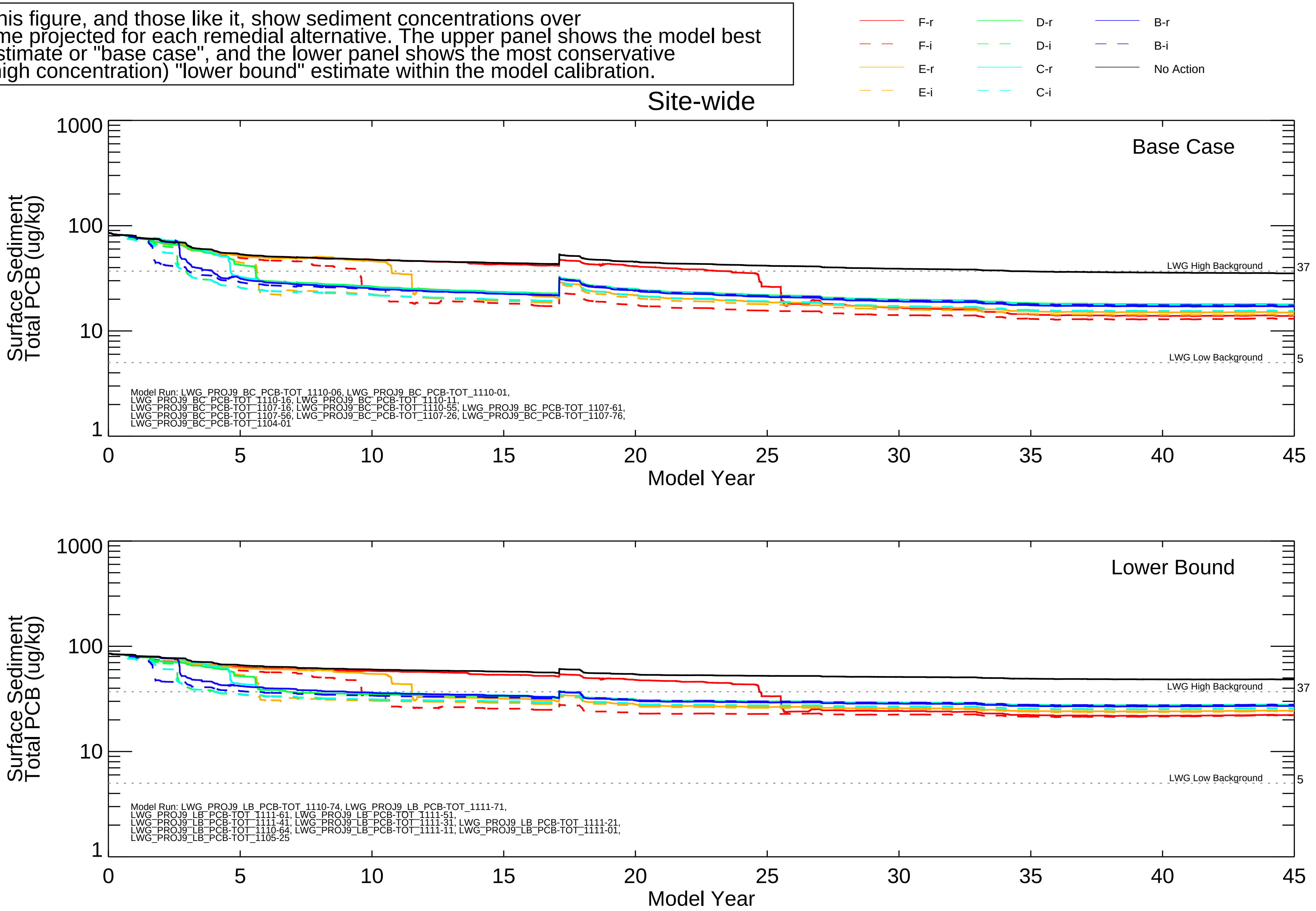

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Figure 8.2.2-1

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations (Site-wide Average)

MCS - Z:\010142-01_LWG-Willamette\model\EFDC\Post_process\Bed_Sed\plot\batch\proj_45\temp\plot_chem_bed_temp_bat_proj_45_oplot_SIL_ucr_2_panel_sa.pro Wed Mar 14 14:01:06 2012

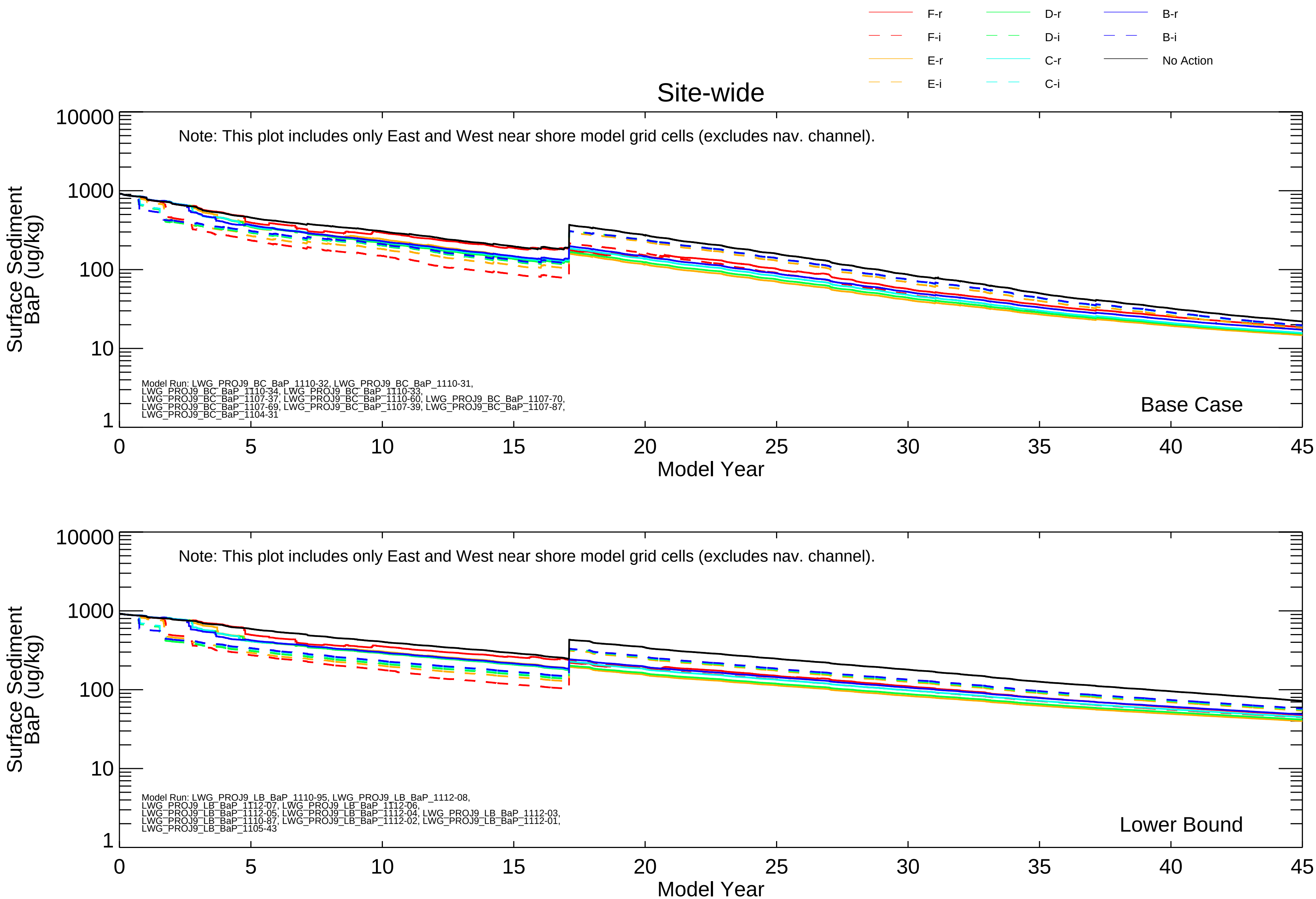

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Figure 8.2.2-2

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Simulation of FS Alternatives
Time Series of Surface Sediment (Top 1-ft) BaP Concentrations (Site-wide Average)

MCS - H:\010142-01_LWG-Willamette\model\EFDC\Post_process\Bed_Sed\plot\batch\proj_45\temp\plot_chem_bed_temp_bat_proj_45_oplot_SIL_ucr_2_panel_sa.pro Wed Mar 14 14:59:12 2012

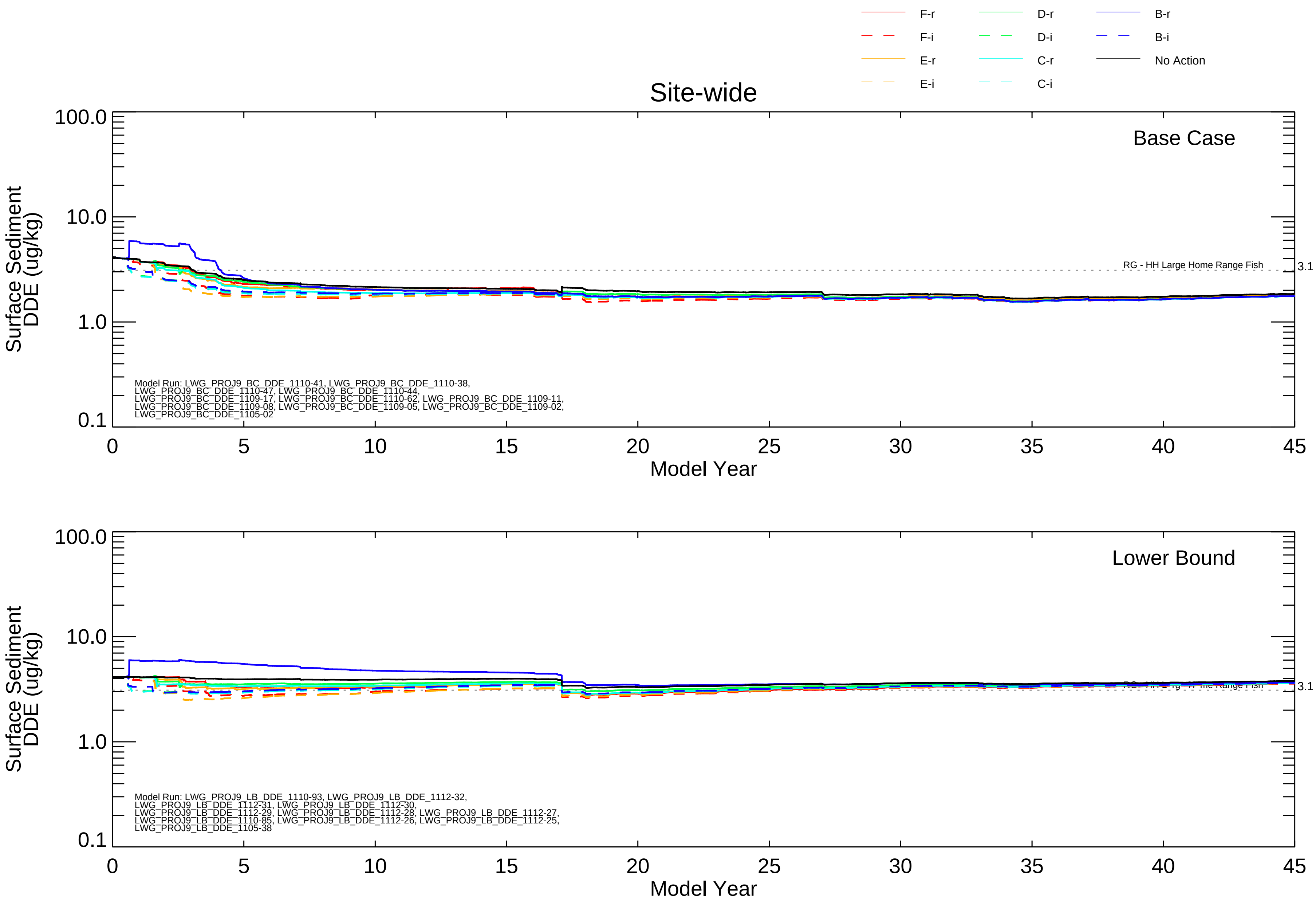

Figure 8.2.2-3

Portland Harbor RI/FS
Draft Feasibility Study
Simulation of FS Alternatives
Time Series of Surface Sediment (Top 1-ft) DDE Concentrations (Site-wide Average)

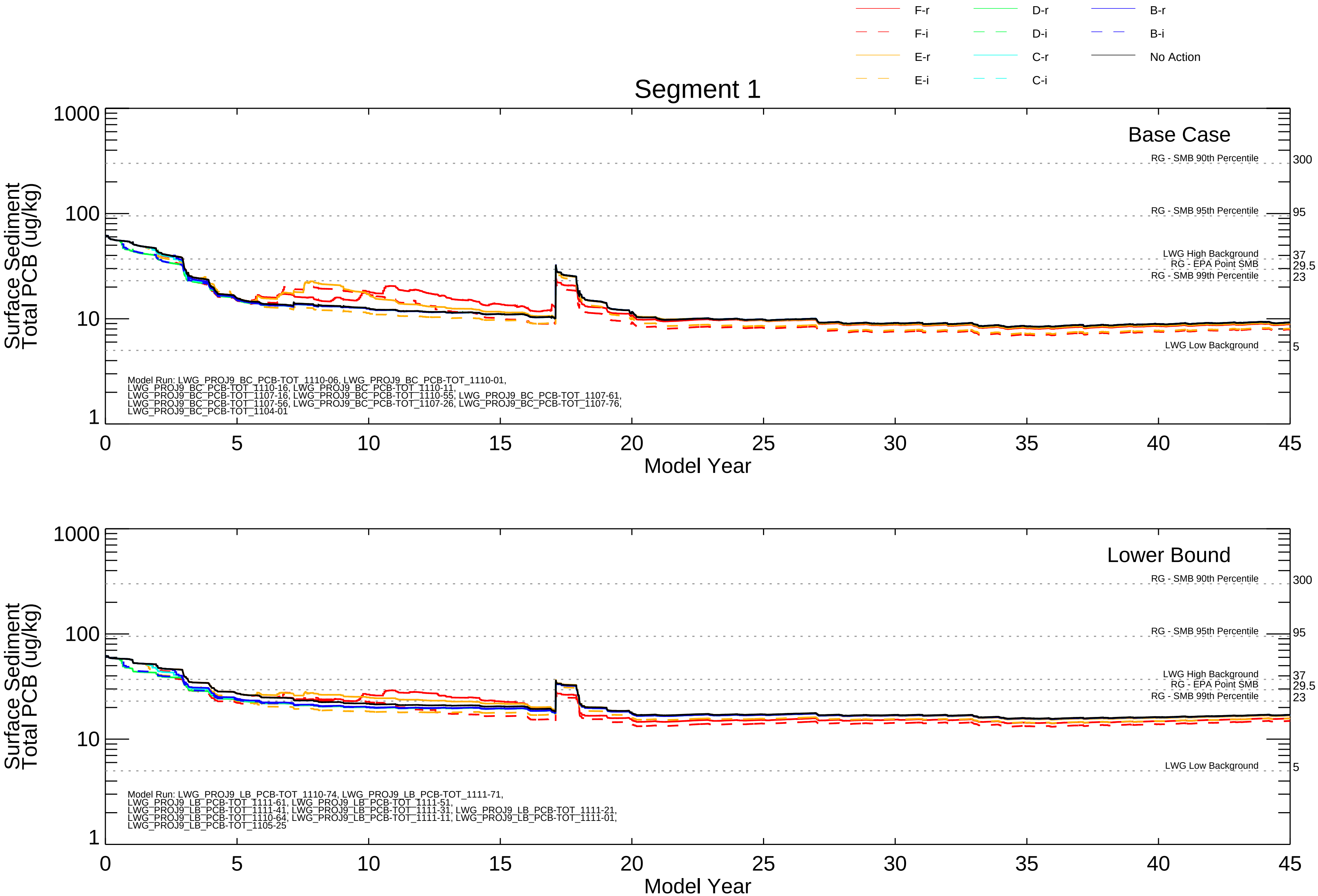

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Figure 8.2.2-4a

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations (Site Segment Average)

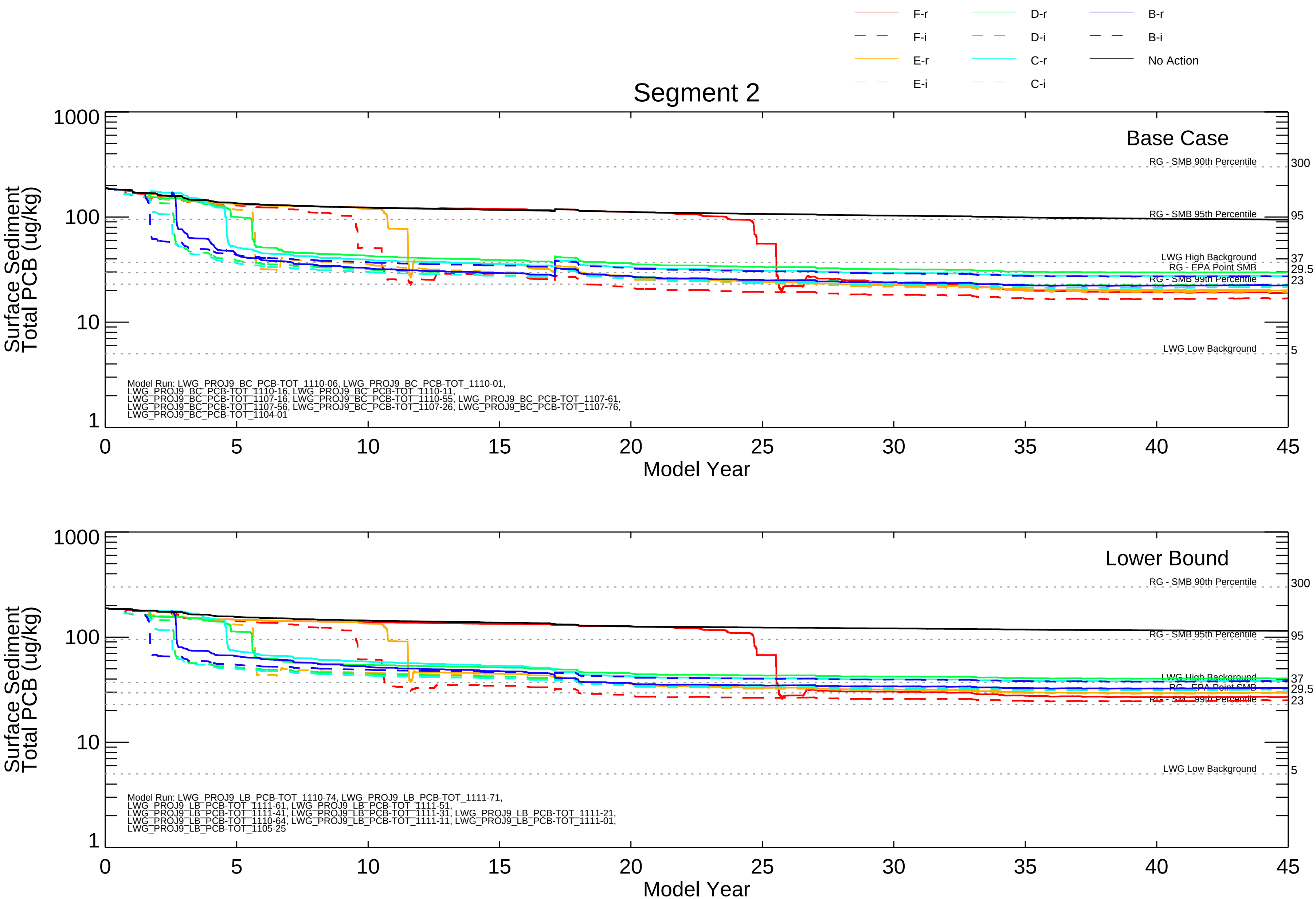

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Figure 8.2.2-4b

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations (Site Segment Average)

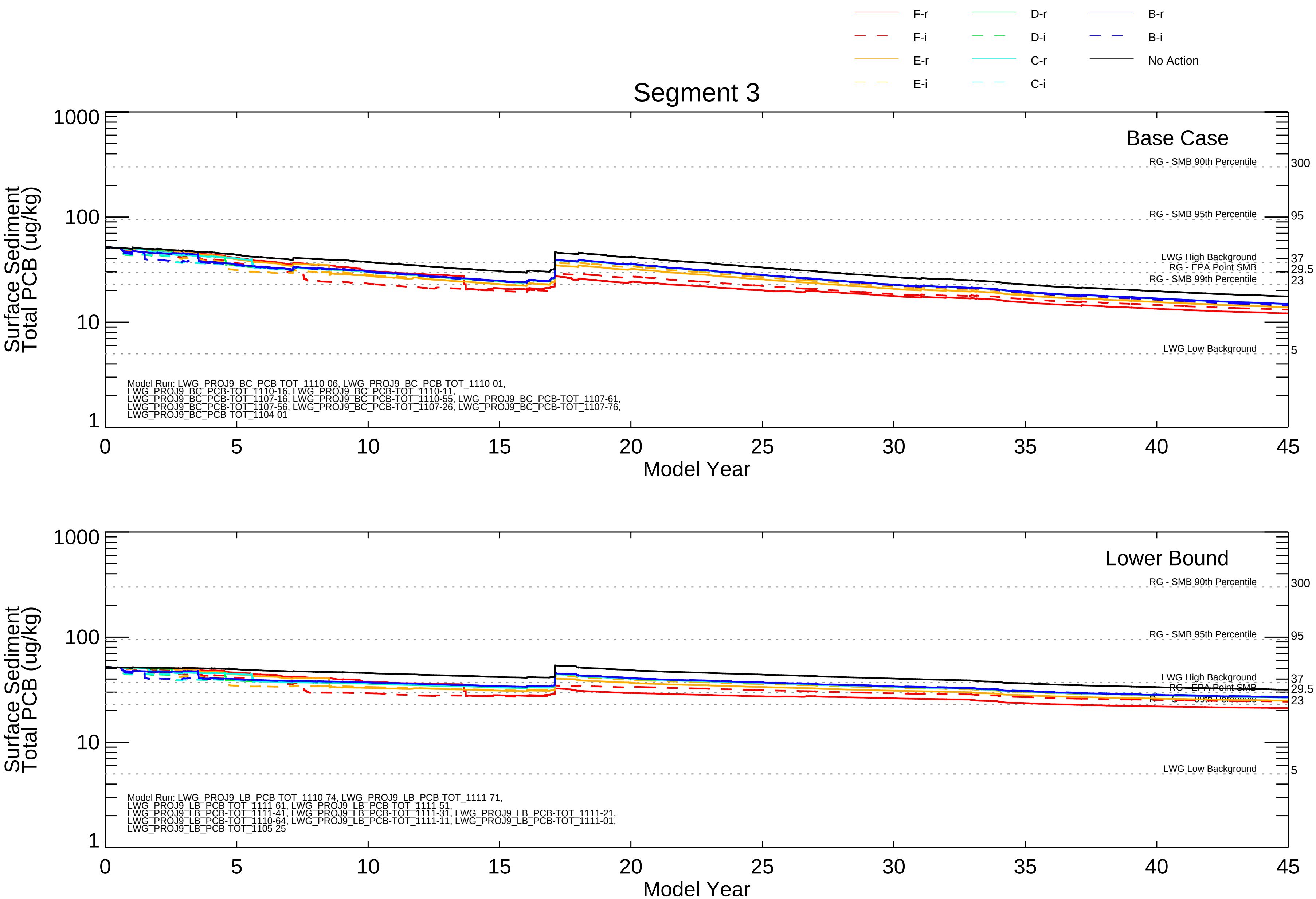

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Figure 8.2.2-4c

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations (Site Segment Average)

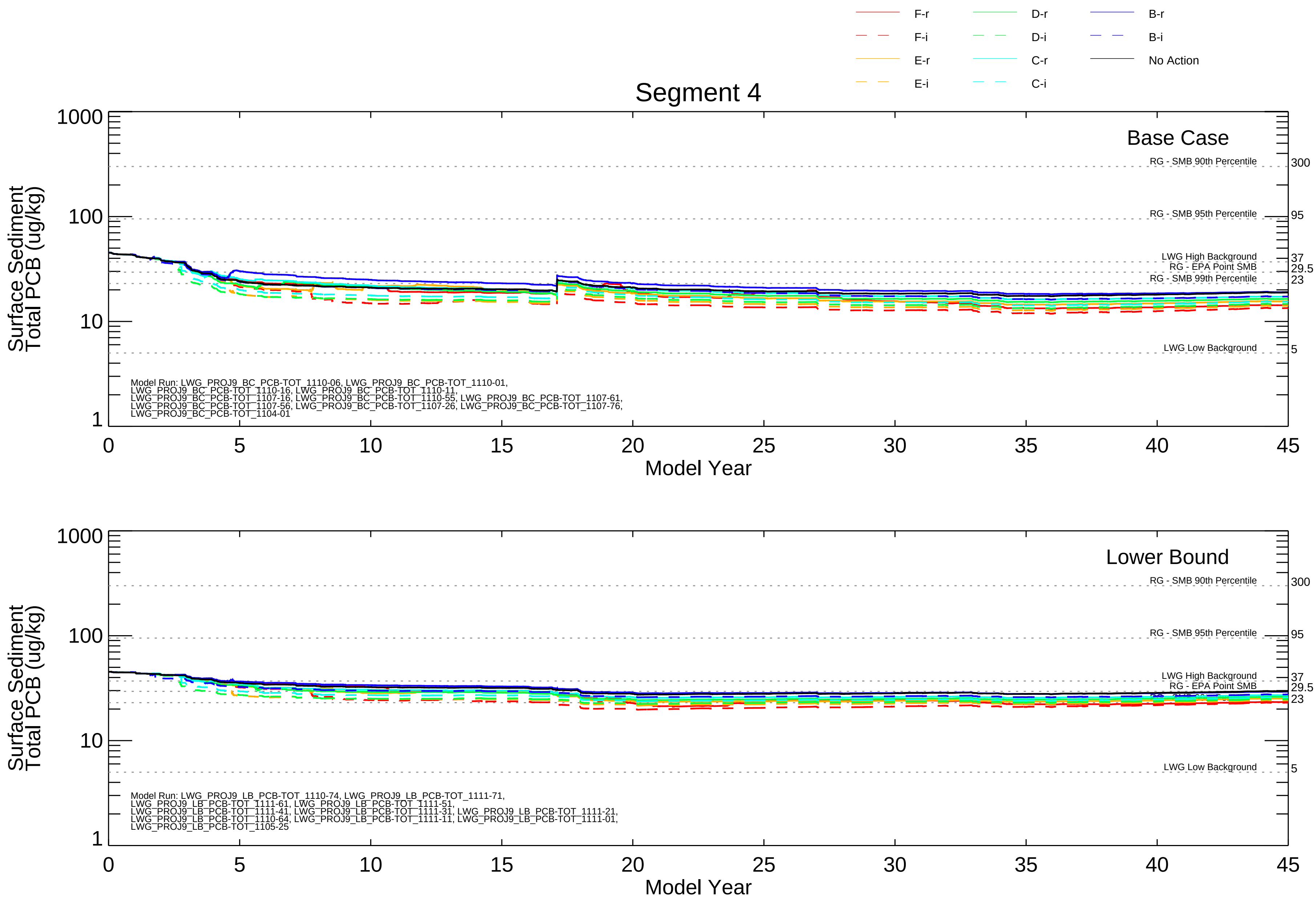

Figure 8.2.2-4d

Portland Harbor RI/FS

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations (Site Segment Average)

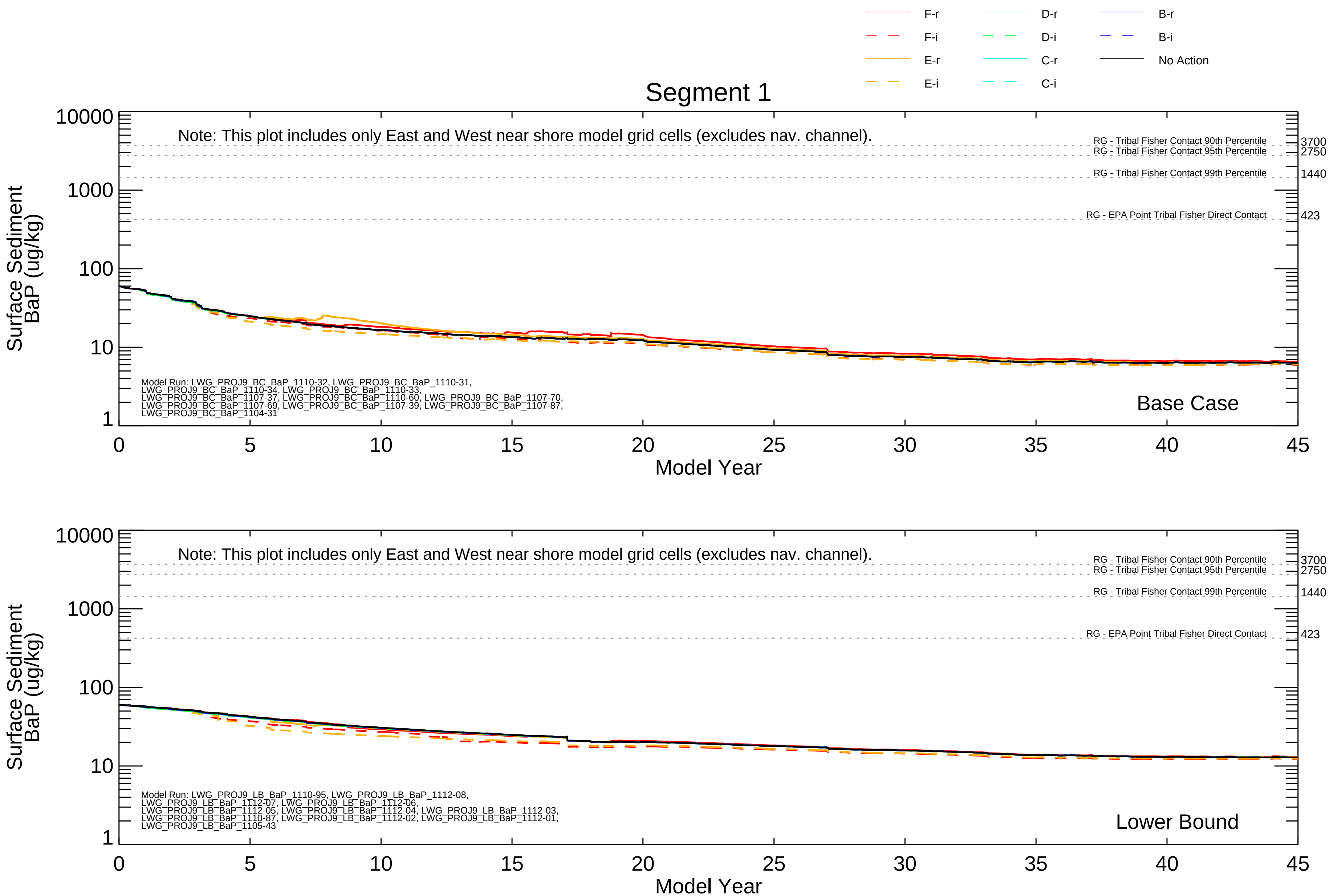

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Figure 8.2.2-5a

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) BaP Concentrations (Site Segment Average)

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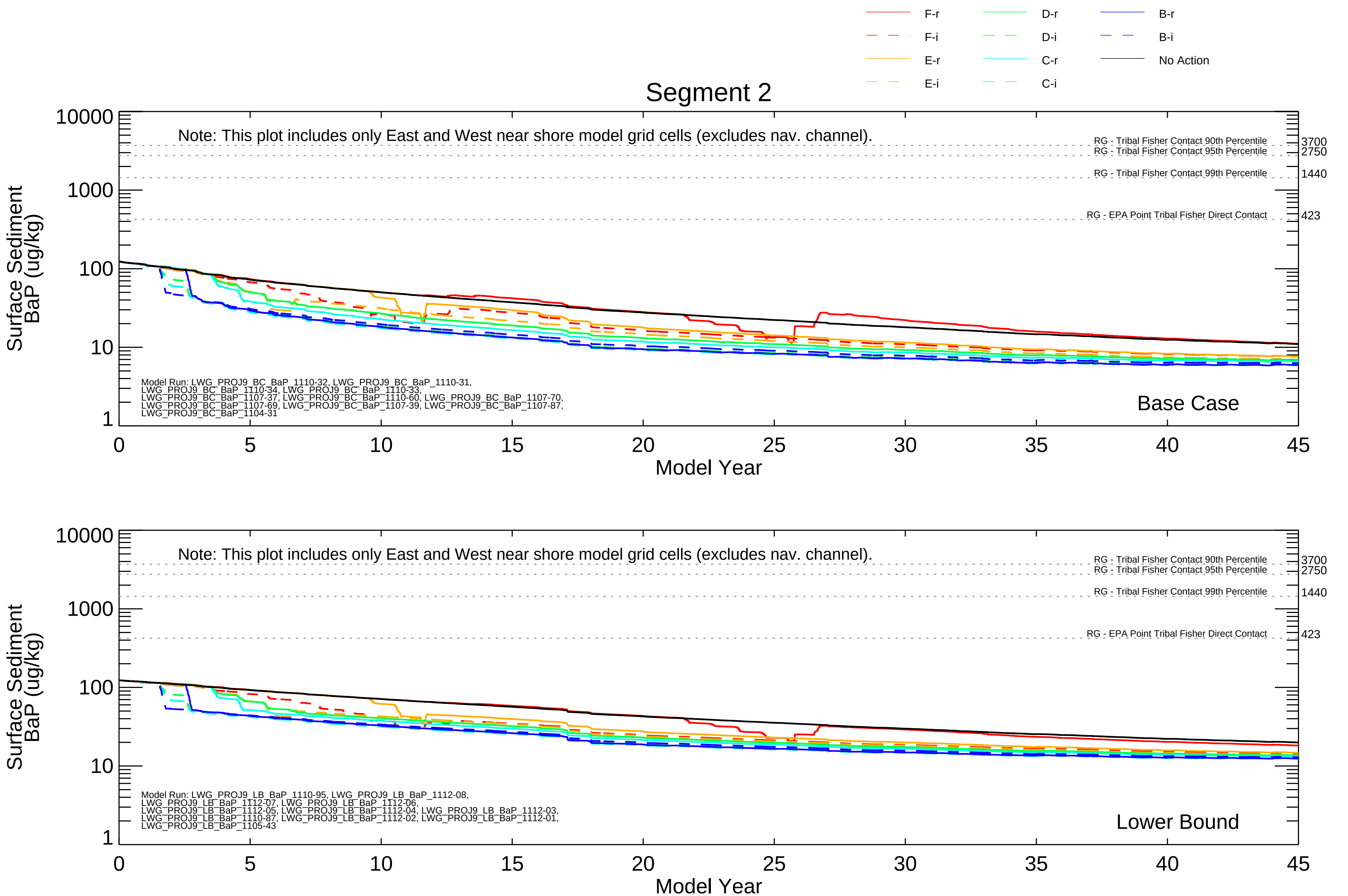

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Figure 8.2.2-5b

Portland Harbor RI/FS
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Simulation of FS Alternatives
Time Series of Surface Sediment (Top 1-ft) BaP Concentrations (Site Segment Average)

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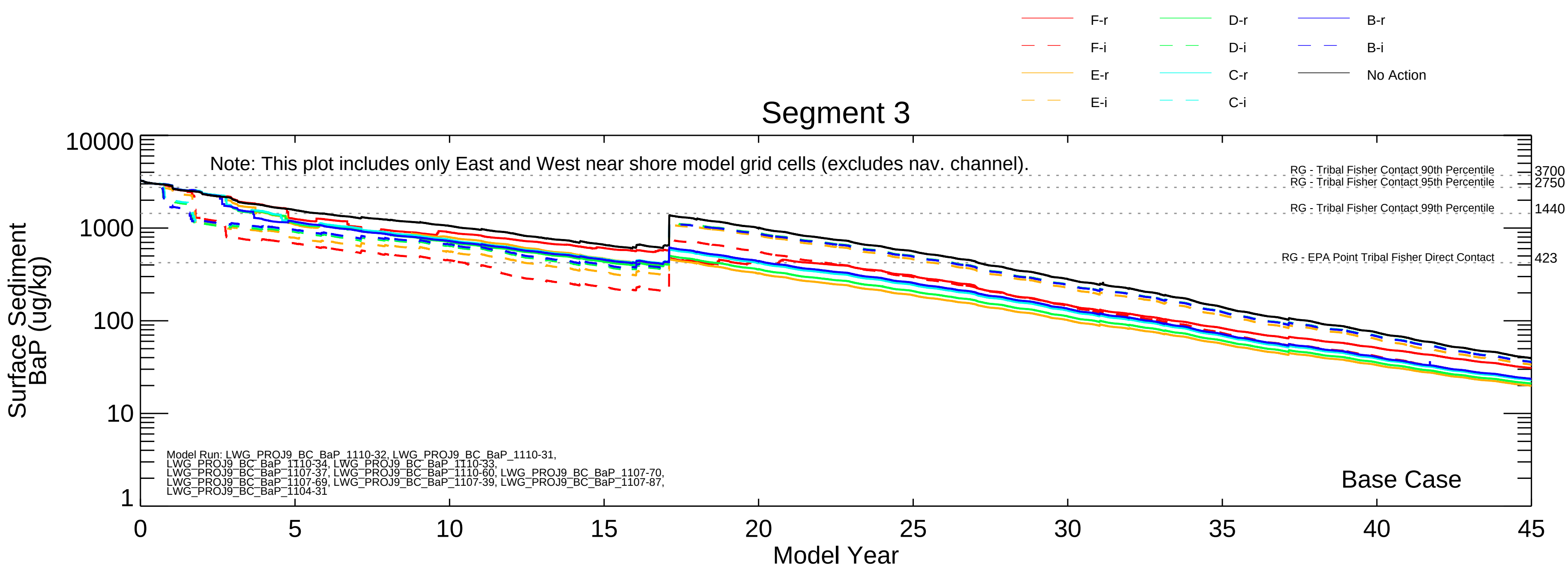


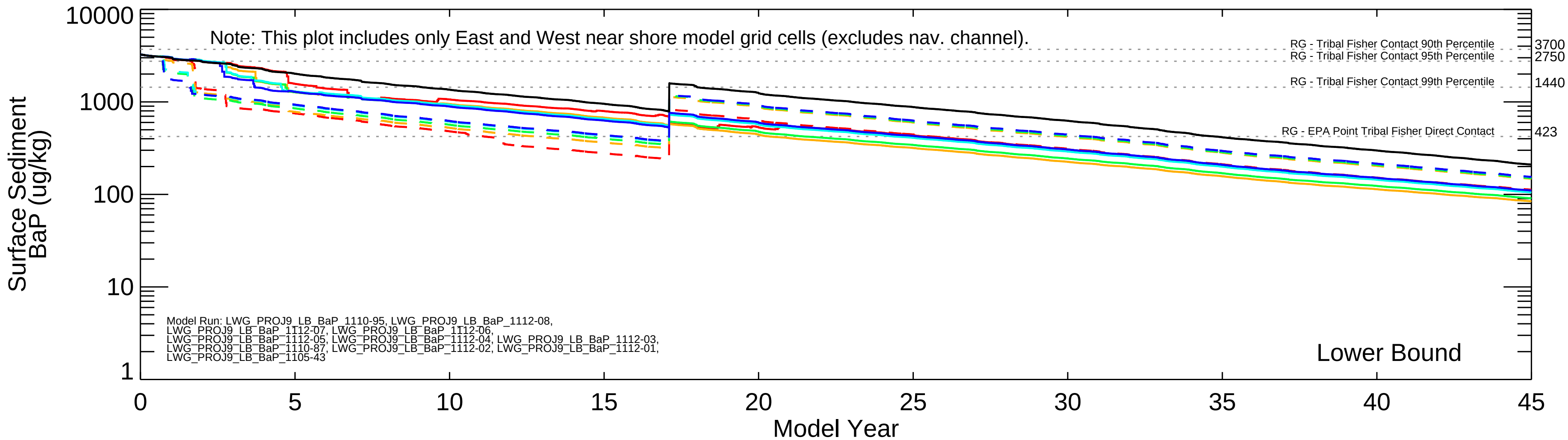


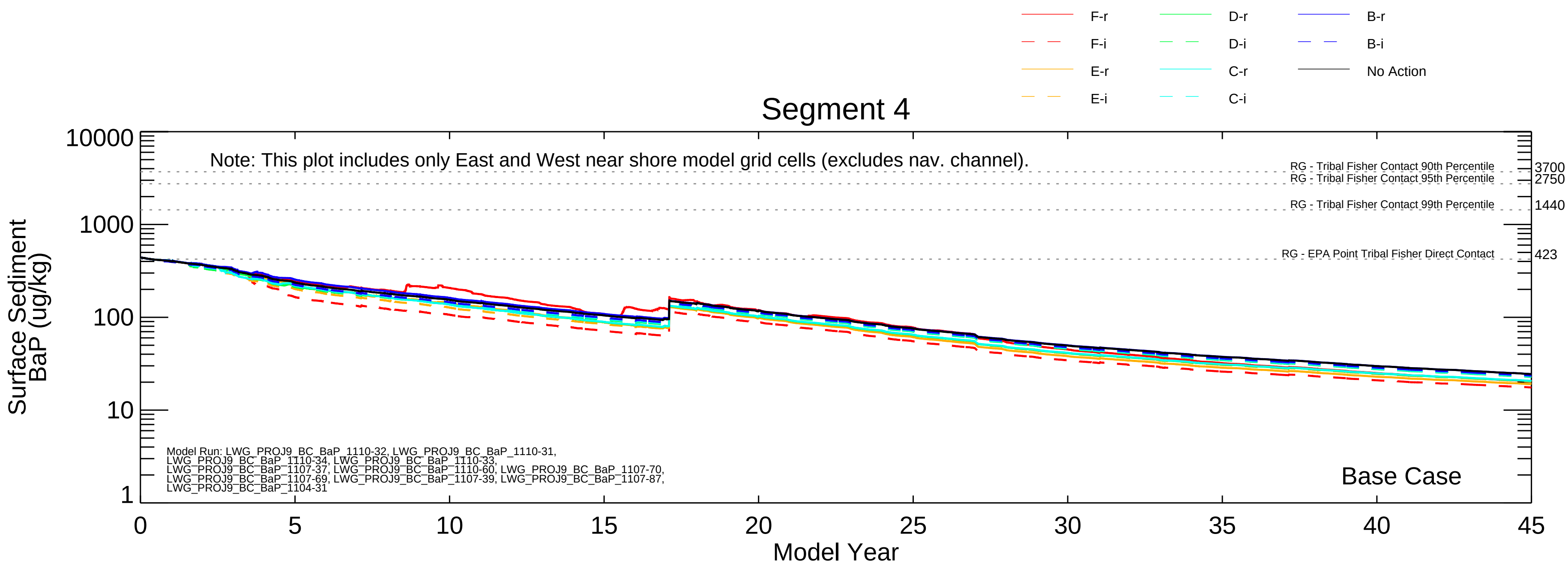
Figure 8.2.2-5c

Portland Harbor RI/FS

Draft Feasibility Study

Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) BaP Concentrations (Site Segment Average)



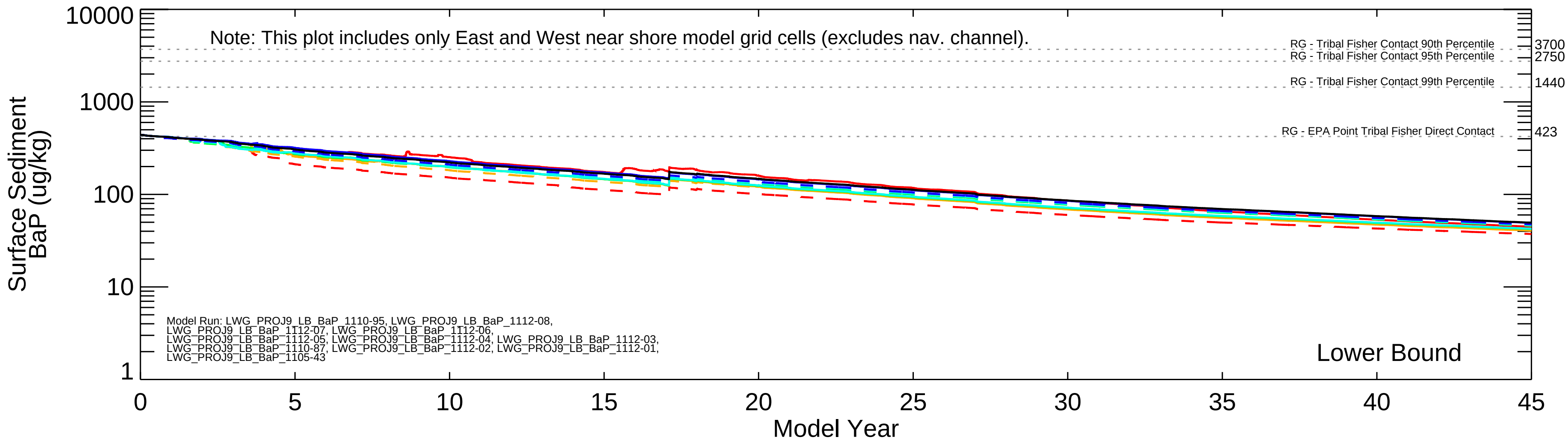


Figure 8.2.2-5d

Portland Harbor RI/FS

Draft Feasibility Study

Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) BaP Concentrations (Site Segment Average)

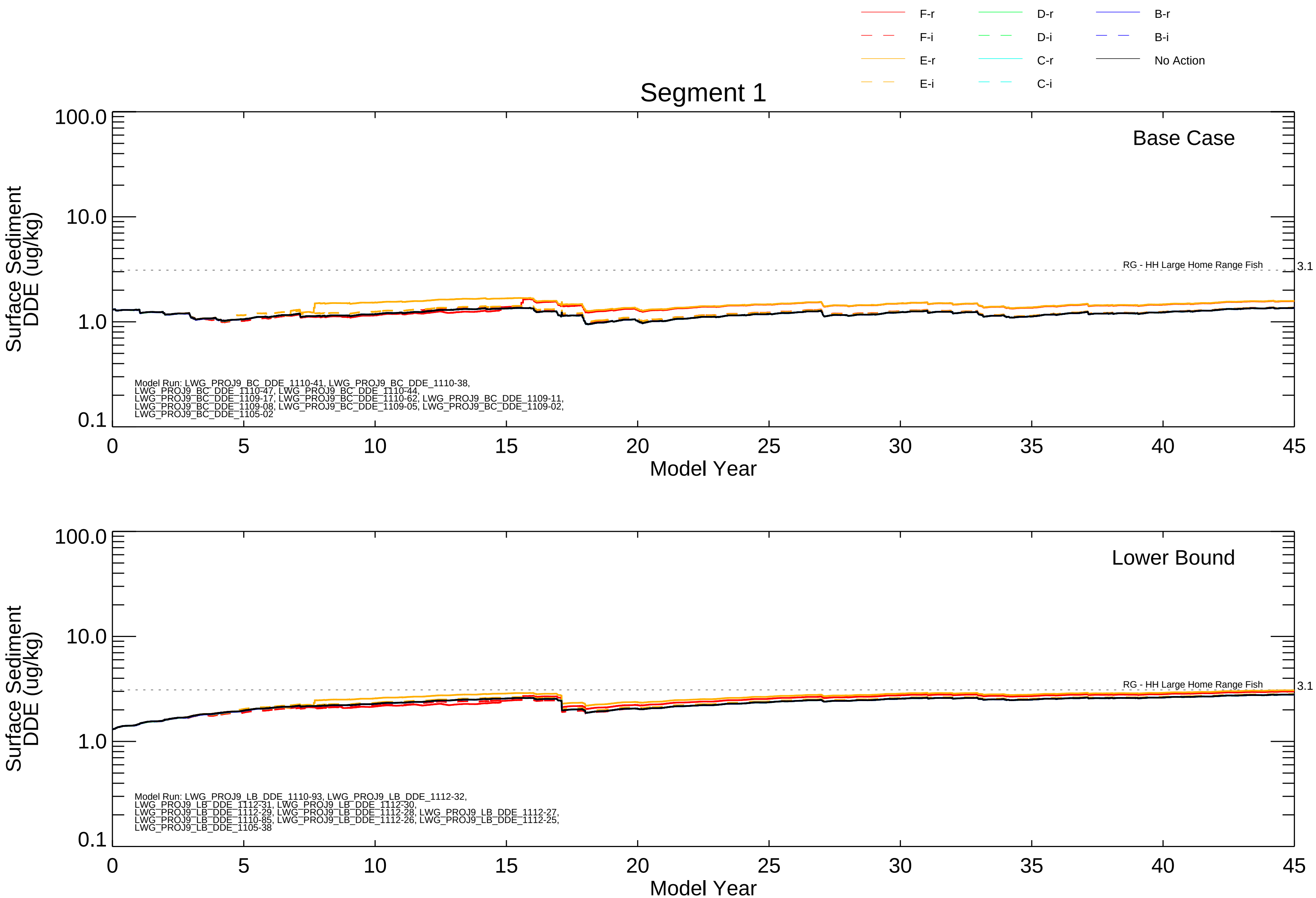


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Figure 8.2.2-6a

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Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) DDE Concentrations (Site Segment Average)

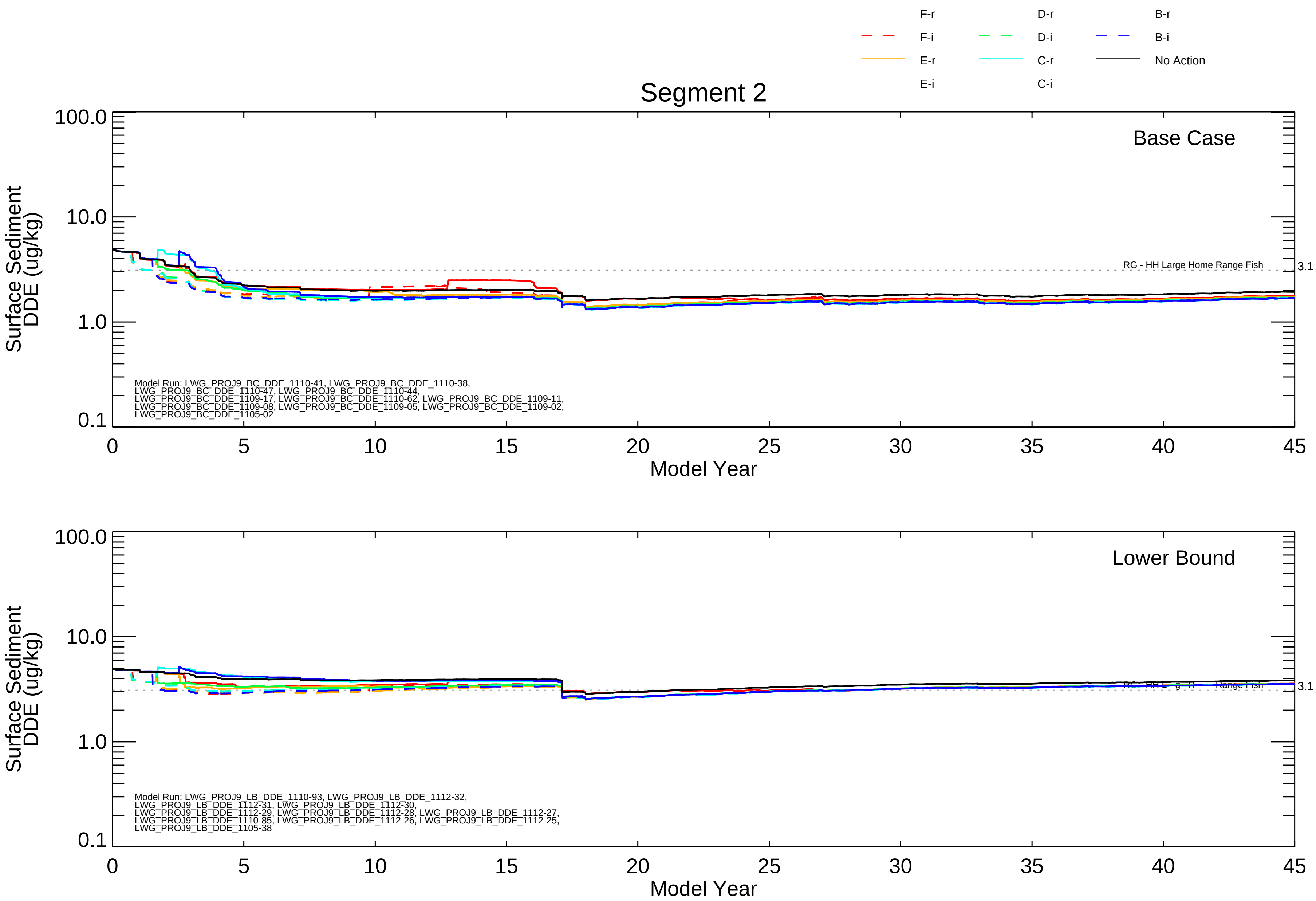

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Figure 8.2.2-6b

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Draft Feasibility Study

Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) DDE Concentrations (Site Segment Average)

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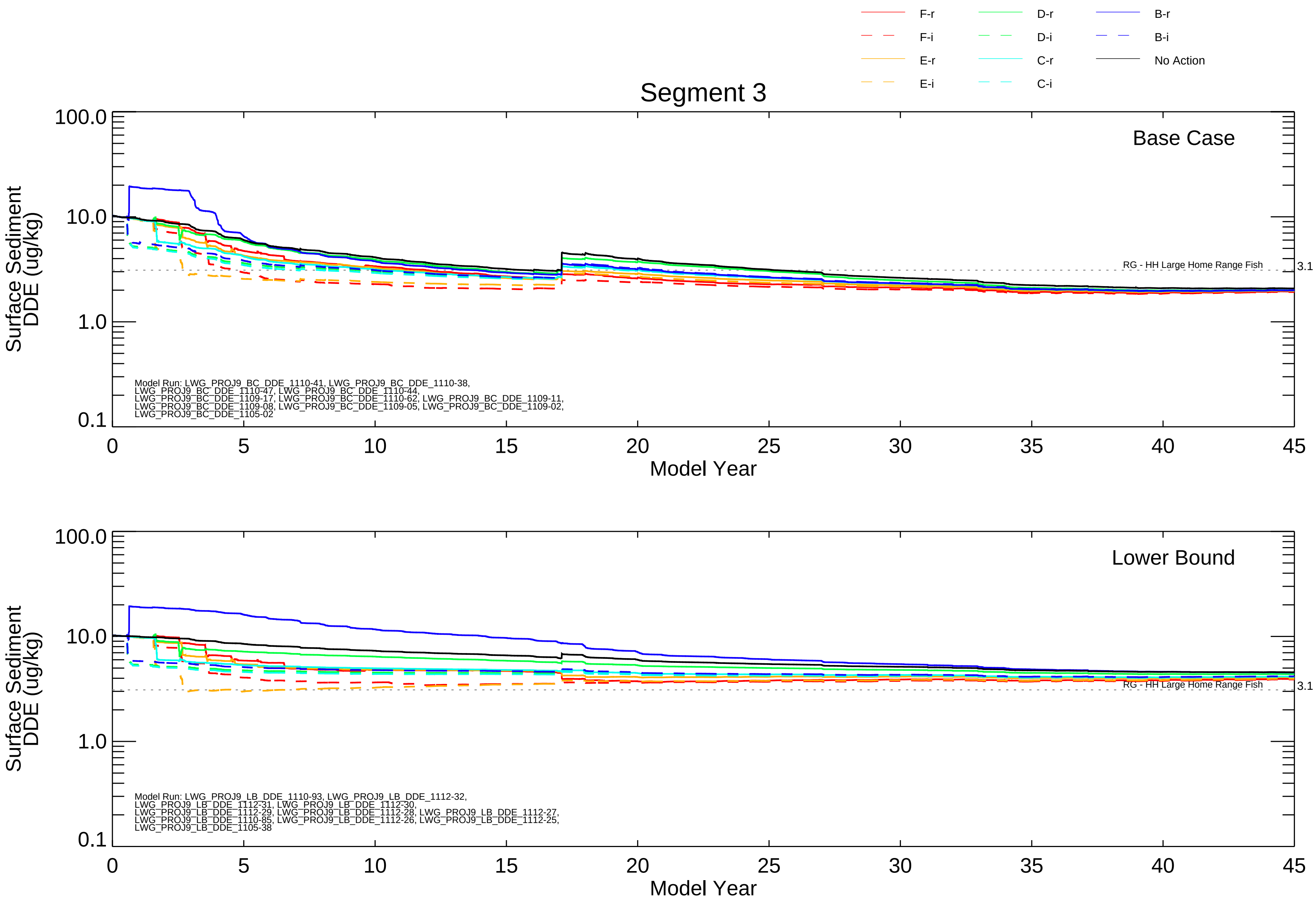

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Figure 8.2.2-6c

Portland Harbor RI/FS

Draft Feasibility Study

Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) DDE Concentrations (Site Segment Average)

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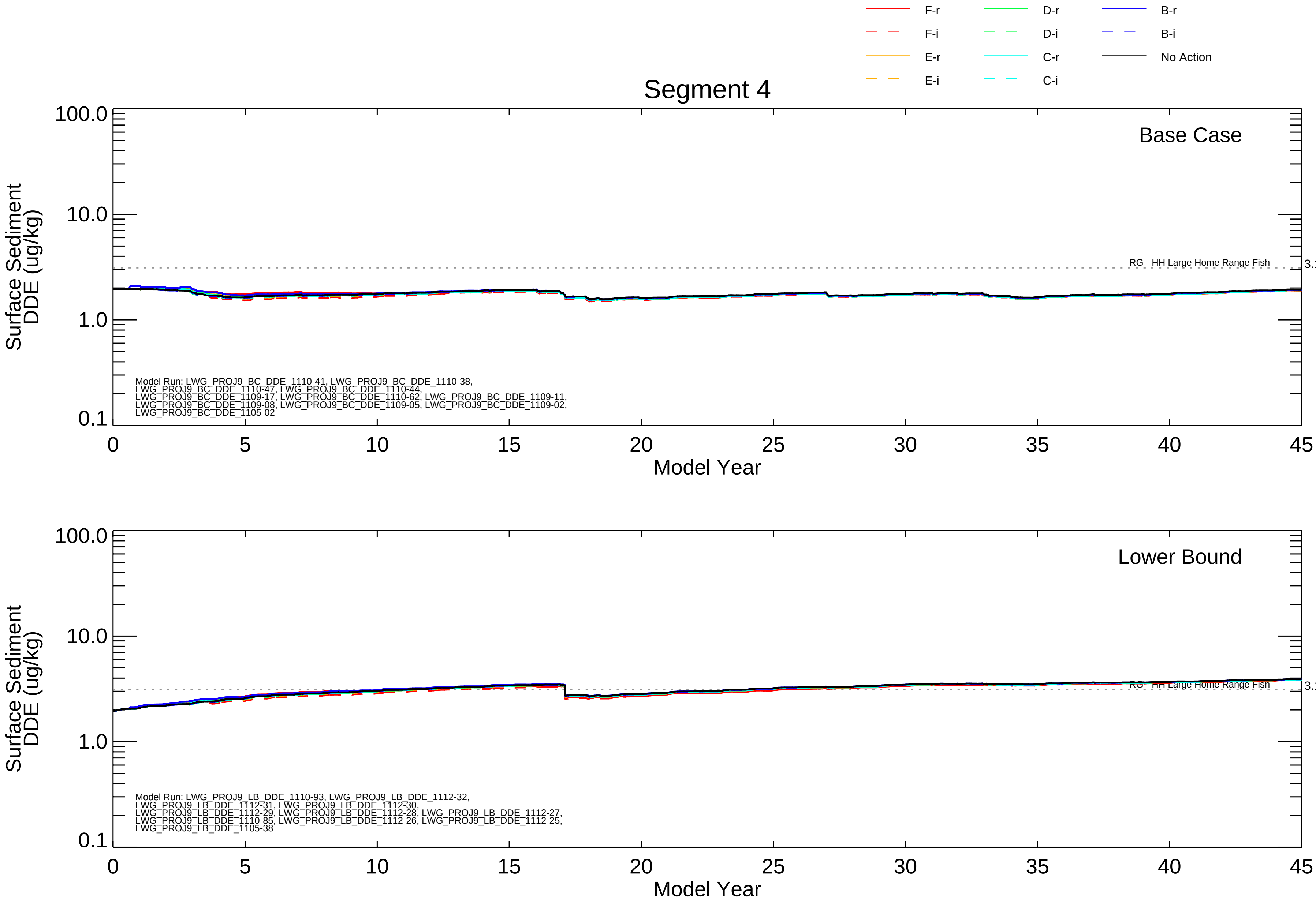

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Figure 8.2.2-6d

Portland Harbor RI/FS

Draft Feasibility Study

Simulation of FS Alternatives

Time Series of Surface Sediment (Top 1-ft) DDE Concentrations (Site Segment Average)

This figure, and those like it, show smallmouth bass tissue concentrations over time projected for each remedial alternative. The upper panel shows the model best estimate or "base case", and the lower panel shows the most conservative (high concentration) "lower bound" estimate within the model calibration.

Segment 1

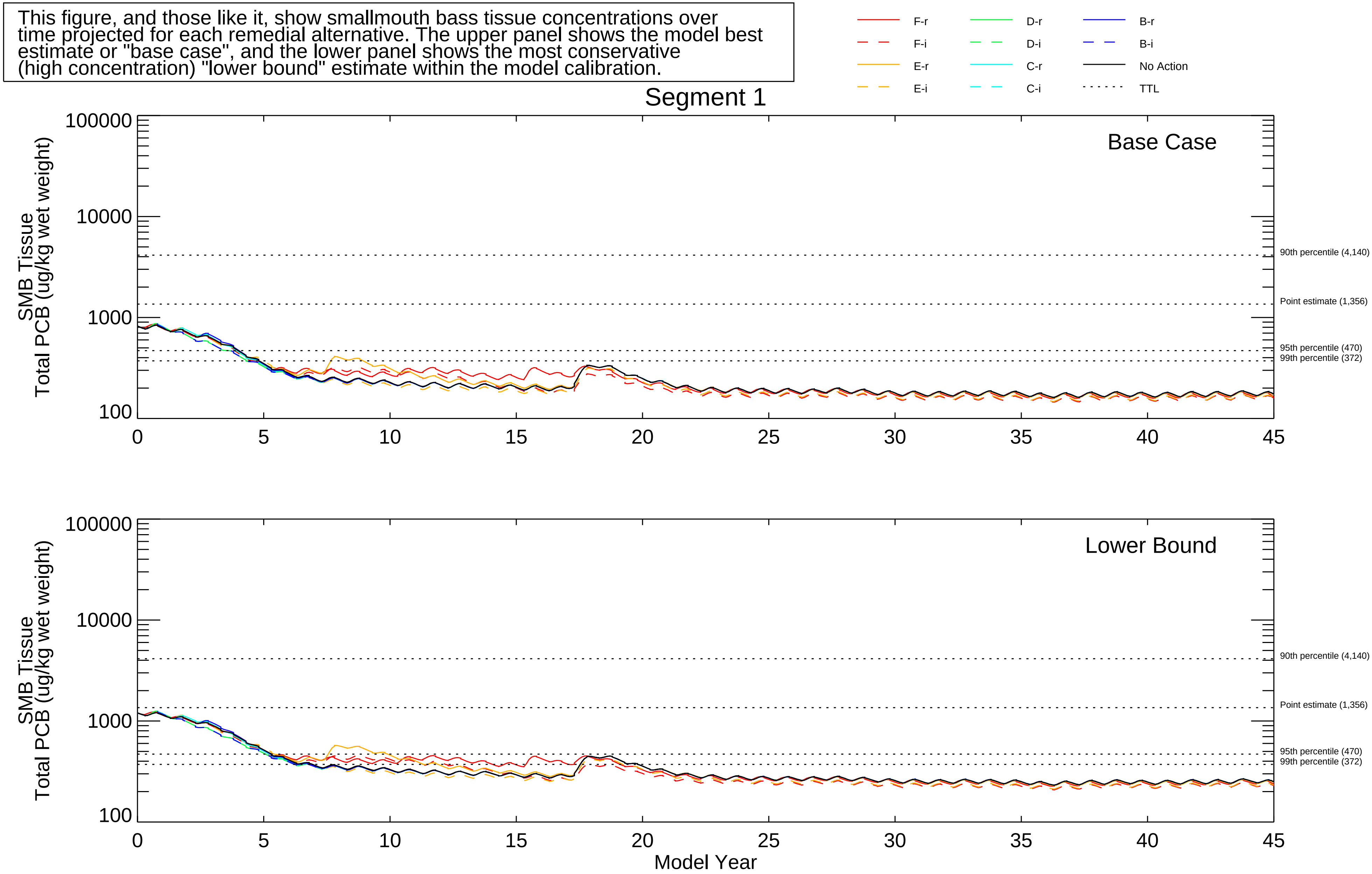

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Figure 8.2.2-7a
Portland Harbor RI/FS
Draft Feasibility Study
Comparison of Predicted SMB Tissue Total PCB Concentrations

MJR - B:\Projects\Lower_Willamette_Group\Lower_Willamette_Group_(010142-01)\Model\Windward_Food_Web\LWG_Time_Series_Windward_Food_Web_Results.pro Tue Mar 13 10:41:36 2012

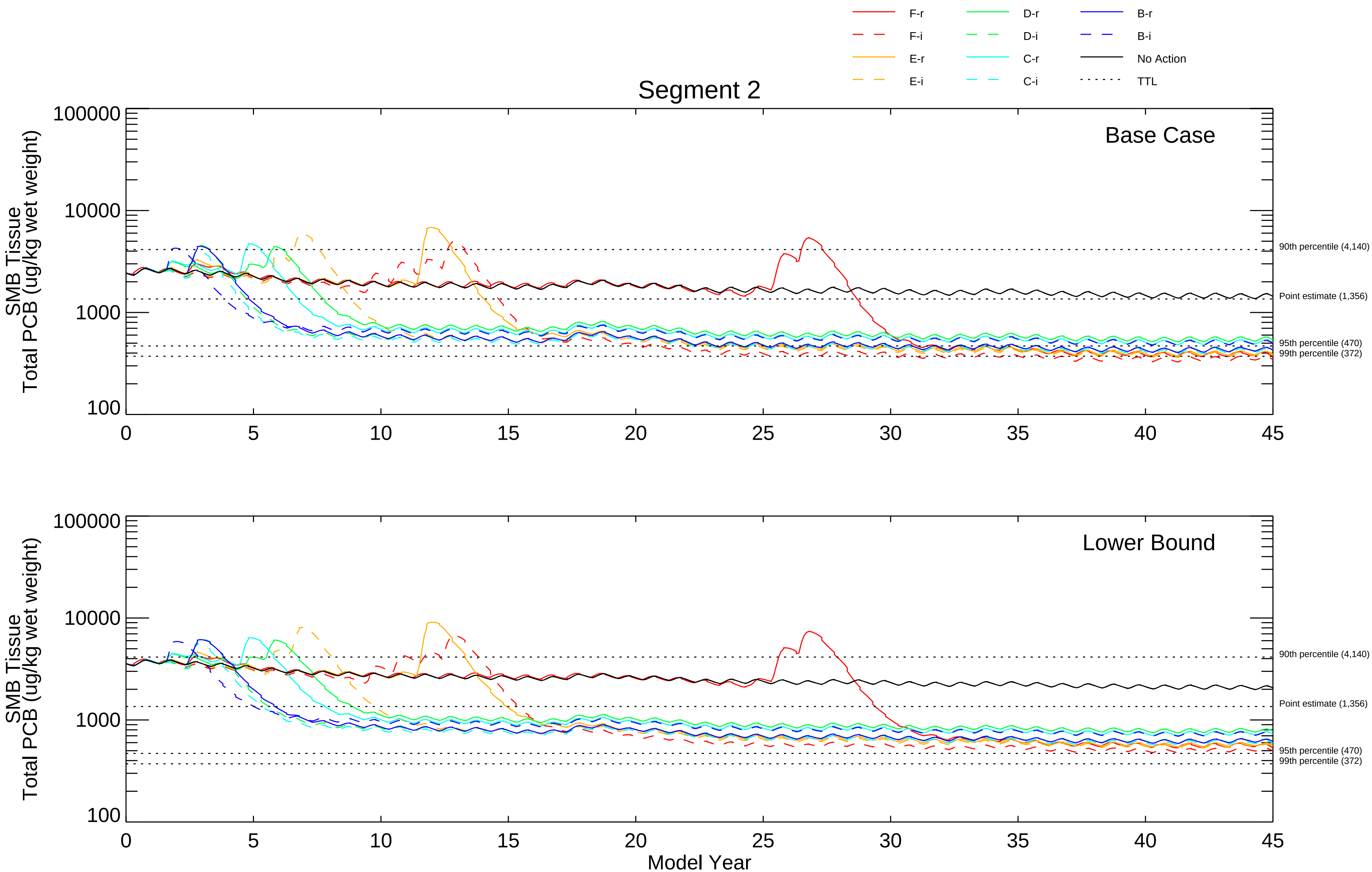

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Figure 8.2.2-7b

Portland Harbor RI/FS

Draft Feasibility Study

Comparison of Predicted SMB Tissue Total PCB Concentrations

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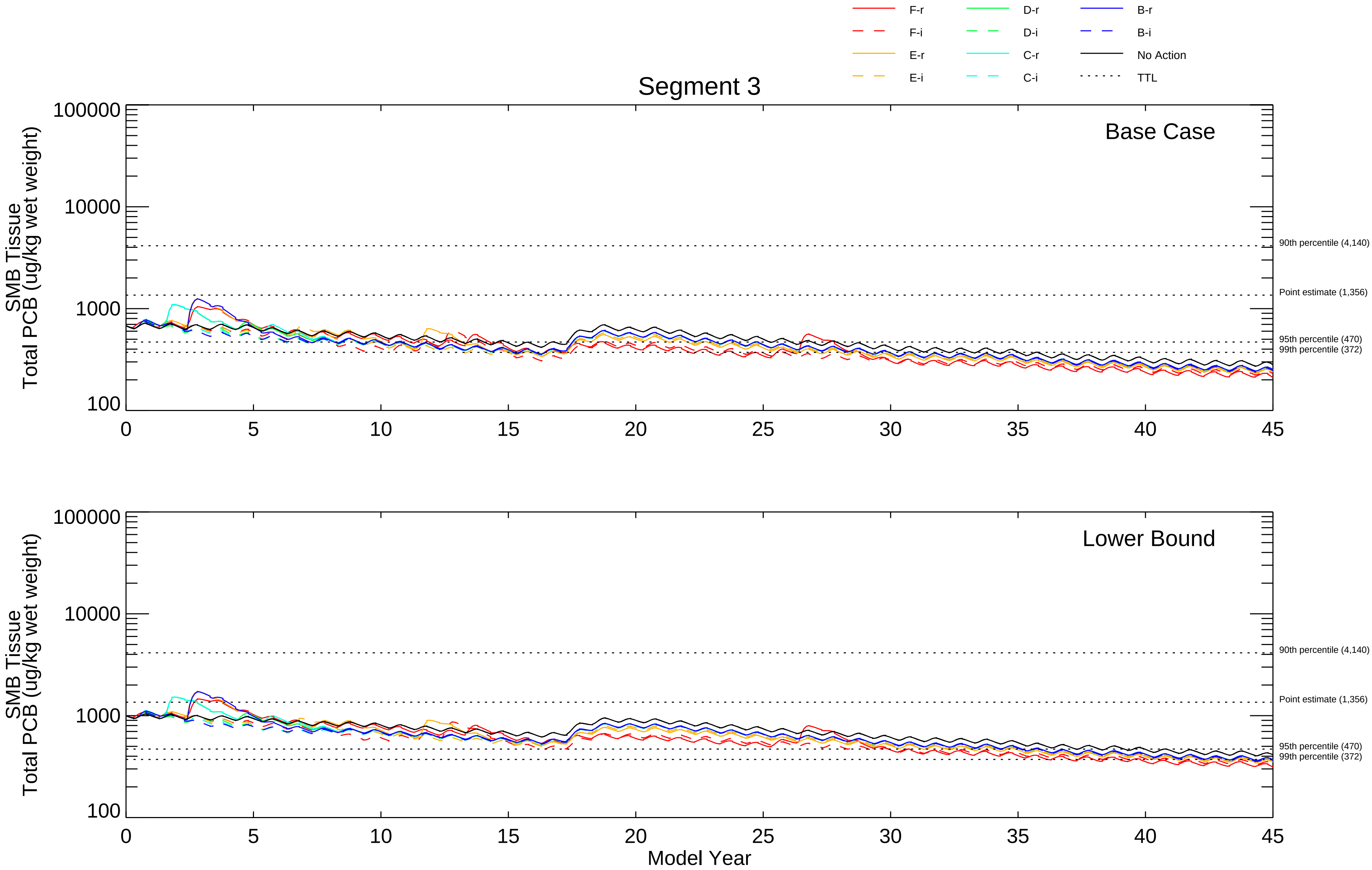

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Figure 8.2.2-7c

Portland Harbor RI/FS

Draft Feasibility Study

Comparison of Predicted SMB Tissue Total PCB Concentrations

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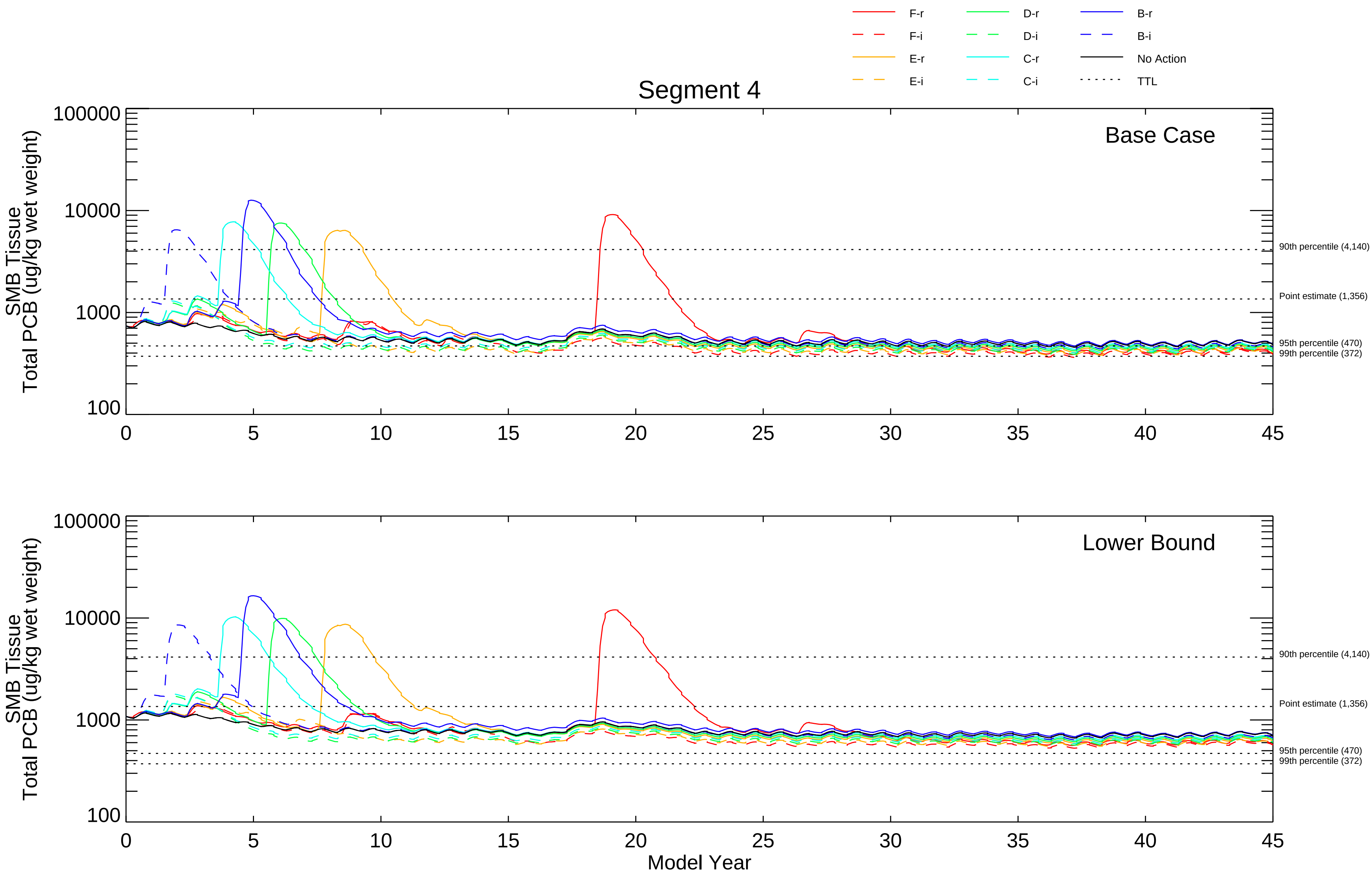

Figure 8.2.2-7d

Portland Harbor RI/FS

Draft Feasibility Study

Comparison of Predicted SMB Tissue Total PCB Concentrations

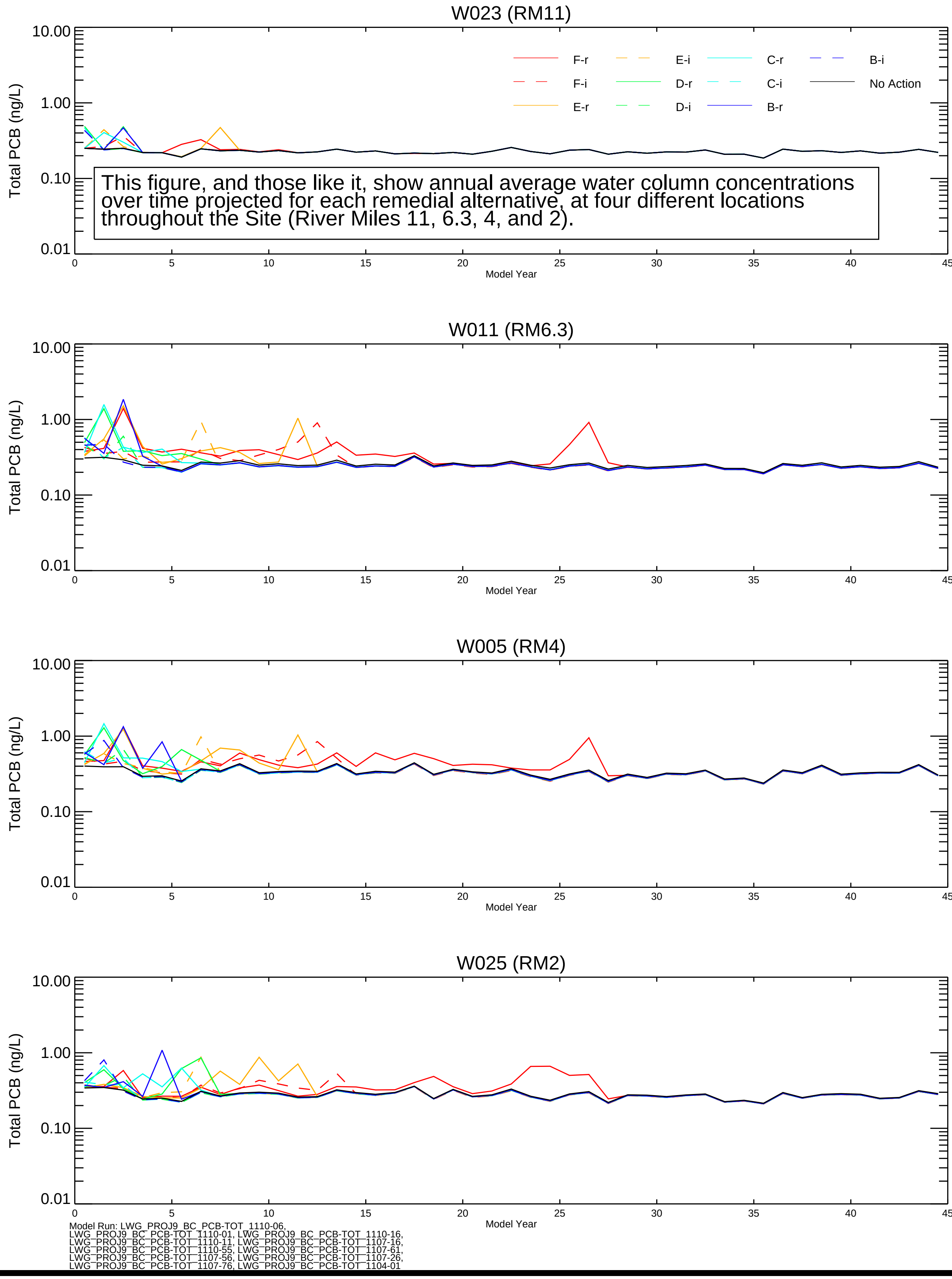

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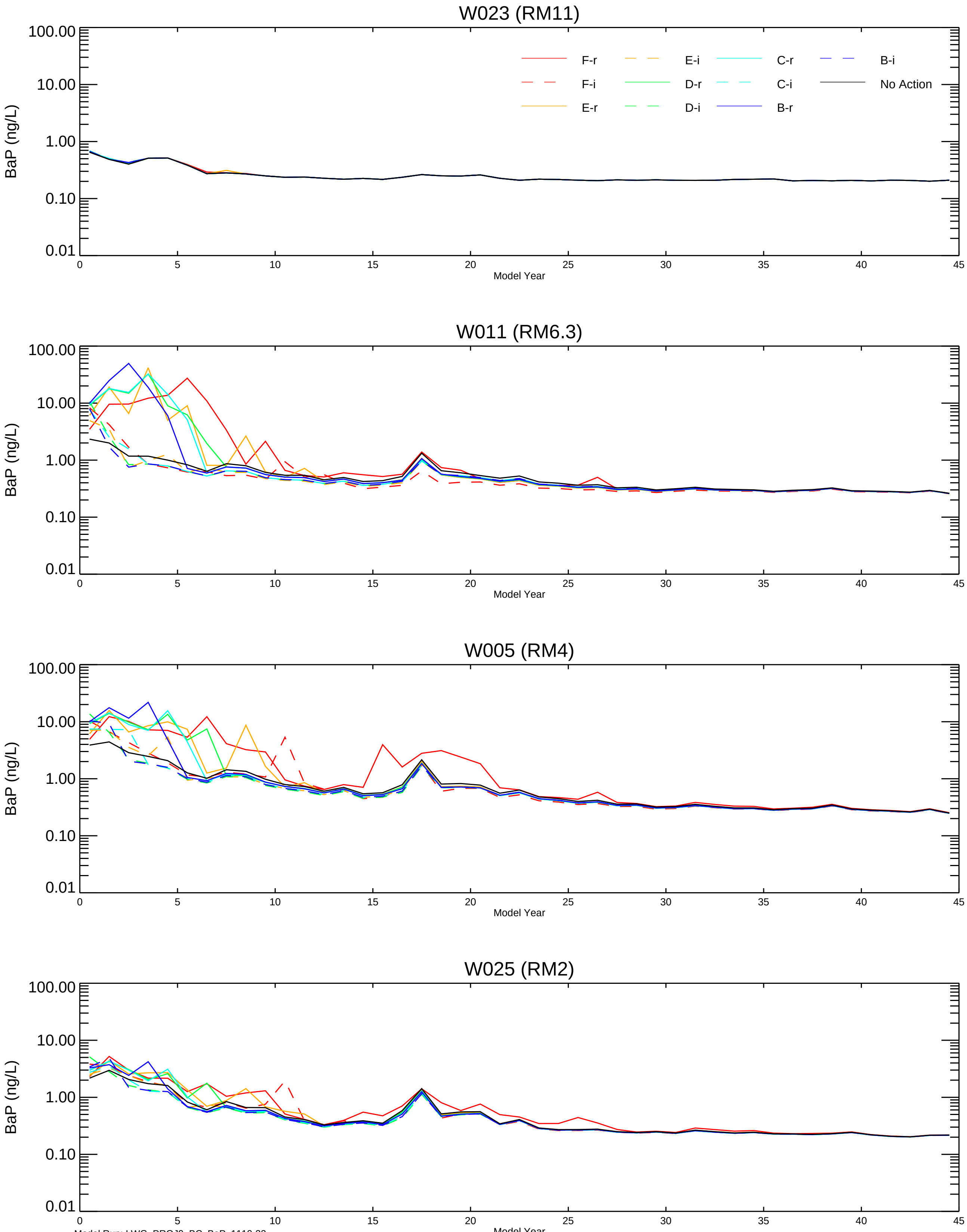
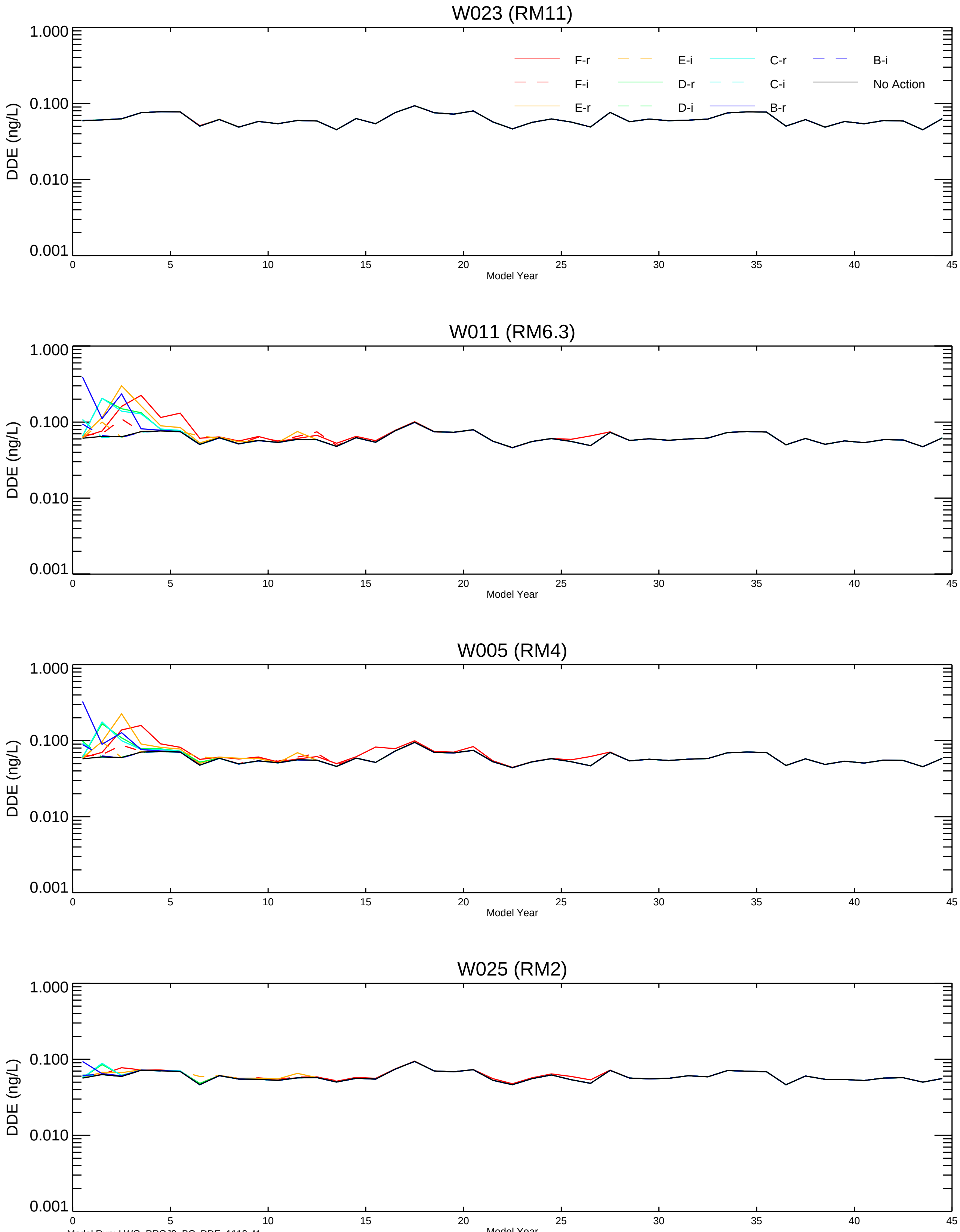
Figure 8.2.2-8
Portland Harbor RI/FS
Draft Feasibility Study
Simulation of FS Alternatives
Long Term Model-Projected Water Column Total PCB Concentrations



Model Run: LWG_PROJ9_BC_BaP_1110-32,
LWG_PROJ9_BC_BaP_1110-31, LWG_PROJ9_BC_BaP_1110-34,
LWG_PROJ9_BC_BaP_1110-33, LWG_PROJ9_BC_BaP_1107-37,
LWG_PROJ9_BC_BaP_1110-60, LWG_PROJ9_BC_BaP_1107-70,
LWG_PROJ9_BC_BaP_1107-69, LWG_PROJ9_BC_BaP_1107-39,
LWG_PROJ9_BC_BaP_1107-87, LWG_PROJ9_BC_BaP_1104-31

Figure 8.2.2-9

Portland Harbor RI/FS
Draft Feasibility Study
Simulation of FS Alternatives
Long Term Model-Projected Water Column BaP Concentrations



Model Run: LWG_PROJ9_BC_DDE_1110-41,
LWG_PROJ9_BC_DDE_1110-38, LWG_PROJ9_BC_DDE_1110-47,
LWG_PROJ9_BC_DDE_1110-44, LWG_PROJ9_BC_DDE_1109-17,
LWG_PROJ9_BC_DDE_1110-62, LWG_PROJ9_BC_DDE_1109-11,
LWG_PROJ9_BC_DDE_1109-08, LWG_PROJ9_BC_DDE_1109-05,
LWG_PROJ9_BC_DDE_1109-02, LWG_PROJ9_BC_DDE_1105-02

Figure 8.2.2-10

Portland Harbor RI/FS
Draft Feasibility Study
Simulation of FS Alternatives
Long Term Model-Projected Water Column DDE Concentrations

Table 8.2.2-1 Summary of Select Total PCB Sediment Remedial Goals (RGs), PCB Sediment Background Estimates, PCB Tissue Target Levels (TTLs), DDE Sediment RGs and BaPEq Sediment RGs Used in Section 8 and 9 Alternatives Evaluations[1]

RG/TTL Basis	Whole Body Bass PCB Sediment RG (µg/kg), 10^{-4} Cancer Risk Level	Bass Fillet w/ Skin PCB Sediment RG (µg/kg), 10^{-5} Cancer Risk Level	Bass Skinless Fillet PCB Sediment RG (µg/kg), 10^{-5} Cancer Risk Level	PCB Tissue TTL (µg/kg ww), 10^{-4} Cancer Risk Level	PCB Sediment Background Estimates (µg/kg)	BaPEq Sediment RG (µg/kg)	DDE Sediment RG (µg/kg)
PCB Background Low Estimate (see Appendix E)	NA	NA	NA	NA	5	NA	NA
99th Percentile	23	14	49	372	NA	1,437	NA
PCB Background High Estimate (see Appendix E)	NA	NA	NA	NA	37	NA	NA
EPA Point Estimate	29.5	NA	NA	470	NA	423	3.02
95th Percentile	95	71	205	1,356	NA	2,750	NA
90th Percentile	300	224	630	4,140	NA	3,702	NA

Notes:
1 - Per Section 3.5, these RGs and TTLs are based on the EPA Focused PRGs.

Table 8.2.2-2. Comparison of PCB RG and PRG Ranges Presented in Appendix E to Site-Wide SWACs and Percent Reduction from Current Site-wide SWACs Represented by Those RG/PRG Ranges

PCB (ppb)	% Reduction from Current SWAC	Background (PRG)	SMB Cancer (RG) Whole Body			SMB Cancer (RG) Fillet with skin			SMB Cancer (RG) Fillet without skin			Mink Risk (PRG)	SMB Non-Cancer (PRG) HQ = 1
		NA	10^{-6}	10^{-5}	10^{-4}	10^{-6}	10^{-5}	10^{-4}	10^{-6}	10^{-5}	10^{-4}		
0	100	5 ppb	90th	99th		99th			99th				
9	90	EPA		95th		90th	99th						Fillet w/ Skin 99th
17	80	Point		90th	99th				95th				
26	70				EPA Point							Point PRG	
34	60	37 ppb										LB 5th	
43	50												Fillet w/ Skin 95th
51	40								90th	99th			
60	30												
68	20						95th						
77	10				95th[1]		90th[2]	99th[3]		95th[4]	99th[5]	5th 50th[6]	Fillet w/ Skin 90th[7]
>85	0												

Notes:

1 - Actual value = 95 ppb
2 - Actual value = 224 ppb
3 - Actual value = 201 ppb
4 - Actual value = 205 ppb
5 - Actual value = 566 ppb
6 - Actual value = 194 ppb
7 - Actual Value = 131 ppb
LB - Lower Bound

Current Site-wide PCB SWAC is equal to approximately 84 ppb.

PCB (ppb) – This column shows Site-wide PCB SWAC that is equivalent to the percent reduction noted in the next column.

EPA Point – Refers to EPA's Preferred Point Estimate within the RG or PRG range (see Section 3.6).

90th, 95th, and 99th – Refers to the percentile estimates of the RG/PRG ranges as provided in Appendix E.

SMB Cancer Whole Body – Human health smallmouth bass consumption of whole body RG range from Appendix E.

SMB Cancer Fillet with Skin – Human health smallmouth bass consumption of fillets with skin RG Range from Appendix E.

SMB Cancer Fillet without Skin – Human health smallmouth bass consumption of fillets without skin cancer RG range from Appendix E.

Background – Full range of background PRG uncertainty estimates based on statistical evaluations of upstream bedded sediment data (Appendix E).

Mink Risk – PRG range percentile estimates for ecological mink risks (Appendix E). "Point PRG" refers to EPA's preferred estimate for the mink endpoint.

SMB Non-Cancer – Human health smallmouth bass consumption of fillet with skin 90th to 99th percentile estimates of potentially unacceptable risk from Appendix E.

10^{-6}, 10^{-5}, and 10^{-4} – Refers to the excess cancer risk level for each RG range (i.e., one in a million, one in one-hundred thousand, and one in ten-thousand excess chance of risk, respectively.

RGs or PRGs that are below EPA's Point Estimate background value of 17 ppb.

The projected percent PCB concentration reductions presented here are on a Site-wide basis. More or less reductions in concentrations would occur at smaller spatial scales and over individual SMAs.

Section 8 presented a detailed individual analysis of each of the comprehensive remedial alternatives developed for the Site against seven of the nine NCP evaluation criteria. The results of those analyses are used in this section to compare the relative advantages and disadvantages of the alternatives. The same set of information, empirical data and sediment, tissue, and water projections are used here as presented in Section 8, along with additional supporting documentation to better illustrate the differences between the alternatives. The primary findings of the comparative evaluation are that all of the alternatives provide overall protection of human health and the environment over the long term, with the exception of Alternative A (No Action). However, there are notable differences in how the alternatives achieve this protection with the larger alternatives (E and F) and removal focused alternatives ("-r" options) having substantially more environmental, community, and worker impacts; implementability issues; and disproportionately high costs as detailed more below.

9.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

Section 8 presented a detailed analysis of each of the comprehensive remedial alternatives developed for the Site against seven of the nine NCP evaluation criteria. The results of those analyses are used in this section to compare the relative advantages and disadvantages of the alternatives, consistent with EPA (1988, 2005a) guidance. The comparative analysis in the following sections is summarized in Table 9.0-1.

9.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

This criterion addresses the overall ability to eliminate, reduce, or control potential exposures to hazardous substances in both the short and long term. As discussed in EPA (2005a), the NCP evaluation of overall protectiveness is highly location-specific.

Capping or removal with residuals management (where needed) is expected to contain in place or remove the majority of buried contamination above the RALs present at the Site for all active alternatives (B through F).

As discussed in Section 8.2, reduced concentrations of and exposure to contaminants in surface sediment, tissue, and the water column are achieved over time under all comprehensive alternatives through a combination of capping (with or without armoring, as necessary), dredging[1]/removal with post-dredge residual covers (where needed), EMNR/in situ treatment, and ongoing natural recovery. All of the alternatives integrate to varying degrees ongoing Site-wide natural recovery processes (which RI data, Section 2.6, and Section 6.2.2 evaluation indicate is taking place) with more active technologies. Per Section 5.6.6, capping or removal with residuals management (where needed) is expected to contain in place or remove the majority of buried contamination above the RALs present at the Site for all active alternatives (B through F). Given these common themes across the alternatives are discussed in Section 8.2, the rest of this overall protectiveness comparative evaluation focuses on the differences between the alternatives.

[1] As discussed in Section 6.2.7, unless otherwise noted, all dredging discussed in Sections 8 and 9 refers to remediation or environmental dredging (as opposed to navigation or maintenance dredging).

The alternatives with more removal of sediment via environmental dredging results in unavoidable resuspension, release, and residuals that reduce the overall protection of human health and the environment provided by these alternatives, particularly in the short term (USACE 2008a; Bridges et al. 2010).

The primary difference between the alternatives is that they use different RALs and include different combinations of MNR, EMNR/in situ treatment, capping, and dredging/removal technologies to highlight the tradeoffs between alternative approaches. For example, the alternatives with more removal of sediment via environmental dredging results in unavoidable resuspension, release, and residuals that reduce the overall protection of human health and the environment provided by these alternatives, particularly in the short term (USACE 2008a; Bridges et al. 2010). (As discussed in Section 6.2.7, the application of rigid barriers or silt curtains is not expected to appreciably improve the protection of alternatives with more removal, and may cause some additional unintended consequences.) Alternatives with more in-place technologies such as EMNR/in situ treatment or capping materials represent an effective means of rapidly reducing surface sediment contaminant concentrations. Sand covers are also incorporated as a post-dredge residuals management technique (where needed) for each of the alternatives that have a dredging component.

Per the methods described in Section 8.2, the following subsections compare and contrast the alternatives relative to each of the RAOs that are used to define overall protectiveness of the alternatives.

9.1.1 Surface Sediment RAOs

All of the comprehensive alternatives are anticipated to achieve long-term surface sediment COC concentrations that are either below the lowest RGs or within the estimated background range.

Projected Site-wide changes in surface sediment concentrations (SWACs) of select COCs including total PCBs, BaP, and DDE during and following implementation of each comprehensive alternative are presented in Figures 8.2.2-1, 8.2.2-2, and 8.2.2-3, respectively. Similar projections by river Segment are presented in Figures 8.2.2-4, 8.2.2-5, and 8.2.2-6, respectively. Based on these projections, all of the comprehensive alternatives are anticipated to achieve long-term surface sediment COC concentrations that are either below the lowest RGs or within the estimated background range. Alternative A is expected to achieve higher contaminant concentrations than Alternatives B through F, particularly on smaller spatial scales and thus, is not expected to meet sediment RAOs 1 and 5. All of the “action” alternatives (Alternatives B through F) would achieve surface sediment RAOs 1 and 5. As discussed in Section 3.6 and Appendix E, the lower ends of the ranges of RGs are within estimated background range, are conservative, and many of the higher range RG estimates are likely to be protective of human health and the environment.

On smaller spatial scales (i.e., river Segments, river miles, or shoreline half river miles),[2] some of the comprehensive alternatives may not achieve SWACs that meet the lowest PCB RGs selected by EPA in localized areas of the Site, particularly in RMs 3 to 4 and in Swan Island Lagoon (see Figure 8.2.2-4 for the Site Segments and Appendix U Section 3.1 for smaller scales). But the resulting exposures may be adequately protective, especially considering the variability and uncertainty in the exposure assumptions and RG estimates. In the RM 3 to 4 area, stormwater analyses indicate this is likely due to ongoing projected stormwater sources that enter this reach; the conservative end of the PCB RG range is projected to be achieved in this area following completion of ongoing stormwater source controls (Appendix Ha, Section 6).

Given that the low end of the PCB RG range represents a conservative risk estimate, all of the action alternatives attain, even at the smallest appropriate spatial scales, the 10^{-4} cancer risk level for whole body smallmouth bass consumption. For several different fillet consumption scenarios, risk levels in the 10^{-5} range are attained, as well as a noncancer HQ below 1 (see Table 5.6-1 of Appendix E).

In Swan Island Lagoon, all of the action alternatives are estimated to attain similar long-term surface sediment PCB concentrations in the range of approximately 60 to 110 ppb (Appendix U, Figure 3.1-3). These projections represent significant reductions from current sediment concentrations in Swan Island Lagoon. The surface sediment concentrations reached in Swan Island Lagoon exceed the point estimate RG for 10^{-4} cancer risk level for whole body smallmouth bass consumption scenario. However, the surface area of Swan Island Lagoon is about one half of other river miles for which SWACs are compared to the RGs. This makes the comparison for Swan Island Lagoon more conservative (likely to overestimate potentially unacceptable risk).

EPA's point estimate RG for PCBs corresponds to approximately the upper 99th percentile for the whole body smallmouth bass 10^{-4} risk level scenario (see Appendix E, Table 3.3-2). However, the projected PCB SWAC in Swan Island Lagoon for all action alternatives are below the RGs corresponding to the 95th percentile for the smallmouth bass whole body 10^{-4} risk level (95 ppb), and other fish ingestion scenarios with RGs ranging from 71 to greater than 200 ppb (Table 8.2.2-1). EPA and DEQ policies include reference to acceptable risk thresholds corresponding to probabilities lower than the 99th percentile. For example, EPA risk assessment guidance (EPA 2001c) requires exposure point concentrations (EPCs) represented by UCL95 of the mean, which corresponds to a concentration range that has a probability 95 percent of including the mean concentration. DEQ regulations specify use of the UCL90, which corresponds to 90th percentile. At the 95th percentile for exposure scenarios, the protective sediment RG is 95 ppb for whole body smallmouth bass consumption scenario at the 10^{-4} risk level, and 71 ppb for 10^{-5} risk level for smallmouth bass fillet (with skin) consumption (Table 8.2.2-1). Based on implications from EPA and DEQ guidance cited above, these RGs should be considered adequately protective for the fish consumption pathway.

[2] The shoreline half river mile spatial scale is only used in comparison to sediment direct contact BaPEq RGs.

Alternatives that include more environmental dredging/removal, particularly Alternatives E-r and F-r, are projected to result in higher overall surface sediment concentrations over substantial periods of time due to the effects of dredge residuals (i.e., approximately 10 to 30 years) compared to those with more emphasis on EMNR/in situ treatment and capping (see Figures 8.2.2-1 to 8.2.2-6).

Alternatives that include more environmental dredging/removal, particularly Alternatives E-r and F-r, are projected to result in higher overall surface sediment concentrations over substantial periods of time due to the effects of dredge residuals (i.e., approximately 10 to 30 years) compared to those with more emphasis on EMNR/in situ treatment and capping (see Figures 8.2.2-1 to 8.2.2-6). Despite these interim sediment concentration increases associated with unavoidable dredging releases and residuals, all of the action alternatives are projected to achieve the surface sediment RAOs in similar timeframes.

As noted above, BaP is projected to achieve very conservative (>99th percentile 10^{-6} cancer risk level for human health sediment direct contact; Table 8.2.2-1) RGs throughout the Site, including every shoreline half river mile, which is the smallest spatial scale relevant to these RGs. Every shoreline half river mile is expected to achieve the lowest BaP RG in less than 30 years for all alternatives, except one (Appendix U, Figures 3.1-6a-u). (Further, for these half river miles, remediating larger areas does not result in faster time to achieve the lowest RG; e.g., in half river mile 5.5 to 6 East, Alternative F-r has the longest time to achieve the lowest RG.) The one exception is half river mile 6 to 6.5 West where the highest BaP sediment concentrations occur, and here the difference in time to achieve the RGs (as shown in Appendix U Figure 3.1-6l) ranges between approximately 30 to 40 years across all alternatives. Thus, the difference between Alternative A (No Action) and Alternative F-r, is only 10 years.[3]

Empirical data on sedimentation rates, upstream sediment loads, bathymetry, and core profiles reviewed in Section 6.2.2 indicate overall deposition of low contaminant concentration sediments across the majority of the Site over the long term. This supports the concept that active remedies combined with MNR would result in substantially reduced long-term sediment concentrations for all alternatives as noted above.

9.1.2 Tissue RAOs

All of the action alternatives are projected to attain tissue RAOs 2 and 6, as these alternatives achieve long-term PCB tissue concentrations that are at or below conservative estimates of acceptable risk levels (i.e., lower TTLs).

Projected changes in whole body smallmouth bass tissue total PCB concentrations by river Segment during and following implementation of each comprehensive alternative are presented in Figure 8.2.2-7. All of the action alternatives are projected to attain tissue RAOs 2 and 6, as these alternatives achieve long-term PCB tissue

[3] Section 9.5.5 discusses the uncertainties associated with estimating time to achieve RAOs. This section describes that there are few measurable differences between the alternatives in time to achieve RAOs, when relevant uncertainties are factored into the evaluation.

concentrations that are at or below conservative estimates of acceptable risk levels (i.e., lower TTLs). The conservative ranges of TTLs used in this evaluation are consistent with the conservative ranges of RGs discussed above (Table 8.2.2-1), and comparisons with these relatively low TTLs illustrate the protectiveness of the alternatives relative to a conservative and highly protective range of values.

Dredging actions included in all of the action alternatives are projected to result in elevated tissue PCB concentrations during and immediately following dredging operations due to unavoidable dissolved PCB releases to the water column. (Note that even the integrated alternatives include substantial amounts of dredging. Therefore, tissue PCB elevations due to dredging are observed for all alternatives, not just the removal focused alternatives.) As discussed in Section 6.2.7, the application of rigid barriers or silt curtains is not expected to appreciably improve the protection of alternatives with more removal and may cause some additional unintended consequences. The largest environmental dredging-related increases in tissue levels are projected to occur in Segments 2 and 4 as a result of removing buried sediment deposits within SMA 17S (Swan Island Lagoon), SMA 19, and SMA 3 that contain, relative to the Site, high sediment PCB concentrations (i.e., these SMAs all have areas with concentrations in excess of 1 ppm). Although only PCBs were modeled in fish, similar dredging-related tissue level increases are anticipated for other bioaccumulative contaminants when dredging locally elevated sediment concentrations. The projected short-term tissue increases, which are particularly associated with alternatives with larger dredging volumes (e.g., Alternatives E-r and F-r), are expected to be followed by tissue recovery and long-term attainment of the tissue RAOs. The time required to achieve the tissue RAOs is projected to be similar across the action alternatives, particularly when the uncertainties of the analysis are considered.

The projected short-term fish tissue increases, which are particularly associated with alternatives with larger dredging volumes (e.g., Alternatives E-r and F-r), are expected to be followed by tissue recovery and long-term attainment of the tissue RAOs.

9.1.3 Surface Water RAOs

Projected changes in surface water concentrations of select contaminants including total PCBs, BaP, and DDE during and following implementation of each comprehensive alternative are presented by river Segment in Figures 8.2.2-8, 8.2.2-9, and 8.2.2-10, respectively. Projected differences in long-term surface water contaminant concentrations are indistinguishable among the comprehensive alternatives at all of the spatial scales assessed. None of the comprehensive alternatives are expected to achieve different long-term results with regards to the water column concentrations in the Site. Also, none of the alternatives are expected to achieve certain risk-based water quality criteria and standards, particularly certain of those based on fish consumption, in cases where upstream concentrations entering the Site already exceed these criteria. As discussed in Section 8.2.3, for the contaminants that exceed these criteria, no alternative is projected to contribute more than any other alternative to reduction in surface water concentrations post-remedy.

Short-term increases in surface water contaminant concentrations during dredging operations are anticipated, particularly for those alternatives with the greatest dredging volumes (e.g., Alternatives.)

Although comparison to fish consumption surface water criteria suggests that all the alternatives would pose potentially unacceptable risk, tissue projections for PCB discussed in the prior section indicate instead that all the alternatives would meet the tissue RAOs, which include fish consumption. Consequently, the Site-specific risk-based analysis based on tissue above is expected to be a more relevant determination of actual reduction of risk provided by the alternatives, as opposed to using generalized surface water criteria. Also, as noted in Section 9.2.2.1, due to upstream PCB surface water loading, cancer risk levels less than 10^{-5} are not projected to be achievable. Short-term increases in surface water contaminant concentrations during dredging operations are anticipated, particularly for those alternatives with the greatest dredging volumes (e.g., Alternatives E-r and F-r).

9.1.4 Groundwater RAOs

Several potential combinations of in-river technologies and upland source control actions are available to address groundwater RAOs, and in-river technologies are incorporated into all of the alternatives evaluated in this draft FS. Upland source controls by themselves may be sufficient to achieve the groundwater RAOs. When combined with upland source controls, those alternatives that incorporate greater amounts of capping provide additional opportunities to assist in achieving RAOs 4 and 8 and reduce groundwater impacts in the complete groundwater plume areas. Under all of the comprehensive alternatives, the need to further address groundwater RAOs would be determined in SMA-specific design efforts, considering the effectiveness of separate upland groundwater source controls.

9.1.5 Summary of Comparative Evaluation Relative to RAOs

The primary differences in overall protectiveness achieved by the comprehensive alternatives are related to the extent and duration of shorter term changes in risks that occur during remedy implementation.

Because all of the action alternatives attain long-term RAOs to a similar degree and in similar timeframes, the primary differences in overall protectiveness achieved by the comprehensive alternatives are related to the extent and duration of shorter term changes in risks that occur during remedy implementation. Those comprehensive alternatives that include greater dredging volumes and/or longer construction durations (especially Alternatives E-r and F-r) provide less overall protection of human health and the environment than shorter duration alternatives that focus on in situ treatment and/or containment. Further comparative evaluations of the comprehensive alternatives relative to combinations of the NCP criteria including overall protectiveness metrics are presented in Section 10.

9.2 COMPLIANCE WITH ARARS

Comparative evaluations of each potential ARAR are provided in the sections below.

9.2.1 Chemical-Specific ARARs

Those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to require the longest time to achieve the WQS/NRWQC.

As noted in Section 8.3, none of the comprehensive alternatives are capable of achieving all potential chemical-specific WQS/NRWQC due to Site background loading conditions (i.e., upstream river contaminants entering the Site). Those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to require the longest time to achieve the WQS/NRWQC.

To provide a comparison of projected exceedances of chemical-specific ARARs, a screening exercise was performed to assess the cumulative surface water volume (acre-feet) and duration (days) of exceedance of each of these WQS/NRWQC over the 45-year period following the ROD.[4] Graphs (e.g., Figure 9.2.1-1a-b) compare the alternatives and depict the amount and duration (volume-days) exceeding the specified WQS for each of the remedial alternatives both during the period of alternative construction as well as the entire 45-year period evaluated. This provides a measure of compliance with potential WQS/NRWQC as well as a measure of the long-term effectiveness of the alternatives.[5] Graphs depicting the volume-days exceeding the specified criteria for each of the remedial alternatives during the last five years of the modeled period (i.e., model years 40 to 45) are presented in Appendix U (see Appendix U Figures 3.2-6a through 3.2-10b). Comparisons with the different chemical-specific criteria including drinking water MCLs, human health fish consumption WQS/NRWQC, and aquatic life WQS/NRWQC are presented in the following sections. Also, maps showing the locations of exceedances for Alternative A are provided in Appendix U, Section 2.1. Alternative A is used as an example because it shows the general patterns of where most exceedances occur under all the alternatives.

[4] These units are a measure of the volume of water (as projected using the QEAFATE model) in the Site and the time over which that volume of water exceeds the criteria. The total volume of the Site over the entire 45-year modeling period is equal to 1.4 billion acre-feet-days, and thus, represents the largest possible result for this comparison. In Section 8 for each alternative (e.g., Section 8.3.2), this value is used to represent 100 percent of the simulation to determine the percentage of the simulation where exceedances occur. One acre-foot is the amount of water that it takes to cover an acre to a depth of 1 foot, and is approximately equal to 43,560 cubic feet of water.

[5] The data in these graphs are consistent with the percentages of simulation time and areas discussed in Section 8 (e.g., Section 8.3.2).

9.2.1.1 Compliance with MCLs

None of the depth-integrated water column samples collected from the Site during the RI exceeded drinking water MCLs.[6] However, detailed fate and transport modeling (Appendix Ha) suggests that localized areas (e.g., quiescent embayments and slips) of the Site may periodically exceed MCLs for total PCBs and BaP under current baseline conditions. Moreover, significant increases in water column concentrations of these contaminants are projected during dredging in certain areas (Figures 8.2.2-8, and 8.2.2-9).[7] The projected volume-day exceedances of MCLs for total PCB and BaP under each alternative are summarized in Figure 9.2.1-1a-b. Alternative A (No Action) is projected to have the lowest combined extent/duration of MCL exceedances, while those alternatives that include the largest dredging volumes (e.g., Alternatives E-r and F-r) are projected to have the highest extent/duration. As noted in Section 8 (e.g., 8.3.2), these exceedances represent very small areas and periods (Appendix U, Section 2.1). Differences in projected volume-days exceedances among the alternatives over the last five years of the model projection are minimal (see Appendix U Figures 3.2-6b and 3.2-7b).

9.2.1.2 Compliance with Human Health Fish Consumption WQS/NRWQC[8]

Surface water total PCB concentrations are projected to exceed the human health fish consumption criterion throughout the Site over the next 45 years under all alternatives due to Site background loading conditions. Thus, in order to provide a more meaningful but still highly conservative metric for comparison, the upstream background 95th percentile UPL concentration value for total PCBs (0.39 ppt; see Appendix C, Section 1) was used for this comparative evaluation. The projected volume-day exceedances of the total PCB background concentration under each alternative are summarized in Figure 9.2.1-2a (also see Appendix U, Section 2.1). While all alternatives resulted in a similar range of combined extent/duration of background exceedances, the lowest number of volume-day exceedances was projected for Alternative D-i, while the highest was projected for Alternative F-r.

The lowest combined extent/duration of exceedances of the BaP water quality criterion are projected for Alternative A (No Action) and for those comprehensive alternatives focused on in-place containment, while those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to have the highest extent/duration of exceedances.

None of the depth-integrated water column samples collected from the Site during the RI exceeded human health fish consumption values for BaP. However, detailed fate and transport modeling (Appendix Ha) suggests that localized areas of the Site (e.g., quiescent embayments and slips) may periodically exceed these criteria

[6] Per Section 8.2.3, the LWG believes that direct application of MCLs to individual, untreated surface water samples at the Site is inappropriate. This analysis was, nonetheless, carried through as directed by EPA.
[7] There are no MCLs for DDD, DDE, and DDT, so comparison to MCLs was not performed for these COCs.
[8] As discussed in Section 3.1.3, the FS generally has not been updated to incorporate the Oregon Human Health Water Quality Criteria for Toxic Pollutants that became effective October 17, 2011 due to insufficient time to integrate these criteria in the developing draft FS.

under current baseline conditions. The projected volume-day exceedances of the BaP human health fish consumption criterion (0.018 ppb) under each alternative are summarized in Figure 9.2.1-2b. The lowest combined extent/duration of exceedances of the BaP water quality criterion are projected for the No Action Alternative A and for those comprehensive alternatives focused on in-place containment, while those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to have the highest extent/duration of exceedances. As discussed in Section 8 (e.g., Section 8.3.2), these exceedances are projected to occur over relatively small areas and periods (Appendix U, Section 2.1).

Similar to BaP, none of the depth-integrated water column samples collected from the Site during the RI exceeded human health fish NRWQC consumption values for DDD, DDE, and DDT, but detailed fate and transport modeling (Appendix Ha) suggests that localized areas of the Site (e.g., quiescent embayments and slips) may periodically exceed these criteria under current baseline conditions. Model-projected volume-day exceedances of both the DDT and DDE human health NRWQC fish consumption criteria (0.22 ppt for both chemicals) were similar between all of the alternatives (Appendix U, Section 2.1), though there were projected differences between alternatives for DDD. The projected volume-day exceedances of the DDD human health fish consumption criterion (0.31 ppt) under each alternative are summarized in Figure 9.2.1-2c. As discussed in Section 8 (e.g., Section 8.3.2), these exceedances are projected to occur over relatively small areas and periods (Appendix U, Section 2.1). Similar to BaP, the lowest combined extent/duration of exceedances of the DDD criterion are projected for the No Action Alternative A and for those comprehensive alternatives focused on in-place containment, while those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to have the highest extent/duration of exceedances.

9.2.1.3 Compliance with Chronic and Acute Aquatic Life WQS

Some near-bottom and water column samples collected from the Site during the RI exceeded chronic aquatic life WQS[9] for aluminum, DDx, total PCBs, mercury, and zinc[10] (see Table 5.5-2), indicating that No Action Alternative A does not currently meet these standards in some locations. The projected volume-day exceedances of the Oregon chronic aquatic life WQS for total PCBs under each alternative are summarized in (Figure 9.2.1-3a; also see Appendix U, Section 2.1). The lowest combined extent/duration of exceedances of the total PCB water quality chronic criterion are projected for those comprehensive alternatives focused on in-place containment, while both the No Action Alternative A, and those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to have the highest (and

[9] Chronic and acute WQS should be applied consistent with the temporal and spatial averaging provisions of Oregon regulations.

[10] Surface water samples also exceeded an EPA non-priority criteria for aluminum that is based on toxicity testing in waters with ph <6.6 and hardness <10 milligrams per liter (mg/L). When Oregon adopted this criterion in its Table 33B aquatic life criteria, it adopted the criterion only under those specific circumstances—where pH is < 6.6 and hardness <10 mg/L, conditions which do not apply to the Site. See OAR 340-041-033 Table 33C note w.

similar) extent/duration of exceedances of this criterion, though for different reasons. These exceedances are projected by the model in quiescent embayments and slips, even under the No Action alternative A (Figure 9.2.1-4). However, for those alternatives that include the largest dredging volumes (e.g., Alternatives E-r and F-r), unavoidable dredging-induced resuspension and release of dissolved PCBs into the water column during the relatively long-duration construction period results in an overall projected extent/duration of exceedances similar to the no action alternative (see Figure 9.2.1-3a for differences between the alternatives). Differences in projected volume-days exceedances of the PCB chronic aquatic WQS among the comprehensive alternatives over the last five years of the model projection are insignificant, and all of the comprehensive alternatives have substantially fewer volume-day exceedances than the No Action Alternative (Appendix U Figure 3.2-6c).

The lowest combined extent/duration of exceedances of the total PCB chronic water quality criterion are projected for those comprehensive alternatives focused on in-place containment, while both the No Action Alternative A and those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to have the highest (and similar) extent/duration of exceedances of this criterion.

The acute aquatic life WQS for total PCBs (2 ppb) is a relevant and appropriate criterion for dredging and other activities that result in discharges to surface waters. The lowest combined extent/duration of exceedances of the total PCB acute criterion are projected for the No Action Alternative A, while all of the comprehensive alternatives are projected to have higher exceedances, primarily attributable to dredging in SMA 3 where relatively high sediment PCB deposits are present at depth (Figure 9.2.1-3b). As discussed in Section 8 (e.g., Section 8.3.2), these exceedances are projected to occur over relatively small areas and periods (Appendix U, Section 2.1). Because SMA 3 is targeted to be dredged under all of the comprehensive alternatives, similar extents/durations of exceedances of the acute criterion are projected. Focused USACE DREDGE modeling (Appendix Ia) suggests that surface water column exceedances of the total PCB acute aquatic life WQS under all alternatives would likely be localized to within approximately 300 feet from the point of dredging in SMA 3.

9.2.2 Location- and Action-Specific ARARs

All of the comprehensive alternatives are expected to comply with location- and action-specific ARARs, including the Oregon Environmental Cleanup Law, ESA, CWA Section 404(b)(1), and FEMA requirements. Comparative evaluations of the alternatives relative to each of these ARARs are provided in the following subsections.

9.2.2.1 Oregon Environmental Cleanup Law

Oregon Hazardous Substances Remedial Action Rules

Oregon Hazardous Substance Remedial Action Rules establish acceptable risk levels for human health at 10^{-6} for individual carcinogens and 10^{-5} for multiple carcinogens. (Other aspects of this rule [i.e., human health noncancer endpoints and ecological risk levels] are similar to CERCLA criteria and are discussed under long-term effectiveness.)

While the No Action Alternative A is projected to result in higher long-term potentially unacceptable risks than the other alternatives evaluated in this draft FS, all of the comprehensive alternatives are projected to achieve relatively similar Site-wide surface sediment concentrations and associated potentially unacceptable risk reductions over the long term. Surface sediment total PCB concentrations equivalent to a projected 10^{-5} cancer risk level, using an assumption of smallmouth bass whole body consumption (consistent with the total PCB 10^{-4} cancer risk RG for the same scenario), range from approximately 0 to 26 ppb for the 99th and 90th percentile estimates, respectively (see Table 8.2.2-1 and Table 5.6-1 of Appendix E). This potentially unacceptable risk range also overlaps with the estimated background range of approximately 5 to 37 ppb (see Section 3.6 and Appendix E). All of the comprehensive alternatives are projected to result in long-term sediment concentrations that enter this 10^{-5} cancer risk level range and/or are within the background range, though none of the alternatives are projected to achieve the lower levels of these ranges due to Site background loading conditions, which have been accounted for in model projections.

All of the comprehensive alternatives are projected to result in long-term sediment concentrations that enter the 10^{-5} cancer risk level range (0 to 26 ppb) and/or are within the background range (5 to 37 ppb), though none of the alternatives are projected to achieve the lower levels of these ranges due to Site background loading conditions, which have been accounted for in model projections.

All of the comprehensive alternatives are projected to achieve similar long-term surface sediment BaP concentrations in the shoreline portions of all Segments and river miles, below the full range of BaP 10^{-6} cancer risk level sediment direct contact RGs.

Similarly, all of the comprehensive alternatives are projected to achieve similar long-term surface sediment DDE concentrations in all Segments, below EPA's 10^{-6} cancer risk level point estimate RG for DDE, which is appropriately applied on a Site-wide basis. DDD and DDT concentrations are also projected to achieve their respective smallmouth bass whole body consumption 10^{-6} cancer risk level point estimates (see Appendix U, Section 3.1). No Action Alternative A is projected to achieve a lower long-term surface sediment DDD concentration than those alternatives that include more dredging (particularly Alternatives E-r and F-r), primarily due to dredging residuals resulting from exposing relatively deeply buried DDD deposits.

In summary, for all action alternatives, potentially unacceptable risks from PCB are projected to approximately attain the 10^{-5} cancer risk level per the ARAR, but no lower, due to upstream surface water loading. For the other contaminants, the projections indicate that the individual 10^{-6} cancer risk level required per the ARAR can be met for all action alternatives.

Potential Hot Spots under Oregon Law

Section 5.5 discusses the determination of potential Oregon hot spots at the Site and does not identify any Oregon hot spots.

Nonetheless, the draft FS evaluated a preference for treatment or excavation and off-Site disposal for all active remedy alternatives (i.e., Alternatives B through F), by applying a higher threshold for evaluating the reasonableness of the cost of treating or excavating the areas with the highest concentrations of the bounding COCs. The LWG believes that even if potential hot spots were identified, the intent of the Oregon hot spot rule is addressed through this approach because each active remedy alternative (i.e., Alternatives B through F) identifies the relatively highest concentration areas and volumes and evaluates the cost-effectiveness of dredging or treating those areas and volumes.

Each alternative from B-i to F-r includes physical removal of sediments exceeding the respective RALs. As shown in Table 9.0-1, the cost of Alternative F-r is more than 10 times higher than Alternative B-i. Per Section 9.1.1, there is no appreciable long-term incremental risk reduction from Alternative F-r to Alternative B-i.

The above evaluation demonstrates that any approach to identifying potential Oregon hot spots would not result in proportionately greater risk reduction for the cost involved and is not feasible given the greater short term risks associated with physical removal of such very large volumes of sediment across so many areas of the Site. Thus, although no Oregon hot spots were identified, the intent of the rule (i.e., evaluation of a preference for treatment or removal) is met through the analysis of this draft FS.

9.2.2.2 Endangered Species Act (ESA)

As part of ESA compliance, all of the comprehensive remedial alternatives include impact avoidance and minimization and conservation measures, including performing in-water work during an approved work window, corresponding to times of the year when salmonids are expected to be present only in very low numbers.

As detailed in the Preliminary Draft BA (Anchor QEA 2012), with the implementation of potential impact avoidance, minimization, and conservation measures, very few individual species would be impacted during each work window such that, regardless of the duration of the alternative, the impacts are not expected to affect the species at the population level. Furthermore, those individuals that are present within the Site during each work window are not expected to spend much time within the Site. Thus, all of the comprehensive alternatives are anticipated to comply with the substantive provisions of the ESA.

9.2.2.2.1 CWA Section 404(b)(1)

As discussed in more detail in the Preliminary Draft Section 404(b)(1) analysis[11] presented in Appendix M, all of the comprehensive alternatives are anticipated to comply

[11] This document will be reviewed and refined by the EPA, including the issuance of findings.

with the substantive provisions of this ARAR. The 404(b)(1) analysis revealed that although short-term construction-related impacts may occur to potential jurisdictional waters, vegetated shallows, water quality, and human uses, projected longer term reductions in contaminant concentrations resulting from construction could offset many or all of the short-term impacts under the CWA. Thus, if any of the comprehensive alternatives evaluated in this draft FS were to be selected by EPA consistent with detailed NCP criteria, they would also be identified as the "least environmentally damaging practicable alternative" when considering cost, logistics, technology, and including balancing criteria. The integration of BMPs and compensatory mitigation would also compensate for any potentially unavoidable significant adverse impacts associated with each comprehensive alternative.

9.2.2.3 FEMA Flood Rise Requirements

As discussed in Section 8.2.3, for all communities participating in the National Flood Insurance Program, FEMA requires that any action that encroaches on the floodway cannot cause an increase in water surface elevation in the river during a 100-year flood event. A one-dimensional hydrodynamic model (HEC-RAS) of the Lower Willamette River and Multnomah Channel was used to evaluate compliance of each of the comprehensive alternatives with this ARAR (Appendix Lb). All of the alternatives except the No Action Alternative A had maximum projected increases in water surface elevation greater than the FEMA requirement, but these rises were well within the model's precision and, therefore, are considered to be negligible and not significantly different between alternatives. Therefore, compliance of Alternatives B through F with this ARAR cannot be confirmed. To demonstrate compliance with the ARAR in remedial design for any alternative selected by EPA, one or more of the following actions would need to be taken: 1) additional modeling with a higher precision; 2) revisions to effective Flood Insurance Studies, Flood Insurance Rate Maps, or Flood Boundary Floodway Maps following FEMA regulations (FEMA 2011); or 3) mitigation for any unacceptable flood rise that can be confirmed in remedial design.

9.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

The long-term effectiveness and permanence of the comprehensive alternatives was evaluated using several methods, each of which relates to determining attainment of specific RAOs. To quantitatively compare each alternative's ability to meet this NCP criterion, Site-specific modeling was performed to project long-term surface sediment, fish tissue, and water column concentrations under each alternative. These results were evaluated against both the magnitude of residual and adequacy of controls as described in Section 8.2.4.

9.3.1 Magnitude of Residual Risk – Long-Term Surface Sediment COC Concentrations

Projected Site-wide changes in surface sediment concentrations of select COCs including total PCBs, BaP, and DDE during and following implementation of each comprehensive alternative are presented in Figures 8.2.2-1, 8.2.2-2, and 8.2.2-3, respectively. Similar projections by river Segment are presented in Figures 8.2.2-4, 8.2.2-5, and 8.2.2-6, respectively. Projections on a Site-wide and Segment bases for DDD and DDT are shown in Appendix U, Section 3.1. Relative to current conditions and No Action Alternative A, substantial reductions in surface sediment COC concentrations are expected for all comprehensive alternatives over the long term. Moreover, all of the comprehensive alternatives are projected to achieve relatively similar Site-wide surface sediment COC concentrations over the long term. As discussed above, the resulting risk reductions are also similar given that the uncertainty of the various RGs is generally much greater than the differences in COC concentrations achieved across the alternatives.

As noted in Section 8.2.2, the uncertainty results show that the model projection uncertainties do not change conclusions regarding the overall effectiveness of the action alternatives, which are all projected to reach relatively similar and protective sediment COC concentrations in the long term.

For PCBs, the active alternatives are projected to achieve long-term levels at or below EPA's point estimate RG in all Segments. For BaP, the active alternatives are projected to achieve shoreline sediment concentrations in all segments well below the full range of BaP RGs. For DDE, all alternatives in all Segments are projected to attain long-term levels below EPA's point estimate RG for DDE, which is more appropriately applied on a Site-wide basis. Figures 8.2.2-1 through 8.2.2-6 show the uncertainty associated with the conservative case or lower bound estimate for these projections. The uncertainty of the modeling projections is also summarized in Tables 9.3.1-1 and 9.3.1-2 for the Site-wide and Segment spatial scales, respectively. As noted in Section 8.2.2, these uncertainty results show that the model projection uncertainties do not change conclusions regarding the overall effectiveness of the action alternatives, which are all projected to reach relatively similar and protective sediment COC concentrations in the long term. Appendix U (Section 5) presents additional evaluations of uncertainty associated with other MNR LOEs (beyond modeling uncertainty), which also do not substantially alter these conclusions.

Appendix U (Section 3.1) presents model projections of long-term changes in surface sediment concentrations by river mile for PCBs and DDE (as well as DDD and DDT) and shoreline half river mile for BaP over the 45-year simulation period. For PCBs, all river miles are projected to attain similar long-term concentrations that are generally below the range of smallmouth bass RGs. In RM 3 to 4, little future sediment recovery is projected under any of the alternatives. This is due to the combined effect of localized quiescent conditions and limited sediment deposition in slips within this area as well as projected stormwater loading. Stormwater loading is currently being addressed by DEQ through implementation of additional stormwater source controls in this area. Modeling projections in Appendix Ha (Section 6) indicate that when the uniquely high stormwater loads in this area are reduced, a greater decline in river mile sediment concentrations is observed, which illustrates the partial contribution of stormwater to these projected sediment concentrations. The Appendix Ha (Section 6) results also project that if these source controls are successful, EPA's point estimate PCB RG could potentially be met. In Swan Island Lagoon, all of the alternatives are projected to achieve similar long-term surface sediment PCB concentrations in the range of approximately 60 to 110 ppb (Appendix U, Figure 3.1-3). As noted in Section 9.1.1, these PCB concentrations are significantly less than current concentrations in Swan Island Lagoon and represent risk levels in the 10^{-4} to 10^{-5} cancer risk level range (including some noncancer HQs less than 1) depending on the fish consumption scenario assumed (see Section 3.6 and Appendix E).[12] Thus, these risk levels are in a similar range to background (e.g., the background range for cancer risk is 10^{-4} to 10^{-5}; the background concentration extends up to 37 ppb and above EPA's point estimate RG of 29.5 ppb for whole body smallmouth bass consumption, which is set at a 10^{-4} cancer risk level).

The fate and transport model was also used to assess long-term effectiveness of the alternatives during an extreme flood event (similar to the 1996 flood) simulated in Year 17 of the projection. Under all alternatives, the modeled flood event in Year 17 was projected to result in a relatively short-term increase in surface sediment concentrations over most spatial scales and areas assessed. Erosion is projected to temporarily expose higher concentration subsurface sediments previously buried as part of earlier natural recovery processes. However, following the temporary concentration increases associated with the erosional event, deposition is projected to continue, which would allow local sediment concentrations to recover to pre-flood conditions within a few years. Thus, periodic peak flood events are not projected to adversely impact the long-term effectiveness of any of the comprehensive alternatives.

Alternatives that include more environmental dredging/removal, particularly Alternatives E-r and F-r, are projected to result in higher overall surface sediment concentrations over substantial periods of time (i.e., approximately 10 to 30 years during construction) as compared to the integrated alternatives with more emphasis on EMNR/in situ treatment and capping (see Figures 8.2.2-1 to 8.2.2-6) due to the effects of dredge residuals.

As noted in Section 9.1.1, BaP is projected to achieve very conservative RGs (>99th percentile 10^{-6} cancer risk level for sediment direct contact; Table 8.2.2-1) throughout the Site including every shoreline half river mile, which is the smallest spatial scale relevant to these RGs. There is very little discernible difference between no action in Alternative A and Alternative F-r in terms of achieving the lowest BaP RG, even in the most contaminated shoreline half river mile at 6 to 6.5 West (as shown in Appendix U Figure 3.1-6l).

[12] Also, the surface area of Swan Island Lagoon is about half the size of most river miles, and therefore, these comparisons to river mile-based RGs are roughly twice as conservative in Swan Island Lagoon on a spatial scale basis.

9.3.2 Magnitude of Residual Risk – Long-Term Biota Tissue Concentrations

Projected changes in whole body smallmouth bass tissue total PCB concentrations by river Segment during and following implementation of each comprehensive alternative are presented in Figure 8.2.2-7. Overall trends in fish tissue PCBs are relatively similar among the alternatives across each river Segment. These results are discussed by Segment below including information from the FWM sensitivity/uncertainty analyses (Appendix Hb, Section 5.2). The Segment spatial scale is judged to be the most representative overall spatial scale for evaluation of fish tissue risks given that the exposure scales for PCB bioaccumulation human health and ecological RGs/PRGs range from 1 river mile to Site-wide.

In Segment 1, all of the alternatives, including the No Action Alternative A, are projected to achieve tissue PCB levels that are below the range of TTLs (Table 8.2.3-1). In Segment 2, all of the comprehensive alternatives are projected to achieve long-term fish tissue PCB levels at or below the TTL associated with the EPA point estimate RG. In Segment 3, all of the alternatives are projected to achieve long-term fish tissue PCB levels below the range of TTLs. Similarly, in Segment 4, all of the alternatives are projected to achieve long-term fish tissue PCB levels at or below the TTL associated with the EPA point estimate RG. As noted for sediment above, Segment 4 concentrations are attributable to the combined effects of limited circulation in off-channel areas, PCB porewater exchange flux from the sediment bed to the water column, and uniquely high stormwater inputs near RM 3 to 4. (Appendix Ha, Section 6 addresses the relative contribution from stormwater in these areas.)

Table 9.3.2-1 summarizes the uncertainty analyses of the model tissue projections by Segment. The table shows that the alternatives would be expected to perform similarly relative to one another across the range of modeling uncertainties, although under the upper bound modeling projections some of the lower range of TTLs would not be met in Segments 2 and 4. As noted for sediments above, the differences in tissue concentrations in the upper bound estimate are very small as compared to the uncertainty/sensitivity in the TTLs.

In all Segments, a short-term increase in fish tissue PCB concentrations is projected around the flood event modeled at Year 17 as a result of a temporary erosional disturbance as discussed in the previous subsection. However, deposition is projected to follow the temporary erosional event under more normal flow conditions, which would allow fish tissue levels to recover to pre-flood conditions within several years. Thus, periodic peak flood events are not projected to adversely impact the long-term effectiveness of any of the comprehensive alternatives.

Dredging actions included in all of the comprehensive alternatives are projected to result in elevated tissue PCB concentrations during and immediately following dredging operations due to unavoidable dissolved PCB releases to the water column. The largest dredging-related increases in tissue levels are projected to occur in Segments 2 and 3 as a result of removing buried sediment deposits that contain relatively high sediment PCB concentrations within SMA 17S (Swan Island Lagoon), SMA 19, and SMA 3. Although only PCBs were modeled in fish, similar dredging-related tissue level increases are anticipated for other bioaccumulative contaminants when dredging locally elevated sediment concentrations. The projected short-term tissue increases, which are higher for those alternatives with larger dredging volumes (e.g., Alternatives E-r and F-r), are expected to be followed by tissue recovery within a period of approximately 5 years. Such a pattern is consistent with case studies of PCB dredging releases observed at other sites including Commencement Bay, Duwamish River, Hudson River, and Grasse River (Bridges et al. 2010; Patmont 2010; Alcoa 2011).

9.3.3 Magnitude of Residual Risk – Long-Term Surface Water Contaminant Concentrations

All of the alternatives are predicted to result in similar long-term surface water contaminant concentrations (Figures 8.2.2-8 through 8.2.2-10). Projected changes in surface water concentrations of select contaminants including total PCBs, BaP, and DDE during and following implementation of each comprehensive alternative are presented in Figures 8.2.2-8, 8.2.2-9, and 8.2.2-10, respectively. Appendix U, Section 3.2 contains similar figures for DDD and DDT as well as figures similar to those presented in Section 9.2.1 of the model-projected volume-days exceedances of various WQS and NRWQC criteria at the end of the model period (i.e., model years 40 to 45) for all five select contaminants. Appendix U, Section 2.1 contains maps showing the spatial extent of model-projected exceedances of WQS/NRWQC over the model simulation period for select contaminants for Alternative A, which provides a good visual example of where water quality exceedances occur most often (e.g., quiescent bays and slips) in all the alternatives. As noted in Section 9.2.1, none of the depth-integrated water column samples for BaP or DDx collected from the Site during the RI exceeded human health NRWQC fish consumption values.

9.3.4 Magnitude of Residual Risk – Minimization of Potential Long-Term Sediment Recontamination

Section 9.3.1 discusses the potential for long-term sediment recontamination at the Site over relatively large spatial scales (which are most relevant to evaluating risk). An additional evaluation of the potential for long-term recontamination at smaller spatial scales was conducted using the results from the fate and transport model and case histories from other similar sediment cleanup projects. Certain remediation areas (e.g., following dredging/cover or capping) were evaluated relative to recontamination potential associated with ongoing inputs from known sources such as stormwater, permitted industrial discharges, groundwater, and loads from upstream, as well as recontamination due to releases from dredging in adjacent areas.

Figures 9.3.4-1, 9.3.4-2, and 9.3.4-3 present time-series plots of model-projected surface sediment concentrations in example areas within SMAs 5, 9D, 9U, 14, 17S, and 19 that would be capped under the remedial alternatives for these SMAs for total PCB, BaP, and DDE, respectively.[13] Appendix U, Section 3.3 contains figures for DDD and DDT. These SMAs provide examples of remediated areas to evaluate recontamination potential. In these example areas, following initial reductions in surface sediment COC concentrations from caps, the post-cap sediment surface COC concentrations are projected to increase due to continuing contaminant inputs; however, these projected increases are lower than current COC concentrations and no areas exceed the EPA point estimate RG.

9.3.5 Magnitude of Residual Risk – Minimization of Potential Groundwater Impacts

As discussed in Section 8.2.4, upland contaminated groundwater is currently being controlled through separate upland source control actions administered by DEQ working with individual upland parties. Downgradient groundwater contaminants would be expected to remain after upland source controls are in place but dissipate or naturally attenuate over time. However, fate and transport modeling used in this draft FS conservatively assumed no reduction in the groundwater source loads over time (Appendix Ha, Section 3.2).

Additional evaluations were conducted for relatively mobile groundwater COCs using a select set of three contaminants (i.e., benzene, chlorobenzene, and vinyl chloride). Appendix C (Section 3) contains more information regarding the selection of these contaminants. As discussed in Section 6.2.6, active capping was modeled in these plume areas and projected concentrations at the base of the cap bioactive zone were compared to available water quality benchmarks for these COCs assuming upland source controls in these areas were in place. The evaluation results indicated that active caps (potentially of varying types) could reasonably be designed to be protective of groundwater source contaminants in SMAs 9U and 14 (see Section 6.2.6 and Appendix Hc, Section 3 for detailed results).

Several promising combinations of in-river and upland source control actions were incorporated into all of the comprehensive alternatives evaluated in this draft FS. Thus, there are no differences between the comprehensive alternatives relative to their ability to minimize potential groundwater impacts. Where the alternatives do not cover the entire plume areas, upland source controls may still be sufficient by themselves to ensure groundwater protection. Under any of the comprehensive alternatives, the potential need to expand any in-water remedial areas would need to be determined in SMA-specific design efforts coupled with modeling and other assessments of the effectiveness of upland groundwater source controls. Appendix U, Section 3.5 contains a more detailed description of this issue.

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[13] Note that these graphics only include alternatives for which a cap was placed in a given SMA. Also note that in some cases, the cap areas are relatively small; the legend for each graphic indicates the number of model grid cells that were capped under each alternative.

EPA commented (EPA 2009c; Appendix O) that in areas of groundwater plumes only, and for the portion of a groundwater plume that remains downgradient of upland source controls, MCLs should be met downgradient of the upland source control measure and throughout the groundwater plume [emphasis added]. Because sediment remedies cannot affect groundwater plumes deep under the river, the primary mechanism of meeting RAO 4 (the human health groundwater RAO relevant to MCLs) would be through upland source control and natural attenuation of the downgradient plume over time, where this is technically practicable to achieve the MCLs in a reasonable timeframe. Appendix U, Section 3.5 contains some additional details on this issue.

9.3.6 Magnitude of Residual Risk – Minimization of Potential Downstream Transport

Long-term transport of contaminants downstream from the Site was evaluated for each alternative using the calibrated contaminant fate and transport model. This is relevant to residual risk per the NCP criterion (as well as Management Goal 2 described in Section 3.3). Figure 9.3.6-1a-c depicts the projected masses of total PCBs, BaP, and DDE exiting the Site over the 45-year model projection period for each comprehensive alternative. Note that the estimated COC mass estimates presented in the figures represent the combined masses of COCs exiting the downstream end of the Site (i.e., the mass passing RM 1.9) and exiting through Multnomah Channel.

The projected mass of total PCBs transported downstream is relatively similar across the action alternatives and also compared with the No Action Alternative A. Those alternatives that include the greatest environmental dredging volumes (e.g., Alternatives E-r and F-r) are projected to result in slightly higher PCB mass transported downstream compared with Alternative A due to dredging releases. Conversely, Alternatives C-i and D-i are projected to result in small reductions of the estimated PCB mass exiting the Site relative to Alternative A, due to reductions in PCB flux from areas of sediment that are capped or treated in place under these alternatives. Similar results are projected for BaP.

Downstream transport was also evaluated for DDT and DDD; results are presented in Appendix U, Section 3.4. DDT is relatively similar to DDE in that there is little to no difference in the amount of mass potentially transported downstream among the various alternatives, with the exception of Alternative B-r for DDT. Alternative B-r is projected to result in a higher mass transported downstream due primarily to a localized area of high concentration sediment in SMA 14 removed under this alternative during dredging.

9.3.7 Adequacy of Controls

This factor assesses the adequacy and suitability of controls, if any, that are used to manage residuals or wastes that remain at the Site. All of the alternatives result in some residual concentrations of contaminants at the Site whether it is beneath dredge residual covers, caps, or buried beneath natural sedimentation as part of natural recovery. Note that areas subject to in situ treatment are considered treated materials, although the long-term permanence of the treatment needs to also be considered. For all alternatives, the controls for these residual concentrations include the physical/chemical barriers provided as part of the technologies as well as institutional controls that ensure the ongoing effectiveness and maintenance of these barriers. Monitoring of dredge residual, capping, EMNR/in situ treatment, and MNR areas is designed to identify any problems with expected controls before or soon after they occur (Appendix T, Section 3). Similarly, the alternatives include additional operations and maintenance procedures for caps (Appendix T, Section 5). Capping evaluations in Appendix Hc (Sections 3 and 4) indicate that cap armoring and contaminant isolation components can be readily designed to minimize movement of underlying contaminants consistently over very long periods. EMNR/in situ treatment and cap areas would also have specific institutional controls to prevent, for example maintenance dredging or other impacts from routine Site uses.

Finally, modeling projections indicate that for MNR and EMNR/in situ treatment, contaminant concentrations within biologically active sediments will decrease over time, and once the projected reduced concentrations are achieved, there is very little potential for buried contaminants to be substantially released. As noted in Section 5.6.6, very little contamination above the RALs is left in place outside active remedy areas with any of the active alternatives. Consistent with this, extreme flood events are projected to cause minor and temporary (a few years) increases in sediment concentrations that quickly recovery to the previous ongoing equilibrium, as already discussed in Section 9.3.l.

9.3.8 Other Factors – Habitat Restoration Potential Integration

As discussed in Section 8.2.4, the potential overlap between potential habitat restoration areas (Table 2.4-3)[14] and SMAs was examined to determine if sediment remediation would preclude habitat restoration (e.g., relevant to Management Goal 3 in Section 3.3). Alternative A would not preclude any restoration concepts because no sediment remediation would occur with this alternative. Issues related to the action alternatives are discussed next.

Figure 9.3.7-1 identifies the locations within the Site boundary where a portion of a preliminary potential habitat restoration site overlaps with one or more remedial alternatives. For most of these potential locations, there are greater overlaps and potential conflicts between remediation and habitat restoration with Alternatives E and F, which cover the largest areas.

Due to the uncertainty of where habitat restoration may occur within the Site in the future, the determination of whether a remedial action would prevent a potential restoration activity from occurring will need to be made during SMA-specific remedial designs for areas where any restoration projects come to fruition.

[14] These concepts are very preliminary and it is uncertain whether any of them will actually be built (see Section 8.2.4 for more discussion).

9.3.9 Disposal Site Long-Term Effectiveness

Evaluations of long-term effectiveness and permanence of the comprehensive alternatives also considered disposal in CDFs, CADs, or landfills. The long-term effectiveness of each on-Site CDF or CAD was evaluated in terms of the FS CDF Performance Standards as described in Section 8.2.4 (EPA 2010e and LWG 2010a and b; Appendix O). The standards are for draft FS purposes only and other equally protective standards could be determined in remedial designs. The evaluation of each disposal option relative to each FS CDF Performance Standard and the full text of the standards are provided in Appendix U (Section 6). These performance standards do not apply to upland off-Site facilities as discussed in Section 8.2.4.

9.3.9.1 Magnitude of Residual Risk – FS CDF Performance Standards 6, 9, 10, 11, 14, 15, 16, and 27

FS CDF Performance Standards 6, 9, 10, 14, 15, 16, and 27 all address containment of CERCLA material over the long term. Performance Standards 6, 9, 10, 15, and 16 require that the CDF contain CERCLA material such that groundwater discharges do not exceed specified standards for protection of health and the environment. Per Section 8.2.4, many of these standards contain specific conservative assumptions for FS purposes that may differ from eventual design-level standards that are determined to be equally protective. Performance Standard 14 specifically requires that the contaminated sediment in the CDF remain saturated or unsaturated to minimize the mobility of contaminants. Performance Standards 16 and 27 specifically address the long-term protectiveness of the CDFs by requiring that the CDF contain CERCLA material in perpetuity (No. 16) and requiring that the CDFs are monitored in perpetuity (No. 27).

The modeling results, summarized in Appendix Jb (Section 3), show that all contaminant concentrations for the Terminal 4 CDF are projected to remain below the relevant water quality criteria for the duration of the evaluation period. The Terminal 4 CDF groundwater flow modeling was also used to determine the elevation at which contaminated sediment would remain saturated at all times to conform to Performance Standard 14 and reduce the mobility of contaminants. This elevation was determined to be +9.5 feet National Geodetic Vertical Datum (NGVD), which was used as the upper elevation for the placement of contaminated sediment in the CDF.

For the Swan Island Lagoon CDF, the groundwater flow modeling was used to determine the minimum elevation of the groundwater table in the CDF. As discussed in Appendix Jb (Section 3), the long-term contaminant transport evaluation indicates that the CDFs as proposed would effectively contain contaminants for centuries even if biodegradation is ignored. Over this timeframe, biodegradation will certainly be the controlling mechanism for contaminant fate, and the modeling scenarios that included very conservative estimates of biodegradation indicate that contaminants will be contained in perpetuity.

The primary design issue to ensure contaminant containment in the Swan Island Lagoon CAD is the long-term effectiveness of the cover. The results of in situ cap modeling (Section 6.2.5) indicate that a 1-foot-thick layer of sand placed as part of an engineered cap would provide containment of existing bed contaminants in Swan Island Lagoon and throughout the Site. The conservative 6-foot-thick cover incorporated into the conceptual layout of the Swan Island Lagoon CAD is therefore projected to be more than adequate to limit upward migration of contaminants to acceptable levels. The proposed total cover thickness for the Swan Island Lagoon CAD is an FS-level assumption that may be refined (including a potentially thinner cover) during remedial design. The capping evaluation indicates that much thinner covers could easily be designed in the future that would meet either the FS CDF Performances Standards or other future standards developed in remedial design. Because a CAD is subaqueous, sediments would remain saturated at all times, thereby reducing the potential mobility of contaminants. To further confirm that contaminants are contained over the long term at Swan Island, additional modeling would be performed during remedial design.

For the Arkema one- and two-berth preliminary design options, much of the details that are needed to meet the FS CDF Performance Standards or alternate standards that may be developed during remedial design will be addressed as part of the EE/CA, including a full ARARs analysis. The current design concept is presented in the *Preliminary CDF Screening Evaluation* (Arcadis 2010); the eventual design may be a different EPA-approved configuration. Although a quantitative analysis has not been performed, leaching from sediments in the CDF is expected to be minimal due to the limited solubility and mobility of the primary contaminants. The design concept includes a groundwater extraction system as a potential secondary containment measure to address the effects of transient potentiometric surface reversals (ERM 2011). Extracted groundwater would be treated and discharged to the Willamette River.

For all the on-Site disposal options, monitoring would be performed in perpetuity or until EPA approves a reduced monitoring plan. The draft FS includes costs associated with long-term monitoring of the Terminal 4 CDF, Swan Island Lagoon CDF, and Swan Island Lagoon CAD options (Appendix K, Section 2.3). For the Arkema CDF preliminary design option long-term monitoring, groundwater monitoring wells would be used to monitor the effectiveness of the CDF.

Performance Standard 11 requires that the design of the CDFs conform to the project RAOs and that the draft FS include costs for habitat mitigation and land acquisition for the CDFs. The overall goal of the conceptual designs of the disposal options included in the alternatives is to minimize transport of contaminants to any of the pathway/receptors defined in the RAOs, and as discussed above, groundwater modeling results indicate that this overall goal would be met for all of the disposal options considered. Further, costs for mitigation and land acquisition are included in the cost estimate for each alternative are detailed in Appendix K (Section 2.1). Habitat issues related to the overall alternatives including their component CDFs are discussed above.

9.3.9.2 Adequacy of Controls – Performance Standard 12

Performance Standard 12 contains specific requirements for the design of the CDF containment berms relative static stability, seismic stability, and erosive forces due to 100-year floods or waves. This performance standard also requires that the CDF containment berm allow the passage of groundwater without allowing the passage of contaminated sediment. This last element is covered by the discussion of the other long-term effectiveness standards above. Stability and erosive forces are discussed below.

Regarding berm stability, for the Terminal 4 CDF conceptual design, modeling was performed to determine the stability of the berm design using GeoSlope's software package SLOPE/W. Results show that the berm would be stable under normal operating conditions in the long term (Anchor QEA 2011c). Although design components such as a CDF containment berm may undergo deflections, containment of the contaminated sediments would not be jeopardized. The qualitative evaluation of Swan Island Lagoon stability is included in Appendix Jc, and the information reviewed suggests that a CDF or CAD berm can be built to meet the performance standard used for the draft FS evaluation. For the Arkema preliminary design one- and two-berth options, an evaluation was performed to determine the stability of the cofferdam design. The evaluation established that an effective cofferdam width of 54 feet is required to meet the minimum factors of safety for sliding and overturning (Arcadis 2010). Based on these results, a circular cell cofferdam structure can be sized to meet this performance standard and is generally considered a feasible containment structure option. It is important to note that this is a preliminary design and the eventual design may be a different EPA-approved configuration.

Regarding protection of the berm against erosive forces, a shoreline armoring evaluation was conducted for the entire Site including the disposal option locations (Appendix Hc, Section 4). This evaluation included river current, wind/vessel wake generated waves, and propwash analyses. This evaluation was conducted in the context of cap armoring requirements but is equally valid for CDF cover and berms. The evaluation indicated that shoreline armoring could be designed for all of the shoreline erosive conditions occurring at the Site, even the most extreme of those conditions. A similar analysis was conducted in the Terminal 4 Design Analysis Report specifically for the Terminal 4 CDF berm. The Design Analysis Report includes a design berm with an armor layer large enough to protect the berm from erosion (Anchor QEA 2011c), and thus corroborates the Site-wide analysis in Appendix Hc (Section 4). For the Arkema CDF preliminary design options, coffer dams would be expected to withstand all of the potential erosive forces at the Site and may need to include armoring at the cofferdam sediment bed interface to prevent localized bed scour, but this would be determined in remedial design.

9.3.9.3 Adequacy of Controls – Performance Standard 25

Performance Standard 25 requires that the CDF cover consist of uncontaminated fill. For the Terminal 4 CDF, the cover would consist of two layers. The contaminated sediment would be covered with approximately 464,000 cy of suitable fill and/or suitable navigational dredged material, with top layer consisting of approximately 272,000 tons of aggregate. Both layers would meet the specified physical and chemical requirements that would be established in design to provide the necessary structural integrity for terminal development and to be protective of human health and ecological receptors via direct contact or through leaching to groundwater and surface water resources (Anchor QEA 2011c). It is anticipated that the covers for the Swan Island Lagoon CDF and CAD options would also be material that has been physically and chemically characterized before placement. For the Arkema preliminary design one- and two-berth options, the material would be encapsulated with a geomembrane liner, covered with uncontaminated fill material, and then a final surface layer potentially consisting of asphalt pavement would be placed.

9.4 REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Under this NCP criterion, the degree to which each comprehensive alternative reduces toxicity, mobility, or volume through treatment was evaluated. This includes evaluation of the factors described in Section 8.1.

For the integrated alternatives, toxicity and mobility of contaminants in sediments are reduced by in situ treatment and active capping. For draft FS purposes, the example in situ treatment technology assumed for alternative development was direct placement of AC. Table 9.4-1 summarizes the areas treated via AC placement for each alternative. In general, the larger integrated alternatives result in more acreage being treated, with the greatest area of application occurring in Alternative F-i.

As noted previously, active capping in certain groundwater plume areas is included in the high-range cost estimates for the integrated alternatives. Application of active caps in these areas would provide a permanent reduction of the flux of contaminants by actively adsorbing contaminants into the cap materials. Although the additional area of sediments treated through this technology is relatively minor in comparison to in situ treatment, active capping may be an important aspect of the treatment provided in remedial design in certain groundwater plume areas of the Site.

Also, all removal in both removal focused and integrated alternatives includes dewatering and/or stabilization of sediments. Dewatering using diatomaceous earth is a treatment that reduces the contaminants in free water, which reduces contaminant mobility. Stabilization (e.g., using Portland cement or other pozzolanic material) would provide further treatment reducing both contaminants in free water and contaminant leaching in the resulting solid stabilized materials.

Also, as discussed in Section 6.2, several forms of ex situ treatment were retained for potential further evaluation and use in SMA-specific remedial designs. Thus, additional sediments may be treated as determined in remedial design.

9.5 SHORT-TERM EFFECTIVENESS

This criterion is used to evaluate the effects and potentially unacceptable risks associated with alternative implementation considering potential environmental impacts, time until protection is achieved, and protection of the community and workers. This criterion also considers the effectiveness of mitigation measures as noted in the NCP (i.e., measures such as BMPs that are intended to reduce the short-term impacts of the alternatives). Per the NCP, specific considerations in the assessment of short-term effectiveness that are evaluated here are described in Section 8.2.6.1.

Comparative analyses of the comprehensive alternatives relative to specific short-term impacts are presented below.

9.5.1 Environmental Impacts – Water Quality During Construction

The integrated alternatives generally have fewer PCB acute water quality exceedances than the removal alternatives, with Alternative F-r having the greatest projected exceedances.

Site-wide contaminant fate and transport modeling (Appendix Ha) and DREDGE water quality modeling (see Appendix Ia) projected exceedances of some water quality criteria during the construction periods, as discussed in Section 9.2. Acute aquatic life WQS are ARARs for dredging operations and other activities that result in discharges to the Site. Site-wide fate and transport model projections suggest that surface water concentrations of total PCBs will exceed acute aquatic life WQS in very small areas and periods, for example in SMA 3. The integrated alternatives generally have fewer PCB acute water quality exceedances than the removal alternatives, with Alternative F-r having the greatest projected exceedances (see figures in Appendix U, Section 4.1).

Although not an ARAR, a secondary acute aquatic life value for BaP was used to evaluate model-projected BaP surface water concentrations during construction. Model results (Appendix Ha and Ia) suggest that BaP concentrations would also exceed the acute aquatic life value in very small areas and periods during dredging, primarily in SMAs 6 and 9U, though differences between the comprehensive alternatives were small (see figures in Appendix U, Section 4.1). However, no exceedances of either acute or chronic BaP guidelines were observed during the water quality monitoring program for the Port of Portland’s 2008 interim action, which involved interim dredging of the most contaminated material in SMA 6 and therefore represents a conservative scenario for any future remedial action (Anchor QEA et al. 2009).

Alternate acute water quality values are available for DDD and DDE, and Appendix Ia modeling projected some potential for exceedances of the DDD alternate acute value at SMA 14.

Overall, those alternatives that include the greatest dredging volumes (e.g., Alternatives E-r and F-r) are projected to result in higher water column concentrations and associated water quality impacts during the construction period, while the integrated alternatives are projected to result in the lower surface water contaminant concentrations and lower impacts (see discussion in Section 9.2 and Appendix U figures, Section 4.1). Alternatives B-i, C-i, and D-i have lowest volume-days exceeding various water quality criteria during construction, while Alternative F-r has the highest (Appendix U, Section 4.1). As discussed in Section 6.2.7, the application of rigid barriers or silt curtains is not expected to appreciably improve the protection of alternatives with more removal and may cause some additional unintended consequences.

9.5.2 Environmental Impacts – Sediment Recontamination During Construction

Based on modeling projections and comparisons with case study results from other environmental dredging sites (Bridges et al. 2010), dredging is that included as a component of all action alternatives is projected to result in localized sediment recontamination of adjacent areas. Environmental dredging resuspension and residuals would generally be limited to within approximately 500 to 1,000 feet of the dredging activity.

The potential for short-term recontamination due to releases during environmental dredging was evaluated using the fate and transport model by estimating the average increase in total PCB, BaP, and DDx concentration immediately downstream of each SMA during the period of active construction. The maximum SWAC calculated for the 1-mile (or half mile for BaP) averaging reach downstream of each SMA during the period of active construction is summarized for all alternatives in Tables 9.5.2-1 through 9.5.2-3 for PCB, BaP, and DDT, respectively (see Appendix U, Section 4.2 for methods details and similar tables for DDE and DDD).[15] In summary, this analysis suggests that the potential for short-term sediment recontamination due to dredging is relatively low throughout much of the Site. The highest potential for recontamination is projected to occur in quiescent slips (particularly for PCBs) and downstream of relatively higher concentration SMAs. As discussed in Section 8.2.6, it is anticipated that the use of containment structures (i.e., sheetpile) would not significantly reduce the potential for recontamination in these areas.

Note that while the discussion above focuses on short-term recontamination due to releases from environmental dredging, this issue is equally valid for removal of docks (and other structures such as piles) and removal of sediment under docks should that ever be determined necessary during remedial design. It is anticipated that any demolition of docks and removal of sediments from these areas would also have little short-term downstream impact due to recontamination. SMA-specific conditions around in-water structures vary throughout the Site; therefore, further analysis of downstream impacts would be performed in the event that dock removal is appropriate in any SMA.

[15] A complete description of the method used to estimate short-term recontamination concentrations using the fate and transport model is provided in Section 6 of Appendix Ha.

Based on the model projections, specific SMA construction sequencing can likely be flexible; performing dredging in a rigid upstream to downstream construction sequence does not appear to be required to minimize recontamination. This may provide latitude for the various implementing parties at the Site to proceed with remedial actions on somewhat independent timelines. Nevertheless, the modeling projections suggest that there are some SMA remediation sequences that would need to be examined further in remedial design before being implemented:

- Construction of SMAs 16 and 18 before SMA 19
- Construction of outer portions of SMA 3 or SMA 1 before inner (more highly contaminated) portions of SMA 3
- Construction of SMA 9D before SMA 9U
- Construction of SMA 9U before SMA 14
- Construction of SMA 4 before SMA 5.

The modeling projections also suggest that variations in remediated SMA concentrations are anticipated while dredging is still underway throughout the Site. For example, post-remediation surface sediment concentration variations up to approximately 20 ppb for PCBs and 50 ppb for BaP are anticipated; these variations may need to be considered as part of long-term performance goals and monitoring decisions (see Appendix T, Section 3) for each SMA. It should be noted that the above conclusions are based on a set of modeling runs that necessarily have to assume some sequence of remediation as discussed in Section 7. Thus, modeling of other possible sequences of SMA remediation might project somewhat different results, but this is not expected to substantially affect the above conclusions.

9.5.3 Environmental Impacts – Potential Downstream Transport During Construction

Similar to the analysis of downstream transport described in Section 9.3.6 for long-term effectiveness, short-term transport of contaminants downstream from the Site was projected for each alternative using the fate and transport model. Figures 9.5.3-1a-c summarize the masses of total PCBs, BaP, and DDE projected to exit the Site during construction for each alternative (Appendix U, Section 4.3 contains similar graphs for DDD and DDT). Because the period of construction varies by alternative, the magnitude of the mass potentially transported downstream in this modeling analysis is largely driven by the duration of the alternative. For comparison, the corresponding mass projected to be transported downstream under the No Action Alternative A during the same time period has been superimposed in Figures 9.5.3-1a-c along with each comprehensive alternative.

Consistent with other evaluation metrics presented in this draft FS, alternatives with the greatest environmental dredging volumes (e.g., Alternatives E-r and F-r) are projected to result in a greater mass of downstream transport of contaminants during construction, compared with the integrated alternatives. The integrated alternatives (particularly Alternatives B-i, C-i, and D-i) are projected to result in a smaller increase in mass exiting the Site. As discussed in Section 6.2.7, the application of rigid barriers or silt curtains is not expected to appreciably improve the protection of alternatives with more removal, and may cause some additional unintended consequences.

Consistent with other evaluation metrics presented in this draft FS, alternatives with the greatest environmental dredging volumes (e.g., Alternatives E-r and F-r) are projected to result in a greater mass of downstream transport of contaminants during construction, compared with the integrated alternatives.

9.5.4 Environmental Impacts Air Pollutant and Greenhouse Gas Emissions

As an additional measure of short-term impacts, air pollutant and GHG emissions were projected for each remedial alternative. This inventory, presented in Appendix Ic, accounts for the major sources of direct emissions resulting from the activities associated with implementation of each potential remedial alternative. The GHG and air pollutant components assessed and the emissions-generating activities evaluated are defined in Section 8.2.6. Table 9.5.4-1 summarizes direct CO_2-eq emissions by alternative. Figure 9.5.4-1 summarizes the relative contribution of CO_2-eq emissions by major component remedial activity.

The mass of CO_2-eq and air pollutant emissions increases with the quantities of removed sediments, volume of sediments disposed of off-Site, and the quantities of capping and similar materials placed, due to the associated increase in energy requirements. These quantities, and thus CO_2-eq and air pollutant emissions, are highest for Alternatives E and F (Table 9.5.4-1). On average, across alternatives, emissions associated with dredging and transportation for upland disposal are each projected to comprise 40 to 50 percent of total emissions, with remaining emissions generally split between capping, transportation of capping/treatment materials, and transportation of diatomaceous earth.

Carbon dioxide equivalent and air pollutant emissions are highest for Alternatives E and F (Table 9.5.4-1).

In order to put the estimated GHG emissions for these remedial alternatives into perspective, several comparison equivalencies are presented in Table 9.5.4-2. This table illustrates the magnitude of other activities that result in emissions equivalent to the estimated emissions from each alternative. Specifically, the number of passenger vehicles that would emit an equivalent quantity of CO_2-eq in one year, the number of barrels of oil consumed that would emit an equivalent amount of CO_2, and the number of homes from which the annual energy use would result in an equivalent amount of CO_2 emitted, are presented.

9.5.5 Time Until Protection Is Achieved – Time to Achieve RAOs

Potentially unacceptable risks are posed solely due to upstream or background levels, and as a result, it is unclear whether some ranges of RGs would be achievable.

This section discusses the time until protection is achieved per the NCP, which is as the estimated time to achieve RAOs. Section 3.2.2 discusses the framework for determining attainment of RAOs by remedial alternatives for this draft FS. The time to achieve RAOs was evaluated by comparing projected COC concentrations in various media (sediment and tissue) for each alternative to numeric criteria such as sediment RGs. Each numeric value used is assumed to represent attainment of "acceptable" risk levels as described in the RAOs above. However, caveats to this evaluation include:

- Potentially unacceptable risks are posed solely due to upstream or background levels, and as a result, it is unclear whether some ranges of RGs would be achievable.
- The sensitivity/uncertainty associated with any particular RG used in the comparison is categorized as large in Section 3.6.

This draft FS uses a range of RGs to evaluate acceptable risk ranges, in accordance with guidance, as well as other factors that help put into context any particular point within that acceptable risk range. As such, attainment of acceptable risk levels for each RAO cannot be simply defined as a single numeric value for each COC.

As discussed in Section 8.2.2, the ranges of potentially acceptable RGs are generally larger than the differences between the projected outcomes of the alternatives. This highlights the difficulty in stating an exact time when RAOs will be attained. The times to achieve RAOs were estimated using modeling projections to estimate the time to achieve a range of RGs and TTLs from Table 8.2.2-1:

- PCBs in sediment
  - EPA's point estimate smallmouth bass RG for PCBs (29.5 ppb)
  - Smallmouth bass RG 95th percentile estimate (95 ppb)
- PCBs in smallmouth bass tissue
  - EPA point TTL (470 ppb)
  - 95th percentile TTL (1,356 ppb)
- BaP in sediment
  - Direct contact EPA point estimate RG >99th percentile (423 ppb)
  - Direct contact 95th percentile RG (2,750 ppb)
- DDE in sediment

- EPA Point RG (3.02 ppb); no sensitivity ranges are available for this contaminant.

Modeling uncertainty (upper and lower bound modeling projections, as described in Appendix Ha, Section 4) was also considered in estimating the time to attain these ranges of RGs. As described previously, the EPA point estimates used in this evaluation represent very conservative points within the overall RG ranges. Higher RG estimates may be equally protective (see Section 3.6 and Appendix E) and consistent with acceptable risk level ranges stated in the NCP.

Table 9.5.5-1 summarizes the ranges of estimated times to achieve RAOs for each alternative by Segment. As discussed previously, the Segment spatial scale is in the approximate middle of the range of potentially relevant RG spatial scales from shoreline half river mile to Site-wide. Based on this summary, there is little difference in the estimated time to achieve RAOs between Alternatives B through F when the entire range of outcomes is considered. For example, in Segment 2 for PCBs in sediments, the mid-range estimate for Alternative B-i indicates a time to achieve RAOs is 28 years, while the time for Alternative F-i is 11 years, which would appear to be a measurable difference between the alternatives. However, the range of times for Alternative B-i is from 2 years to after the end of the simulation (at 45 years) and the range of times for Alternative F-i is 9 to 19 years. Thus, given these ranges, Alternative B-i could actually attain the RAO in a similar timeframe as Alternative F-i.

The overall times to achieve RAOs, based on RG ranges that could represent attainment of acceptable risk levels, often range from 0 to 30 or 45 years depending on the RG selected.

The time ranges in Table 9.5.5-1 also illustrate the importance of EPA decisions with regards to time to achieve RAOs. The overall times to achieve RAOs, based on RG ranges that could represent attainment of acceptable risk levels, often range from 0 to 30 or 45 years depending on the RG selected. The modeling uncertainty also contributes to these time ranges, but not nearly as much as the range of the RGs.

9.5.6 Community Risks and Quality of Life

Alternatives with longer construction durations have larger community quality of life impacts.

Per the NCP, community risk should be considered in comparative evaluations of short-term effectiveness of the alternatives. The primary potentially unacceptable community risk during construction would occur through the short-term water quality, downstream transport, recontamination, and air pollutant impacts discussed above. In addition, “quality of life” during the short-term construction phase of the alternatives is also a consideration. Quality of life generally refers to the human use environment, and the potential for each alternative to impact aesthetics, odor and dust, traffic, noise, commercial navigation, and recreation. These issues are reviewed in detail in Appendix U, Section 4.4 and are summarized below. In general, alternatives with longer construction durations have larger community quality of life impacts.

- **Aesthetics –** Increased visual impacts from remedial construction activities are similar in type to normal activities at the Site. Although the draft FS alternatives assume daytime construction, if the need for nighttime construction were determined during remedial design, there may also be localized light impacts. Impacts would be greater for the longer duration alternatives.
- **Odors and Dust –** Increased diesel emissions from remedial construction activities are also similar to the types of normal activities at the Site. Dredging and potential stockpiling of dredge sediments could produce localized sulfuric or similar (anoxic) odors as well. Increased dust emissions could occur near stockpile, truck, and train loading, and barge unloading areas. Construction of CDFs would likely result in increased diesel and dust emissions in these localized areas. BMPs would likely be incorporated into remedial designs to mitigate or reduce the dust impacts. Impacts would be greater for longer duration alternatives and alternatives that involve more removal and transport of sediments for disposal.
- **Noise –** Increased noise during remedial construction would occur for all alternatives. Although the draft FS alternatives assume daytime construction, if nighttime construction were determined during remedial design, localized noise impacts might have more substantial effects on quality of life. Impacts would be greater for longer duration alternatives.
- **Recreation –** Shoreline recreation at the Site is currently centered around Cathedral Park and other informal localized beach use areas. A variety of water-based (e.g., boating/fishing) recreation occurs throughout the Site including a number of boat launches. Under all remedial alternatives, both water- and select shoreline-based recreational activities in the Site may be temporarily impacted during the construction windows due to construction-related effects noted above as well as safety restrictions that limit use of specific areas during construction. Impacts would be greater for the longer duration alternatives.
- **Traffic –** Increased truck and rail traffic would occur from all draft FS active alternatives, which could result in temporary adverse effects on vehicular traffic conditions and cause additional delays near rail lines within and around the Site. Impacts would likely be greater for alternatives with longer durations. Also, remedial alternatives that include on-Site disposal of a significant percentage of dredged sediment would likely have less impact on traffic than alternatives requiring significant volumes of sediment to be transported off-Site.
- **Navigation –** Construction of the remedial alternatives would temporarily impact commercial marine navigational use of the Site during the construction window. Limits to navigation would occur while remedial construction takes place in specific areas where navigation normally occurs in this window. Also, all active alternatives would increase barge traffic. The longer duration alternatives generally would have a greater impact on navigation both in terms of the number

of navigation areas temporarily impeded and the amount of additional vessel traffic in the Site area.

9.5.7 Potential Impacts to Workers

In order to estimate the number of non-fatal and fatal injuries that may be anticipated over the course of project construction, a review of incident occurrence rate data was utilized in conjunction with the construction operations associated with each alternative to develop construction injury and fatality projections for each comprehensive alternative. Information used to develop the estimates is discussed in Section 8.2.6.

Alternatives F-i and F-r are projected to be between 5 and 10 times more likely to experience a worker fatality than Alternatives B-i, C-i, and D-i.

The incident occurrence rates were combined with the estimated construction durations and associated labor forces for each individual remedial alternative. Table 9.5.7-1 presents the projected results by alternative for construction operations utilizing the incident occurrence estimating procedures described in Section 8.2.6. This table illustrates that shorter duration alternatives and/or alternatives with less removal volume are projected to experience less injury and fatality events. For example, Alternatives B-i, B-r, C-i, C-r, D-i, and E-i all have projected non-fatal incidents less than 13, while the remaining, mostly removal focused alternatives, have projected non-fatal incidents substantially in excess of this rate. Similarly, Alternatives F-i and F-r are projected to be between 5 and 10 times more likely to experience a worker fatality than Alternatives B-i, C-i, and D-i. This is due to longer construction durations resulting in increased work hours for all construction workers. Work hours increase as greater volumes of material are removed, and to a lesser extent, as more area is remediated in place. The majority of the injury and fatality projections are projected to occur during what have been deemed “transportation” operations. Such operations include barge transport, material stabilization, material offloading, and off-Site disposal operations. Incidents associated with these operations typically account for more than half of the projected incidents. Incidents associated with dredging operations (open water dredging, confined dredging, shoreline removal, and residual dredging) combine to contribute the next highest portion of incidents for an alternative. Incidents associated with Site set-up/staging and sediment capping operations make up a minimal portion of projected incidents (typically less than 5 percent). Figure 9.5.7-1 illustrates the results of this analysis, broken down by construction subtask.

9.5.8 Disposal Option Short-Term Effectiveness

Short-term effectiveness of the various disposal options was assessed in terms of environmental impacts, time until protection is achieved, community risks, and impacts on workers. Both upland off-Site and on-Site in-water disposal options are evaluated in this section.

For on-Site in water disposal options, the short-term effectiveness of each option was evaluated in terms of the FS CDF Performance Standards discussed in Section 8.2.4 (EPA 2010e and LWG 2010a and b; Appendix O). The standards are for draft FS purposes only and other equally protective standards could be determined in remedial designs. The evaluation of each disposal option relative to each FS CDF Performance Standard and the full text of the standards are provided in Appendix U, Section 6. These performance standards do not apply to upland off-Site facilities, which are the subject of the next subsection.

9.5.8.1 Upland Off-Site Disposal Options

The issues pertinent to the short-term effectiveness evaluation for upland disposal options are associated with the transportation of sediment from the Site to the disposal facility. The assumed work process for draft FS purposes is that sediment will be dredged mechanically and loaded into barges. Depending on the upland facility selected for disposal, there are two options for transporting sediment from the Site to the upland disposal facility once it is loaded into barges:

1. Transload sediment from barges to rail cars near the Site, transport by rail directly to the landfill, and offload at the landfill for disposal

2. Transload sediment from barges to trucks and transport the sediment from the transloading facility to the landfill by truck.

Potential environmental, community, and/or worker impacts associated with these transportation methods include:

- Release of contaminated solids or water during barge transport
- Release of contaminated solids or water during transload operations
- Release of contaminated solids or water during rail or truck transport
- Physical hazards associated with transportation by truck, rail, or barge
- Air emissions from contaminated sediment and from equipment used to manage sediment

Specific BMPs would be identified in remedial design and used to minimize releases, collisions, and emissions. For example, the decks of barges would be sealed to contain sediments and water, and spill-control equipment would be kept on hand to respond to releases. Secondary containment would be incorporated into the design of transload facilities to capture contaminated materials that may escape from buckets while offloading barges or loading rail cars and trucks. If material is stockpiled at transload facilities, stockpiles will have curbing and sumps to facilitate the collection of runoff. Stockpiles and materials in transit would be managed to control emissions of harmful levels of vapors and dust. Transportation methods would be selected, in part, to minimize the use of fuel and generation of engine exhaust. There is an advantage, relative to short-term effectiveness, to use rail as opposed to truck transport based on the lower chance of accidental collision, reduced impacts on traffic between the Site and the landfill, cost, lower fuel use, and fewer emissions of exhaust gases.

9.5.8.2 Environmental, Community, and Worker Impacts – On-Site Disposal Options FS CDF Performance Standards 17, 21, 22, and 23

FS CDF Performance Standards 17, 21, 22, and 23 address protection of water quality near or within the berm and at the point of compliance during construction and filling activities. Performance Standard 17 specifically addresses protection of water quality during construction of the berm. Performance Standard 21 requires management of CDF filling to avoid overflows and evaluation of unavoidable overflows. Performance Standard 22 addresses protection of water quality during the filling of the CDF. Performance Standard 23 requires closure of surface hydraulic connections between the CDF and adjacent surface water except during periods of approved overflows. Short-term water quality effects related to Terminal 4 CDF and Swan Island Lagoon CDF berm construction are discussed in Appendix Jb (Section 2). In summary, given that the berm would be constructed with suitable materials, water quality impacts would be limited to turbidity and suspended solids and are manageable through operational BMPs.

With regard to potential over-berm flows during filling, for both the Terminal 4 and Swan Island Lagoon CDFs, the likely fill method assumed for draft FS purposes is to place mechanically dredged sediment into the CDF with a high-solids pump using water from within the CDF as the conveyance fluid or mechanical loading over the berm. No effluent would be expected at either CDF during filling by this method. Therefore, impacts to water quality due to overflow discharge are not expected under the assumptions of the draft FS technologies. Appendix Jb (Section 2) includes additional evaluations considering a hydraulic dredging and placement scenario and discusses how such an approach could be made compliant with the FS CDF Performance Standards. Further, other performance standards may be devised in remedial design and the evaluations in Appendix Jb (Section 2) indicate that CDF filling could be conducted under a variety of scenarios that would likely be protective.

With regard to berm porewater quality, modeling results discussed in Appendix Jb (Section 2) demonstrate that water quality criteria would likely be met in the Terminal 4 berm porewater without dilution in the water column. Short-term water quality in the berm has not been modeled for the Swan Island Lagoon CDF, although the results are expected to be similar to those for the Terminal 4 CDF since the construction and filling techniques are also similar.

For the Swan Island Lagoon CAD, the berm would most likely be constructed entirely underwater, although more logistically complicated ways of filling a CAD site in an isolated area such as Swan Island Lagoon could be devised. Short-term impacts related to berm construction are anticipated to be controllable through operational BMPs, particularly because this facility is isolated from the main channel. Unlike with the CDF options, the disposal site would most likely not be isolated from Swan Island Lagoon surface water during filling for the CAD, since the crest of the berm would be submerged in most potential design scenarios. Short-term water-quality impacts related to filling the CAD would be minimized with BMPs to the extent possible, including controlling the rate and method of placement of contaminated sediment in the disposal unit. The location of the facility, isolated from the main channel of the river, would help limit the impacts from filling the Swan Island Lagoon CAD. If Swan Island Lagoon CAD is selected as a disposal option, the remedial design will need to consider the exact parameters for minimizing water quality impacts during filling consistent with any future remedial design performance standards.

For the Arkema preliminary design one- and two-berth options, an impermeable cofferdam design would be used instead of a berm for sediment containment. The conceptual plan for the CDF is described in detail in the *Preliminary CDF Screening Evaluation* (Arcadis 2010). Controlling short-term contaminant transport during CDF construction would be addressed in design and may include the use of silt curtains, turbidity controls, and mitigation measures. The preliminary conceptual design anticipates that there will be no effluent from the CDF during filling. Unlike the Terminal 4 and Swan Island Lagoon facilities, the Arkema CDF would be located in the main channel of the Willamette River. BMPs would be used to minimize the potential for releases of contaminants from outside the CDF during filling.

9.5.8.3 Environmental Impacts – On-Site Disposal Options – FS CDF Performance Standard 24

Performance Standard 24 addresses protection of fisheries and wildlife prior to the closure of the CDF. For both the Terminal 4 and Swan Island Lagoon CDF options, reasonable attempts would be made to remove fish from the CDF before and/or following berm closure. During the initial stages of the filling operations, the water would be sufficiently deep to protect other wildlife from the contaminated sediments. When the water depth in the CDFs becomes shallow enough to pose a potentially unacceptable risk, a thin layer of suitable sand would likely be placed over the contaminated sediment between filling seasons. For the Swan Island Lagoon CAD, the design would consider options for limiting potential fish exposure to contaminated sediment, potentially through the use of engineering barriers and BMPs. An engineering barrier could include the installation of a temporary fish curtain and physical removal of fish prior to placing sediment in the CAD. The Arkema CDF preliminary concept would isolate the contaminated sediment from fish and wildlife. The EE/CA for the Arkema CDF will further address this performance standard (Arcadis 2010).

9.6 IMPLEMENTABILITY

Section 6 presents a detailed evaluation of the implementability of each of the remedial technologies considered for the Portland Harbor FS. Technologies identified as implementable and effective were carried forward and used as part of the remedial alternatives presented in Section 7. Per the NCP and FS guidance (EPA 1988, 2005a), this section evaluates the implementability of the comprehensive alternatives, focusing on the following elements:

- Technical feasibility
- Administrative feasibility
- Availability of services and materials

Per Section 8.1, additional NCP factors associated with each of these elements are also evaluated as detailed below. In general, the ease of implementation decreases as the alternatives become larger and more complex, involving more area, increasing volumes, and remedial components as detailed below. Duration is a good overall surrogate for the implementability issues associated with any given alternative.

The ease of remedy implementation decreases as the alternatives become larger and more complex (e.g., involving more area, increasing volumes, and remedial components). Therefore, duration is a good overall surrogate for the implementability issues associated with any given alternative.

9.6.1 Technical Feasibility

NCP and FS guidance (EPA 1988, 2005a) guidance identifies the following technical feasibility criteria:

- Ability to construct – difficulties and uncertainties associated with construction
- Reliability – likelihood that technical problems will lead to schedule delays
- Ease of undertaking additional remedial action – what future remedial actions could be anticipated and how difficult would it be to implement, if necessary
- Ability to monitor – are there exposure pathways that cannot be monitored adequately and that would pose a potentially unacceptable risk should monitoring be insufficient.

Ability to Construct. Section 6 concluded that the technologies carried forward and used to build the alternatives are implementable. As noted in Section 8.2.2, an important implementability issue that applies to all alternatives is integration with ongoing Site navigation and other uses, which is built into all the remedial technology assignments made to develop alternatives for draft FS purposes. Similarly, as part of any future refinements or changes to the technology assignment assumptions for the draft FS, remedial design efforts will also have to fully consider Site navigation and other uses.

As part of any future refinements or changes to the technology assignment assumptions for the draft FS, remedial design efforts will also have to fully consider Site navigation and other uses.

Alternatives E and F have the largest amounts of dredging and capping and the longest durations. Therefore, they will be the most difficult to implement.

Despite all alternatives being implementable, the larger and more complex the project, the more difficulties and uncertainties will arise with implementation of that alternative. Table 9.6.1-1 summarizes the scope of dredging and capping for each alternative. Alternatives E and F have the largest amounts of dredging and capping and the longest durations. Therefore, they will be the most difficult to implement. Because it involves no construction, MNR has no effect on the ability to construct. Therefore, more MNR and less active remedial technologies in an alternative mean the alternative is generally easier to construct.

To provide perspective on the remedial alternatives evaluated in this draft FS, the following large-scale, contaminated sediment dredging and/or capping projects in the United States are either completed, partially completed, or will be initiated soon:

- Fox River, Wisconsin – 4,100,000 cy of dredging and 350 acres of capping (approximately 50 percent complete with dredging; approximately 7 percent complete with capping)
- Hudson River, New York – 2,650,000 cy of dredging (approximately two seasons of dredging complete)
- Onondaga Lake, New York – 2,000,000 cy of dredging and 421 acres of capping planned (dredging begins in 2012)
- Ashtabula River, Ohio – 640,000 cy of dredging (completed 2008)
- Sitcum Waterway, Washington – 428,000 cy of contaminated sediment dredging (completed 1994)

In addition, EPA recently released the Proposed Plan for the Lower Duwamish River, Washington, which includes 750,000 cy of dredging, 47 acres of capping, and 53 acres of EMNR or in situ treatment.

A number of other elements further complicate the remediation of the Lower Willamette River as compared to the examples presented above:

- **Large Number of PRPs**. Portland Harbor has multiple PRPs. Numerous PRPs could potentially be actively involved in remedial design and construction at the Site. Coordination between parties will make construction more difficult than a comparable sized project with one or two responsible parties. The larger projects listed above had relatively few responsible parties involved (typically one or two).
- **Limited Construction Window**. The limited construction work window at the Site will not only extend construction further but will make competition for resources much more intense. The larger projects listed above typically had at least 6- to 7-month construction windows with only weather-related limitations. As discussed in Section 7.5, the action alternatives assume approximately three

projects underway in each annual construction window until work is complete. For this to be implementable, a very high level of coordination between EPA, PRPs, contractors, and other stakeholders will be needed. As a consequence, the actual durations of the alternatives may be significantly longer than assumed for the purposes of this draft FS.

- **Multiple Disposal Sites**. With the exception of Alternative B-i, all of the other action alternatives would require more than one disposal facility. At least two disposal facilities would be needed under Alternatives B-r, C-i, and D-i; at least three disposal facilities would be needed under Alternatives C-r, D-r, and E-i; and at least four different disposal facilities would be needed under Alternatives E-r, F-i, and F-r. The other large-scale projects listed above involve only a single disposal facility to handle all of the dredged sediment. Multiple disposal sites managed by different contractors coupled with multiple dredging contractors working the different SMAs will increase the likelihood of conflicts and/or claims.
- **Dredging Method**. Because of multiple dredge sites at varying distances from the CDFs, FS CDF Performance Standards producing effluent restrictions and the use of upland landfills, the use of hydraulic dredging would be limited. Most of the larger sediment dredging projects listed above involved the use of hydraulic dredging.
- **Offloading Facilities**. The larger volume alternatives may require multiple offloading facilities in order to keep the project on schedule. Multiple offloading facilities add to the complexity of the project.

All of these elements can be overcome with good engineering and planning; however, they increase project complexity compared to projects without these complicating factors.

Reliability. The remedial technologies proposed in the different alternatives are proven technologies with a high degree of reliability. However, the larger the scope of the alternative, the increased likelihood of an active technology having implementation issues during construction. As the area of MNR increases the likelihood of isolated areas of reduced effectiveness would also increase. Table 9.6.1-1 summarizes the scope of each alternative.

Ease of Undertaking Additional Remedial Action. If one of the remedial technologies is not successful, additional remedial actions would be required. Additional remedial actions in areas of MNR or dredging would be relatively easy. For other technologies, the ease of additional required remedial actions would depend on the action required. Placing additional cap or armor material over capped or in situ treatment areas would generally not be difficult. Removal of capped or in situ treated areas would generally not be difficult, although additional material would need to be disposed.

Ability to Monitor. Monitoring and contingency implementability issues are discussed in Appendix T, Section 4. Implementability considerations include:

- It will likely be difficult to assess the effects and potential contingency actions related to upstream and upland ongoing sources, if any are not adequately controlled in the future. Thus, objective assessments of the achievability over time of selected remediation goals will be needed. This may need to be supported by additional monitoring related to these sources to define achievable RGs.
- RG and cleanup level uncertainty will need to be considered in assessing remedy performance using monitoring data. Thus, although a specific RG or cleanup level may be selected by EPA, the monitoring and contingency decisions should allow for quantitative assessments of the uncertainty ranges associated with any particular value.
- EPA will need to determine methods to administer SMA-specific versus Site-wide monitoring and which parties participate in one or both. This applies to both monetary participation as well as physical implementation of monitoring efforts, laboratory analyses, production of monitoring reports, etc.
- EPA will need to determine when the baseline sampling event should occur and who should conduct it. Per Appendix T (Section 3.4), the LWG recommends that baseline monitoring be conducted sometime after the ROD is finalized so that baseline data are not out of date by the time the long-term monitoring begins.
- EPA will need to determine the integration of long-term monitoring with institutional controls (as well as coordination with other parties involved in institutional controls) and technology-specific operations/maintenance monitoring and compliance.
- EPA will need a contingency framework that has a clear process and hierarchy or steps of actions that can be applied to all monitoring outcomes. Appendix T, Section 4 contains the LWG's recommendations for such a framework.

9.6.2 Administrative Feasibility

EPA guidance (1988, 2005a) encourages identification of potential implementability issues associated with administration of the remedial action be addressed in the draft FS. Administrative implementability is defined as:

- "Activities needed to coordinate with other offices and agencies (e.g., obtaining permits for offsite activities or rights-of-way for construction)"
- "Ability to obtain approvals from other agencies."

Overall, the number of parties involved and the amount of administrative logistics increases as the alternatives get larger and include additional remedial construction components. The following administrative logistics related to both of the above guidance factor have been identified that pertain to some or all of the comprehensive alternatives:

- Coordination with EPA's Water Quality section, and USACE as necessary, to agree on steps necessary to avoid and minimize adverse impacts as well as to agree on compensatory mitigation for unavoidable impacts under CWA section 404(b)(1). As discussed in Appendix M, the LWG recommends that the 404(b)(1) analysis be undertaken on a programmatic basis. As discussed in Appendix M, the alternatives with larger footprints (E-i, E-r, F-i, and F-r) will have greater mitigation requirements.
- Consultation by EPA on a Site-wide biological opinion for its preferred remedy with the Services (NMFS and USFWS). The biological opinion will identify long-term and short-term minimization and avoidance elements that will be necessary to avoid jeopardy with respect to the selected remedy and provide a framework so that the individual remedial action projects proceeding after the ROD is issued may efficiently proceed through the ESA consultation process either pursuant to the Site-wide biological opinion or through tiered individual informal or formal consultations.
- To the extent viable restoration projects overlap with areas of remedial action, coordination of the two actions will likely be required. As discussed above, greater coordination will likely be required with comprehensive Alternatives E and F (both integrated and removal focused options), which are associated with the largest footprints.
- All alternatives that have capping options will require DSL involvement. Alternatives with more capping will have more coordination with DSL.
- Coordinate and obtain RNAs from the Coast Guard. Alternatives with more capping, EMNR, or in situ treatment will require more RNA development and administration.
- EPA will need to administer SMA-specific reviews and requirements associated with institutional controls as well as a system for making changes to institutional controls where parties are willing to conduct additional or different cleanups as appropriate to the requested change in institutional controls.
- Under the assumptions of the alternatives, with approximately three SMA-specific projects being simultaneously constructed each annual construction window, EPA will need to administer and coordinate a large number of simultaneous efforts in order to keep remedial activities on the assumed pace. This is true both in terms of the need for a continual "train" of reviews and approvals of remedial designs so that multiple projects are ready for construction each year, as well as construction oversight each season.
- EPA will need to administer the long-term monitoring and contingency plan. Given that all alternatives have a long-term monitoring program, the logistical differences between the alternatives is likely minimal.

- Coordination with FEMA and affected municipalities on flood elevation requirements/mitigation, if necessary. Draft FS flood modeling of the alternatives indicates this would be unlikely to be necessary for any of the alternatives.
- Coordination with DEQ on upland source control issues including a determination that groundwater and stormwater source controls are adequately completed for the sediment remedy to proceed.
- Similarly, riverbank remedies will need to be integrated between upland source controls and sediments remedies, which will overlap. A clear, consistent, and repeatable system is needed for delegation of lead agencies, responsibilities, and determinations in the riverbank area. Alternatives that require remediation to lower RALs will likely have larger areas of bank remediation and more overlap with upland source controls in these areas.
- Coordination with Oregon Department of Health on fish consumption advisories. Due to long-term nature of all alternatives, there is likely minimal difference between the alternatives.

9.6.3 Availability of Services and Materials

Per the NCP, availability of services and materials specifically addresses:

- Availability of adequate off-Site treatment, storage capacity, and disposal capacity and services
- The availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources
- The availability of services and materials
- Availability of prospective technologies

Each of these factors is considered in the discussion below.

Disposal capacity is available for all alternatives, although the alternatives with higher dredge volumes will require more and/or larger in-water and upland disposal facilities. Disposal site implementability is discussed in more detail below. Materials, labor, and equipment for all of the remedial technologies are fairly common and available or can be made available in the Portland Harbor area. The only unique materials that are available but not as common are the materials necessary for in situ treatment and active caps. They will likely need to be produced outside of the region and shipped to the area. As with the other implementability discussions, a larger scope of the alternative, will result in a larger strain on materials, labor, and equipment resources (see Table 9.6.1-1). As detailed in Section 7.5, the alternative durations assume that approximately three projects will be operating simultaneously in each and every annual construction window until all work is complete. This will likely tax the capacity of regionally available qualified contractors and equipment, and these projects will compete for these resources with ongoing navigation dredging/construction within Portland Harbor each year. Alternatives C-r, D-r, E-i, E-r, F-i, and F-r will likely require equipment from outside of the region (Puget Sound or San Francisco Bay) to accommodate the larger scopes of work. The other alternatives likely can be performed with locally available equipment, but may still strain these local resources given the assumed number of projects each season. All of the technologies included in the alternatives are generally available because they have widespread historical use for sediment remediation (e.g., dredging, capping, disposal, MNR, and EMNR). In situ treatment is the most innovative of the technologies, but given that AC or similar technologies are widely used in other industries, this technology is also readily available.

9.6.4 Disposal Site Implementability

Each disposal alternative was evaluated with respect to the implementability factors noted above. Also, as discussed in Section 8.2.4, the implementability of each in-water disposal option was evaluated in terms of the FS CDF Performance Standards. The performance standards are for draft FS purposes only and other equally protective standards could be determined in remedial designs. The results of this evaluation are presented for each disposal option and each implementability performance standard in Appendix U, Section 6. Some performance standards address similar issues and are therefore discussed concurrently in the subsections below.

The FS CDF Performance Standards do not apply to the upland disposal options. The factors affecting the implementability of upland disposal are waste acceptance criteria of the landfills, the availability of transportation from the Site to the landfills, and the ability to site, permit, and construct the necessary transload facility or facilities. Several landfills are available that can accept sediment from the Site for disposal. As discussed in Section 6.2.9, the Columbia Ridge landfill was used as a surrogate for the upland disposal sites for the detailed evaluation of remedial alternatives. The Columbia Ridge landfill can accept nearly any of the sediment from the Site and it is served by rail for efficient shipment of sediment. For maximum efficiency, the transload facility would be located in Portland Harbor, near the dredging sites. As noted in Section 6.2, several potential sites exist in the harbor that could be built out as transload facilities. Sediment would be offloaded from barges and transferred to rail cars for transportation to the landfill. The transload facility would need a transfer station permit issued by the DEQ and may require other regulatory approvals. These permits have been obtained for Portland Harbor early removal actions, and this requirement is not expected to significantly impede the implementation of remedial action.

One specific CAD or CDF implementability issue is that multiple parties/sources would contribute to the overall disposal volumes for such facilities. Unlike commercial upland facilities that exist regardless of this project, and could take sediments as an incremental waste stream to their existing operations, a CAD or CDF would need to be constructed by one party based on assumptions and in anticipation of sediments for disposal at the facility. This includes the assumption that sufficient quantities of sediments from future cleanup projects by other parties will be available at high enough market rates to warrant a very significant investment and undertaking by that one party to make the construction of the CAD or CDF viable. Unlike some other larger national projects with one or two cleanup parties, there is a significant and unique market risk for CAD or CDF facilities for this project given that the total volume of sediments to be disposed will likely be split between so many different parties and SMA sources.

Another important implementability factor for the Swan Island Lagoon CAD or CDF is that building such facilities will need to be coordinated with multiple shoreline landowners in this area. It will be necessary to obtain agreements from adjacent property owners and/or acquire property adjacent to the proposed facility footprints. Further, existing shoreline uses may either need to be eliminated, relocated, or altered to be compatible with any new disposal facility and owner agreements on these changed uses would be needed as well.

9.6.4.1 Technical Feasibility – FS CDF Performance Standards 8 and 26

FS CDF Performance Standards 8 and 26 involve minimizing water flow into the CDF. Performance Standard 8 states that water flow moving into and out of the CDF should be minimized, including preventing or restricting preferential groundwater flowpaths. Performance Standard 26 specifically prohibits the discharge of stormwater into the CDF. Utility lines are not allowed under or within the fill prism and none have been identified for any of the potential disposal sites. For the Terminal 4 CDF, five stormwater outfalls currently empty into the potential CDF site, all of which would be relocated prior to any disposal construction activities. For the Swan Island Lagoon CDF and CAD, there are no known utilities under the shared footprint of these disposal options. There are multiple stormwater outfalls that discharge into the Swan Island Lagoon area where a CDF would exist that would need to be rerouted; specific requirements for this action would be assessed in design. Likewise, any preferential flowpaths entering the fill prism of the Swan Island Lagoon CAD would be relocated, details of which would be addressed in design. Within the fill prism of the Arkema CDF preliminary design, there is a discharge pipe present from the groundwater remediation system located on the former Rhône Poulenc site, as well as inactive Rhône Poulenc outfalls. Details of potential impacts and proposed actions needed to minimize water movement through the CDF will be addressed in the EE/CA. The FS CDF Performance Standards are relatively general for these issues. Thus, for all the potential disposal sites, more refined and site-specific performance standards will likely need to be determined in remedial design.

9.6.4.2 Administrative Feasibility

9.6.4.2.1 FS CDF Performance Standards 7 and 13

FS CDF Performance Standards 7 and 13 involve minimizing physical intrusion into United States waters and having no impact on flood storage following disposal construction. The Terminal 4 and Swan Island Lagoon CDF/CAD disposal options would be built within the footprint of an existing slip that is not part of the primary waterway of the Willamette River. The Arkema CDF preliminary design would extend into the primary waterway, but not into the navigation channel.

Flood modeling was conducted for each of the alternatives, which include various combinations of on-Site disposal options as well as various amounts of capping. As discussed in Section 9.2.2, all of the alternatives except the No Action Alternative A had maximum projected increases in water surface elevation greater than the FEMA requirements, but these rises were well within the model's precision, and therefore, are considered to be negligible and not significantly different between alternatives. Additional evaluations and/or actions (described in Section 9.2.2) would need to be taken in remedial design for any in-water disposal facility to fully demonstrate compliance with the ARAR.

9.6.4.2.2 FS CDF Performance Standard 18

Performance Standard 18 requires the removal of fish, to the extent practical, from the CDF prior to placement of dredged material in order to minimize potentially unacceptable risk to fish and wildlife. For the Terminal 4 and Swan Island Lagoon CDF, a plan would be developed in design to remove sensitive species from the fill prism before sediments are placed. Because the Swan Island Lagoon CAD is subaqueous, fish removal is more difficult; however, in design there may be a plan to attempt some level of fish removal effort or placement of a permeable fish barrier to deter fish from entering the construction area. For the Arkema CDF preliminary design option, this performance standard will be addressed in the EE/CA for this SMA.

9.6.4.2.3 FS CDF Performance Standard 20

Performance Standard 20 requires the establishment of sediment acceptance criteria for the CDF. It further requires that the only material allowed in the CDF will be approved by EPA. Sediment acceptance criteria were developed for the Terminal 4 CDF and are identified in the project's Design Analysis Report. Sediment acceptance criteria will be developed for the other in-water disposal sites and submitted to the EPA for review if the selected remedy incorporates those disposal options.

9.6.4.2.4 FS CDF Performance Standard 28

Performance Standard 28 requires the provision of financial assurance for the development, closure, long-term monitoring, mitigation (as needed), and contingencies. Financial assurance can be provided in a variety of ways and the methods of assurance would likely be highly related to the type of entity involved in construction and operation of the disposal site. Cost estimates would be developed for these items in remedial design and financial assurance would be provided as part of project development.

9.6.4.2.5 FS CDF Performance Standard 29

Performance Standard 29 requires the implementation of institutional controls to prohibit activities that would expose confined sediment or increase the mobility of contaminants from the confined sediment. Specific controls that are required include those to prevent disturbance of the sediment, prevent stormwater infiltration, prevent the installation of groundwater extraction wells, and restrict future development to limit the depth of foundations to no deeper than 3 feet above the upper surface of the confined sediment.

These institutional controls would be imposed on any of the in-water disposal options that are incorporated into the selected remedy.

For the Terminal 4 60 percent design submittal, the EPA clarified restrictions to future development improvements for the Terminal 4 CDF in a meeting with the Port of Portland in April 2010 as documented in the Attachment 2 of the Long-Term Groundwater Modeling Results Memorandum in Appendix A of the Design Analysis Report (Anchor QEA 2011c). Amendments to Performance Standard 29 include a provision that installation of piles driven through the contaminated sediment zone is not allowed without further analysis and EPA approval, and evaluation of stormwater infiltration facilities would require further analysis and EPA approval.

9.6.4.3 Availability of Services and Materials – Performance Standard 19

Performance Standard 19 requires that acceptable materials are used for construction of the CDF. EPA required that the materials specified for the McCormick & Baxter sediment cap be used as the model for developing the cost estimate for construction of the CDFs. For the purposes of this draft FS, a range of suitable cover materials were used as the basis for that portion of the cost estimate. For the Terminal 4 and Swan Island Lagoon CDF and Swan Island Lagoon CAD, it is expected that the cover design would meet this performance standard. For the Arkema CDF preliminary design option, this performance standard will be addressed in the EE/CA for this SMA.

9.7 COST

Costs were estimated for the different alternatives following methods described in Section 7.5 and Appendix K. Per the NCP, capital costs, including both direct and indirect costs, annual operation and maintenance costs, and net present value of capital and operations/maintenance costs are included in the estimates. Uncertainties in some of the select elements of the cost estimates were accounted for as follows:

- **Depth of impacted sediment in inconclusive cores**. Some of the analyzed cores still had impacted sediment in the bottom-most sample. Therefore, the actual depth of impacted sediment in such cases is unknown. To account for this uncertainty, an additional depth (1 to 3 feet depending on the specific circumstances) was added to the depth of the core when determining the depth of impacted sediment.
- **Dredge volume**. An EPA-directed multiplier of 1.5 to 2.0 times the NV was used to estimate the final dredge volume (see Section 5.10). This multiplier accounts for the following uncertainty factors:
  - Overdredge volumes necessary to ensure removal of the target sediments
  - Dredge volumes associated with the transition slopes between deep and shallow cuts and around the dredge perimeter

  - Volume creep associated with going from limited data at the FS level to more SMA-specific data available at the design level
  - Dredge volumes associated with a single residual dredge pass after initial cuts are made
- **Disposal location**. It is difficult to project the final disposal location for sediments removed from the different SMAs during the draft FS. Therefore, the cost analysis evaluated disposal of the sediments within an in-water CDF for the lower cost estimate to disposal in an upland landfill for the upper cost estimate.
- **Impacted habitat acreages and mitigation costs**. Two different methods were used to determine the possible mitigation requirements for each alternative (see Appendix M, Attachment 1 for more detail). To account for the uncertainty in methods, the low and high acreages estimated from each method were used. If a habitat credit was calculated by either method, the dollar value was set to zero—no monetary credit was given to the remedial alternative. The cost of mitigation debits is also an uncertainty at the time. For instance, on-Site mitigation creation will have a different cost than off-Site mitigation. Therefore, a low and high cost range was used to encompass the possible cost ranges.

Table 9.7-1 presents the estimated cost ranges for each alternative and Figure 9.7-1 graphically presents the data. These costs are net present value costs using a discount factor of 2.3 percent, per EPA guidance (EPA 2000b) and the estimated construction duration and long-term monitoring, maintenance, and institutional control schedule.

As can be seen in the table and figure, as the scope and duration of the project increases, the cost also increases. Figure 9.7-2 presents a stacked bar showing the different components of the total costs. The estimated incremental costs for Alternative F (both integrated and removal focused options) are disproportionally larger than the increments between the other alternatives. Alternatives F-i and F-r are estimated to cost nearly two times more than the respective Alternatives E-i and E-r and approximately five times more than the respective Alternatives B-i and B-r.

> *The estimated incremental costs for Alternative F (both integrated and removal focused options) are disproportionally larger than the increments between the other alternatives. Alternatives F-i and F-r are estimated to cost nearly two times more than the respective E-i and E-r Alternatives and approximately five times more than the respective B-i and B-r Alternatives.*

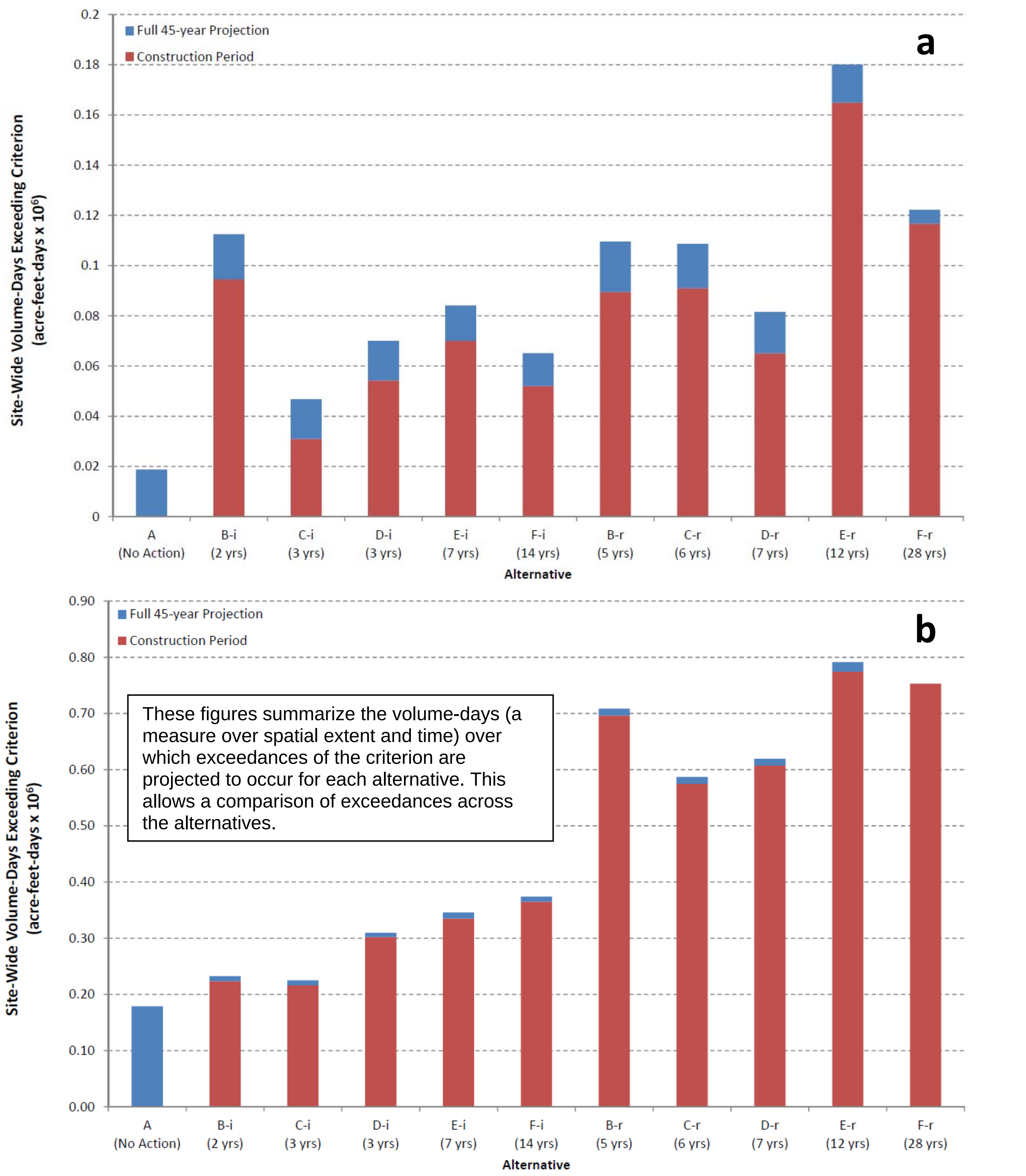
9.8 CONCLUSIONS

The primary findings of the comparative evaluation are:

- All of the alternatives provide overall protection of human health and the environment over the long term, with the exception of the No Action Alternative A.

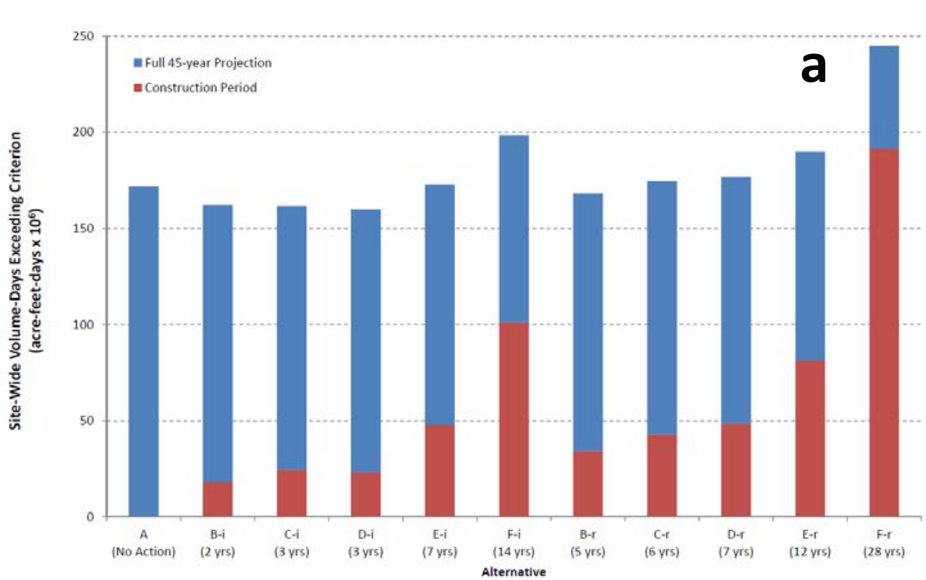
- The primary differences in overall protectiveness achieved by the comprehensive alternatives are related to the extent and duration of shorter term changes in potentially unacceptable risks that occur during remedy implementation.
- The alternatives from A through F involve progressively larger areas and volumes and durations of remediation, and as a result, involve progressively more impacts, particularly for Alternative E and F including:
  - Longer times to achieve the WQS/NRWQC and magnitudes of water quality impacts
  - More downstream and off-Site transport of contaminants
  - Greater air pollution and GHG emissions
  - Greater community quality of life impacts (aesthetics, odor and dust, traffic, noise, and impediments to commercial navigation and recreation)
  - Greater number of work accidents and higher chance of worker death (e.g., more than one in five chance of a worker death with Alternative F-r)
- As compared to the integrated (i) alternatives, the removal focused (r) alternatives have higher amounts of all these impacts because they have greater volumes and durations. The removal focused alternatives have particularly increased construction-related releases, water quality impacts, and downstream transport of contaminants due to resuspension and residuals.
- The integrated alternatives result in more acreage being innovatively treated through in situ treatment using AC (or similar treatment agents).
- The alternatives with the largest footprints (E and F) and removal focused options, which involve greater volumes and durations, also have much greater potential implementability issues across a range of feasibility factors as compared to the alternatives with smaller footprints (Alternatives B, C, and D) and the integrated alternatives.
- The alternatives with larger footprints (E and F) and removal focused options, which involve greater volumes and durations, have much higher costs than the alternatives with smaller footprints (Alternatives B, C, and D) and the integrated alternatives. Alternatives F-i and F-r are estimated to cost approximately five times more than the respective Alternatives B-i and B-r.

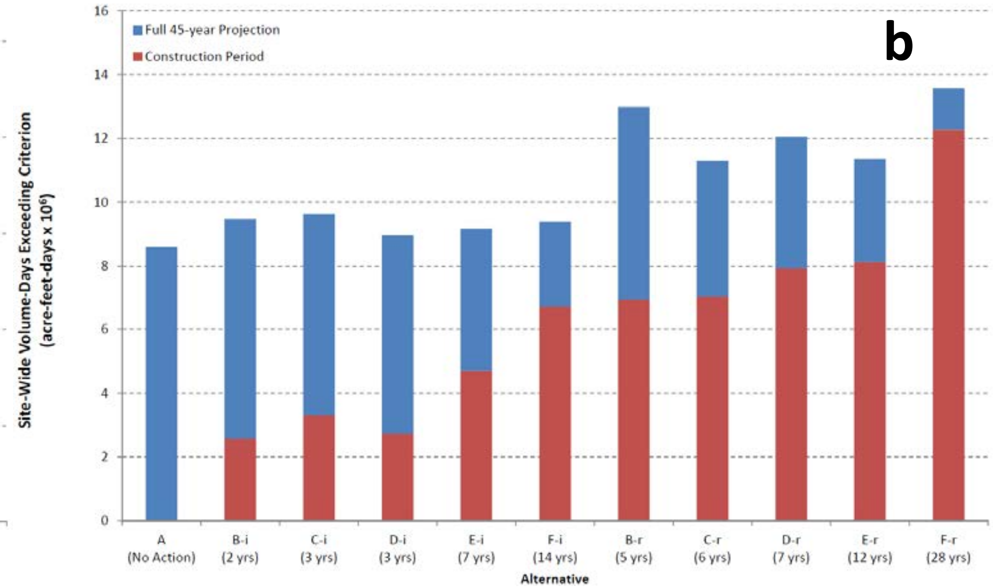
As a result, the smaller integrated alternatives that have a combination of dredging and in-place remediation compare favorably to the larger and removal focused alternatives, per the NCP criteria.



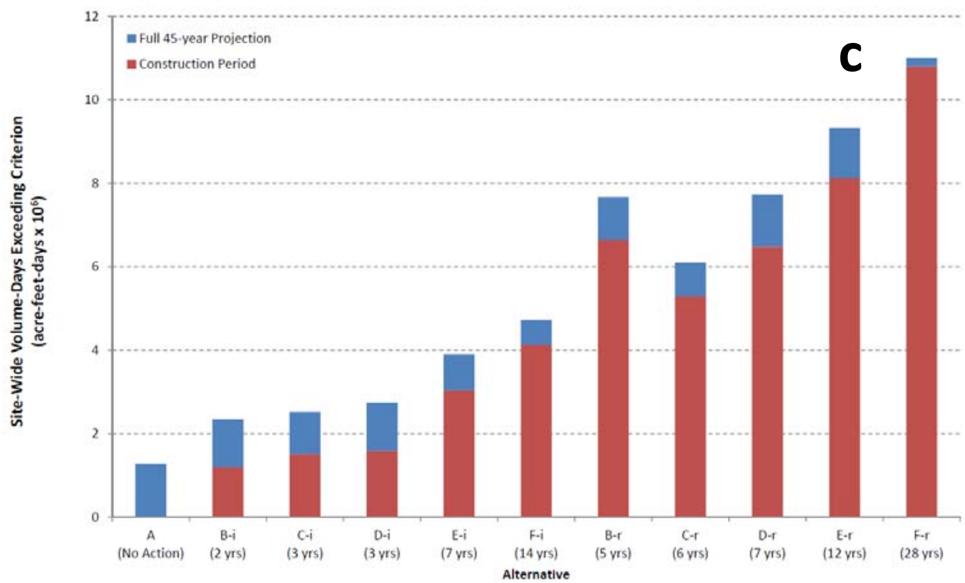
Note: Duration of construction period for each alternative shown in parentheses.

Figure 9.2.1-1a-b
Portland Harbor RI/FS
Draft Feasibility Study
a. Projected Volume-Days Exceeding Total PCB Maximum Contaminant Level (0.5 µg/L)
b. Projected Volume-Days Exceeding BaP Maximum Contaminant Level (0.2 µg/L)



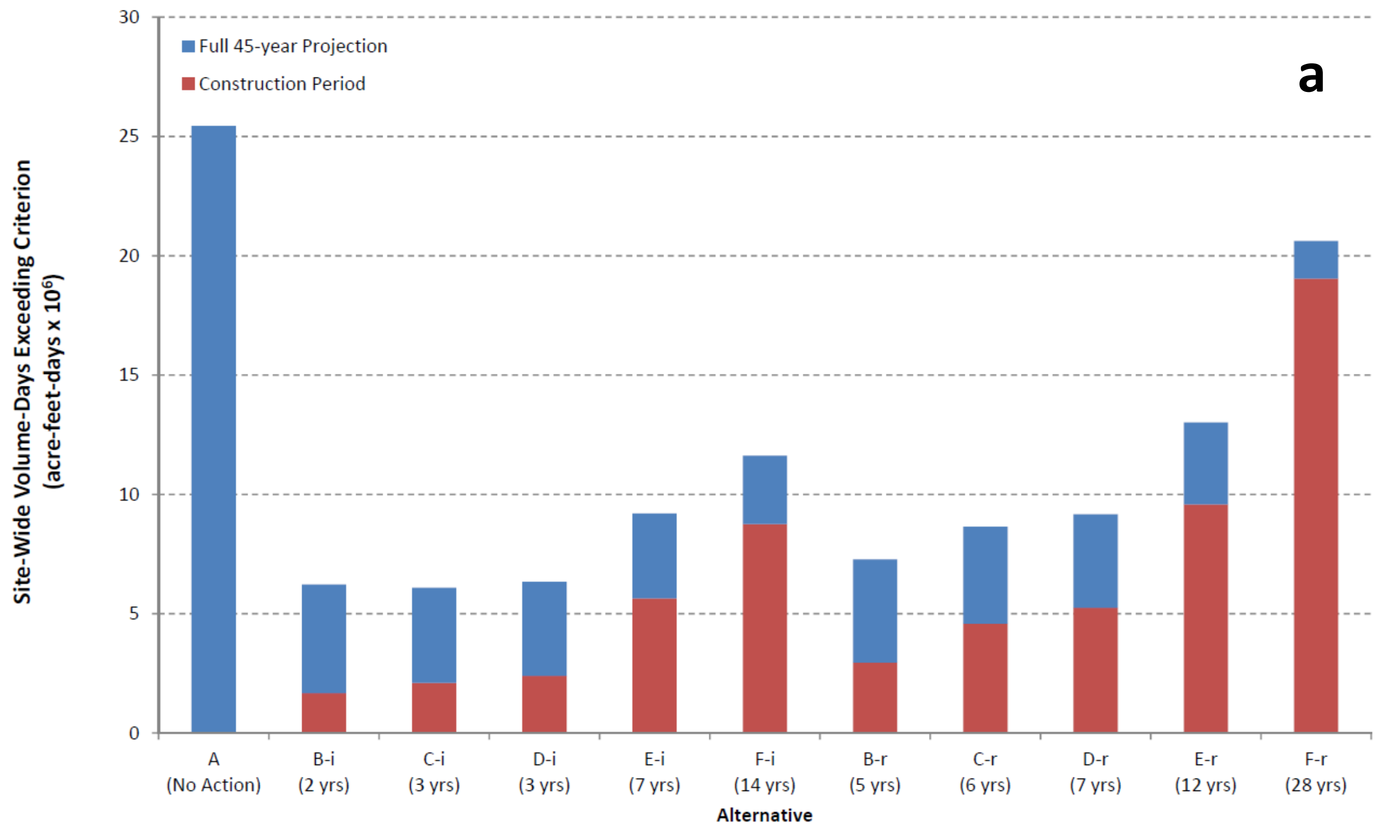


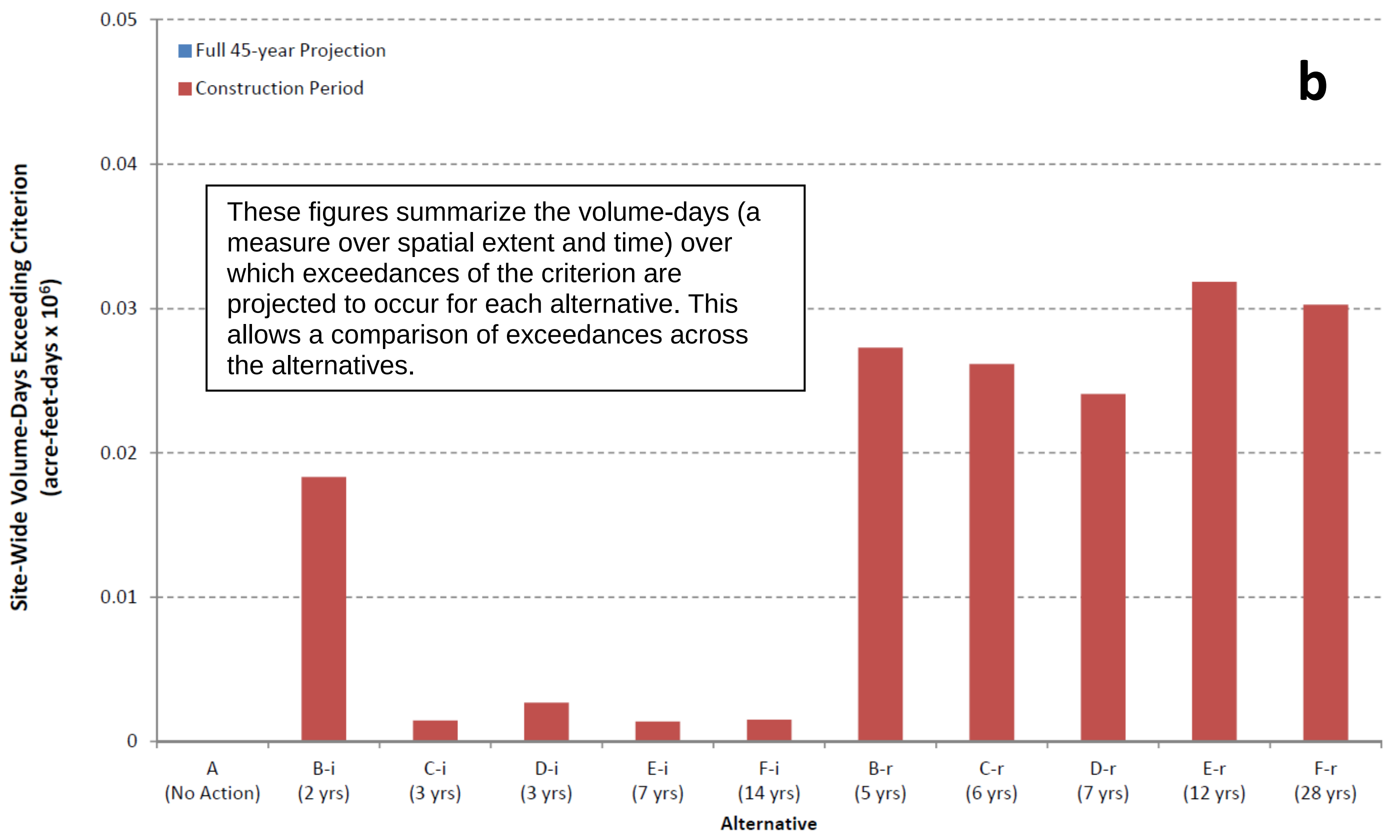
These figures summarize the volume-days (a measure over spatial extent and time) over which exceedances of the criterion are projected to occur for each alternative. This allows a comparison of exceedances across the alternatives.



Note: Duration of construction period for each alternative shown in parentheses.

Figure 9.2.1-2a-c
Portland Harbor RI/FS
Draft Feasibility Study
a. Projected Volume-Days Exceeding Total PCB Surface Water Background Value (0.00039 µg/L)
b. Projected Volume-Days Exceeding BaP Human Fish Consumption Water Quality Standard (0.018 µg/L)
c. Projected Volume-Days Exceeding Total DDD Human Fish Consumption Water Quality Standard (0.00031 µg/L)





Note: Duration of construction period for each alternative shown in parentheses.

Figure 9.2.1-3a-b
Portland Harbor RI/FS
Draft Feasibility Study
a. Projected Volume-Days Exceeding Total PCB Chronic Aquatic Life Water Quality Standard (0.014 µg/L)
b. Projected Volume-Days Exceeding Total PCB Acute Aquatic Life Water Quality Standard (2 µg/L)

This figure provides an example of the spatial extent of water quality exceedances for this criterion. Alternative A is used as an example because it shows the typical locations where most of the exceedances occur for all the alternatives.

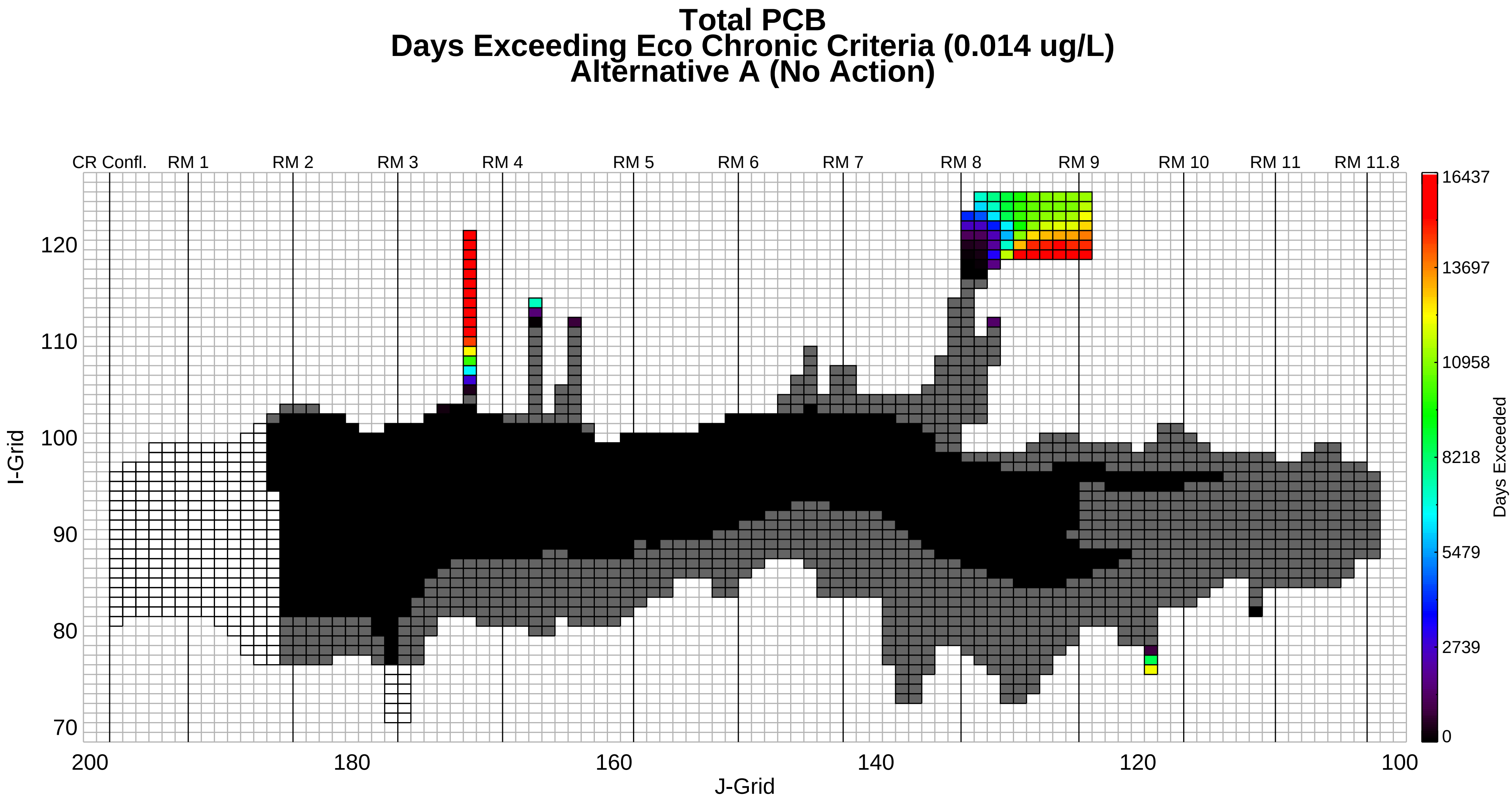


Figure 9.2.1-4

Portland Harbor RI/FS

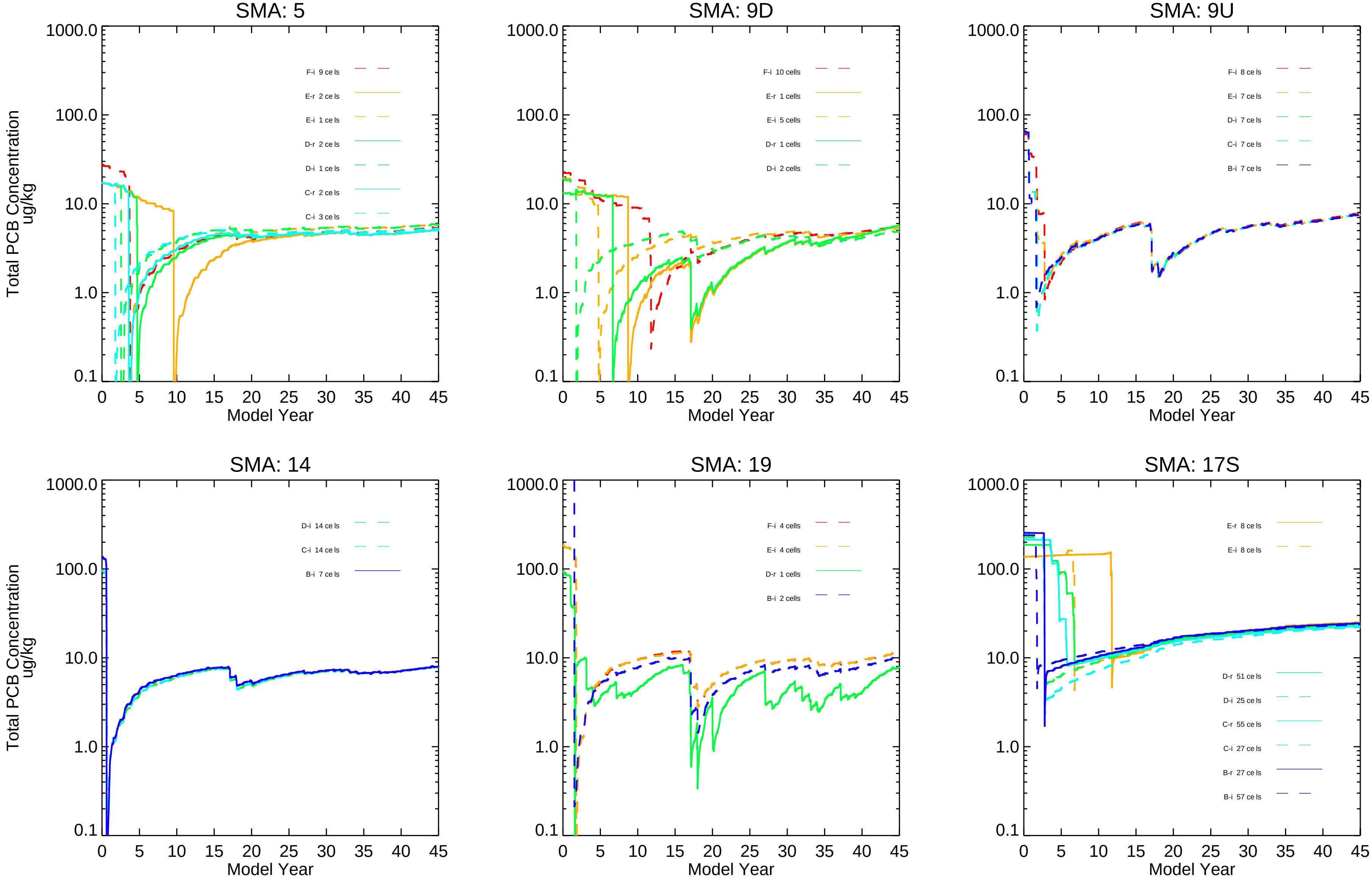
Draft Feasibility Study

Projected Cumulative Number of Days Exceeding Total PCB Water Quality Criterion over the 45-year Model Simulation; Eco Chronic Criteria = 0.014 ug/L

Notes: LWG_PROJ9_BC_PCB-TOT_1104-01 - AltMNR

RRM - \\helios\D_Drive\IDL\AQ_IDL_routines\Project_specific\LWG\LWG_Spatial_Grid_plot_land_WQ.pro Wed Mar 14 13:58:26 2012

These graphs show sediment concentrations over time in select areas of capping. While some recontamination does occur following capping (and active remediation in general), projected increases in concentration are lower than current contaminant levels in all areas examined.



ANCHOR QEA

LWG Lower Willamette Group

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Figure 9.3.4-1

Portland Harbor RI/FS

Draft Feasibility Study

Time Series of Surface Sediment (Top 1-ft) Total PCB Concentrations of Capping Cells in Example SMAs

Number of cells included in SWAC are posted in legend next to alternative name

MCS - H:\010142-01_LWG-Willamette\model\EFDC\Post_process\Bed_Sed\plot\batch\proj_45\temp\plot_chem_bed_temp_bat_proj_45_FS_rem_specific_6panel.pro Wed Mar 14 15:19:19 2012

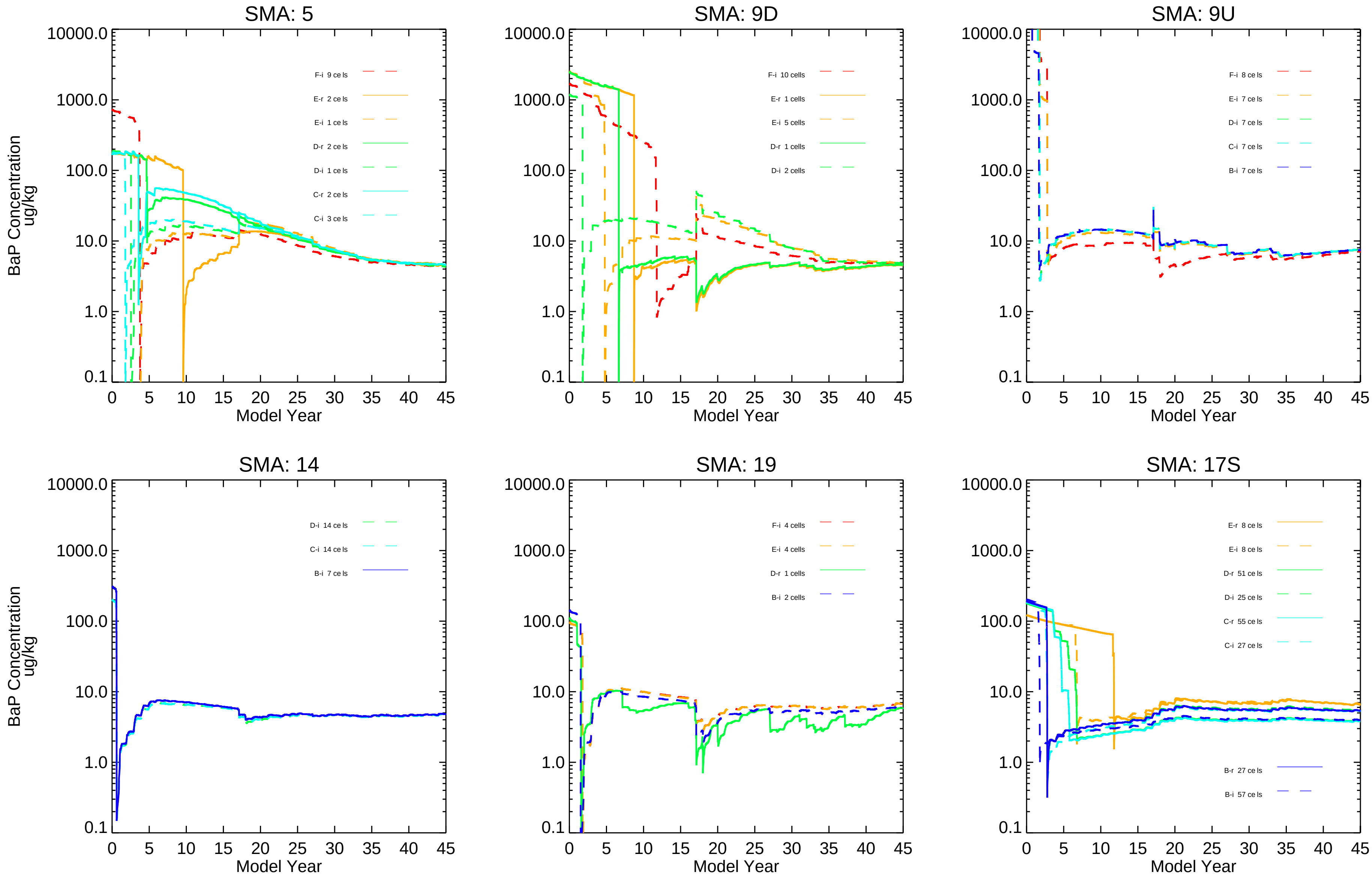

Figure 9.3.4-2

Portland Harbor RI/FS

Draft Feasibility Study

Time Series of Surface Sediment (Top 1-ft) BaP Concentrations of Capping Cells in Example SMAs

Number of cells included in SWAC are posted in legend next to alternative name

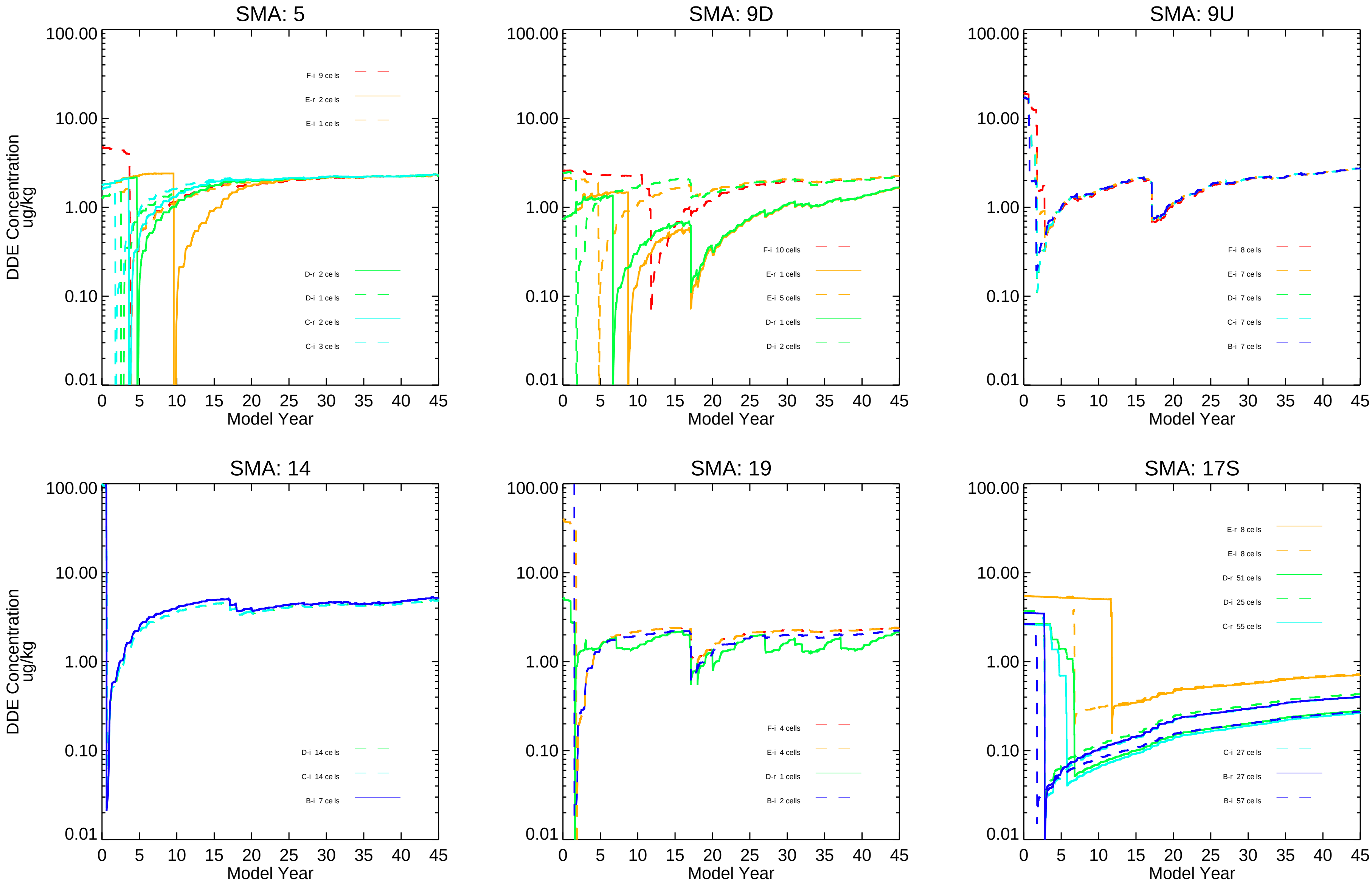

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Figure 9.3.4-3

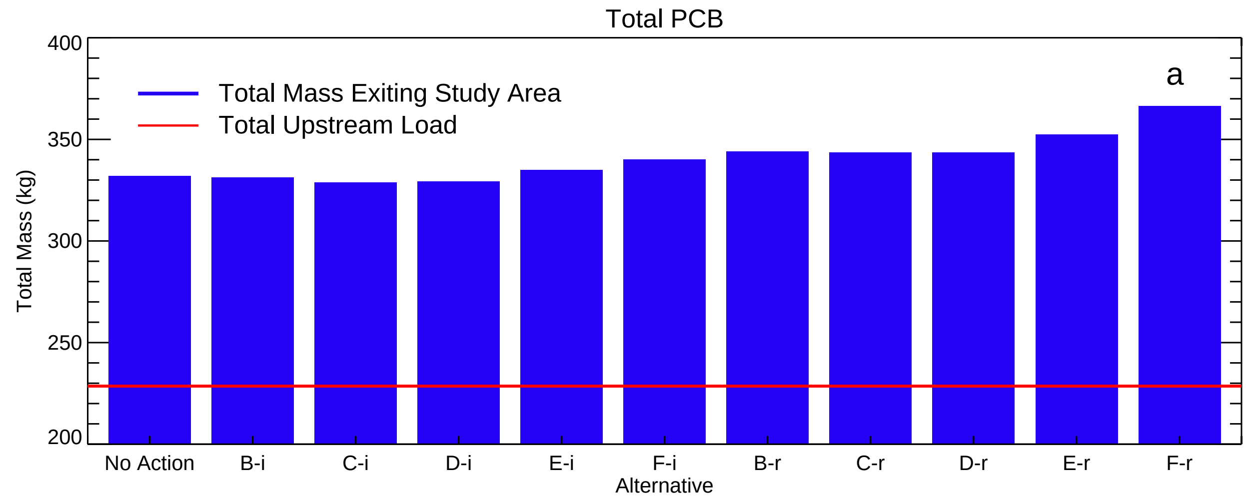
Portland Harbor RI/FS

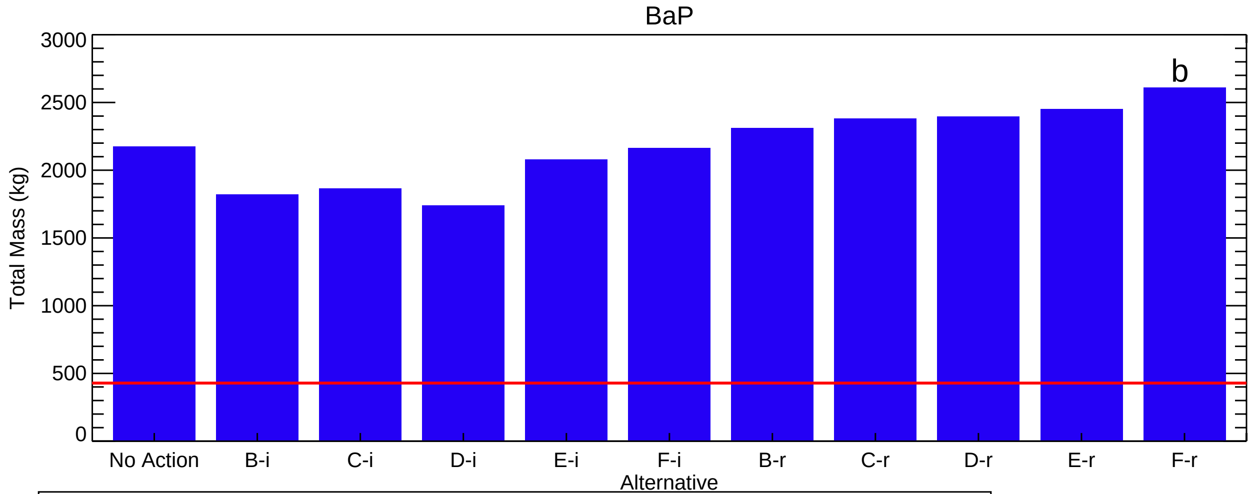
Draft Feasibility Study

Time Series of Surface Sediment (Top 1-ft) DDE Concentrations of Capping Cells in Example SMAs

Number of cells included in SWAC are posted in legend next to alternative name

MCS - H:\010142-01_LWG-Willamette\model\EFDC\Post_process\Bed_Sed\plot\batch\proj_45\temp\plot_chem_bed_temp_bat_proj_45_FS_rem_specific_6panel.pro Wed Mar 14 14:31:34 2012





These graphs summarize the total contaminant mass exiting the Study Area for each alternative. Although the differences are small in many cases, the larger alternatives with more dredging cause more downstream transport.

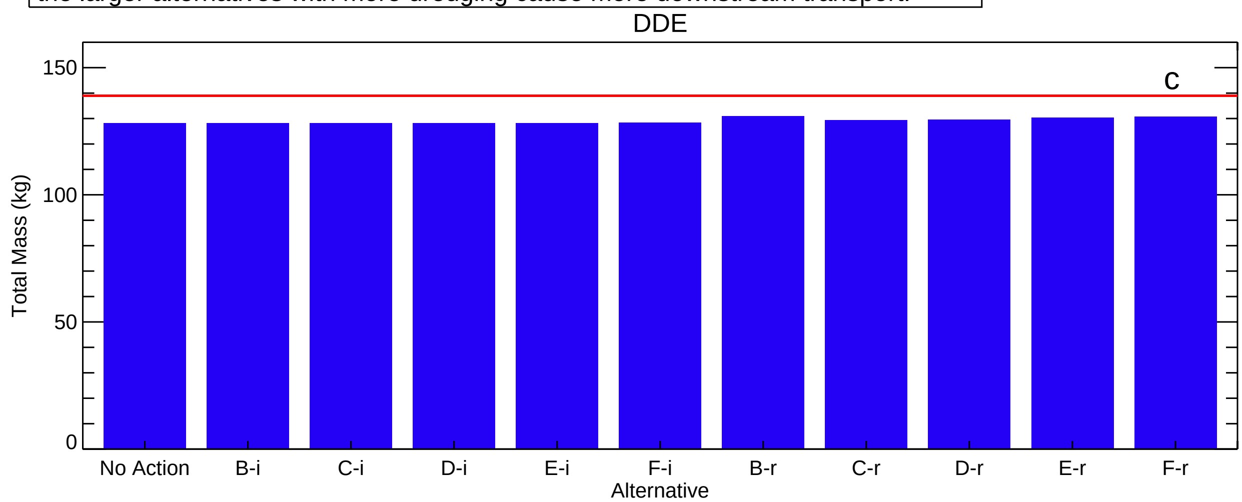
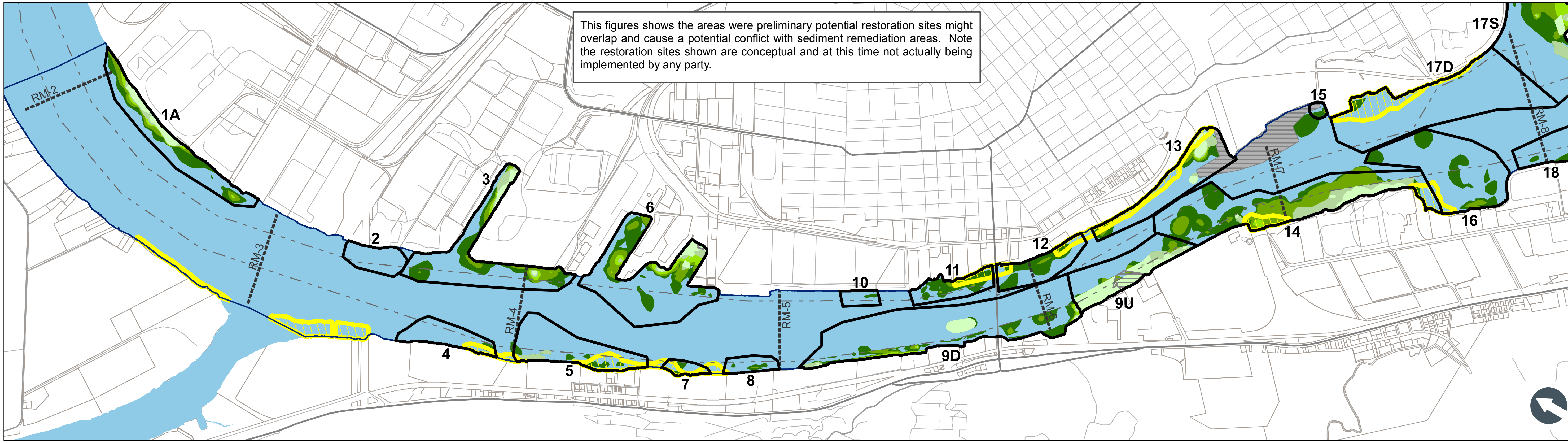


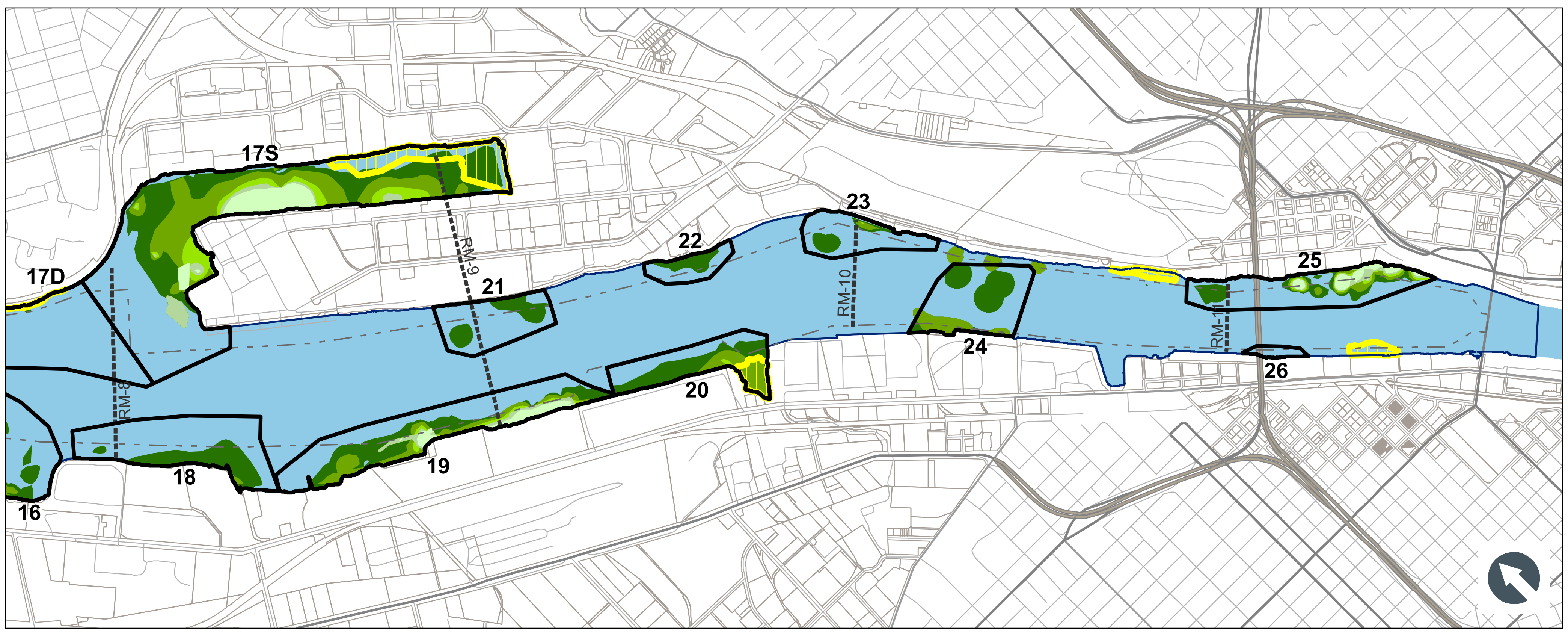
Figure 9.3.6-1

Portland Harbor RI/FS

Draft Feasibility Study

Comparison of Projected Total PCB, BaP, and DDE Mass Transport Exiting the Study Area during 45-year Simulations





LEGEND

- Potential Future Habitat Restoration Sites
- Alternative B Active Remediation
- Alternative C Active Remediation
- Alternative D Active Remediation
- Alternative E Active Remediation
- Alternative F Active Remediation
- Areas of Potential Concern (August 2011)
- River miles
- Portland Harbor Study Area
- Tax Lots
- Navigation Channel
- Existing Remediation Cap

Feet

0 1,000 2,000 3,000 4,000

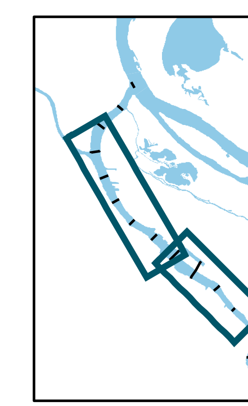


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Figure 9.3.7-1
Portland Harbor RI/FS
Draft Feasibility Study
Potential Restoration Concept Locations Overlap with Remedial Alternatives by SMA

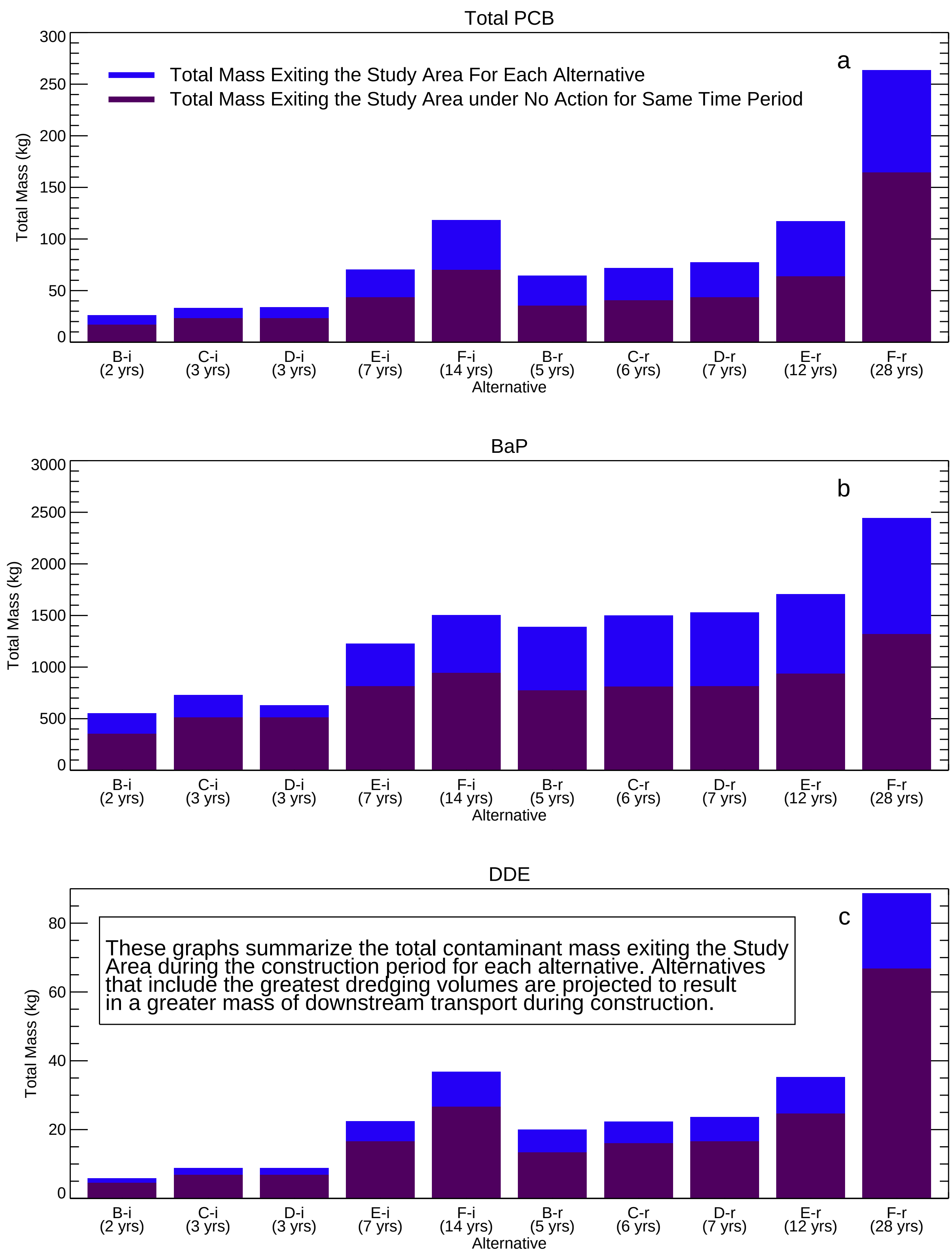

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Figure 9.5.3-1

Portland Harbor RI/FS

Draft Feasibility Study

Comparison of Projected Total PCB, BaP, and DDE Mass Transport Exiting the Study Area During Construction Period for Each Alternative

Number of years under each alternative represents construction duration.

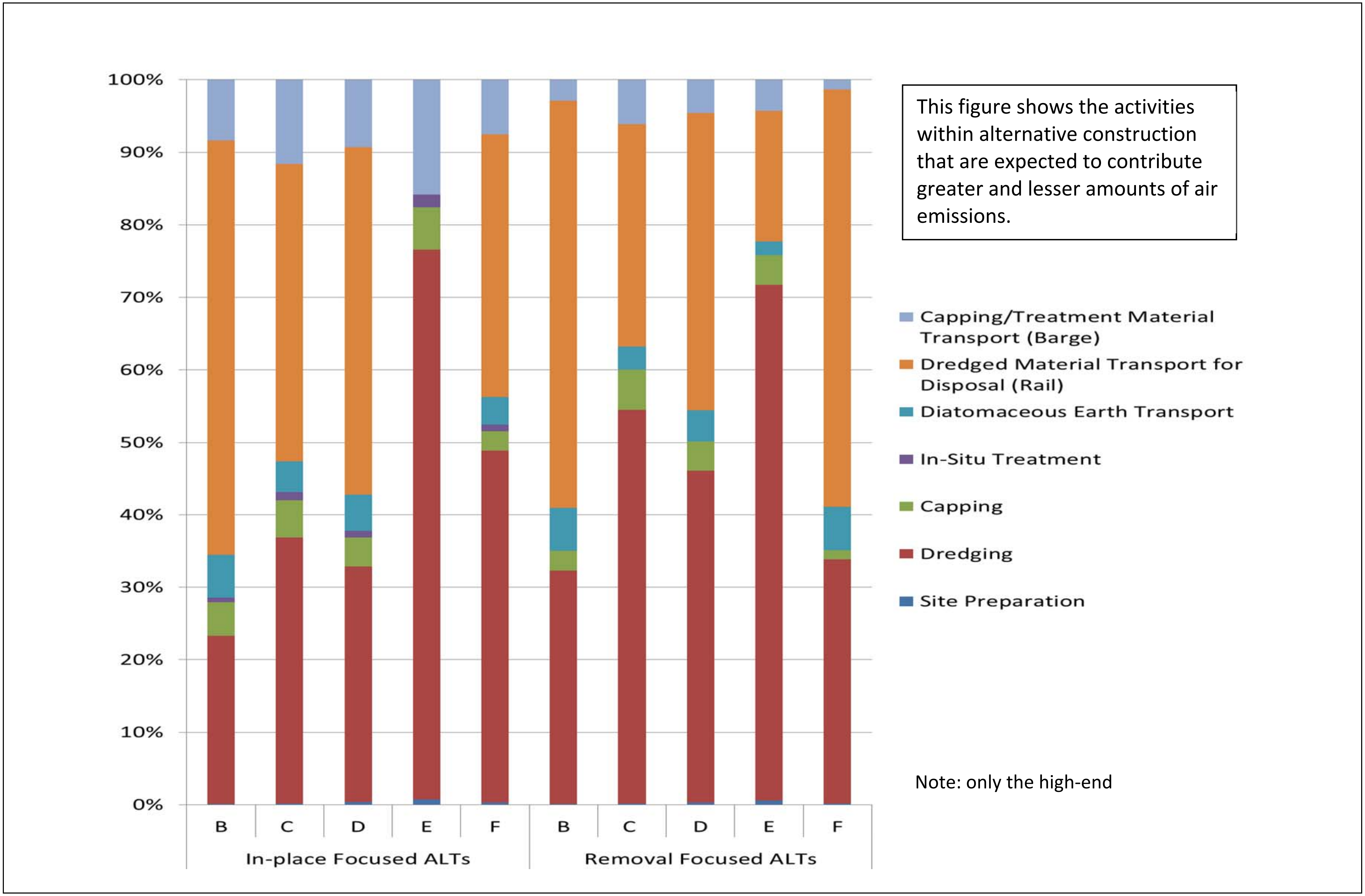

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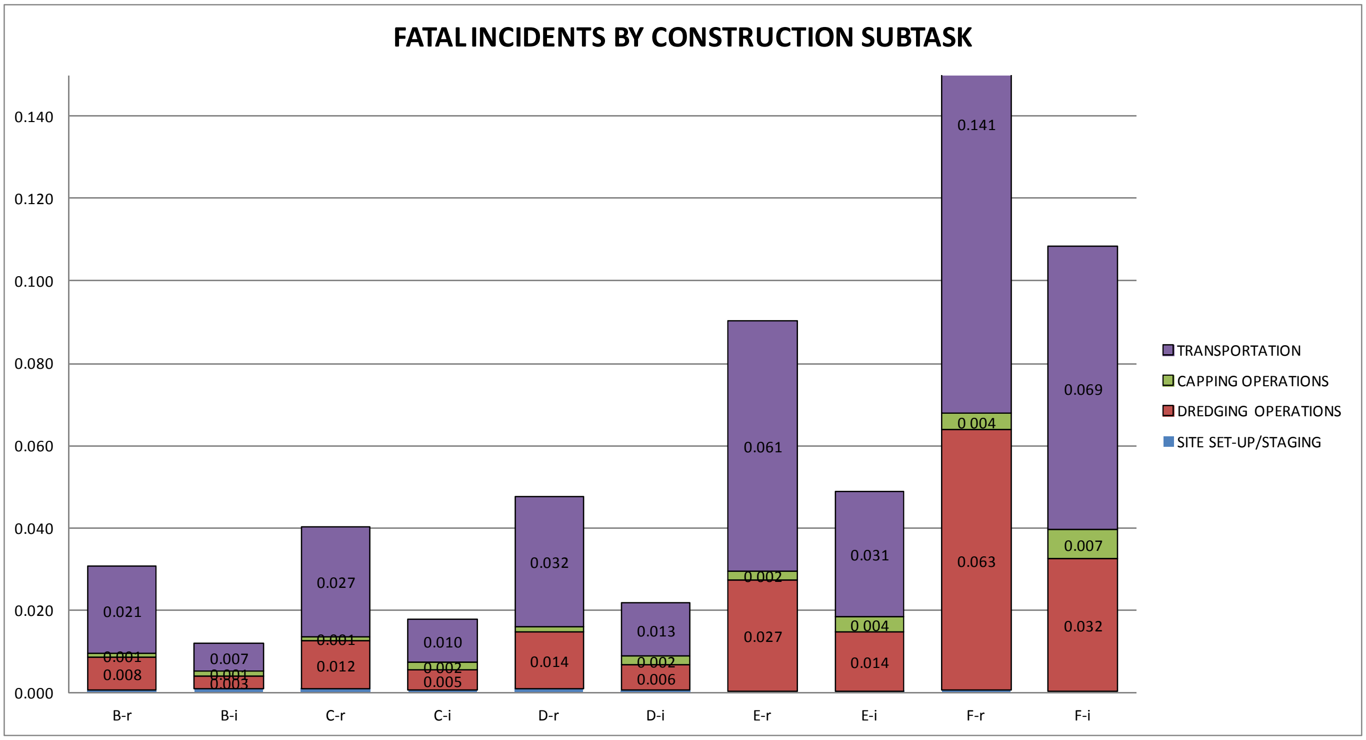
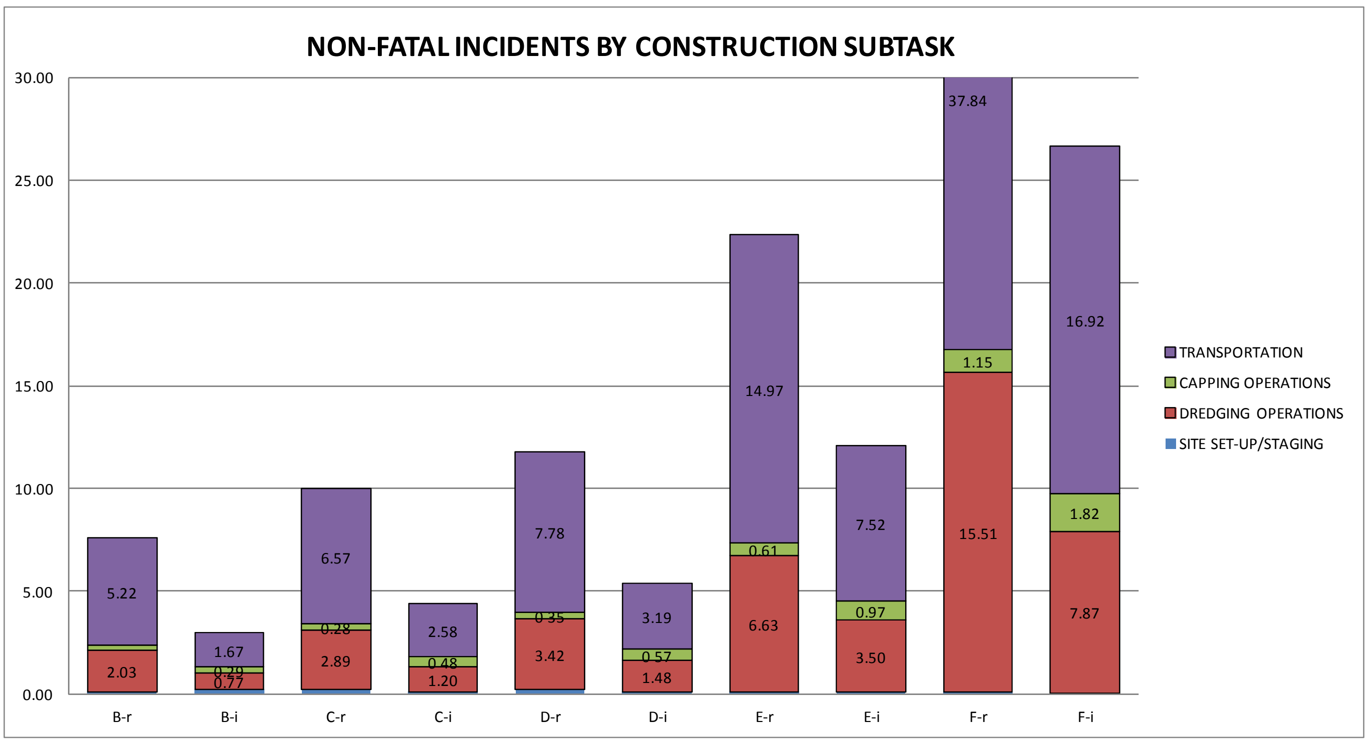
Figure 9.5.4-1
Portland Harbor RI/FS
Draft Feasibility Study
Relative Contribution of CO2-eq Air Emissions by Major Component of Remedial Activity

This figure shows the number of projected construction worker health incidents for each alternative. Generally, alternatives with more construction work result in higher potential for worker health incidents.





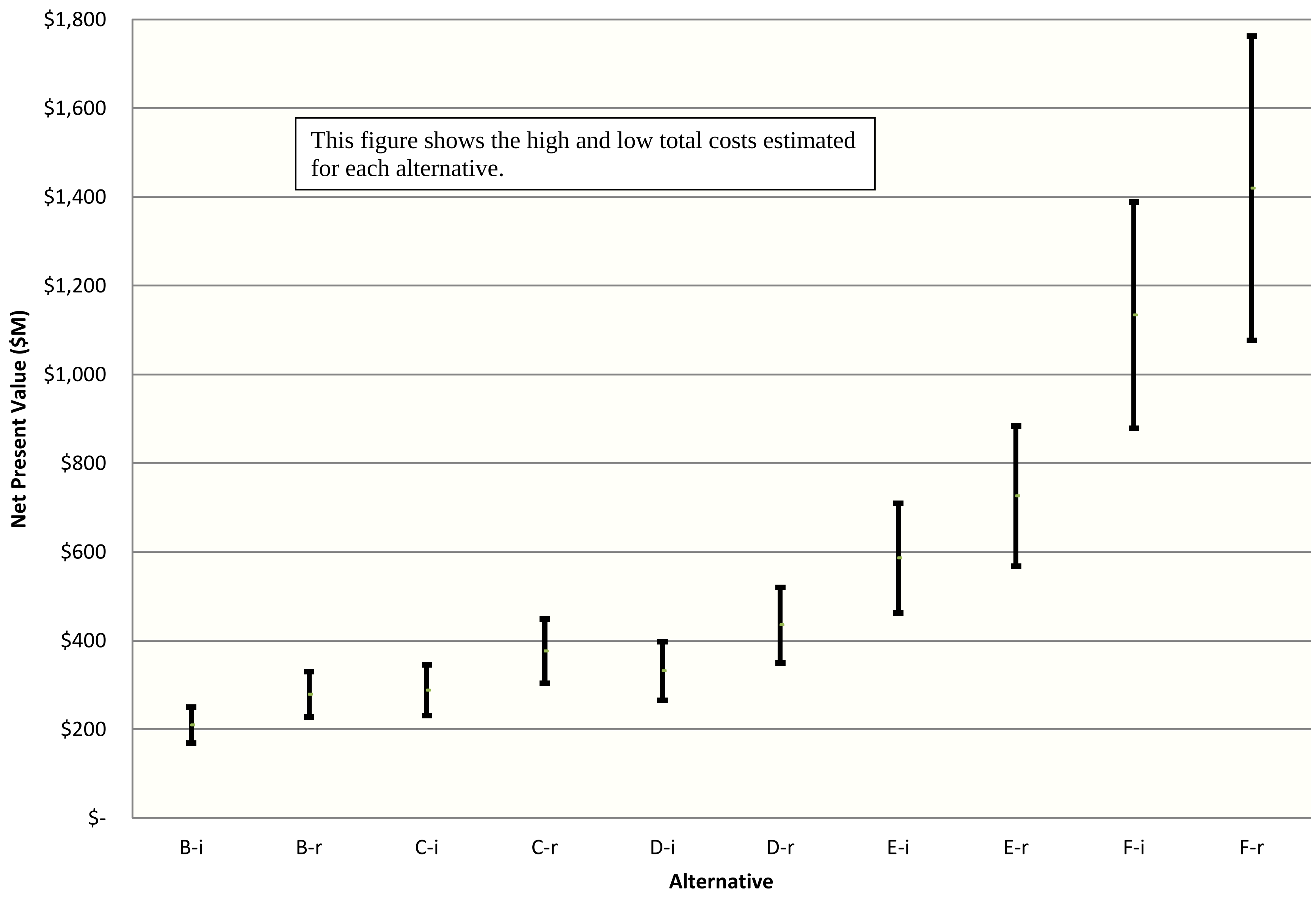


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Figure 9.7-1
Portland Harbor RI/FS
Draft Feasibility Study
Net Present Value by Alternative

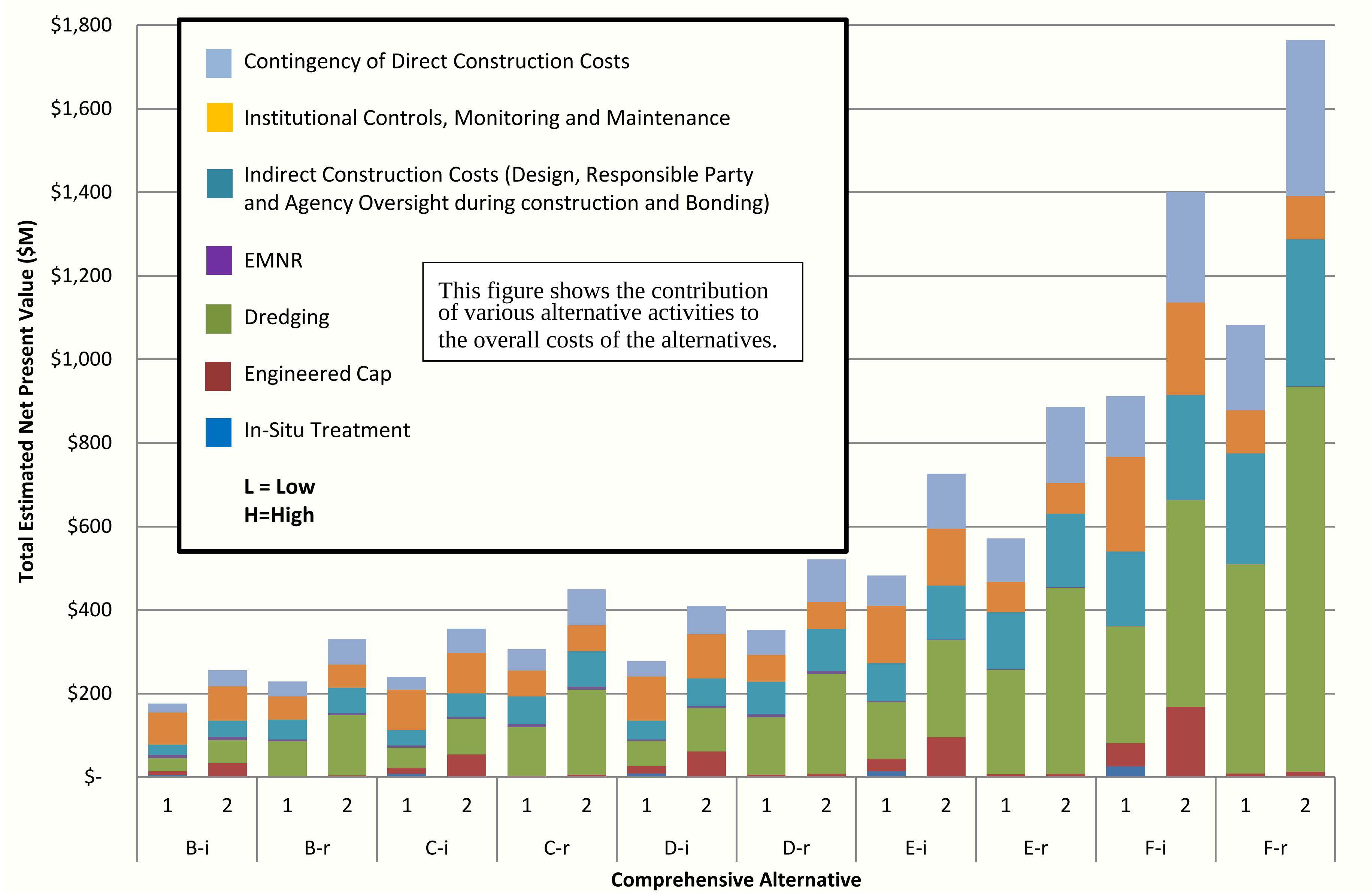

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Figure 9.7-2
Portland Harbor RI/FS
Draft Feasibility Study
Breakout of Net Present Value Cost by Alternative

Table 9.0-1. Summary of Comparative Analysis of Alternatives

Alternative Comparative Criteria			A	B-i	B-r	C-i	C-r	D-i	D-r	E-i	E-r	F-i	F-r
Physical Characteristics	Dredge Volume in CY (Low Estimate)		0	199,000	542,000	314,000	777,000	387,000	914,000	937,000	1,775,000	2,130,000	4,196,000
	Dredge Volume in CY (High Estimate)		0	294,000	784,000	459,000	1,127,000	565,000	1,322,000	1,363,000	2,596,000	3,151,000	6,183,000
	SMA Area in Acres		0	49	49	76	76	95	95	191	191	391	391
	Remediation Technology as a Percentage of SMA Area	Dredge	NA	47%	85%	44%	83%	46%	83%	48%	76%	45%	78%
		Engineered Cap	NA	14%	15%	17%	13%	15%	13%	13%	11%	12%	10%
		In-Situ Treatment	NA	39%	0%	38%	0%	36%	0%	30%	0%	30%	0%
		Confined Beneath CAD/CDF	NA	0%	0%	1%	4%	3%	4%	9%	13%	13%	13%
Overall Protection of Human Health and the Environment		Sediment (Expected to Meet RAOs 1 and 5?)[1]	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
		Tissue (Expected to Meet RAOs 2 and 6?)	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
		Surface Water (Expected to Meet RAOs 3 and 6?)[2]	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN
		Groundwater (Expected to Meet RAOs 4 and 8?)[3]	POSSIBLY	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Compliance with ARARs		Expected to Meet Chemical-Specific Water Quality Standards (WQS/NRWQC)?[4]	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN	UNCERTAIN
		Expected to Meet All Location/Action-Specific ARARs (Oregon Cleanup Rules, CWA, FEMA, ESA)?	NO	YES[5]	YES[5]	YES[5]	YES[5]	YES[5]	YES[5]	YES[5]	YES[5]	YES[5]	YES[5]
Long-Term Effectiveness and Permanence		Surface Sediment COC Projections	Achieves some RGs	Achieves low RG range	Achieves low RG range	Achieves low RG range	Achieves low RG range	Achieves low RG range	Achieves low RG range	Achieves low RG range[6]	Achieves low RG range[6]	Achieves low RG range[6]	Achieves low RG range[6]
		Biota Tissue COC Projections	Achieves some TTLs	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range	Achieves low TTL range
		Minimization of Long-Term Sediment Recontamination Potential[7]	Possibly Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective	Effective
		Minimization of Potential Groundwater Impacts[8]	Possibly Effective	Effective	Possibly Effective	Effective	Possibly Effective	Effective	Possibly Effective	Effective	Possibly Effective	Effective	Possibly Effective
		Minimization of Potential Long-Term Downstream COC Transport [9]	Less Effective	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective	Less Effective	Less Effective
		Habitat Restoration Integration Potential Conflict[10]	NA	Minimal Conflict	Minimal Conflict	Minimal Conflict	Minimal Conflict	Minimal Conflict	Minimal Conflict	Potential Conflict	Potential Conflict	Potential Conflict	Potential Conflict
		Disposal Site Long-Term Effectiveness - Meets EPA Performance Standards?	NA	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Reduction of Toxicity, Mobility, & Volume Through Treatment (Acreage of Area Treated through In Situ Treatment)			0	19	0[11]	29	0[11]	34	0[11]	56	0[11]	117	0[11]

Table 9.0-1. Summary of Comparative Analysis of Alternatives

Alternative Comparative Criteria			A	B-i	B-r	C-i	C-r	D-i	D-r	E-i	E-r	F-i	F-r
Short-Term Effectiveness	Construction Water Quality Impacts[12]		NA	Less Impacts	More Impacts	Less Impacts	More Impacts	Less Impacts	More Impacts	Less Impacts	More Impacts	More Impacts	More Impacts
	Potential Sediment Recontamination During Construction[13]		NA	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective	Effective	Less Effective
	Construction Potential Downstream Transport[14]		NA	Decreased	Increased	Decreased	Increased	Decreased	Increased	Decreased	Increased	Decreased	Increased
	Estimated Timeframe to Meet RAOs[15]		0-45	0-45	0-45	0-45	0-45	0-45	0-45	0-45	0-45	0-45	0-45
	Other Types of Construction Impacts	Tonnes of Increased CO_2 (Average of Low and High Estimates)	NA	4,800	7,650	3,450	5,350	5,100	7,000	5,150	9,550	16,300	55,000
		Estimated Non-Fatal Incidents	NA	3	8	4	10	5	12	12	22	27	51
		Percent Chance Estimated Fatal Worker Incidents	NA	1.2%	3.1%	1.8%	4.0%	2.2%	4.8%	4.9%	9%	11%	21%
	Disposal Site Short-Term Effectiveness - Meets EPA Performance Standards?		NA	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Implementability		Estimated Construction Duration (years)[16]	NA	2	6	3	7	3	8	7	12	15	28
Cost in $Millions		Low Estimated Present Value	$ -	$ 169	$ 228	$ 231	$ 304	$ 266	$ 351	$ 463	$ 568	$ 878	$ 1,077
		High Estimated Present Value	$ -	$ 250	$ 330	$ 345	$ 449	$ 398	$ 520	$ 709	$ 884	$ 1,389	$ 1,762

Notes:
Dark Gray – Does not meet criteria or relatively low performance per the criteria
Gray – May meet the criteria or mid-range performance per the criteria
White – Meets the criteria or high performance per the criteria

1 - All alternatives except Alternative A are expected to achieve long-term sediment concentrations below the most conservative estimates of PCB RG ranges in all river miles except for one (see long term effectiveness).
2 - Compliance with surfacewater RAOs is determined via compliance with surface water ARARs. EPA will determine whether the alternatives meet those ARARs with respect to contamination that will remain on Site or whether waivers of certain surface water ARARs are appropriate due to background and other issues. As discussed in Section 9 of the draft FS, the alternatives do not differ with respect to long-term projected post-remedy surface water concentrations.
3 - Upland source control actions by themselves may be able to address groundwater RAOs 4 and 8, but implementation of the in-place focused alternatives would likely further assist achieving these RAOs. Also, the alternatives with larger footprints would have more opportunity to assist with attainment of groundwater RAOs in the river.
4 - With respect to surface water ARARs, EPA will determine whether the alternatives meet those ARARs with respect to contamination that will remain on Site or whether waivers of certain surface water ARARs are appropriate due to background and other issues. As discussed in Section 9 of the draft FS, the alternatives do not differ with respect to long-term projected post-remedy surface water concentrations.
5 - All action alternatives meet the location/action-specific ARARs including Oregon Cleanup Rules which require attainment of 10^{-5} cancer risk level for summed or totaled contaminants and 10^{-6} cancer risk level for individual contaminants. The action alternatives will need further evaluation in remedial design to confirm compliance with FEMA Floodplain regulations.
6 - All alternatives are expected to achieve long term sediment concentrations at or below the below EPAs conservative point estimate RGs, except for PCBs in one river mile. Concentrations in this river mile are at or near the 95th percentile PCB RG estimate for Alternatives B-i, B-r, C-i, and C-r, and below the 95th percentile estimate for Alternatives E-i, E-r, F-i, and F-r.
7 - Long-term sediment recontamination is generally not expected, even using the conservative assumumptions that current upland loadings continue.
8 - Implementation of in-place alternatives would provide greater opportunities for in-water remedies (e.g., capping) to assist in minimizing potential ground impacts.
9 - Removal based alternatives are projected to result in additional short-term downstream transport of COCs due to dredging releases, but all alternatives would provide similar long-term controls of downstream transport following construction.
10 - There is somewhat greater potential for conflicts between remediation and restoration for alternatives with the large active remedy areas.
11 - The removal based alternatives would provide a small degree treatment, primarily through dredged sediments dewatering/stabization.
12 - Integrated alternatives and alternatives with smaller footprints are projected to have fewer short-term construction water quality impacts than removal alternatives and alternatives with larger footprints.
13 - Removal focused alternatives have a higher potential for adjacent recontamination because of the greater amount of dredging included in the alternatives, and could require additional residual management to control short-term risks (see Section 6.2.7).
14 - The removal focused alternatives are projected to result in a usually small additional downstream transport of contaminants due to dredging releases during construction, while the integrated alternatives results in a decrease in downstream transport that would otherwise take place without the remedy, primarily due to reductions in PCB flux from areas of sediment that are capped or treated in place.
15 - Given the overall range of RGs that could represent attainment of the RAOs, a large range of times to meet RAOs is projected.
16 - Construction duration is a good overall predictor of the implementability issues associated with any given remedy.

Table 9.3.1-1. Summary of Total PCB, BaP, and DDE SWACs for the Site at Year 45

Contaminant (ppb)	Model Simulation	Alternative										
		A - No Action	B-i	B-r	C-i	C-r	D-i	D-r	E-i	E-r	F-i	F-r
Total PCB	Lower Bound	29	13	12	11	13	11	13	9	10	8	10
	Calibrated Model	35	18	17	15	18	16	18	14	15	13	14
	Upper Bound	48	28	27	26	28	26	28	24	25	22	22
BaP	Lower Bound	7	6	7	6	6	6	6	6	6	6	7
	Calibrated Model	22	20	17	19	16	19	15	18	15	15	19
	Upper Bound	72	58	48	57	45	56	42	54	40	45	48
DDE	Lower Bound	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9
	Calibrated Model	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Upper Bound	3.8	3.6	3.7	3.6	3.6	3.6	3.7	3.6	3.7	3.6	3.6

Notes:

Lower and Uppder estimates based on QEAFATE Model Uncertainty analysis in Appendix Ha.

Exceeds 99th percentile RG

Exceeds EPA point estimate RG

Exceeds 95th percentile RG

Table 9.3.1-2. Summary of Total PCB, BaP, and DDE SWACs by Segment at Year 45

			Alternative										
	Segment	Model Simulation	A	B-i	B-r	C-i	C-r	D-i	D-r	E-i	E-r	F-i	F-r
Total PCBs	1	Lower Bound	5	5	5	5	5	5	5	4	4	4	4
		Calibrated Model	9	9	9	9	9	9	9	8	9	8	9
		Upper Bound	17	17	17	17	17	17	17	16	17	15	16
	2	Lower Bound	84	23	19	18	24	19	26	14	14	12	15
		Calibrated Model	94	27	22	21	28	23	30	19	20	17	19
		Upper Bound	115	38	33	32	38	33	41	29	30	25	27
	3	Lower Bound	11	9	10	10	10	10	10	9	10	9	9
		Calibrated Model	18	14	15	15	15	15	15	14	14	13	12
		Upper Bound	32	27	27	27	27	27	27	27	25	24	21
	4	Lower Bound	14	12	14	10	12	10	11	9	11	9	10
		Calibrated Model	19	17	19	15	17	15	16	14	16	13	14
		Upper Bound	30	28	29	26	27	25	26	24	25	23	23
BaP	1	Lower Bound	3	3	3	3	3	3	3	3	3	3	4
		Calibrated Model	6	6	6	6	6	6	6	6	6	6	7
		Upper Bound	13	13	13	13	13	13	13	12	13	12	13
	2	Lower Bound	6	3	3	3	3	3	4	3	4	4	7
		Calibrated Model	11	6	6	6	7	6	7	7	8	8	11
		Upper Bound	20	13	12	12	13	12	14	14	15	14	18
	3	Lower Bound	4	4	4	4	4	4	4	4	4	4	6
		Calibrated Model	39	36	24	36	23	36	21	34	20	23	31
		Upper Bound	210	154	110	154	105	150	91	148	84	112	108
	4	Lower Bound	11	11	11	10	10	11	10	9	9	8	10
		Calibrated Model	24	24	24	23	21	23	21	20	19	18	20
		Upper Bound	49	48	49	46	43	46	42	42	41	37	45

Table 9.3.1-2. Summary of Total PCB, BaP, and DDE SWACs by Segment at Year 45

	Segment	Model Simulation	Alternative										
			A	**B-i**	**B-r**	**C-i**	**C-r**	**D-i**	**D-r**	**E-i**	**E-r**	**F-i**	**F-r**
DDE	1	Lower Bound	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.6	0.8
		Calibrated Model	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.6	1.4	1.6
		Upper Bound	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	3.1	2.8	3.0
	2	Lower Bound	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9
		Calibrated Model	1.9	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.7	1.8	1.8
		Upper Bound	3.8	3.6	3.6	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	3	Lower Bound	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		Calibrated Model	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	2.0
		Upper Bound	4.6	4.2	4.5	4.1	4.2	4.2	4.4	4.0	4.1	3.9	3.9
	4	Lower Bound	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
		Calibrated Model	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
		Upper Bound	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8

Notes:

Lower and Uppder estimates based on QEAFATE Model Uncertainty analysis in Appendix Ha.

Exceeds 99th percentile RG

Exceeds EPA point estimate RG

Exceeds 95th percentile RG

Table 9.3.2-1. Summary of Total PCB Smallmouth Bass Tissue Concentrations by Segment, Average from 40 to 45 Year Period in the Food Web Model Simulation (µg/kg ww)

Segment	Estimate	Alternative										
		A - No Action	B-i	B-r	C-i	C-r	D-i	D-r	E-i	E-r	F-i	F-r
1	Lower Bound	102	102	102	102	102	102	102	95	101	94	100
	Calibrated Model	175	175	175	175	175	175	175	162	172	160	171
	Upper Bound	251	251	251	251	251	251	251	233	248	230	246
2	Lower Bound	852	299	256	247	303	257	322	229	235	208	230
	Calibrated Model	1459	507	432	417	513	435	547	387	398	350	390
	Upper Bound	2096	731	622	601	739	626	788	558	574	505	563
3	Lower Bound	164	143	146	144	146	144	146	142	139	133	127
	Calibrated Model	297	260	266	261	266	261	265	258	253	242	230
	Upper Bound	437	384	392	385	392	385	391	380	373	357	339
4	Lower Bound	298	284	302	265	283	257	275	251	266	243	254
	Calibrated Model	498	474	505	441	472	428	457	417	443	403	421
	Upper Bound	721	686	731	638	682	618	661	602	640	583	608

Note:

Lower and Upper estimates based on Food Web Model Uncertainty analysis in Appendix Hb.

Exceeds 99th percentile TTL for human health smallmouth bass whole body consumption

Exceeds EPA point estimate TTL for human health smallmouth bass whole body consumption

Exceeds 95th percentile TTL for human health smallmouth bass whole body consumption

Table 9.4-1. Summary of In Situ Treatment Areas

	Total SMA Area (acres)	Total In Situ Treatment (acres)	Percent of SMA Area Treated In Situ
Removal Focused Alternatives	Varies	0	0%*
B-i	49	19	39%
C-i	76	29	38%
D-i	95	34	36%
E-i	191	58	30%
F-i	391	117	30%

* Although removal focused alternatives do not include in situ treatment, as described in the text, they do include treatment through ex situ dewatering and/or reduction in leaching potential for all dredged sediments.

Table 9.5.2-1. Maximum Average 1-Mile PCB Concentration Increase Downstream of Each SMA Resulting From Remediation of SMA (µg/kg)

SMA	B-i	C-i	D-i	E-i	F-i	B-r	C_r	D-r	E-r	F-r
run#	1107-76	1107-56	1110-55	1110-11	1110-01	1107-26	1107-61	1107-16	1110-16	1110-06
25	0.4	0.5	0.6	0.4	0.4	0.5	0.3	0.6	0.9	0.6
26	--	--	--	--	--	--	--	--	--	--
24	--	--	--	0.3	0.5	--	--	--	0.2	0.4
23	--	--	--	0.1	0.1	--	--	--	0.1	0.1
22	--	--	--	--	0.1	--	--	--	--	0.1
20	--	--	--	0.4	0.4	--	--	0.2	1.0	0.7
21	--	--	--	--	1.4	--	--	--	--	0.2
19	0.1	0.2	0.2	0.2	0.2	2.8	4.7	3.7	3.3	3.5
17S	0.5	2.0	2.6	5.4	4.3	0.4	2.7	2.0	6.3	4.7
18	--	--	--	--	0.1	--	--	--	--	0.4
17D	--	--	--	--	--	--	--	--	--	--
16	--	--	--	0.1	0.1	--	--	--	0.2	0.1
14	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.8	0.2
13	--	--	--	--	--	0.2	0.2	0.3	0.2	0.2
9U	0.1	0.1	0.1	0.1	0.1	1.0	0.6	0.5	0.1	0.7
12	--	--	--	--	--	--	--	--	0.1	0.1
11	--	--	--	0.1	0.1	--	--	--	0.1	0.2
9D	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2
10	--	--	--	--	0.1	--	--	--	--	0.1
8	--	--	--	--	0.1	--	--	--	--	0.1
7	--	--	--	--	0.1	--	--	--	--	0.1
6	0.4	0.2	0.2	0.2	0.1	0.5	0.2	0.2	0.1	0.1
5	--	0.1	0.1	0.1	0.1	--	0.1	0.1	0.1	0.1
3	10	0.3	0.2	0.5	0.6	19	7.6	11	2.7	2
4	--	--	--	--	--	--	--	--	--	0.1
2	--	--	--	--	--	--	--	--	--	--
1A	--	--	--	0.1	0.4	0.6	1.0	0.6	0.7	1.2

Note:

--- indicates SMAs with no removal cells in the specified alternative

Table 9.5.2-2. Maximum Average 1/2-Mile BaP Concentration Increase Downstream of Each SMA Resulting From Remediation of SMA (µg/kg)

SMA	B-i	C-i	D-i	E-i	F-i	B-r	C_r	D-r	E-r	F-r
run#	1107-87	1107-69	1110-60	1110-33	1110-31	1107-39	1107-70	1107-37	1110-34	1110-32
25	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2
26	--	--	--	--	--	--	--	--	--	--
24	--	--	--	0.4	0.3	--	--	--	0.3	0.3
23	--	--	--	0.2	0.5	--	--	--	0.1	0.5
22	--	--	--	--	0.1	--	--	--	--	0.1
20	--	--	--	0.7	0.6	--	--	0.2	1.8	1.4
21	--	--	--	--	0.3	--	--	--	--	0.1
19	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
17S	0.2	0.8	1.3	3.4	2.4	0.1	1.0	0.5	3.2	2.2
18	--	--	--	--	0.1	--	--	--	--	0.1
17D	--	--	--	--	--	--	--	--	--	--
16	--	--	--	0.1	0.1	--	--	--	0.1	0.1
14	0.3	0.1	0.2	0.2	0.4	3.4	0.3	0.2	1.2	1.5
13	--	--	--	--	--	0.2	0.2	0.3	0.2	0.2
9U	5.5	7.1	6.8	1.8	8.1	50	60	60	46	47
12	--	--	--	--	--	--	--	--	0.1	0.1
11	--	--	--	0.4	0.7	--	--	--	0.6	1.4
9D	1.1	0.9	2.5	1.7	3.2	0.9	1.2	2.9	3.1	5.6
10	--	--	--	--	3.6	--	--	--	--	3.3
8	--	--	--	--	0.2	--	--	--	--	1.0
7	--	--	--	--	0.1	--	--	--	--	0.4
6	7.6	8.4	10.0	5	8.3	16	5.0	22	8	2.4
5	--	0.1	0.1	0.1	0.1	--	5.5	25	0.1	1.5
3	0.5	0.1	0.1	0.4	0.5	3.6	1.6	2.1	0.6	0.7
4	--	--	--	--	--	--	--	--	--	0.1
2	--	--	--	--	--	--	--	--	--	--
1A	--	--	--	0.1	0.3	0.1	0.1	1.3	0.1	0.3

Note:

--- indicates SMAs with no removal cells in the specified alternative

Table 9.5.2-3. Maximum Average 1-Mile DDE Concentration Increase Downstream of Each SMA Resulting From Remediation of SMA (µg/kg)

SMA	B-i	C-i	D-i	E-i	F-i	B-r	C_r	D-r	E-r	F-r
run#	1109-03	1109-09	1110-63	1110-45	1110-39	1109-06	1109-12	1109-18	1110-48	1110-42
25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
26	--	--	--	--	--	--	--	--	--	--
24	--	--	--	0.1	0.1	--	--	--	0.1	0.1
23	--	--	--	0.1	0.1	--	--	--	0.1	0.1
22	--	--	--		0.1	--	--	--	--	0.1
20	--	--	--	0.1	0.1	--	--	0.1	0.1	0.1
21	--	--	--		0.1	--	--	--	--	0.1
19	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2
17S	0.1	0.1	0.1	0.4	0.4	0.1	0.1	0.1	0.3	0.4
18	--	--	--	--	0.1	--	--	--	--	0.1
17D	--	--	--	--	--	--	--	--	--	--
16	--	--	--	0.1	0.1	--	--	--	0.1	0.1
14	0.2	0.2	0.2	0.3	0.5	23	1.1	1.4	0.9	1.0
13	--	--	--	--	--	0.1	0.1	0.1	0.1	0.1
9U	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
12	--	--	--	--	--	--	--	--	0.1	0.1
11	--	--	--	0.1	0.1	--	--	--	0.1	0.1
9D	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
10	--	--	--	--	0.1	--	--	--	--	0.1
8	--	--	--	--	0.3	--	--	--	--	0.1
7	--	--	--	--	0.1	--	--	--	--	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
5	--	0.1	0.1	0.1	0.1	--	0.1	0.1	0.1	0.1
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4	--	--	--	--	--	--	--	--	--	0.1
2	--	--	--	--	--	--	--	--	--	--
1A	--	--	--	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note:

--- indicates SMAs with no removal cells in the specified alternative

Table 9.5.4-1. Summary of Direct CO_2-eq Emissions (tonnes) by Remedial Alternative and Component Activity

Alternative	Site Preparation	Dredging		Capping	In Situ Treatment	Transportation of Materials/Waste							Overall Total CO2-Eq. Emissions	
						Disposal-Related					Total			
						DE[2]		Rail Transport[3]						
		Low	High			Low	High	Low	High	Capping[4]	Low	High	Low	High
B-i	5.5	880	1,300	260	34	230	330	2,100	3,200	470	2,800	4,000	4,000	5,600
C-i	9.1	1,100	1,700	240	51	38	200	370	1,900	540	948	2,640	2,300	4,600
D-i	24	1,400	2,100	260	59	120	320	1,200	3,100	600	1,920	4,020	3,700	6,500
E-i	43	3,100	4,400	340	100	--	--	--	--	920	920	920	4,500	5,800
F-i	65	7,000	11,000	600	200	--	860	--	8,200	1,700	1,700	10,760	9,600	23,000
B-r	9.1	2,100	3,100	260	--	300	570	2,800	5,400	280	3,380	6,250	5,700	9,600
C-r	14	2,600	3,900	400	--	--	230	--	2,200	440	440	2,870	3,500	7,200
D-r	31	3,100	4,800	430	--	--	450	--	4,300	480	480	5,230	4,000	10,000
E-r	75	6,000	8,700	500	--	--	230	--	2,200	530	530	2,960	7,100	12,000
F-r	120	16,000	24,000	870	--	2,000	4,300	19,000	41,000	960	21,960	46,260	39,000	71,000

Notes:

1. Values presented in tonnes and reflect rounding to two significant digits.
2. DE - Diatomaceous Earth. Transport assumed to occur from mine location in George, WA, approximately 265 miles from Portland Harbor, via truck.
3. Rail Transport for disposal of sediments to Subtitle D landfill located approximately 150 miles from Portland Harbor.
4. Transport of capping (and treatment) material (armor stone, sand, gravel, etc.) via barge from assumed distance of 20 miles from Portland Harbor.

Table 9.5.4-2. Equivalencies of Total CO_2-eq Emissions

Alternative	Estimated Total CO_2-eq Emissions[1]			Equivalent to Remedial Alternative Emissions[2]								
				Number of Passenger Vehicles with Annual CO_2-eq Emissions			Number of Barrels of Oil Consumed Resulting in CO_2 Emissions			Number of Homes with CO_2 Emissions Due to Annual Energy Usage		
B-i	4,000	-	5,600	780	-	1,100	9,300	-	13,000	350	-	490
C-i	2,300	-	4,600	450	-	900	5,300	-	11,000	200	-	400
D-i	3,700	-	6,500	730	-	1,300	8,600	-	15,000	320	-	570
E-i	4,500	-	5,800	880	-	1,100	10,000	-	13,000	390	-	500
F-i	9,600	-	23,000	1,900	-	4,500	22,000	-	53,000	830	-	2,000
B-r	5,700	-	9,600	1,100	-	1,900	13,000	-	22,000	500	-	830
C-r	3,500	-	7,200	690	-	1,400	8,100	-	17,000	300	-	630
D-r	4,000	-	10,000	780	-	2,000	9,300	-	23,000	350	-	870
E-r	7,100	-	12,000	1,400	-	2,400	17,000	-	28,000	620	-	1,000
F-r	39,000	-	71,000	7,600	-	14,000	91,000	-	170,000	3,400	-	6,200

Notes:

1. Range respresents low-end volume estimate to high-end volume estimate.
2. Values presented were generated from EPA's Greenhouse Gas Equivalencies Calculator, and have been rounded herein. EPA's website provides detailed explanations pertaining to how each calculation is derived:
   » http://www.epa.gov/cleanrgy/energy-resources/refs html

   Emission rates utilized herin as follows:
   » 5.1 tonnes CO_2/vehicle/year
   » 0.43 tonnes CO_2/barrel oil
   » 11.53 tonnes CO_2/home/year

Table 9.5.5-1. Summary of Lower, Mid, and Upper Estimated Times to Attain RAOs (Years) in Sediments (for PCBs, BaP, and DDE) and Smallmouth Bass (SMB) Tissue (for PCBs only) by Segment
(Ranges represent low and high values as determined through fate and transport model or food web model uncertainty analyses per Appendices Ha and Hb as well as a RG ranges from 95th to >99th percentile esitmates.)

Segment/ Contaminant	Alternative																																	Endpoints Attained
	Alt A - No Action			Alt B-i			Alt B-r			Alt C-i			Alt C-r			Alt D-i			Alt D-r			Alt E-i			Alt E-r			Alt F-i			Alt F-r			
	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper	
Segment 1																																		
PCBs Sediments	0	4	5	0	3	4	0	4	4	0	3	4	0	3	4	0	3	4	0	3	4	0	3	4	0	4	5	0	3	4	0	4	5	Ranges from SMB RG 95th% (95 ppb) to EPA Point RG (29.5 ppb)
PCBs SMB Tissue	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	4	5	Ranges from 95% SMB TTL (1,356 ppb) to EPA Point TTL (470 ppb)
BaP Sediments	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Ranges from Direct Contact RG 95th% (2750 ppb) to EPA EPA Point >99th% RG (423 ppb)**
DDE Sediments	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EPA Point RG (3.1 ppb). Ranges provided for modeling uncertainty only.
Segment 2																																		
PCBs Sediments	28	*	*	2	28	*	3	15	*	2	11	*	5	30	*	3	19	*	5	*	*	6	19	35	11	19	*	9	11	19	23	26	33	Ranges from SMB RG 95th% (95 ppb) to EPA Point RG (29.5 ppb)
PCBs SMB Tissue	0	*	*	0	*	*	0	36	*	0	30	*	0	*	*	0	36	*	0	*	*	0	28	*	0	30	*	0	21	*	0	34	*	Ranges from 95% SMB TTL (1,356 ppb) to EPA Point TTL (470 ppb)
BaP Sediments	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Ranges from Direct Contact RG 95th% (2750 ppb) to EPA EPA Point >99th% RG (423 ppb)**
DDE Sediments	2	3	*	2	2	*	2	4	*	1	2	*	3	4	*	1	2	*	2	3	*	2	2	*	2	3	*	1	2	*	2	3	*	EPA Point RG (3.1 ppb). Ranges provided for modeling uncertainty only.
Segment 3																																		
PCBs Sediments	0	28	*	0	24	38	0	24	37	0	24	38	0	24	37	0	24	38	0	24	37	0	23	36	0	22	34	0	8	30	0	11	21	Ranges from SMB RG 95th% (95 ppb) to EPA Point RG (29.5 ppb)
PCBs SMB Tissue	0	28	40	0	24	36	0	25	36	0	24	36	0	25	36	0	24	36	0	24	36	0	24	35	0	23	35	0	19	30	0	28	31	Ranges from 95% SMB TTL (1,356 ppb) to EPA Point TTL (470 ppb)
BaP Sediments	1	28	35	1	27	31	1	21	26	1	27	31	1	20	25	1	27	31	1	19	22	1	26	30	1	17	21	1	23	26	1	22	26	Ranges from Direct Contact RG 95th% (2750 ppb) to EPA EPA Point >99th% RG (423 ppb)
DDE Sediments	21	26	*	20	21	*	20	21	*	19	21	*	19	21	*	19	21	*	21	25	*	3	3	*	6	12	*	4	5	*	7	12	*	EPA Point RG (3.1 ppb). Ranges provided for modeling uncertainty only.
Segment 4																																		
PCBs Sediments	0	4	18	0	4	16	0	6	19	0	3	6	0	4	17	0	3	4	0	4	9	0	4	5	0	4	9	0	4	8	0	4	17	Ranges from SMB RG 95th% (95 ppb) to EPA Point RG (29.5 ppb)
PCBs SMB Tissue	0	*	*	0	*	*	0	*	*	0	44	*	0	*	*	0	22	*	0	*	*	0	22	*	0	44	*	0	21	*	0	30	*	Ranges from 95% SMB TTL (1,356 ppb) to EPA Point TTL (470 ppb)
BaP Sediments	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	0	<1	<1	Ranges from Direct Contact RG 95th% (2750 ppb) to EPA EPA Point >99th% RG (423 ppb)
DDE Sediments	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	0	0	*	EPA Point RG (3.1 ppb). Ranges provided for modeling uncertainty only.

Notes:
* The RAO is not attained at the end of the 45 year simulation, and thus, the time to attain the RAO cannot be estimated.
** This segment currently achieves the RAO as represented by this conservative point estimate RG.
SMB - Smallmouth Bass
DDE RG is a based on a Site-wide exposure area, but is compared on a segment basis in this table for reference.

Table 9.5.7-1 Estimated Worker Non-Fatal and Fatal Incidents by Alternative

Alternative	Total Project Work Hours	Estimated Non-Fatal Incidents	Estimated Fatal Incidents
B-r	382,138	7.59	0.031
B-i	148,504	2.98	0.012
C-r	503,857	9.98	0.040
C-i	220,014	4.4	0.018
D-r	595,321	11.79	0.048
D-i	269,392	5.38	0.022
E-r	1,128,752	22.33	0.090
E-i	607,015	12.07	0.049
F-r	2,599,913	51.43	0.209
F-i	1,343,327	26.68	0.108

Table 9.6.1-1. Level of Effort for Each Remedial Alternative

Alternative	Dredge Area (acres)	Removal Volume (CY)	Engineered Cap Area (acres)*	In-Situ Treatment Area (acres)	Sand (Tons)**	Armor (Tons)***	EMNR Area (Acres)
B-i	23	199,000 - 294,000	7 - 26	0 - 19	274,000 - 298,000	82,000 - 172,000	75
B-r	42	542,000 - 784,000	7	0	176,000 - 176,000	45,000 - 45,000	41
C-i	34	314,000 - 460,000	13 - 42	0 - 29	243,000 - 277,000	152,000 - 282,000	40
C-r	63	777,000 - 1,127,000	10	0	289,000 - 289,000	65,000 - 65,000	73
D-i	43	387,000 - 565,000	15 - 49	0 - 34	263,000 - 304,000	173,000 - 325,000	37
D-r	78	914,000 - 1,322,000	13	0	304,000 - 304,000	80,000 - 80,000	68
E-i	91	937,000 - 1,363,000	25 - 83	0 - 58	355,000 - 426,000	302,000 - 537,000	15
E-r	146	1,775,000 - 2,596,000	21	0	283,000 - 283,000	137,000 - 137,000	15
F-i	176	2,130,000 - 3,152,000	49 - 166	0 - 117	647,000 - 845,000	639,000 - 1,093,000	3
F-r	304	4,196,000 - 6,183,000	38	0	501,000 - 501,000	256,000 - 256,000	3

Note:
* Includes area associated with Engineered Active Cap
** Includes sand associated with EMNR, In Situ Treatment, Engineered Cap, Residuals Cap, and Engineered Active Cap
*** Includes armor associated with Armor Type A, Armor Type B, Armor Type C, and ODOT Armor 200.

Table 9.7-1. Total Net Present Value Cost by Alternative

Alternative	Net Present Value ($M) Low	High
B-i	$ 169	$ 250
B-r	$ 228	$ 330
C-i	$ 231	$ 345
C-r	$ 304	$ 449
D-i	$ 266	$ 398
D-r	$ 351	$ 520
E-i	$ 463	$ 709
E-r	$ 568	$ 884
F-i	$ 878	$ 1,389
F-r	$ 1,077	$ 1,762

Note: Details of cost estimating are provided in Section 7.6 and Appendix K.

10.0 CONCLUSIONS

The Portland Harbor RI/FS provides EPA with information and tools to reduce potentially unacceptable risks to human health and the environment in the Portland Harbor Site. EPA will use the FS to evaluate the alternatives for sediment remedies based on the NCP criteria and select a harbor-wide sediment remedy.

This section presents:

- A review of the most recent national risk management principles and guidance for remedy selection at contaminated sediment sites and comparisons with the draft FS evaluations
- A summary of risk management uncertainties relevant to remedy selection, consistent with national guidance
- A summary of conclusions of the comparative evaluation of comprehensive alternatives relative to the NCP criteria for remedial alternative selection, including comparing and contrasting the costs and benefits of the various remedies as part of a risk management decision-making framework.

10.1 RISK MANAGEMENT PRINCIPLES AND NATIONAL GUIDANCE

EPA's 11 Risk Management Principles Memorandum was developed to provide guidance to site managers in, "*making scientifically sound and nationally consistent risk management decisions at contaminated sediment sites*" (2002b). As such, the risk management principles contained within the memorandum should be applied to all contaminated sediments sites under the CERCLA process. The following discussion briefly summarizes the 11 principles and how these principles were addressed in this draft FS evaluation of remedial alternatives.

1. **Control sources early –** An effective and efficient Portland Harbor sediment remedy will need to be coordinated with upland source control measures, so that the potential for sediment recontamination following cleanup is minimized. This draft FS assumes sources will be sufficiently controlled prior to implementation of sediment remedies.

   > *Model projections and empirical trends observed at the Site suggest that long-term contaminant concentrations may remain above some of the lowest RGs due primarily to background concentrations in upstream surface water entering the Site. This is consistent with observations at other similar waterbodies.*

   Upland source controls are determined by DEQ working with individual parties along the river under a regulatory program that is managed by DEQ under the Oregon Cleanup Law. The source control program is a long-term effort, and there are uncertainties with the future level and extent of potential recontamination from multiple sources. Therefore, sediment remedies at the Site will need to be implemented in a timeframe consistent with ongoing and future source control activities in order to achieve effective and permanent long-term reductions in Site risks.

Even with sources controlled, long-term sediment contaminant concentrations at the Site may remain above some of the lowest RGs, due primarily to background concentrations in upstream surface water entering the Site. This is confirmed by the draft FS model projections and empirical trends observed at the Site and in similar waterbodies.

2. **Involve the community early and often** – Public involvement activities conducted throughout the RI/FS process have kept the community informed and provided a mechanism for interaction with EPA and the LWG. These activities have included ten years of monthly Community Advisory Group (CAG) meetings and presentations, public Site tours, and the development of a project website. EPA will continue public involvement activities during the proposed plan, remedy selection, and implementation.

3. **Coordinate with States, Local Governments, Tribes, and Natural Resource Trustees –** This principle is administered by EPA and has been accomplished through monthly Technical Assistance Team (TAT) meetings that include these "partner" entities. EPA has a formal Memorandum of Understanding (MOU) with these partners, which establishes specific relationships and coordination efforts for this Site. Pursuant to the AOC, the LWG has provided direct funding to the Tribal governments and other federal agencies to ensure their ability to actively participate in the entire RI/FS process. Also, EPA and DEQ have signed the Joint Source Control MOU (EPA 2001b) that outlines their shared goals and objectives as well as details of the respective agency roles and responsibilities.

4. **Develop and refine a conceptual site model that considers sediment stability** – The Site CSM (Section 2.6) based on numerous detailed Site-specific RI/FS investigations comprehensively describes sediment stability. As discussed in Sections 2.6.1 and 6.2.2, multiple datasets and independent LOEs consistently indicate that the Site is predominantly depositional, although deposition rates vary spatially across the Site (both laterally and longitudinally), and there are localized areas of the Site where sediments are in dynamic equilibrium (alternating deposition and erosion). This spatial variability in sediment stability was addressed through detailed modeling of sediment transport processes and additional evaluations of other forces potentially affecting sediment stability (i.e., wind/wake generated waves, propwash, and navigation dredging activities). Numerous LOEs reveal that relatively small areas of the Site are potentially subject to episodic disturbances; these areas have been accounted for in the development and evaluation of the alternatives.

Multiple datasets and independent lines of evidence consistently indicate that the Site is predominantly depositional, although deposition rates vary spatially across the Site.

5. **Use an iterative approach in a risk-based framework –** As discussed in Section 2.7, EPA has entered into separate orders for three locations in the Site:
    a. Terminal 4 (conducted by the Port of Portland)
    b. Gasco and Siltronic (conducted by NW Natural and Siltronic)
    c. Arkema

   Detailed designs developed for these areas, including potential disposal facility designs, have been incorporated into this draft FS evaluation to strengthen and inform the overall evaluation of alternatives. In addition, lessons learned from early removal actions in these areas and at similar sites throughout the United States have provided valuable information to further inform risk-based evaluations. For example, remedial alternatives that rely primarily on dredging to achieve risk-based goals have demonstrated practical limitations as a result of the effects of sediment resuspension and residuals (Bridges et al. 2010), and the timeframes for completing sediment cleanup at the Site may span decades. These considerations have been accounted for in the development and evaluation of the alternatives.

6. **Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models –** Extensive data collection and evaluation efforts have sufficiently reduced uncertainty of the CSM to evaluate alternatives for the draft FS. These data evaluations were supplemented with a comprehensive predictive model designed to address the spatial variability of Site conditions and estimate the short-term construction impacts and long-term risk reductions resulting from each comprehensive alternative. The model has been extensively peer-reviewed and approved by EPA for use in this draft FS. The Site characterization data and modeling results both reveal that the Site is recovering naturally in many areas, and that focused remedial actions can accelerate the rate of recovery. Projected changes in surface sediment, fish tissue, and water column concentrations used in the detailed evaluation of alternatives were derived from model simulations. Because the considerable body of Site-specific empirical data and analyses were used to develop and calibrate the detailed hydrodynamic, sediment transport, and contaminant fate/transport models of Portland Harbor (see Appendices La and Ha), the Site-specific modeling tools provide an objective quantitative framework to support the detailed evaluation of comprehensive alternatives. Importantly, a quantitative means of bounding model uncertainty was developed to assess the accuracy and reliability of these evaluations. These uncertainties have been

These data evaluations were supplemented with a comprehensive predictive model designed to address the spatial variability of Site conditions and estimate the short-term construction impacts and long-term risk reductions resulting from each comprehensive alternative. The model has been extensively peer-reviewed and approved by EPA for use in this draft FS.

considered in evaluations of the individual alternatives and in comparative analyses among the alternatives.

7. **Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals** – EPA's policy is that there is no presumptive remedy. As a result, a range of remedial alternatives was evaluated using Site-specific data, RAOs, and CERCLA evaluation criteria, including the NCP criteria. As part of assembling the alternatives, a range of remedial actions and RALs was developed and has been used to evaluate the reduction in risks that may be achievable under each comprehensive alternative. Based on the results of these evaluations, a combination of remedial technologies, including focused dredging at targeted locations and integration of capping, in situ treatment, EMNR, and MNR technologies are projected to be an effective approach for achieving the RAOs (with institutional controls needed to manage residual risks). All of the comprehensive alternatives are projected to achieve the same long-term risk levels with some differences in how quickly those levels would be achieved. The overall risk reductions achieved by the comprehensive alternatives have been compared considering a variety of temporal and spatial scales. Risk management decisions and uncertainties are discussed in more detail in Section 10.2.

All of the comprehensive alternatives are projected to achieve the same long-term risk levels with some differences in how quickly those levels would be achieved.

8. **Ensure that sediment cleanup levels are clearly tied to risk management goals** – RAOs that describe the desired results of the remedy—reduction of unacceptable risks to human health and ecological receptors—have been developed for the Site. The RAOs are based on the CSM and the results of the draft final BERA and BHHRA. Under each comprehensive alternative, contaminant sediment concentrations targeted for remedial action (i.e., RALs) have been identified, and RAOs intended to protect human and ecological receptors have been established. Metrics tied to these RAOs were then used to evaluate projected changes to surface sediment, fish tissue, and water column contaminant concentrations resulting from implementation of each potential remedial alternative using detailed, Site-specific modeling supported by the considerable empirical data. Final cleanup levels will be determined by EPA based on risk management principles, the NCP, and the information presented in this draft FS. RAOs, cleanup levels, and related metrics will all be refined based on EPA's determinations in the ROD.

9. **Maximize the effectiveness of institutional controls and recognize their limitation**s – Institutional controls (e.g., fish consumption advisories) have been in place for Portland Harbor and are considered in all the comprehensive alternatives. These controls would be maintained or refined as part of the remedy to be selected by EPA as long as necessary. To be fully protective, all of the comprehensive alternatives will require similar institutional controls. Fish

consumption advisories will be especially important during construction, when tissue concentrations are projected to increase as a result of dredging. Alternatives that include containment components (such as capping and/or CDFs/CADs) that leave contaminated sediment in place at depth will require additional institutional controls, such as restrictions on activities that could disturb these areas (Section 6.2.1 and Appendix T, Section 5). These controls have been successfully implemented at a wide range of sediment cleanup sites both regionally and nationally.

10. **Design remedies to minimize short-term risks while achieving long-term protection** – The comprehensive alternatives evaluated in this draft FS highlight the tradeoffs associated with unavoidable short-term risks associated with larger and more dredging intensive alternatives and long-term protection provided by a range of remedial technologies. Alternatives have been developed that achieve similar long-term risk reduction. The alternatives differ significantly in short-term construction-related environmental impacts, risks to the community, and risks to workers. Short-term risks during construction include increases to contaminant concentrations in sediment, fish tissue, and water during dredging; air and GHG emissions; construction worker risks; quality of life impacts on local communities; and habitat disruption. Both the magnitude and extent of these short-term risks are tied closely to the dredging volumes associated with each alternative and the durations over which those volumes are removed, regardless of dredge management and containment technology. Again, EPA will identify a recommended alternative considering the NCP objectives of achieving the most effective and efficient long-term protection with costs proportional to overall effectiveness, while minimizing short-term impacts.

The alternatives differ significantly in short-term construction-related environmental impacts, risks to the community, and risks to workers. Short-term risks during construction include increases to contaminant concentrations in sediment, fish tissue, and water during dredging; air and greenhouse gas emissions; construction worker risks; quality of life impacts on local communities; and habitat disruption.

11. **Monitor during and after sediment remediation to assess and document remedy effectiveness** – Monitoring during and after sediment remediation to assess and document remedy effectiveness and identify contingency actions is assumed for all of the comprehensive alternatives evaluated in this draft FS (Appendix T). The estimated costs of each comprehensive alternative include detailed monitoring and a conservative (high-range) estimate of operations and maintenance actions

Monitoring during and after sediment remediation to assess and document remedy effectiveness and identify contingency actions is assumed for all of the comprehensive alternatives evaluated in this draft FS (Appendix T).

based on monitoring results. Short- and long-term monitoring data can be evaluated against performance metrics, and appropriate contingency actions (such as dredging, capping, in situ treatment, or EMNR) may be implemented as identified in the final decision documents.

These 11 risk management principles were subsequently incorporated into and expanded upon in EPA's (2005a) *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. This guidance document embodies national EPA policy on contaminated sediment, the focus of which is to reduce potentially unacceptable risks to human health and the environment posed by contaminated sediment sites. It also provides a risk management decision-making framework to assist with selecting appropriate remedies. There are six key principles in the guidance document, which are followed in this draft FS, as outlined below.

First and foremost, the focus of remediation should be on risk reduction, not simply on contaminant mass removal (EPA 2005a – p. 7-1, 7-16). This principle is based on the consideration that contaminated sediment that is not bioavailable or bioaccessible and reasonably stable, meaning that the contaminants are unlikely to be released from the sediment in concentrations that would pose an unacceptable risk to human health and the environment, does not necessarily contribute to site risks (EPA 2005a – p. 7-3). Mass removal, therefore, does not equal risk reduction. This principle was expanded upon by the NRC, "*Remedies should be designed to meet long term risk reduction goals (as opposed to metrics not strictly related to risk, such as mass removal targets*)" (NRC 2007). Consistent with this principle, the comprehensive alternatives evaluated in this draft FS were developed using RALs that are intended to achieve risk-based levels and RAOs from the draft final BERA and BHHRA.

Second, a realistic, site-specific evaluation of the potential effectiveness of each remedial technology, including dredging, capping, in situ treatment, EMNR, and MNR, should be incorporated into the selection of remedies at a site (EPA 2005a – p. 7-3). The extensive series of investigations, empirical data, and detailed modeling conducted for this draft FS are consistent with this principle.

Third, as part of the remedy selection process, an appropriate evaluation of the comparative net risk reduction potential of the comprehensive alternatives, including a realistic evaluation of their respective advantages and site-specific limitations should be conducted, including the risks introduced by implementing the alternatives (EPA 2005a – p. 7-13, 7-14). For example, the risks associated with implementing a dredging remedy include unavoidable contaminant resuspension and releases during sediment removal, continued exposure to contaminants during the construction and implementation phases, residual contamination, disruption of the benthic community, worker risk during sediment removal and handling, and community impacts including accidents, GHG emissions, and quality of life considerations. Further, these risks all become greater as the size of the alternatives and volume of dredging increases. These considerations were identified and discussed in the comparative evaluation of short-term effectiveness provided in Section 9.5. The comparative net risk reduction of the comprehensive alternatives is discussed further in Section 10.3.

Fourth, at large or complex sites, consideration of the use of combinations of remedies may be appropriate (EPA 2005a – p. 7-3). The integrated ("i"-series) alternatives evaluated in this draft FS are consistent with the combination remedy approach, and use different combinations of dredging, capping, in situ treatment, EMNR, and MNR to highlight the tradeoffs associated with different technologies and RALs.

Fifth, monitoring and contingency planning concepts, which involve a stepwise approach to remediation, should be applied where appropriate (EPA 2005a – p. 2-22, 3-1, 7-16). For the Portland Harbor Site, lessons learned from regional and national projects completed to date have been utilized. This draft FS also incorporates information from ongoing remedial design efforts developed for several sub-areas of the Site, which provide valuable Site-specific information for making an informed decision on the sediment cleanup remedy for the Site. The detailed evaluations of comprehensive alternatives presented in this draft FS also highlight the importance of optimizing and sequencing source control and natural recovery at the Site before determining whether dredging, capping, in situ treatment and/or EMNR are warranted in a particular SMA. Monitoring and contingency planning concepts have been incorporated into all of the comprehensive alternatives evaluated in this draft FS and can continue to be refined during remedy design and implementation. The recent NRC (2007) report expands further on this concept:

> *"If there is one fact on which all would agree, it is that the selection and implementation of remedies at contaminated sediment sites are complicated. Many large and complex contaminated sediment sites will take years or even decades to remediate and the technical challenges and uncertainties of remediating aquatic environments are a major obstacle to cost-effective cleanup.*
>
> *Because of site-specific conditions—including hydrodynamic setting, bathymetry, bottom structure, distribution of contaminant concentrations and types, geographic scale, and remediation time frames—the remediation of contaminated sediment is neither simple nor quick, and the notion of a straightforward "remedial pipeline" that is typically used to describe the decision-making process for Superfund sites is likely to be at best not useful and at worst counterproductive.*
>
> *The typical Superfund remedy-selection approach, in which site studies in the remedial investigation and feasibility study establish a single path to remediation in the record of decision, is not the best approach to remedy selection and implementation at these sites owing to the inherent uncertainties in remedy effectiveness. At the largest sites, the time frames and scales are in many ways unprecedented. Given that remedies are estimated to take years or decades to implement and even longer to achieve cleanup goals, there is the potential—*

indeed almost a certainty—that there will be a need for changes, whether in response to new knowledge about site conditions, to changes in site conditions from extreme storms or flooding, or to advances in technology (such as improved dredge or cap design or in situ treatments). Regulators and others will need to adapt continually to evolving conditions and environmental responses that cannot be foreseen.

These possibilities reiterate the importance of phased, adaptive approaches for sediment management at megasites. As described previously, adaptive management does not postpone action, but rather supports action in the face of limited scientific knowledge and the complexities and unpredictable behavior of large ecosystems."

Sixth, comparing and contrasting the costs and benefits of the various remedies is part of the risk management decision-making framework. "*Another important risk management function generally is to compare and contrast the cost and benefit of various remedies*" (EPA 2005a – p. 7-1). The comparative analysis of risk reduction benefits versus project costs and construction durations for the Site is discussed in more detail in Section 10.3.

The guidance concludes that these six principles, if applied appropriately, should lead to protective remedies that are also cost-effective and consistent with the overall objectives of CERCLA and the NCP.

10.2 RISK MANAGEMENT DECISIONS AND UNCERTAINTIES

Remedy selection is ultimately a risk management decision. As discussed in the EPA (2005a) guidance, "*A risk management process should be used to select a remedy designed to reduce the key human and ecological risks effectively*." In support of the overall remedy selection process, this draft FS provides information relevant to the following risk management elements:

- Development of RGs that represent attainment of risk-based RAOs and provide a balance of effectiveness and achievability (Section 3)
- Development of RALs that may achieve the RGs and RAOs in a reasonable timeframe across the Site (Section 4)
- Methods to apply RALs to define SMAs for active remediation that reflect the reasonable potential to achieve RAOs (Section 5)
- Evaluation of a combination of remedial technologies considering the NCP objectives of achieving the most effective, efficient, and cost-effective long-term protection while minimizing short-term impacts (Sections 6 and 7)
- Description and evaluation of the characteristics and performance of the alternatives (Sections 7 through 9), culminating in remedy selection by EPA.

Risk management decision-making for a Site of the size and complexity of Portland Harbor that is changing over time requires careful consideration of uncertainty. This draft FS relies on the best information and science available at this time and, where necessary, made reasonable assumptions to evaluate different remedial alternatives. Uncertainties are appropriately factored into the analysis, and ultimately in remedy selection, as well as in follow-on remedial design and implementation phases.

As described in Section 3.6, EPA and the State of Oregon guidance recognize the importance of assessing uncertainty to provide context to risk management decisions (e.g., EPA 2005a and 2005b). Therefore, when possible, uncertainties were quantitatively assessed in this draft FS for each of the risk-management elements listed above. For those elements that could not be quantified, semi-quantitative or qualitative statements regarding uncertainties were developed and presented in this draft FS. Figure 10.2-1 summarizes these overall uncertainty assessments and presents the hierarchy of uncertainties in terms of their effect on PCB concentration thresholds (e.g., an RG, background level, or RAL) and sediment concentration projections (e.g., SMA footprint mapping, overall natural recovery estimates, or alternative model projections). Uncertainties in RGs contribute the greatest amount of overall uncertainty in the projected outcomes of PCB remediation, while uncertainties associated with RAL, SMA, and alternative projections are relatively minor in comparison. However, as noted throughout this draft FS, the cumulative effect of relatively small uncertainties can propagate when inherently conservative assumptions for multiple parameters are combined, particularly in terms of outcomes for localized SMA-specific remedial designs (Appendix E). Thus, care must be taken to consider the cumulative impact of these uncertainties through each step of the decision process.

Depending on what human health consumption scenario is selected as part of risk management, all of the alternatives could be measured to achieve within a 10^{-4} to a 10^{-6} cancer risk level.

There are uncertainties in the SWAC projections as well as uncertainties associated with selection of any particular RG as part of a risk management decision. Thus, depending on what human health consumption scenario is selected as part of risk management, all of the alternatives could be measured to achieve within a 10^{-4} to a 10^{-6} cancer risk level. The relationship among these uncertainties is visually depicted in Appendix U, Figure 7.2-1, which compares projected long-term PCB sediment concentrations including the estimated uncertainties for the active remedy and MNR portions of the alternatives to a more detailed breakdown of the range of RGs/PRGs developed in Appendix E.

The uncertainty analyses demonstrate that protection of human health and the environment can be adequately attained by achieving sediment concentrations within the various RG ranges (e.g., on an exposure scale pertinent to the risk). Understanding the protectiveness afforded within these acceptable ranges, a single-value RG can be established as a desired target for cleanup, along with the recognition that reducing sediment concentrations to within the acceptable RG and PRG ranges is by definition protective. Additional discussion of the uncertainties of these RG and PRG ranges and the risk reduction achieved by the alternatives is provided in Appendix U, Section 7.2.

Based on the various sensitivity/uncertainty discussions presented throughout the draft FS, the following factors emerge as important for managing uncertainty relative to the time predicted for achieving RAOs, the spatial scales relevant to achieving RAOs (i.e., biologically appropriate scales in setting the RGs), and the projected performance of the comprehensive alternatives:

- Uncertainty in the residual risk conclusions is largely of two kinds: 1) the rate of sedimentation and natural recovery; and 2) the potential for re-exposure of buried subsurface contamination. Ultimately, surface sediment concentrations are expected to converge to levels similar to the quality of incoming sediment resulting in similar levels of risk over time. While future conditions and actual concentrations could vary depending on the effectiveness of source control efforts, it is likely that surface sediment concentrations will be similar, regardless of which comprehensive alternative is selected.
- Long-term projected contaminant concentrations in surface sediment, fish tissue, and surface water were largely insensitive to the range of RALs evaluated in the comprehensive alternatives. An analysis of the potential for small areas to recover more slowly than projected by the model due to additional sediment bed disturbance forces (e.g., propwash and maintenance dredging) further verified the minor differences in projected long-term media concentrations across all RALs and alternatives (Appendix U, Section 5).
- The detailed fate and transport model developed for this draft FS using the considerable empirical data collected during the site characterization allows for a robust quantitative evaluation of stormwater source control effects on sediments (see Appendix Ha, Section 6). In general, the model does not predict that stormwater inputs will have a significant effect on alternative selection; however, such inputs should be considered during remedial design of specific SMAs.
- If lower RALs are selected, uncontrolled sources and upstream inputs may make it more difficult to attain the RALs in localized areas (i.e., short-term effectiveness).
- Likewise, if lower RGs are selected, the potential for long-term recontamination of the Site above the RGs from uncontrolled sources and upstream inputs increases. Furthermore, location-specific analyses and coordination with the source control program will be required during the remedial design phase to ensure that effective source controls are in place. Long-term monitoring and source control measures will be necessary, regardless of the remedial alternative selected.
- All of the remedial technologies have uncertainties with respect to their overall effectiveness. It is now well documented that dredging operations release dissolved contaminants into the water column and also lead to dredge residuals

that will elevate surface sediment and tissue concentrations over the short term (Bridges et al. 2010). While capping, in situ treatment, and EMNR remedies designed and constructed following EPA and USACE guidance have a high factor of safety, localized areas may need periodic repairs and maintenance (e.g., as a result of unanticipated hydrodynamic forces near structures). MNR performance may be slower (or faster) than predicted and may require additional monitoring or supplemental actions based on monitoring results. These potential uncertainties have been incorporated into the cost estimates of all of the comprehensive alternatives as supplemental actions, repairs, and/or additional monitoring.

- Recent projects have shown that actual dredging volumes can be much higher than those estimated during the FS or remedial design phase. Although dredge volumes were estimated for this draft FS using a consistent set of assumptions to support the comparative evaluation, EPA directed use of less conservative volume estimation methods than recommended in the recent literature (e.g., USACE 2008a), which may under-predict remedial design or construction volumes, particularly in areas with relatively shallow sediment deposits (Section 5.11). Within the bounds of the EPA-directed methods, this draft FS presents a range of contaminated sediment volumes and includes these ranges in the cost estimates and construction durations. Also, changes to the draft FS assumptions for residual management (i.e., involving additional cleanup passes to those assumed in the draft FS) in remedial design would add substantial volumes to SMAs.
- The construction durations of the alternatives could vary substantially from the estimates used in this draft FS. As discussed in Section 7.6, qualitatively considering all of the uncertainties with these duration estimates, it appears much more likely that the construction durations assumed in this draft FS are optimistic, likely underestimating actual construction durations given the inherent complexity with a sediment site and the narrow construction window. Also, the ability to implement the larger remedies within the estimated durations is likely even more difficult as compared to the shorter duration alternatives.
- Given upstream contaminant inputs to the Site, there is considerable uncertainty as to whether RGs below background levels can be achieved. Thus, the range of background levels will be an important component in EPA's remedy and RG selection.

10.3 SUMMARY OF COMPARATIVE ANALYSIS OF ALERNATIVES

All of the alternatives (excluding the No Action Alternative A) are projected to be protective of human health and the environment.

Eleven alternatives were evaluated against the CERCLA criteria in Section 8 and compared to one another in Section 9. The types and relative application of the technologies in each alternative are summarized in Figure 10.3-1. All of the alternatives (i.e., not including No Action Alternative A) are projected to be protective of human health and the environment; differences in the overall protectiveness of the alternatives are largely in the context of short-term effectiveness, implementability, and in some cases the timing of substantial risk reductions that lead to achieving the range of risk-based RAOs. The major differences among the comprehensive alternatives are due to: 1) smaller versus larger volumes actively remediated; and 2) more reliance on removal in the “r” alternatives versus an integrated combination of technologies (removal, capping, in situ treatment, and EMNR) for the “i” alternatives.

Differences in the overall protectiveness of the alternatives are largely in the context of short-term effectiveness, implementability, and in some cases the timing of substantial risk reductions that lead to achieving the range of risk-based RAOs.

Table 10.3-1 summarizes the comparative analysis. A high ranking (full black dot) in the table depicts an alternative that ranks relatively high compared to other alternatives, whereas a low ranking (empty circle) means the alternative ranks relatively low compared to other alternatives. In many cases, the comparative evaluation did not identify substantial differences in long-term effectiveness. In contrast, evaluations of short-term effectiveness, implementability, and cost distinguish differences among the alternatives. Table 10.3-2 provides a numeric scoring from 1 to 10 of the alternatives against each of the balancing criteria (i.e., “Summary Score”). Table 10.3-2 is consistent with Table 10.3-1, but provides a finer gradation of scoring that helps illustrate some of the differences between the alternatives. (Appendix U, Section 7.1 contains additional information on the uncertainty and procedures for deriving the scores shown in Table 10.3-2.) The conclusions of the comparative analyses of alternatives are provided in Section 10.3.9.

The following sections summarize the key points of the comparative analyses and performance of the remedial alternatives related to CERCLA and NCP requirements. Note that NCP modifying criteria—state/Tribal and community acceptance—are not discussed below; they will be evaluated by EPA after the FS is completed and will also include consideration of formal public comments on the Proposed Plan.

10.3.1 Overall Protection of Human Health and the Environment

Risk management recommendations for all the contaminants posing potentially unacceptable risks (per the findings of the BHHRA and BERA) are presented in detail in Kennedy/Jenks and Windward Environmental (2011). A subset of the contaminants posing potentially unacceptable risks, called COCs, were recommended for use in the draft FS. These COCs present the primary potentially unacceptable risk in various areas of the Site consistent with EPA risk assessment guidance.

Alternatives that rely more on dredging, and/or have larger amounts of dredging, have higher impacts to human health and the environment in the short term, and would result in elevated fish tissue concentrations over the duration of the dredging activity.

Alternatives that rely more on dredging and/or have larger amounts of dredging have higher impacts to human health and the environment in the short term, and they would result in elevated fish tissue concentrations over the duration of the dredging activity. Residual risks achieved by the comprehensive alternatives are summarized below:

- The No Action Alternative A does not satisfy the threshold requirement for protecting human health and the environment across all spatial scales at the Site.
- Over the long term, all of the comprehensive alternatives are projected to be similarly protective of human health and the environment, including the benthic community, fish, and wildlife. This is reflected in the projected long-term surface sediment and tissue concentrations. Over the long-term, all of the comprehensive alternatives are projected to achieve similar levels of human health protection, with excess cancer risks in the range of 1 in 10,000 to 1 in 1,000,000 (10^{-4} to 10^{-6} magnitude risk), depending on the exposure pathway and contaminant. Both cancer and noncancer risk reductions achieved by all of the comprehensive alternatives are generally within the acceptable risk range for CERCLA and the Oregon Environmental Cleanup Law and are similar across all action alternatives.

Over the long term, all of the comprehensive alternatives are projected to be similarly protective of human health and the environment, including the benthic community, fish, and wildlife. This is reflected in the projected long-term surface sediment and tissue concentrations.

- Regional background conditions make it technically infeasible for any of the comprehensive alternatives to achieve the most conservative total PCB RGs based on human health protection from consumption of resident fish. The regional background concentration ranges calculated by LWG for total PCBs extend higher than the point estimate RGs selected by EPA for use in this evaluation. Because of regional background conditions, fish consumption advisories for resident species are expected to remain in effect at the Site irrespective of which alternative is selected.

Regional background conditions make it technically infeasible for any of the comprehensive alternatives to achieve the most conservative total PCB RGs based on human health protection from consumption of resident fish.

- As discussed in Section 3.6, Section 9.1, and Appendix E, the RGs are expressed as individual point estimates mostly for convenience in the initial analysis of alternatives. However, the exposure scenarios on which the RGs are based are a combination of many parameters and represent a range of values with varying probabilities. For example, the EPA point estimate RG for the 10^{-4} cancer risk for the smallmouth bass whole body consumption is 29.5 ppb and corresponds to approximately the 99th percentile of the statistical distribution underlying the exposure parameters. The 95th percentile of that same distribution corresponds to an RG of 95 ppb. The range between the two almost completely overlaps with the 90th to 99th percentile for the 10^{-5} cancer risk associated with the smallmouth bass fillet (with skin) consumption scenario. There may be no practical difference between the risk levels in the 95th and 99th percentile of the distributions for any of the scenarios. Consistent with EPA guidance, comparing risk reduction should consider the real reduction that is achieved by comparing SWACs to an RG of 29.5 ppb compared to an RG of 95 ppb.

- Implementation timeframes are longer for dredging than for other remedial technologies applied over a similar area, and alternatives with larger dredge volumes and longer timeframes would result in greater short-term risks related to construction duration (e.g., water quality impacts, air emissions, worker safety, and quality of life).

Evaluation of achievement of RAOs and long-term residual risks under each comprehensive alternative was based on modeling projections and comparisons with a range of risk metrics. Uncertainties associated with these risk metrics are discussed further in Section 10.2.

In summary, all alternatives except Alternative A—No Action, provide overall protection of human health and the environment in the long term.

10.3.2 Compliance with ARARs

ARAR compliance under the comprehensive alternatives is summarized below:

- The No Action Alternative A does not satisfy the threshold requirement of complying with ARARs.
- All of the action alternatives comply with ARARs to the extent practicable except as noted below for surface water quality.
- Water quality improvements are projected from sediment remediation and source control. Water quality is likely to be variable throughout the Site, depending on the extent of local source controls. All the comprehensive alternatives are expected to achieve similar reductions in surface water concentrations. None of the comprehensive alternatives are expected to meet all risk-based water quality criteria and standards, particularly those based on fish consumption. For the contaminants that exceed these criteria, no alternative is projected to contribute more than any other alternative to reduction in surface water concentrations post-remedy. To the extent WQS and NRWQC exceedances are driven by upstream loads and not Site sediments, the Site complies with these surface water ARARs “with respect to…contaminants that will remain onsite.” To the extent EPA determines that an ARAR waiver is necessary with respect to any surface water criteria, the draft FS evaluations will assist EPA in making that assessment.

10.3.3 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence considers the magnitude of residual risks that would remain on Site after the RAOs have been achieved and the adequacy and reliability of controls that can be used to manage these residual risks. The comparative analysis is summarized below:

As summarized in Figure 10.3-2, under all of the comprehensive alternatives, natural recovery processes are projected to achieve the majority of Site-wide progress toward PCB SWAC reductions and associated residual risks over the long term.

- Although contaminant concentrations and risks are reduced through natural processes, the No Action Alternative A provides the lowest degree of long-term effectiveness and permanence, primarily for PCBs.
- Residual risks remaining at the Site under all of the action alternatives are similar based on model-projected outcomes, and all of these alternatives are projected to achieve similar risk endpoints. As summarized in Figure 10.3-2, under all of the comprehensive alternatives, natural recovery processes are projected to achieve the majority of Site-wide progress toward PCB SWAC reductions and associated residual risks over the long term.
- For all alternatives, BaP is projected to achieve the very conservative (>99th percentile 10^{-6} cancer risk level for sediment direct contact) RG throughout the Site within 30 years, except in shoreline half river mile 6 to 6.5 West where the highest BaP sediment concentrations occur. This area is projected to meet this RG in 40 years. Alternatives with more active remediation do not appreciably accelerate the achievement of the BaP RGs. Similarly, other COCs evaluated (i.e., DDx) achieve low RGs identified for the Site over the long term.
- Uncertainty in the residual risk from surface sediment is largely associated with the sedimentation rate and stability of incoming sediment from upstream sources in the Lower Willamette River. Ultimately, surface sediment contaminant concentrations are expected to converge to levels similar to the quality of incoming sediment from upstream (which are well characterized) combined with other inputs (which are more uncertain), resulting in similar levels of potentially unacceptable risk over time for all the comprehensive alternatives.
- All of the comprehensive alternatives would require a set of controls consisting of monitoring, maintenance, institutional controls, and periodic reviews (e.g., every 5 years). All of the alternatives would also require continued fish consumption advisories. Notification to waterway users, review of USACE construction permit applications, and where appropriate, the use of restrictive covenants or similar controls such as Coast Guard RNAs to avoid disturbance of subsurface contamination would be required to varying degrees for all of the comprehensive alternatives.
- EPA may select an alternative in the Proposed Plan that represents some combination or incremental version of the specific alternatives evaluated in the draft FS. An example is adjustment of MNR in combination with active construction options in specific reaches of the Site. The draft FS recognizes two

reaches of the Site—RM 11.8 to 11 and Swan Island Lagoon—where the effectiveness of MNR as a remedial technology is more uncertain. Section 7.4.1.2 discusses MNR refinements and potential augmentation of options in Swan Island Lagoon, including enhancing the sedimentation process through placement of suitable sand in areas already below the RALs in SMA 17S. This refinement is already included in all of the action alternatives and, thus, is included in the above evaluations of the most cost-effective Site-wide remedy. Augmentation options, along with additional MNR evaluations and modeling in RM 11.8 to 11, could also be developed prior to or as part of remedial design.

- Although all of the comprehensive alternatives ranked similarly with respect to the overall evaluation of long-term effectiveness and permanence, the integrated alternatives (especially Alternatives C-i and D-i) ranked higher than the other alternatives as they would provide a higher level of overall risk reduction and lower residual risks than the more removal focused alternatives (Table 10.3-2). This is because these alternatives produce fewer releases and residuals during construction as compared to alternatives with more removal, which cause ongoing elevations in sediment and tissue levels over 30 years or more.

> *Although all of the comprehensive alternatives ranked similarly with respect to the overall evaluation of long-term effectiveness and permanence, the integrated alternatives (especially Alternatives C-i and D-i) ranked higher than the other alternatives as they would provide a higher level of overall risk reduction and lower residual risks than the more removal focused alternatives (Table 10.3-2).*

10.3.4 Reductions in Mobility, Toxicity, or Volume through Treatment

This criterion considers the treatment processes used and materials treated; amount of hazardous materials destroyed or treated; degree of expected reductions in toxicity, mobility, and volume; degree to which treatment is irreversible; and type and quantity of residues remaining after treatment. Treatment is generally preferred to address principal threat wastes (e.g., highly toxic or highly mobile waste), but these materials are not found at the Site. The use of institutional and engineering controls is also acceptable for the lower level risks at the Site (40 CFR Section 300.430 (a)(1)(iii)). The comparative analysis is summarized below:

> *The integrated alternatives include more potential for in situ treatment and, therefore, rank higher with respect to the treatment criterion than removal focused alternatives.*

- Those alternatives that include the potential for in situ treatment can effectively reduce the toxicity and mobility of sediment contaminants by controlling their bioavailability through treatment. For example, direct placement of AC in surface sediments has proven effective in reducing the bioavailability of a range of sediment contaminants, including the bounding COCs (i.e., PCBs, PAHs, and

DDx compounds) for a variety of pathways and receptors including the benthic community (Ghosh et al. 2011; Cornelissen et al. 2011).

- The integrated alternatives include more potential for in situ treatment and, therefore, rank higher with respect to the treatment criterion than removal focused alternatives. Those alternatives with lower RALs and corresponding relatively large potential in situ treatment footprints ranked highest (Table 10.3-2).

10.3.5 Short-term Effectiveness

Comprehensive Alternatives B-i and C-i ranked higher than other alternatives for short-term effectiveness (Table 10.3-2).

Short-term effectiveness is a measure of the time required to achieve the RAOs and the risks and impacts that may occur during implementation of the alternative. Each comprehensive alternative was evaluated relative to protection of the community, workers, and the environment during implementation. The comparative analysis is summarized below:

- The larger comprehensive alternatives and those with more dredging have higher and longer duration short-term risks associated with sediment, water, and fish tissue.
- Those comprehensive alternatives with longer construction durations (in this case, as long as 28 years) and greater dredge volumes present proportionately larger risks to workers, the community, and the environment and therefore rank lower for short-term effectiveness factors. Longer construction durations significantly impact water and air quality and increase equipment/vehicle emissions, noise, and other resource use. Larger remediation footprints also increase the short-term disturbance of the existing benthic community and other resident aquatic life.
- Short-term effectiveness of the comprehensive alternatives is also evaluated based on construction durations. Removal focused alternatives would have significantly longer construction durations than the integrated alternatives.
- Comprehensive Alternatives B-i and C-i ranked higher than other alternatives for short-term effectiveness (Table 10.3-2). Differences in these rankings are based on the relative construction durations (shorter durations for dredging-related impacts). In comparison, implementation of Alternatives D through F (particularly those with a removal focus) would result in greater environmental impacts (e.g., water quality, sediment recontamination, and greenhouse gas emissions during construction), longer construction durations, and greater community/worker impacts.

10.3.6 Implementability

Comprehensive Alternative B-i ranked highest for the implementability factors (Table 10.3-2).

This criterion considers reliability of the remedial technology, the technical and administrative ability to implement each alternative, and other related implementability factors. Each of the alternatives involves various combinations of technologies that on their own have been successfully implemented at numerous sites throughout the northwest and across the United States. The required equipment and appropriately skilled personnel are readily available and coordination of the activities among implementing parties and agencies can be achieved, particularly for the alternatives with higher RALs, and smaller areas of active remedy. However, as discussed in Section 9.6, multiple factors (e.g., the number of PRPs, limited construction window, multiple disposal sites) make the combination of technologies in the large alternatives more complex and less implementable. Based on the comparative analysis:

- Alternatives with shorter durations for construction would be easier to implement through the end of the construction period than those with longer construction periods. This reduces the overall level of difficulty both technically and administratively (e.g., coordination with agencies and other stakeholders) and the potential for technical problems leading to schedule delays.
- The reliability of the MNR technology was evaluated through an uncertainty analysis (Appendix U, Section 5). This evaluation indicated that the natural recovery and modeling uncertainties are small compared to the RG and SMA uncertainties (Figure 10.2-1). The MNR uncertainty would not change the conclusions of the comparison evaluation of alternatives.
- Alternatives with lower RALs have a greater potential for technical problems and administrative delays (e.g., water quality monitoring, protection of fish migration windows, and coordination with vessel traffic).
- Comprehensive Alternative B-i ranked highest under this criterion because it represents the best balance of the implementability factors (Table 10.3-2).

10.3.7 Cost

Comprehensive Alternative B-i has the lowest cost range and therefore ranked best for the cost criterion (Table 10.5-2).

The comprehensive alternatives differ significantly in their projected costs:

- Alternative F-r has the highest cost range (approximately $1.1 to $1.8 billion) and therefore ranks the lowest for this criterion (Table 10.3-2). The estimated costs for the remaining comprehensive alternatives range from Alternative B-i (approximately $169 to $250 million) up to Alternative F-i (approximately $0.9 to $1.4 billion).
- Comprehensive Alternative B-i has the lowest cost range and therefore ranked best for the cost criterion (Table 10.5-2).

10.3.8 Cost-Effectiveness

As discussed above, a key FS objective under the NCP is to develop an efficient, coordinated, and cost-effective remediation response for the Site. As discussed in various guidance and laws:

- Comparing and contrasting the costs and benefits of the various remedies is part of the risk management decision-making framework, "*Another important risk management function generally is to compare and contrast the cost and benefit of various remedies*" (EPA 2005a – p. 7-1)
- 40CFR300.430(f)(ii)(D) states that "Each remedial action selected shall be cost-effective; cost-effectiveness is determined by evaluating long-term effectiveness and permanence, reduction of toxicity, mobility or volume through treatment, and short-term effectiveness to establish overall effectiveness. Overall effectiveness is then compared to cost to ensure that the remedy is cost-effective. A remedy shall be cost-effective if its costs are proportional to its overall effectiveness."

Evaluations of cost-effectiveness can provide a useful measure that compares several of the balancing criteria including long-term effectiveness, short-term effectiveness, and costs.

For this evaluation, several representative measures of short- and long-term effectiveness were developed based on projections of the time-averaged Site-wide PCB sediment SWAC and time-averaged Site-wide smallmouth bass tissue PCB concentrations for each alternative over the first 30 years after cleanup begins. This measure is useful because it provides a projection of the overall potential risk to the next generation of people that would be exposed to Site media during and/or immediately following remedy implementation, and is based on the draft final BHHRA 30-year exposure period for human health exposure scenarios.

These time-averaged measures of overall effectiveness were compared to both cost and construction duration of each alternative to provide an overall evaluation of cost-effectiveness. Figures 10.3-3 and 10.3-4 compare overall total PCB sediment and fish tissue projections, respectively, against cost. Figures 10.3-5 and 10.3-6 compare overall total PCB sediment and fish tissue projections, respectively, against construction duration. PCBs were used for this comparison because they contribute the greatest proportion of baseline risks and also have the most widespread distribution across the Site. Similar relationships occur for other contaminants and spatial scales (see similar figures in Appendix U, Section 7.1). For comparative purposes, the figures also depict uncertainties associated with the SWAC and tissue concentration projections, as well as cost and construction duration estimates. Although these uncertainties are significant, they affect all of the alternatives proportionately, and thus do not alter the fundamental relationships between the various alternatives in the comparative evaluation.

The comparative evaluations reveal that the comprehensive alternatives with lower RALs and greater dredge volumes would provide less overall effectiveness, primarily because they would generate more releases of bioavailable contaminants over significantly longer construction durations and at greater cost. By this measure, the removal focused alternatives are all less cost-effective than the integrated alternatives for similar RALs. The greatest degree of overall effectiveness is achieved under Alternatives B-i, C-i, or D-i, which correspond to total costs of approximately $169 to $368 million and construction durations of approximately 2 to 3 years.

Consistent with the 30-year time-averaged projections, SWACs at year 30 further suggest that implementation of remedies beyond Alternatives B-i or C-i would result in diminishing benefits per incremental cost.

Additional metrics of cost-effectiveness are provided by examining projected changes in the Site-wide sediment PCB SWAC at years 0 and 30 after remedial construction is completed under each alternative, and comparing these projected changes with the cost of the alternatives (Figure 10.3-7). These measures further demonstrate that the more costly alternatives do not result in proportional benefits in terms of improved effectiveness, particularly at the end of the 30-year projection period. Consistent with the 30-year time-averaged projections summarized above, SWACs at year 30 further suggest that implementation of remedies beyond Alternatives B-i or C-i would result in diminishing benefits per incremental cost.

In addition to the PCB comparisons summarized above, another useful method is to compare and contrast the overall benefits and costs of the various remedies consistent with the NCP and EPA (2005a) guidance, combining four balancing "benefit" criteria including: 1) long-term effectiveness; 2) reduction of toxicity, mobility, and volume through treatment; 3) short-term effectiveness; and 4) implementability into a total benefit metric, and comparing this metric with the fifth balancing criteria of cost for each alternative. This analysis can be used to evaluate, among other elements, whether the incremental cost of an alternative is disproportionate to the overall degree of protectiveness it provides, as seen in Figure 10.3-8.

10.3.9 Conclusions of the Comparative Analysis of Alternatives

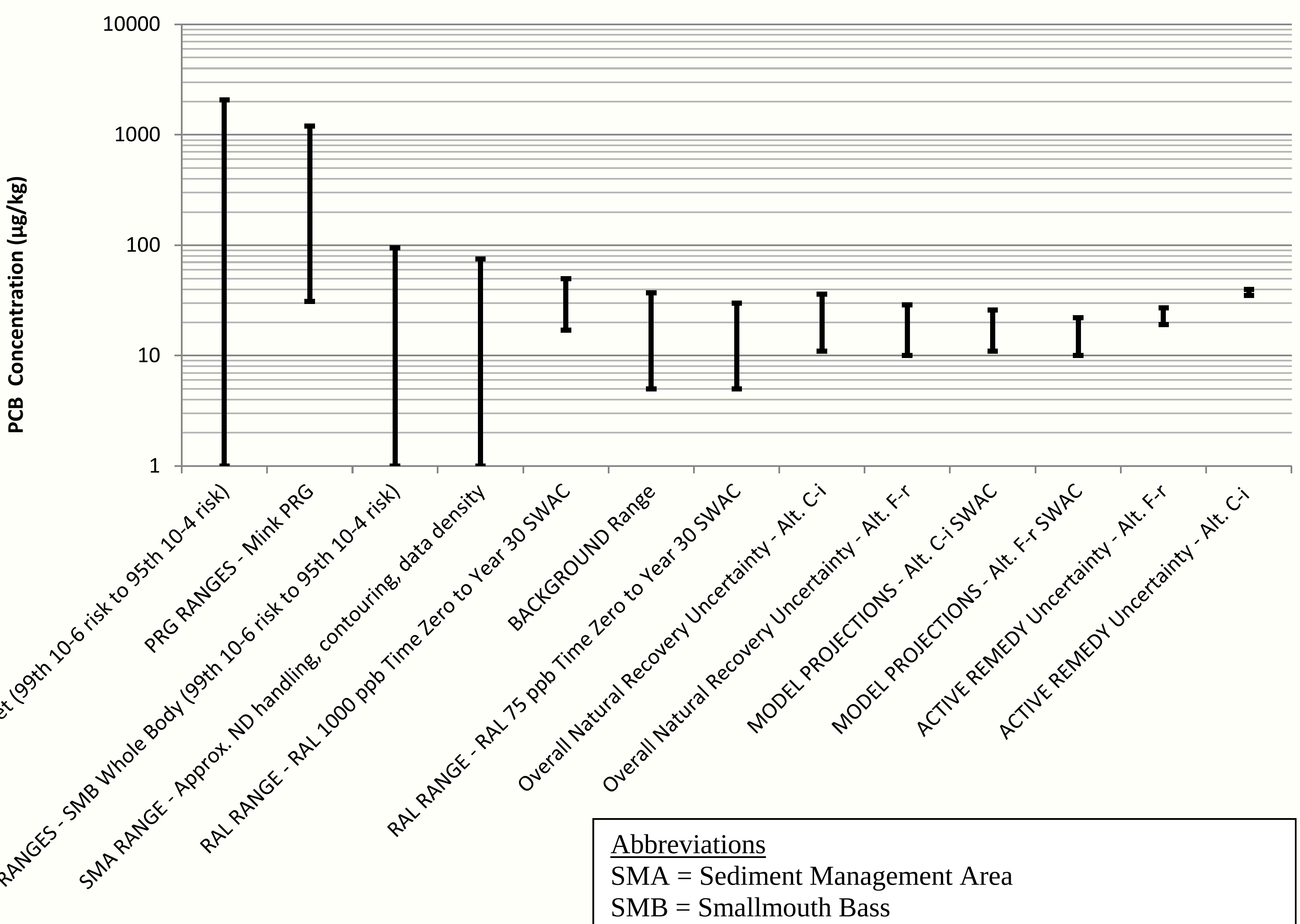
This draft FS has comparatively evaluated eleven potential remedial alternatives, including a series of removal-based ("r"-series) alternatives and integrated ("i"-series) alternatives that combine remedial technologies across the Site. As summarized in Figure 10.3-1, the integrated alternatives incorporate dredging over considerable areas of the Site, ranging from approximately 23 to 176 acres depending on the specific "i"-series alternative. The key findings of the draft FS and the comparative analysis are summarized in Table 10.3-3. The NCP at 40 CFR §300.430(e)(9) establishes a framework of nine criteria for evaluating remedies. This draft FS has comparatively evaluated the eleven potential remedial alternatives against seven of these criteria (protectiveness; compliance with ARARs; long-term effectiveness; reduction of toxicity, mobility and volume; short-term effectiveness; implementability; and cost). Two additional criteria (state and community acceptance) will be considered by EPA during development of the Proposed Plan. As explained in detail in Appendix U, Section 7.2, these alternatives were evaluated both qualitatively and quantitatively by numerically scoring the performance of each alternative against each criterion. The resulting scores of long-term effectiveness; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; and implementability were totaled into a total "Summary Score" for these balancing criteria as shown on Table 10.3-2.

As seen in Figures 10.3-8 and 10.3 -9, Alternative B-i is protective for the least cost, and Alternative C-i scores the highest without consideration of cost.

Based upon this analysis, as seen in Table 10.3-2, Alternatives B-i, C-i, and D-i have the highest Summary Score and are the three alternatives that best meet both the RAOs and the seven NCP criteria. These three alternatives are distinct from the remaining alternatives in achieving adequate protectiveness in substantially shorter durations. As seen in Figures 10.3-8 and 10.3-9, Alternative B-i is protective for the least cost, and Alternative C-i scores the highest without consideration of cost.[1]

[1] Appendix U, Section 7.1 shows an additional similar cost versus benefit graph with the Summary Score on the y axis and the cost on the x axis.

This figure shows the hierarchy of quantified uncertainties in terms of their effect on PCB concentration thresholds (e.g., an RG, background level, or RAL) and sediment concentration projections (e.g., SMA footprint mapping, overall natural recovery estimates, alternative model projections). RG and SMA development uncertainties are large as compared to natural recovery and modeling uncertainties, which are small.



Abbreviations
SMA = Sediment Management Area
SMB = Smallmouth Bass
SWAC = Surface-area Weighted Average Concentration
RAL = Remedial Action Level
RG = Remediation Goal

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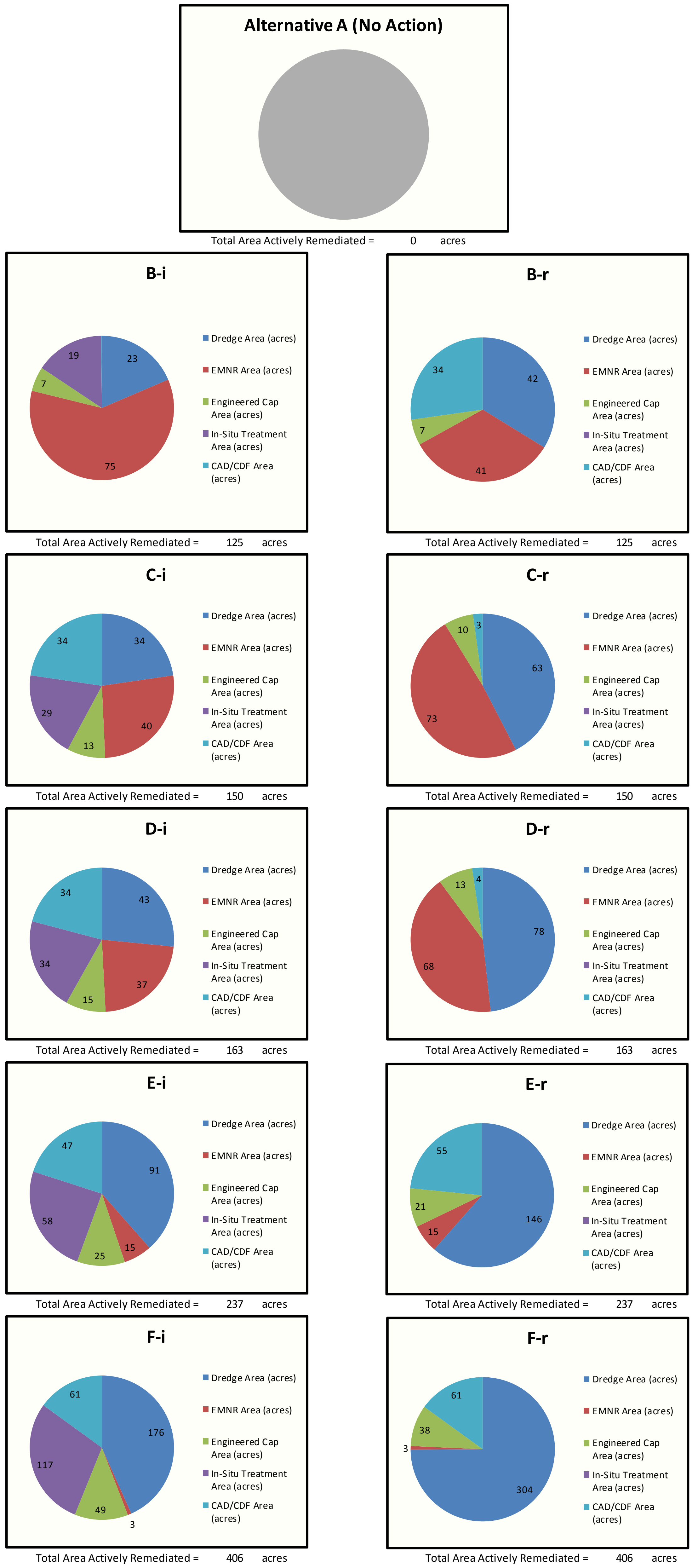
Figure 10.2-1
Portland Harbor RI/FS
Draft Feasibility Study
Comparison of Uncertainties in Total PCB Threshold (RG, RAL, Background) Estimates and SMA/Alternative SWAC Projections

Technology Area Coverage by Alternative



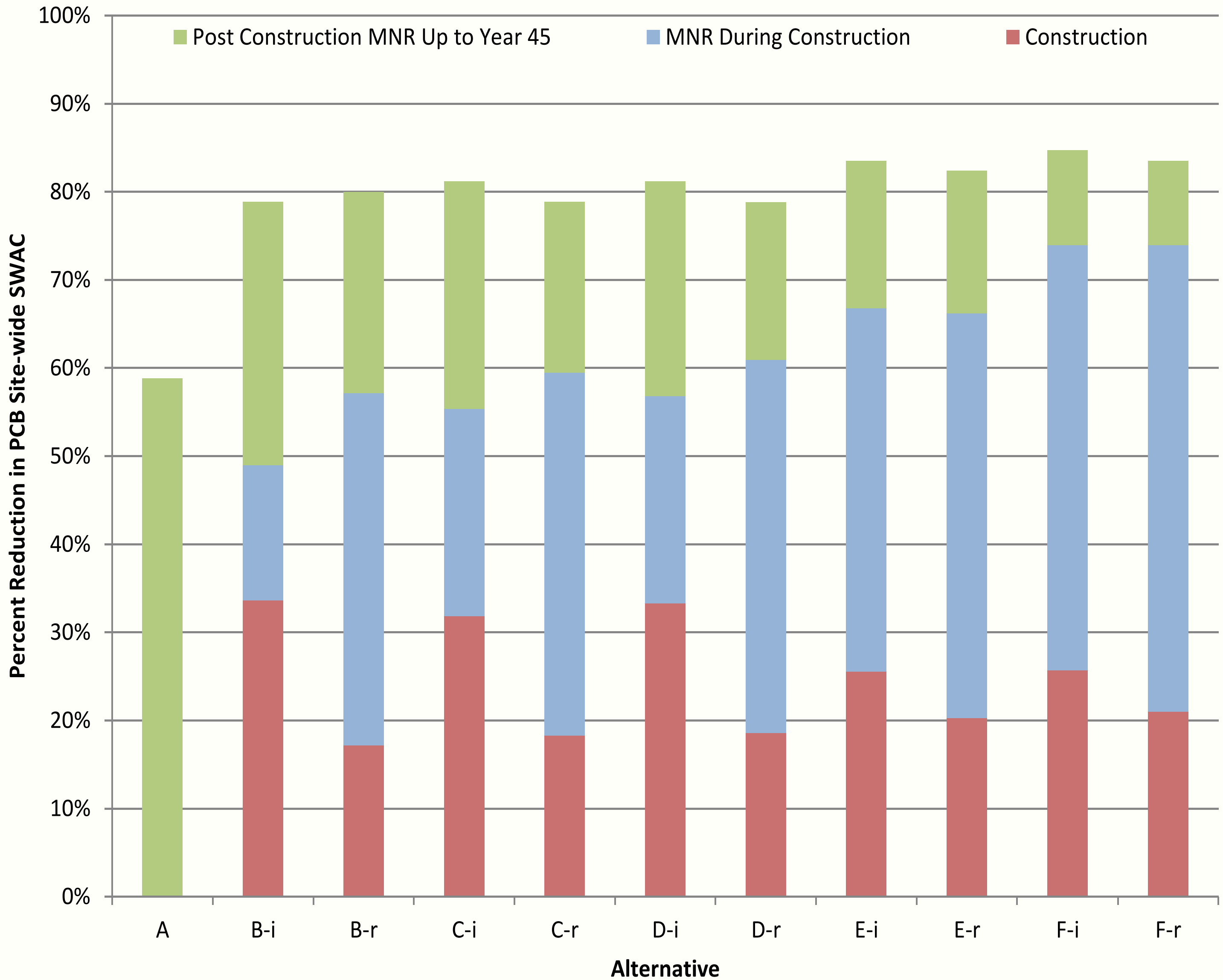
This figure shows the proportions of remedial technologies making up each alternative. The graphs show that integrated alternatives include a substantial amount of dredging/removal.

Notes:

CAD/CDF acreages shown are only for the CAD/CDF area that covers potential remediation area (Dredge Area, Engineered Cap Area, Treatment Area, and EMNR Area). The constructed footprints of the proposed CAD/CDFs could be larger.

The "Total Area Actively Remediated" includes EMNR areas, which are outside the active remediation areas defined by the RALs. Per Section 7, this additional EMNR placement is added in Swan Island Lagoon in areas that are already below the RALs to augment MNR processes in this location.

The acreage of total area actively remediated includes EMNR areas outside the SMAs and, therefore, is somewhat larger than the SMA size presented in Section 7. Also, as discussed in Section 7, the SMA sizes and the technologies applied are estimates for draft FS purposes and are expected to be further refined in remedial design when additional data are collected.



This figure shows the percent PCB Site-wide sediment SWAC reduction achieved long term for each alternative, and processes that contribute to those reductions (i.e., natural recovery vs. active remediation construction).

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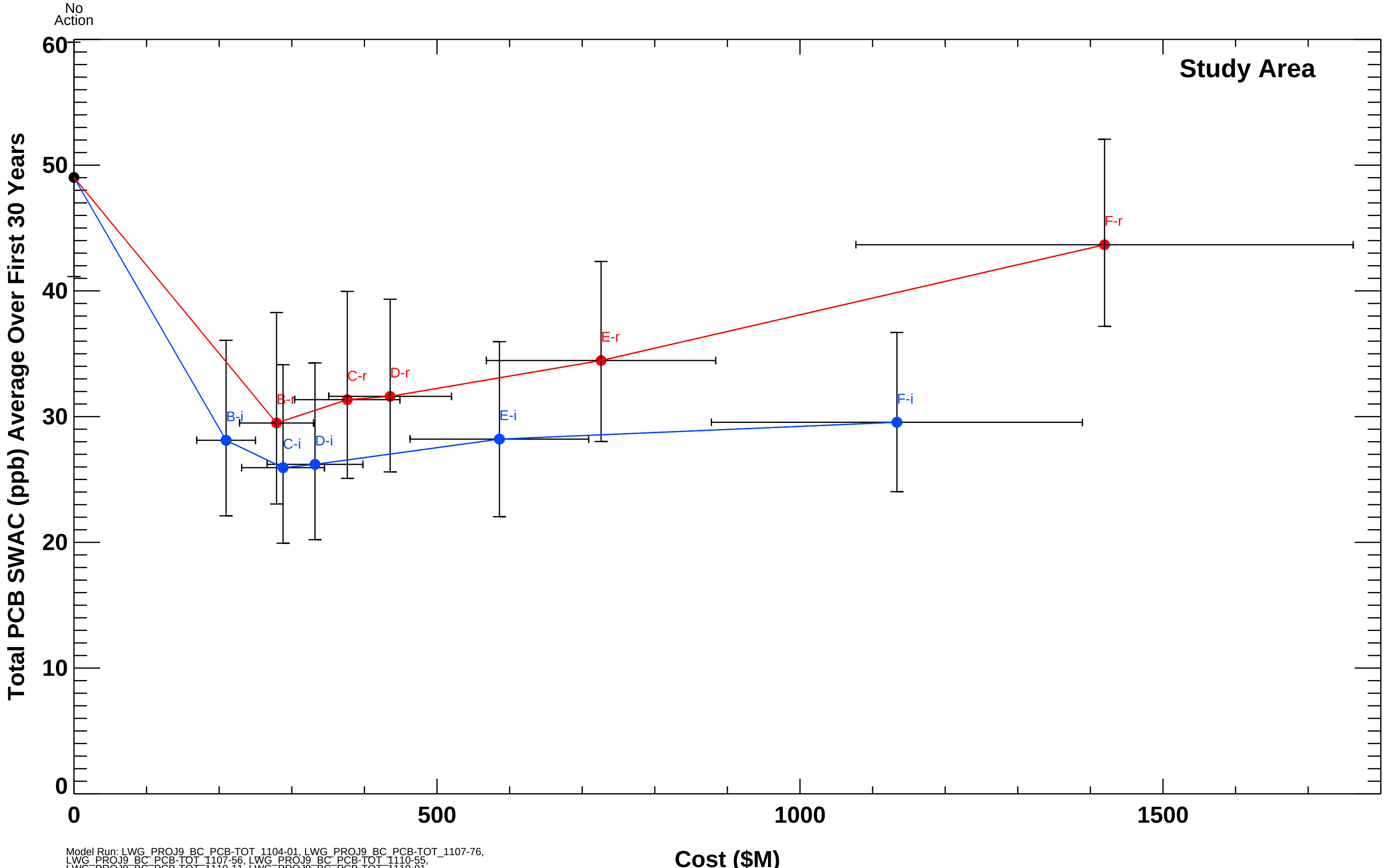
Figure 10.3-2
Portland Harbor RI/FS
Draft Feasibility Study
Projected Percent Reductions in Site-Wide PCB SWAC at Year 45 for all Draft FS Alternatives Provided by Remedial Construction and MNR

This figure compares the Site-wide 30-year time-averaged PCB sediment SWACs achieved to the costs for each alternative, with quantified uncertainties in both parameters shown.



Model Run: LWG_PROJ9_BC_PCB-TOT_1104-01, LWG_PROJ9_BC_PCB-TOT_1107-76, LWG_PROJ9_BC_PCB-TOT_1107-56, LWG_PROJ9_BC_PCB-TOT_1110-55, LWG_PROJ9_BC_PCB-TOT_1110-11, LWG_PROJ9_BC_PCB-TOT_1110-01, LWG_PROJ9_BC_PCB-TOT_1107-26, LWG_PROJ9_BC_PCB-TOT_1107-61, LWG_PROJ9_BC_PCB-TOT_1107-16, LWG_PROJ9_BC_PCB-TOT_1110-16 ,LWG_PROJ9_BC_PCB-TOT_1110-06

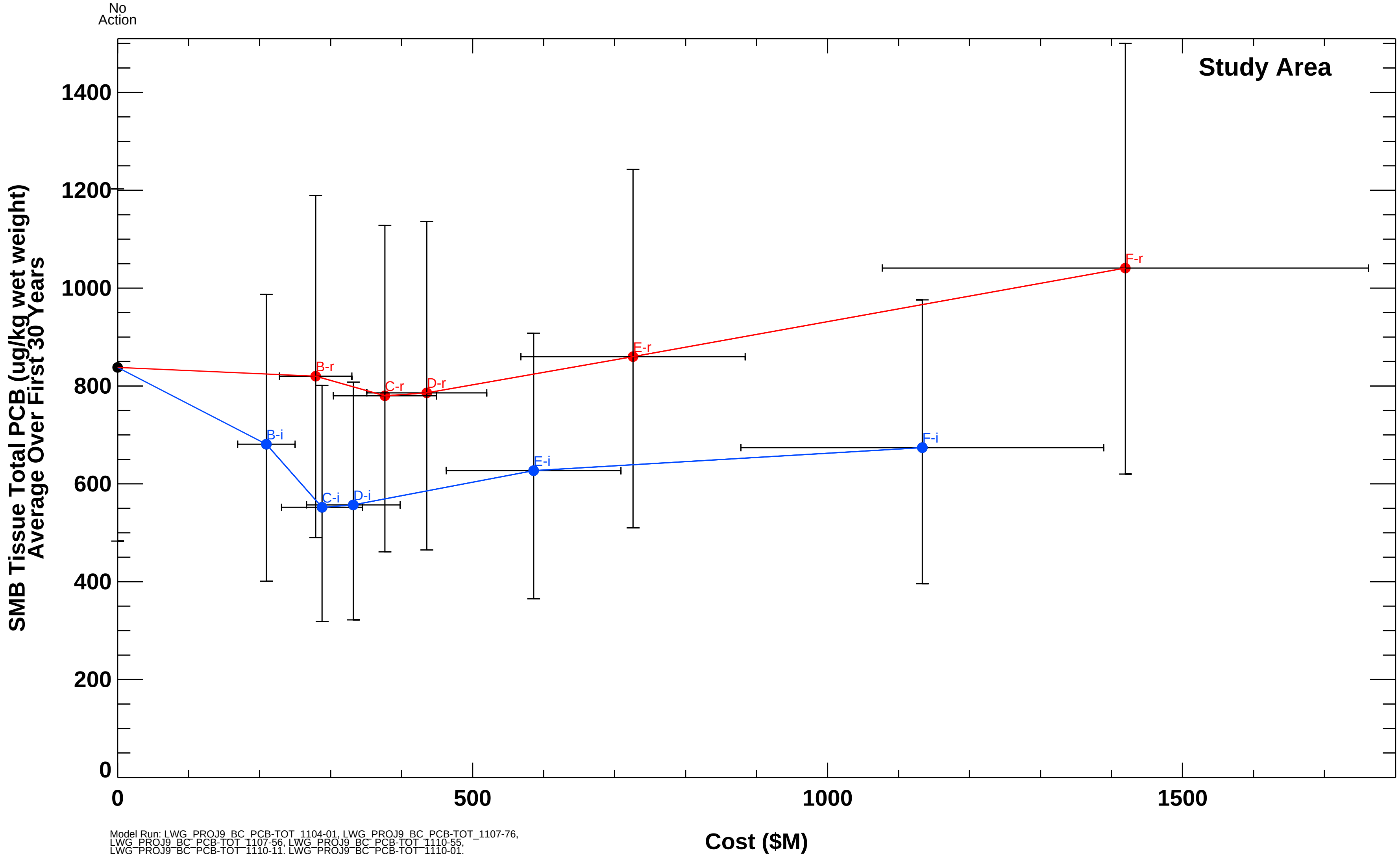
Figure 10.3-3

Portland Harbor RI/FS

Draft Feasibility Study

Sediment Total PCB SWAC versus Cost for all Draft FS Alternatives on a Site-wide Basis

This figure compares the Site-wide 30-year time-averaged PCB smallmouth bass tissue concentrations achieved to the costs for each alternative, with quantified uncertainties in both parameters shown.



Model Run: LWG_PROJ9_BC_PCB-TOT_1104-01, LWG_PROJ9_BC_PCB-TOT_1107-76, LWG_PROJ9_BC_PCB-TOT_1107-56, LWG_PROJ9_BC_PCB-TOT_1110-55, LWG_PROJ9_BC_PCB-TOT_1110-11, LWG_PROJ9_BC_PCB-TOT_1110-01, LWG_PROJ9_BC_PCB-TOT_1107-26, LWG_PROJ9_BC_PCB-TOT_1107-61, LWG_PROJ9_BC_PCB-TOT_1107-16, LWG_PROJ9_BC_PCB-TOT_1110-16 ,LWG_PROJ9_BC_PCB-TOT_1110-06

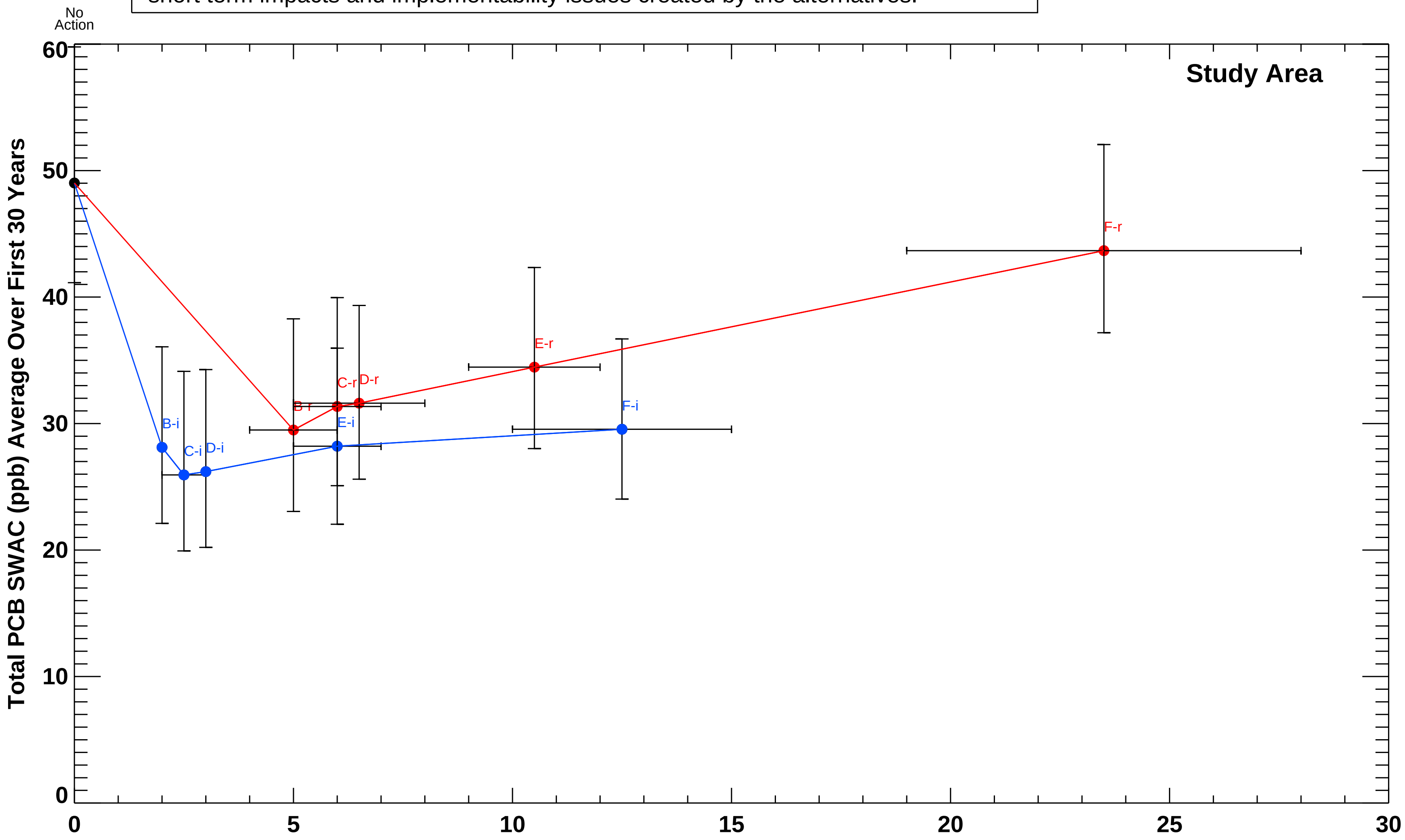
Figure 10.3-4

Portland Harbor RI/FS

Draft Feasibility Study

Smallmouth Bass PCB Tissue SWAC versus Cost for all Draft FS Alternatives on a Site-wide Basis

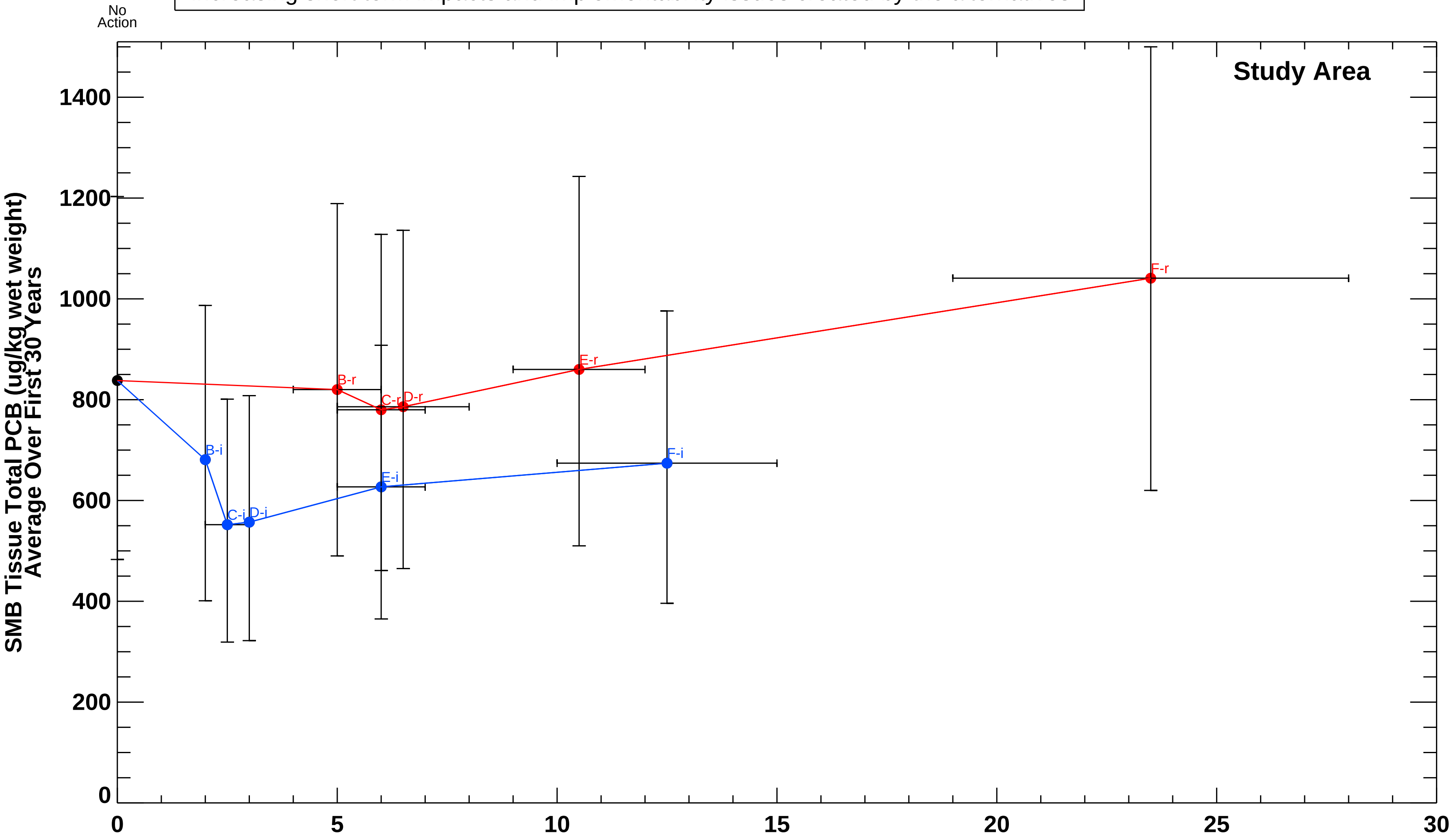
This figure compares the Site-wide 30-year time-averaged PCB sediment SWACs achieved to the duration of each alternative, with quantified uncertainties in both parameters shown. Increasing duration is a good metric of increasing short term impacts and implementability issues created by the alternatives.



Model Run: LWG_PROJ9_BC_PCB-TOT_1104-01, LWG_PROJ9_BC_PCB-TOT_1107-76, LWG_PROJ9_BC_PCB-TOT_1107-56, LWG_PROJ9_BC_PCB-TOT_1110-55, LWG_PROJ9_BC_PCB-TOT_1110-11, LWG_PROJ9_BC_PCB-TOT_1110-01, LWG_PROJ9_BC_PCB-TOT_1107-26, LWG_PROJ9_BC_PCB-TOT_1107-61, LWG_PROJ9_BC_PCB-TOT_1107-16, LWG_PROJ9_BC_PCB-TOT_1110-16 ,LWG_PROJ9_BC_PCB-TOT_1110-06

Figure 10.3-5
Portland Harbor RI/FS
Draft Feasibility Study
Sediment Total PCB SWAC versus Duration for all Draft FS Alternatives on a Site-wide Basis

This figure compares the Site-wide 30-year time-averaged PCB smallmouth bass tissue concentrations achieved to the duration of each alternative, with quantified uncertainties in both parameters shown. Increasing duration is a good metric of increasing short term impacts and implementability issues created by the alternatives.



Model Run: LWG_PROJ9_BC_PCB-TOT_1104-01, LWG_PROJ9_BC_PCB-TOT_1107-76, LWG_PROJ9_BC_PCB-TOT_1107-56, LWG_PROJ9_BC_PCB-TOT_1110-55, LWG_PROJ9_BC_PCB-TOT_1110-11, LWG_PROJ9_BC_PCB-TOT_1110-01, LWG_PROJ9_BC_PCB-TOT_1107-26, LWG_PROJ9_BC_PCB-TOT_1107-61, LWG_PROJ9_BC_PCB-TOT_1107-16, LWG_PROJ9_BC_PCB-TOT_1110-16 ,LWG_PROJ9_BC_PCB-TOT_1110-06

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Figure 10.3-6

Portland Harbor RI/FS

Draft Feasibility Study

Smallmouth Bass PCB Tissue SWAC versus Duration for all Draft FS Alternatives on a Site-wide Basis

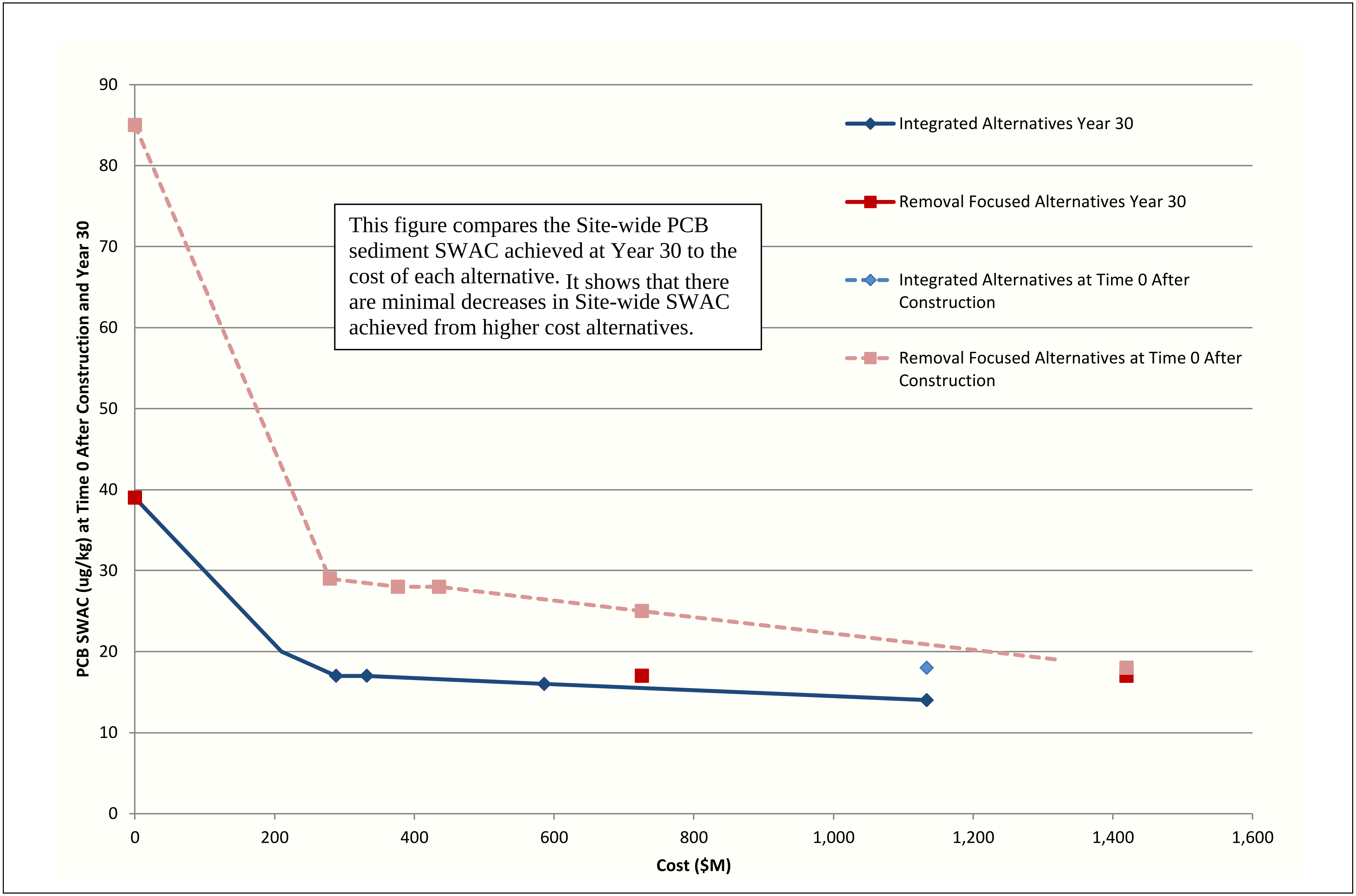

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Figure 10.3-7
Portland Harbor RI/FS
Draft Feasibility Study
Projected Site-Wide Sediment PCB SWAC at Time 0 After Remedial Construction and Year 30 versus Cost for all Draft FS Alternatives

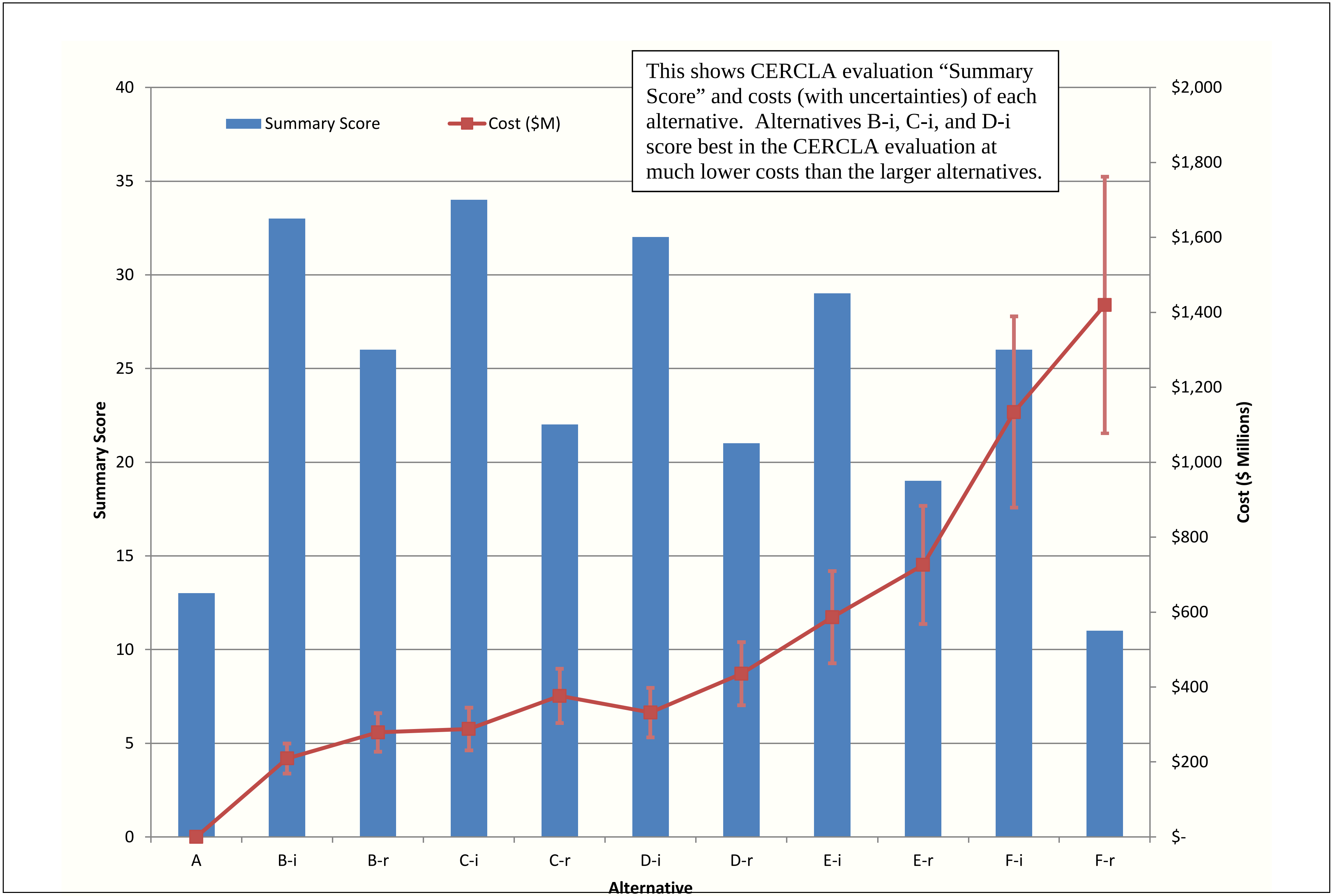

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Figure 10.3-8
Portland Harbor RI/FS
Draft Feasibility Study
Summary Score Versus Cost for All Alternatives

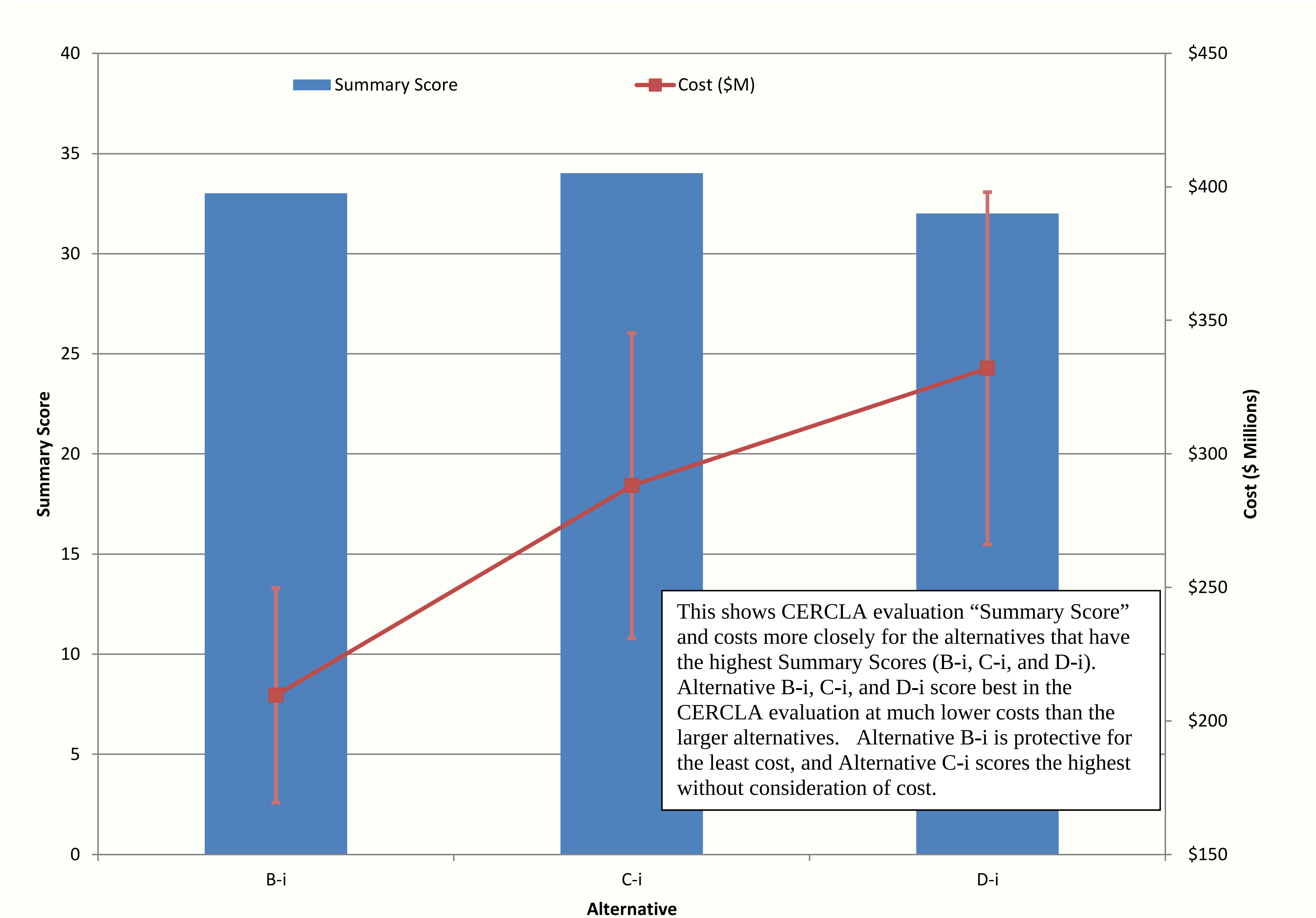

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Figure 10.3-9
Portland Harbor RI/FS
Draft Feasibility Study
Summary Score Versus Cost for Alternatives B-i, C-i, and D-i

Table 10.3-1. Draft Summary of Comparative Analysis of Remedial Alternatives

Alternative	Threshold Criteria		Balancing Criteria						
			Effectiveness Criteria					Cost ($M)	
	Overall Protection	Meets ARARs	Long-term Effectiveness	Reduction of Toxicity…through Treatment	Short-term Effectiveness	Implement-ability	Summary Score	Low	High
A - No Action	No[1]	No	○	○	◑	◑	NA	$ -	$ -
B-i	Yes	Yes[2]	◕	◔	●	●	●	$ 169	$ 250
B-r	Yes	Yes[2]	◕	○	◑	●	◕	$ 228	$ 330
C-i	Yes	Yes[2]	●	◔	●	●	●	$ 231	$ 345
C-r	Yes	Yes[2]	◕	○	◑	◕	◑	$ 304	$ 449
D-i	Yes	Yes[2]	●	◔	●	◕	●	$ 266	$ 398
D-r	Yes	Yes[2]	◕	○	◑	◑	◑	$ 351	$ 520
E-i	Yes	Yes[2]	◕	◑	◑	◕	◕	$ 463	$ 709
E-r	Yes	Yes[2]	◕	○	◔	◑	◔	$ 568	$ 884
F-i	Yes	Yes[2]	◕	◑	◔	◑	◑	$ 878	$ 1,389
F-r	Yes	Yes[2]	◕	○	○	○	○	$ 1,077	$ 1,762

Note:

1 - Alternative A - No Action is protective for some portions of the Site.

2 - With respect to surface water ARARs, EPA will determine whether the alternatives meet those ARARs with respect to contamination that will remain on Site or whether waivers of certain surface water ARARs are appropriate due to background and other issues. As discussed in Section 9 of the draft FS, the alternatives do not differ with respect to long-term projected post-remedy surface water concentrations.

NA - Not applicable. Alternative does not meet threshold criteria.

Legend:

○	1	The alternative scores very low for the criterion.
◔	2	The alternative scores low for the criterion.
◑	3	The alternative scores moderately for the criterion.
◕	4	The alternative scores high for the criterion.
●	5	The alternative scores very high for the criterion.

Table 10.3-2. Draft Numeric Summary of Comparative Analysis of Remedial Alternatives

Alternative	Threshold Criteria		Balancing Criteria						
			Effectiveness Criteria					Cost ($M)	
	Overall Protection	Meets ARARs	Long-term Effectiveness	Reduction of Toxicity…through Treatment	Short-term Effectiveness	Implement-ability	Summary Score	Low	High
A - No Action	No[1]	No	2	1	5	5	NA	$ -	$ -
B-i	Yes	Yes[2]	9	4	10	10	33	$ 169	$ 250
B-r	Yes	Yes[2]	9	1	7	9	26	$ 228	$ 330
C-i	Yes	Yes[2]	10	5	10	9	34	$ 231	$ 345
C-r	Yes	Yes[2]	8	1	6	7	22	$ 304	$ 449
D-i	Yes	Yes[2]	10	5	9	8	32	$ 266	$ 398
D-r	Yes	Yes[2]	8	2	5	6	21	$ 351	$ 520
E-i	Yes	Yes[2]	9	6	7	7	29	$ 463	$ 709
E-r	Yes	Yes[2]	8	2	4	5	19	$ 568	$ 884
F-i	Yes	Yes[2]	8	7	5	6	26	$ 878	$ 1,389
F-r	Yes	Yes[2]	7	2	1	1	11	$ 1,077	$ 1,762

Note:

1 - Alternative A - No Action is protective for some portions of the Site.

2 - With respect to surface water ARARs, EPA will determine whether the alternatives meet those ARARs with respect to contamination that will remain on Site or whether waivers of certain surface water ARARs are appropriate due to background and other issues. As discussed in Section 9 of the draft FS, the alternatives do not differ with respect to long-term projected post-remedy surface water concentrations.

NA - Not applicable. Alternative does not meet threshold criteria.

Table 10.3-3. Summary of Draft FS Key Findings

General Findings:

- An effective and efficient Portland Harbor sediment remedy will need to be coordinated with upland source control measures, so that the potential for sediment recontamination following cleanup is minimized. Lessons learned from early removal actions in Portland Harbor, the region, and at similar sites throughout the United States have provided valuable information to further inform risk-based evaluations.
- Multiple datasets and independent lines of evidence consistently indicate that the Site is predominantly depositional (supporting natural recovery potential), although deposition rates vary across the Site. Data evaluations were supplemented with a comprehensive predictive model designed to address the spatial variability of Site conditions and estimate the short-term construction impacts and long-term risk reductions resulting from each comprehensive alternative.
- The comprehensive alternatives evaluated in this draft FS were developed using RALs that are intended to achieve risk-based levels and RAOs from the draft final BERA and BHHRA.
- Resident fish consumption advisories are in place for the entire stretch of the Willamette River (including Portland Harbor), due to Site and regional background conditions and upstream sources.
- The existing background conditions make it technically infeasible for any of the comprehensive alternatives to achieve the full range of total PCB RGs based on human health protection from consumption of resident fish (e.g., those RGs based on the most conservative fish consumption pathway).
- Surface sediment concentrations are expected to converge to levels similar to the quality of incoming sediment from upstream combined with other inputs, resulting in similar levels of risk over time. While future conditions and actual concentrations could vary depending on the effectiveness of source control efforts, it is likely that surface sediment concentrations will be similar, regardless of which comprehensive alternative is selected.

Results of the Alternatives Evaluation

- All of the alternatives (i.e., not including No Action Alternative A) are projected to be protective of human health and the environment; differences in the overall protectiveness of the alternatives are largely due to short-term effectiveness, implementability, and in some cases the timing of substantial risk reductions that lead to achieving the range of risk-based RAOs.
- Uncertainties in RGs contribute the greatest amount of overall uncertainty in the projected outcomes of PCB remediation, while uncertainties associated with RAL, SMA, and alternative projections are relatively minor in comparison.
- Depending on what human health consumption scenario is selected as part of risk management, all of the alternatives, including the No Action Alternative, could be measured to achieve within a 10^{-4} to a 10^{-6} cancer risk level (deemed acceptable by Superfund law).
- Understanding the protectiveness afforded within the acceptable ranges, a single-value RG can be established as a desired target for cleanup, along with the recognition that reducing sediment concentrations to within the acceptable PRG and RG ranges is by definition protective.
- The comparative evaluations reveal that the comprehensive alternatives with lower RALs and greater dredge volumes would provide less overall effectiveness, primarily because they would generate more releases of bioavailable contaminants over significantly longer construction durations and at greater cost.
- The risks associated with implementing a dredging remedy include unavoidable contaminant resuspension and releases during sediment removal, continued exposure to contaminants during the construction and implementation phases, residual contamination, disruption of the benthic community, worker risk during sediment removal and handling, and community impacts including accidents, GHG emissions, and quality of life considerations. Further, these risks all become greater as the footprints of the alternatives and volume of dredging increases.
- All of the comprehensive alternatives would require a set of controls consisting of monitoring, maintenance, institutional controls, and periodic reviews (e.g., every 5 years).
- The integrated alternatives include more potential for in situ treatment and, therefore, rank higher with respect to the treatment criterion than removal focused alternatives.

Table 10.3-3. Summary of Draft FS Key Findings

Results of the Cost-Effectiveness Evaluation: • Although all of the comprehensive alternatives ranked similarly with respect to the overall evaluation of long-term effectiveness and permanence, the integrated alternatives (especially Alternatives C-i and D-i) ranked higher than the other alternatives as they would provide a higher level of overall risk reduction and lower residual risks than the removal focused alternatives. • Comprehensive Alternatives B-i and C-i ranked higher than other alternatives for short-term effectiveness. The greatest degree of overall effectiveness is achieved under Alternatives B-i, C-i, and/or D-i, which correspond to total costs of approximately $169 to $368 million and construction durations of approximately 2 to 3 years. • Alternatives B-i, C-i, and D-i have the highest Summary Score and are the three alternatives that best meet both the RAOs and the seven NCP criteria. These three alternatives are distinct from the remaining alternatives in achieving adequate protectiveness in substantially shorter durations. • Alternative B-i is protective for the least cost, and Alternative C-i scores the highest without consideration of cost.

Note:

BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
FS	Feasibility Study
GHG	greenhouse gas
NCP	National Contingency Plan
PCB	polychlorinated biphenyl
RAL	remedial action level
RAO	remedial action objective
RG	remediation goal
SMA	sediment management area

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