Western Port Angeles Harbor

Sediment Cleanup Unit

Remedial Investigation/Feasibility Study

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LIMITATIONS

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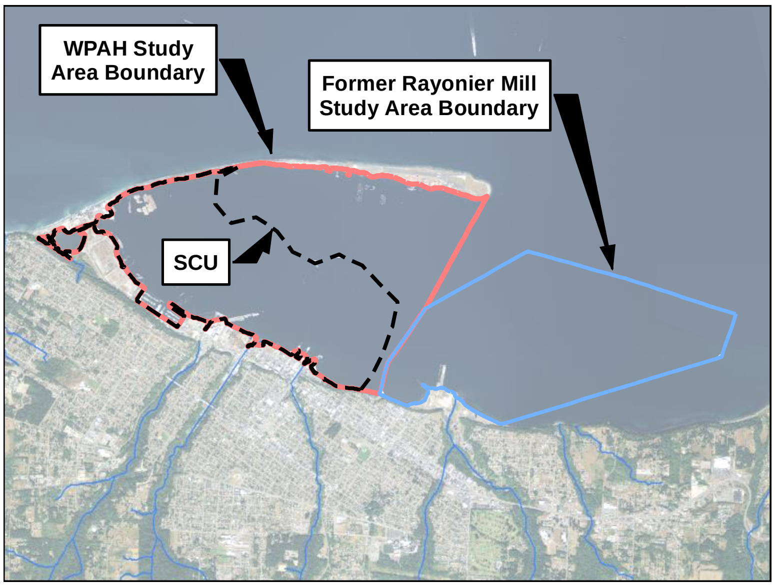
Executive Summary

Port Angeles Harbor (Harbor) is located on the northern coast of Washington's Olympic Peninsula and along the southern shoreline of the Strait of Juan de Fuca in Port Angeles, Washington. The Harbor has been identified as a priority environmental cleanup and restoration project by the Washington State Department of Ecology (Ecology).

This Remedial Investigation/Feasibility Study (RI/FS) has been prepared under the 2013 Agreed Order No. DE 9781 between the Western Port Angeles Harbor Group (WPAH Group) and Ecology, addressing sediments in the western portion of the Harbor. This RI/FS describes the western Harbor[1] sediment cleanup unit where sediment concentrations exceed sediment cleanup levels, and provides a comprehensive evaluation of alternative cleanup remedies, identifying an integrated cleanup alternative that meets the criteria of the Model Toxics Control Act (MTCA) and Sediment Management Standards (SMS) consistent with future uses of the western Harbor.



The RI portion of this report provides an overview of the western Harbor, describing the nature and extent of contamination, identifying hazardous substances, delineating the Sediment Cleanup Unit boundary, summarizing potential risks to human health and the environment, and defining sediment cleanup levels. A conceptual site model of the western Harbor incorporating the information presented below was developed to identify potential or suspected sources of hazardous substances and describe the pathways by which such hazardous substances migrate to and impact sediments and other resources within the western Harbor.

The FS portion of this report develops Sediment Management Areas (SMAs), delineating areas of the western Harbor for remedy implementation and defining and evaluating remedial action alternatives for comprehensive cleanup of each SMA. Consistent with MTCA and SMS evaluation criteria, this FS identifies an integrated cleanup remedy within the western Harbor that protects human health and the environment, is permanent to the maximum extent practicable, and achieves cleanup goals within a reasonable timeframe, among other MTCA and SMS criteria.

[1] For simplicity this Executive Summary uses the term "western Harbor" when discussing the RI/FS report findings. The remainder of the document discusses the Sediment Cleanup Unit, WPAH Study Area, and Harbor at length and use those specific terms to provide the level of detail appropriate for the full RI/FS analysis.

Biological Communities and Fisheries

A variety of marine aquatic species and wildlife currently reside in the western Harbor, including a functional benthic community, macroalgae, seagrass, more than 60 species of fish, shellfish, birds, and marine mammals. The western Harbor is fished recreationally by sportfishers and subsistence (tribal) fishers targeting salmon, Dungeness crab, and other shellfish.

There are five long-standing health advisories related to seafood consumption currently in effect that apply to the western Harbor, including a Puget Sound-wide advisory for mercury and polychlorinated biphenyls (PCBs) and the Harbor-wide closure of shellfish harvesting due to the presence of bacterial pollution and the periodic presence of Paralytic and Diarrhetic Shellfish Poison biotoxin.

Development History and Ownership

The western Harbor is located within the traditional territory of the Lower Elwha Klallam Tribe (LEKT), a part of the Klallam Tribe whose people have lived throughout the Northern Olympic Peninsula for thousands of years. The Harbor's development began in the late 1800s with the growth of the City of Port Angeles (City). Typical historical industries included sawmills, plywood manufacturing, pulp and paper production, other wood processing-related operations, commercial fishing and fish packing, bulk fuel facilities, boat building and refurbishing, marinas, and marine shipping and transport. Maritime operations and industrial and commercial businesses that provide living wage jobs are still active and ongoing at and around the western Harbor.

Periodic dredging and filling historically occurred within the western Harbor, primarily to improve industrial use of the southern shoreline. The shoreline now is predominantly owned by the Port of Port Angeles (Port) and the U.S. Government. The remainder is owned by private entities (e.g., McKinley Paper Company), the City, and LEKT. Subtidal aquatic lands within the western Harbor are owned by the State of Washington and managed either by the Washington State Department of Natural Resources (DNR), or by the Port under a Port Management Agreement with DNR.

Investigations and Development of Sediment Cleanup Standards

Numerous environmental investigations in the western Harbor have occurred since the early 1970s. For this RI/FS, extensive data collected from 2002 to the present were used to characterize current environmental conditions in the western Harbor. The WPAH Group worked collaboratively with Ecology to identify remaining RI/FS data gaps within the western Harbor. Consistent with Ecology-approved work plans, sampling and analysis was conducted in 2013 and 2014 to fill remaining data gaps to support this RI/FS.

Overall, data collected in the western Harbor reveal the following:

- Limited benthic toxicity was observed within the Western Port Angeles Harbor Study Area. Stations with benthic toxicity were primarily located in the inner harbor and were generally associated with chemical contamination.
- Various types of woody debris (e.g., bark) were observed throughout the western Harbor, with higher concentrations observed near historical and current log storage areas.
- The distributions of hazardous substance concentrations vary within the western Harbor, but concentrations in surface sediments are generally greater in the inner harbor and lagoon for metals and combined dioxin/furan toxic equivalent (TEQ) and PCB congener TEQ ("total TEQ"). Other organic compounds, including carcinogenic polycyclic aromatic hydrocarbons (cPAHs), tend to be more widely distributed, and at higher concentrations in areas of the western and southern Harbor shorelines.

Hazardous substances present in the western Harbor have the potential to pose risks to both human health and the environment. Risks to human health may occur from consumption of crab, shrimp, clams, and other species. Additionally, risks may be posed to aquatic life such as benthic invertebrates living within Harbor sediments.

For each exposure pathway, hazardous substances were identified that drive potential human health or environmental risks. Potential human health risks are associated with bioaccumulation of metals (cadmium and mercury), cPAH TEQ, and Total TEQ. Potential environmental risks are only associated with metals (cadmium, mercury, and zinc). Cleanup standards for these hazardous substances were used to focus the development and evaluation of remedial alternatives in the FS.

Development of Cleanup Alternatives

To support the development of remedial alternatives that are easily defined, the western Harbor was subdivided into three SMAs with different environmental and remediation implementability characteristics. SMA 1 is an approximate 37-acre area located in the inner harbor that poses the highest potential risks to human health and the environment and is also readily accessible by remedial construction equipment. SMA 2 encompasses the approximate 25-acre lagoon at the far western end of the Harbor that poses a lesser degree of potential risk to human health and the environment, but access to this area is highly constrained both by its physical configuration as well as potential conflicts with adjacent industrial operations. SMA 3 is an approximate 1,100-acre area that encompasses the remaining area of the western Harbor exceeding sediment cleanup levels and spans the industrial/commercial waterfront of Port Angeles and the adjacent Harbor. Compared to SMAs 1 and 2, SMA 3 poses lower potential risks to human health and the environment, and because of its depth, large size, and proximity to the working waterfront, presents significant implementability challenges for remediation.

Development of an appropriate sediment cleanup remedy for the western Harbor must consider a wide range of potential environmental and implementability challenges. For example, sustainable remedies in intertidal areas of the Harbor must consider lasting erosion protection, potential climate change impacts, and potential alteration of sediment transport along the shoreline, which in turn can impact aquatic habitat functions. Cleanup actions along a working waterfront must take into consideration the ability of the western Harbor to continue to support industrial and maritime operations. The presence of over-water structures and operational areas also presents significant implementability challenges for remediation. Finally, the potentially large scale of cleanup actions in the western Harbor could require years to decades of construction, with corresponding disruptions to both habitat and the working waterfront.

To highlight the tradeoffs associated with different cleanup approaches in the western Harbor, a range of remedial alternatives was developed for the three SMAs, including combinations of the following sediment remediation technologies:

- Intertidal sediment excavation during low tide stages, followed by off-site transportation and disposal.
- Subtidal sediment dredging “in the wet” with associated construction-related releases, followed by transloading, water management, and off-site transportation and disposal.
- Capping sediments with an approximate 2-foot-thick engineered layer composed of clean sand, gravel, and/or rock as appropriate for the specific location.
- Placing a 6-inch layer of clean sand and/or gravel to enhance natural recovery rates.
- Monitoring the continued natural recovery of the western Harbor from the deposition of cleaner sediments over time, requiring no in-water construction.

Evaluation of Cleanup Alternatives

The MTCA and SMS cleanup regulations provide the framework for evaluating remedial alternatives to identify the cleanup remedy that uses permanent solutions to the maximum extent practicable, while also achieving cleanup standards within a reasonable timeframe. In making this determination, each remedial alternative was assessed using MTCA/SMS comparative evaluation criteria as follows:

- Protectiveness (30% of total benefit score)
- Permanence (20% of total benefit score)

- Effectiveness over the long term (20% of total benefit score)
- Management of short-term risks (10% of total benefit score)
- Technical and administrative implementability (10% of total benefit score)
- Consideration of public concerns (10% of total benefit score)
- Cost (compared to total benefits as above)

The MTCA/SMS comparative evaluation revealed the following:

- In parts of SMA 1, intertidal excavation during low tide stages can be efficiently performed from the shoreline with standard construction equipment provided that the potential discovery and protection of cultural resources is anticipated. Intertidal excavation areas would be capped to restore aquatic habitat to the current grade, achieving cleanup standards immediately upon completion of construction.
- Much of the western Harbor is either too deep or inaccessible for subtidal sediment dredging equipment. Moreover, given the buried logs and debris present in the sediment bed, subtidal dredging would result in significant releases of contaminants into the water column, and dredging residuals would require capping to achieve cleanup standards.
- The vast majority of sediments in SMAs 1 through 3 are stable, and engineered caps made of clean sand, gravel, and/or rock as appropriate can provide a permanent cleanup remedy. Engineered caps have been shown to be very effective at numerous other Puget Sound sediment cleanup sites.
- Natural recovery processes in much of the western Harbor occur relatively slowly, requiring many decades. Chemical and biological monitoring to further assess the pace of reductions in contaminant concentrations over time would continue.
- Placing a 6-inch layer of sand and/or gravel would significantly enhance natural recovery rates in the western Harbor, also allowing benthic organisms to rapidly recolonize the clean sediment. Applying this approach to eelgrass meadows in parts of SMA 2 and in the relatively large SMA 3 subtidal area would allow sediment cleanup levels to be achieved throughout the western Harbor within 10 years.

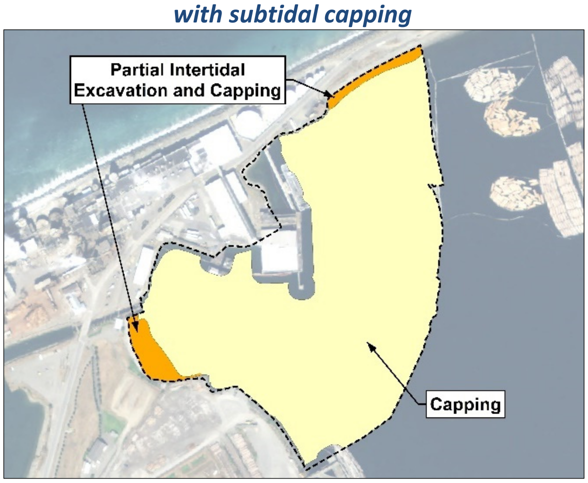
Under the MTCA and SMS cleanup regulations, remedial alternatives must meet minimum requirements for protectiveness. The final step in evaluating alternatives is identifying the protective alternative that is permanent to the maximum extent practicable. This requires weighing incremental costs and benefits of protective cleanup alternatives. Costs are considered disproportionate to benefits when the incremental costs of an alternative exceed the incremental benefits compared to other, lower cost, but still protective alternatives.

Integrated Cleanup Remedy

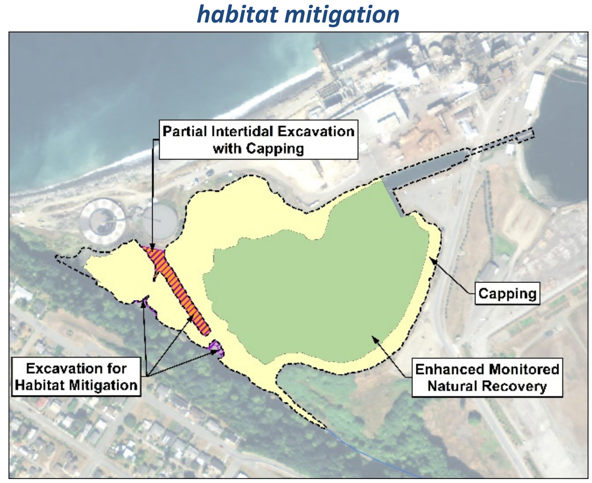
The MTCA/SMS comparative evaluation identified an integrated cleanup remedy for all three SMAs that protects human health and the environment, is permanent to the maximum extent practicable, achieves sediment cleanup levels within a reasonable timeframe, anticipates the potential discovery and protection of cultural resources, and is consistent with current and future recreational, commercial, and industrial uses of the western Harbor. This integrated cleanup remedy is depicted below, and includes:

- 1.3 acres of intertidal excavation (SMA 1)
- 43 acres of engineered capping (SMAs 1 and 2)
- 178 acres of enhanced monitored natural recovery (SMAs 2 and 3)
- 949 acres of monitored natural recovery (Sediment Cleanup Unit-wide)

SMA 1: Partial intertidal excavation and capping, with subtidal capping



SMA 2: Intertidal capping with subtidal enhanced natural recovery and partial excavation for habitat mitigation



SMA 3: Enhanced natural recovery to an extent that cleanup standards will be achieved within 10 years after completion of construction

In addition, the integrated cleanup remedy includes excavation of approximately 0.6 acres of shoreline in SMA 2 to ensure no net loss of aquatic habitat. In total, approximately 9,600 cubic yards of intertidal sediment and nearshore soils would be excavated, and approximately 282,000 cubic yards of sand and gravel would be placed, requiring approximately six seasons of construction, at a cost of approximately $34.4 million. Sediment cleanup levels are anticipated to be achieved throughout the western Harbor within 10 years following completion of construction, with possible institutional controls as necessary to ensure continued protectiveness of the remedy.

Further investigations and source control at upland properties potentially contributing contaminants to the western Harbor and periodic removal of creosote-treated wood piles will continue. Extensive monitoring will be performed to confirm the effectiveness of the cleanup and restoration of sediment quality.

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Acronym/ Abbreviation	Definition
2LAET	Second lowest apparent effects threshold
AC	Activated carbon
alpha-BHC	alpha-Hexachlorocyclobenzene
AO	Agreed Order
ARAR	Applicable or Relevant and Appropriate Requirements
aRPD	Apparent redox potential discontinuity
BAF	Bioaccumulation factor
BMP	Best management practice
BSAF	Biota-sediment accumulation factor
CAP	Cleanup Action Plan
City	City of Port Angeles
cm	Centimeter
COPC	Chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CQAAMP	Construction Quality Assurance and Adaptive Management Plan
Crown Zellerbach	Crown Zellerbach Corporation
CSL	Cleanup Screening Level
CSM	Conceptual Site Model
CSO	Combined sewer overflow
CT	Central tendency
CY	Cubic yards
DAHP	Washington State Department of Archaeology and Historic Preservation
DCA	Disproportionate Cost Analysis
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
DO	Dissolved oxygen
DQO	Data Quality Objective
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
EIM	Environmental Information Management

Acronym/ Abbreviation	**Definition**
EMNR	Enhanced monitored natural recovery
ENE	East-northeasterly
Fibreboard	Fibreboard Paper Products Corporation
Georgia-Pacific	Georgia-Pacific LLC
Harbor	Port Angeles Harbor
HQ	Hazard quotient
IHS	Indicator hazardous substance
ITT Rayonier	ITT Rayonier, Inc.
K Ply	K Ply, Inc.
LAET	Lowest apparent effects threshold
LEKT	Lower Elwha Klallam Tribe
LNAPL	Light non-aqueous phase liquid
MDP	Monitoring and Discovery Plan
µg/kg	Micrograms per kilogram
mg/L	Milligrams per liter
MHHW	Mean higher high water
MLLW	Mean lower low water
MNR	Monitored natural recovery
MTA	Marine Trades Area
MTCA	Model Toxics Control Act
NCD	Nearshore confined disposal
ng/kg	Nanograms per kilogram
NOAEL	No observable adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPIUSA	Nippon Paper Industries USA Co., Ltd.
NRHP	National Register of Historic Places
OC	Organic carbon
OMMP	Operations, Maintenance, and Monitoring Plan
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PenPly	Peninsula Plywood Group, LLC
PMA	Port Management Agreement

Acronym/ Abbreviation	Definition
Port	Port of Port Angeles
PQL	Practical Quantitation Limit
PV	Plan view
RAL	Remedial Action Level
RAO	Remedial Action Objective
Rayonier Study Area	Former Rayonier Mill Study Area
RBC	Risk-based concentration
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable maximum exposure
SAP	Sampling and Analysis Plan
SCL	Sediment Cleanup Level
SCO	Sediment Cleanup Objective
SCU	Sediment Cleanup Unit
SCUM II	Sediment Cleanup User's Manual II
SMA	Sediment Management Area
SMS	Sediment Management Standards
SOD	Sediment oxygen demand
SPI	Sediment profile imaging
SPME	Solid-phase microextraction
SRZ	Sediment Recovery Zone
SVOC	Semivolatile organic compound
SWAC	Surface-weighted average concentration
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TOC	Total organic carbon
Total TEQ	Combined dioxin/furan toxic TEQ and the dioxin-like PCB congener TEQ
TVS	Total volatile solids
U&A	Usual and Accustomed
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish & Wildlife Service

Acronym/ Abbreviation	Definition
UTL	Upper tolerance limit
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish & Wildlife
WDOH	Washington State Department of Health
WHR	Washington Heritage Register
WISAARD	Washington Information System for Architectural and Archaeological Records Data
Work Plan	Western Port Angeles Harbor RI/FS Work Plan
WPAH Group	Western Port Angeles Harbor Group
WPAH Study Area	Western Port Angeles Harbor Study Area
WWTP	Wastewater treatment plant

Section 1.0: Introduction

1.0 Introduction

1.1 BACKGROUND AND OVERVIEW

Port Angeles Harbor (Harbor) is a natural harbor located on the northern coast of Washington's Olympic Peninsula and along the southern shoreline of the Strait of Juan de Fuca in Port Angeles, Washington (Figure 1.1). Since its incorporation in 1890, the City of Port Angeles (City) has grown into the largest urban center on the north Olympic Peninsula. Over the past 130 years, operations within or adjacent to the Harbor have included sawmills, plywood manufacturing, pulp and paper production, other wood processing-related operations, commercial fishing and fish packing, bulk fuel facilities, boat building and refurbishing, marinas, and marine shipping and transport. The Harbor has been identified as a priority environmental cleanup and restoration project by the Washington State Department of Ecology (Ecology) as part of the Puget Sound Initiative.

This document is the Remedial Investigation/Feasibility Study (RI/FS) for the Western Port Angeles Harbor Sediment Cleanup Unit (SCU; defined in Section 8.1.1.1 and presented on Figure 1.2), located within the Western Port Angeles Harbor Study Area (WPAH Study Area; Figure 1.2). The SCU is the area of the WPAH Study Area where contaminant concentrations in sediment exceed cleanup levels, as discussed in this RI/FS. The WPAH Study Area generally includes the area to the south of Ediz Hook and west of the former Rayonier Mill Study Area (Rayonier Study Area; Figure 1.2). The former Rayonier Mill remedial action is being addressed under a separate RI/FS process with Ecology, during which the remedy for the former Rayonier Mill SCU will be determined. This RI/FS focuses on the sediments located below mean higher high water (MHHW) within the SCU, except in areas of the SCU where this tidal level is covered by riprap or bulkheads. In that case, the RI/FS addresses sediments below the toe of the riprap slope or bulkhead (Integral et al. 2013).

The Western Port Angeles Harbor Group (WPAH Group) and Ecology entered into Agreed Order (AO) No. DE 9781 to conduct an RI/FS for the SCU[2] on May 28, 2013 (State of Washington 2013a). Members of the WPAH Group are: Port of Port Angeles (Port), Georgia-Pacific LLC (Georgia-Pacific), Nippon Paper Industries USA Co., Ltd. (NPIUSA), City, and Merrill & Ring. The AO Scope of Work required the WPAH Group to prepare a RI/FS Work Plan, which was attached to and incorporated into the AO. RI/FS sampling and analysis was subsequently conducted in 2013 and 2014, as described below. The AO Scope of Work requires the WPAH Group to prepare this RI/FS Report, which also complies with the current requirements of the Washington State Model Toxics Control Act (MTCA): Chapter 173-340 and the Sediment Management Standards (SMS): Chapter 173-204 of the Washington Administrative Code (WAC).

[2] In the AO, the WPAH Study Area is defined as generally located in the western portion of the Harbor. Subsequent to the AO, Ecology clarified that the area within the larger WPAH Study Area that exceeds preliminary sediment cleanup levels (SCLs) is the SCU, described further in Section 1.2.6. Therefore, this RI/FS specifically focuses on the sediments located within the SCU.

1.2 ASSOCIATED DOCUMENTS

There are 12 key documents that provide relevant information necessary to the understanding of this RI/FS document. These documents are described below.

1.2.1 Western Port Angeles Harbor Remedial Investigation/Feasibility Study Work Plan (WPAH Group 2013), Sampling and Analysis Plan (Integral et al. 2013), and Sampling and Analysis Plan Addendum (Floyd|Snider et al. 2014)

A Western Port Angeles Harbor RI/FS Work Plan (Work Plan) was prepared by the WPAH Group and incorporated into the AO (WPAH Group 2013). A sampling and analysis plan (SAP) was then prepared in accordance with the AO and the Work Plan (Integral et al. 2013). The Work Plan described the tasks to be performed in the RI/FS, including identification of existing data gaps and data collection to complete the RI/FS report. The data quality objectives (DQOs) of the RI/FS study proposed by the WPAH Group were also described. The SAP detailed the data collection tasks and associated methods used to fill identified data gaps and allow completion of the RI/FS report. A SAP Addendum was prepared in August 2014 (Floyd|Snider et al. 2014) to describe additional RI/FS sampling to evaluate subsurface contamination.

1.2.2 Western Port Angeles Harbor Remedial Investigation/Feasibility Study Data Report for the 2013 Field Program (Integral et al. 2014)

The data collection effort proposed in the Work Plan was completed by the WPAH Group in June 2013 and the RI/FS Data Report was submitted to Ecology in February 2014 (Integral et al. 2014). This data report included: an overview of the field program; the chemical and biological testing, photographic data, and documentation of the data quality review process for all data; and the results of sediment chemical, bioassay, bioaccumulation, solid-phase microextraction (SPME), and sediment profile imaging/plan view (SPI/PV) analyses. A summary of the 2013 data report results is presented in Section 7.0. The supplemental data collection effort proposed in the SAP Addendum was completed in September 2014. The results for the 2014 field program (subsurface sediment chemical analyses) are also summarized in Section 7.0.

1.2.3 Site-Specific Sediment Cleanup Levels, Remediation Levels, and Sediment Management Areas for Bioaccumulative Chemicals: Western Port Angeles Harbor (WPAH Group 2014)

This document (the “White Paper”) was prepared as a key building block for the RI/FS and summarized the rationale for developing harbor-specific Sediment Cleanup Levels (SCLs), remediation levels, and sediment management areas (SMAs) that are consistent with SMS cleanup requirements for bioaccumulative chemicals in the Harbor. The White Paper also summarized the rationale for the organization and content of the RI/FS, including the disproportionate cost analysis (DCA).

1.2.4 Memorandum Re: Site-Specific Sediment Cleanup Levels, Remediation Levels, and Sediment Management Areas for Bioaccumulative Chemicals: Western Port Angeles Harbor (Ecology 2015a)

Ecology provided initial comments on the White Paper, described above, to the WPAH Group in May 2015. These comments identified several key issues requiring further discussion including SCLs, identification of a preliminary SCU boundary within which surface-weighted average concentrations (SWACs) would be calculated, and how to address the potential for carcinogenic polycyclic aromatic hydrocarbon (cPAH) recontamination.

Ecology provided estimates of Harbor natural background levels, practical quantitation limits (PQLs), and draft regional background levels. Ecology also provided updated preliminary sediment cleanup objectives (SCOs), cleanup screening levels (CSLs), and SCLs, and requested the use of these numerical values. These values are discussed further in Section 6.0.

1.2.5 Western Port Angeles Harbor Remedial Investigation/Feasibility Study Approach (WPAH Group 2017)

This document is the revised White Paper and described the decisions reached by the WPAH Group and Ecology on a number of technical issues. The revised White Paper topics included the screening approach for bioaccumulative and benthic indicator hazardous substances (IHSs), the development of SCLs, the development of an SCU boundary, and the methodology used to calculate SWACs for the evaluation of SCL compliance for bioaccumulative chemicals. The revised White Paper included the three Ecology technical memoranda described in Sections 1.2.5.1 to 1.2.5.3 as supporting documents. These memoranda from Ecology provided a basis for several of the decisions documented in the revised White Paper. The revised White Paper and Ecology memoranda are presented in Appendix A.

1.2.5.1 Ecology Technical Memorandum: Port Angeles Harbor – Total TEQ, Site-Specific Rationale (Ecology 2016a)

This memorandum proposed a Harbor-specific SCL for the combined dioxin/furan toxic equivalent (TEQ) and the dioxin-like polychlorinated biphenyl (PCB) congener TEQ ("total TEQ"). Further details are provided in Section 6.1.3.

1.2.5.2 Ecology Technical Memorandum: Port Angeles Harbor: Compliance for Bioaccumulative Chemicals Using Sediment Data in Port Angeles Harbor (Ecology 2016b)

This memorandum presented the methodology to be used for demonstrating compliance with the benthic and bioaccumulative SCLs in the Harbor in accordance with the SMS and described the areas of the Harbor within which each bioaccumulative IHS should be averaged. The memorandum identified "sessile shellfish beds" as a separate SMA within the SCU. However, this decision regarding the sessile shellfish beds SMA was later withdrawn, as described in Section 1.2.6.

1.2.5.3 Ecology Technical Memorandum: Port Angeles Harbor – Sediment Interpolation and Recovery Modeling (NewFields 2016)

The primary objective of this memorandum was to document the methodology used by NewFields (on behalf of Ecology) to interpolate surface sediment data across the Harbor and calculate SWACs. It also described the assumptions and methodologies used to project natural recovery. The described methodologies were adopted by the WPAH Group to ensure consistency between the technical analyses of Ecology and the WPAH Group.

1.2.6 Ecology Memorandum Re: Western Port Angeles Harbor: Remedial Investigation/Feasibility Study Approach (Ecology 2017a)

Ecology prepared this memorandum to provide comments to the WPAH Group on the revised White Paper. In these comments, Ecology stated that the term "SCU" should be used to define the area in the WPAH Study Area that exceeds SCLs. In addition, the memorandum defined likely and possible "shellfish harvest areas" in the intertidal zone of the lagoon and inner harbor and requested further RI/FS evaluations of the human consumption of sessile seafood species exposure pathway. The memorandum also requested an evaluation of the human health direct contact exposure pathway in intertidal areas throughout the WPAH Study Area. Ecology designated a 45-centimeter (cm) point of compliance for the likely and possible "shellfish harvest areas" compared to a 10-cm point of compliance in the remainder of the WPAH Study Area. The Ecology-defined "shellfish harvest areas" superseded the concept of a sessile shellfish bed SMA previously described by Ecology in the memorandum discussed in Section 1.2.5.2 (Ecology 2016b). In this RI/FS, the "shellfish harvest areas" refer only to intertidal areas in the lagoon and inner harbor (i.e., a combined lagoon intertidal and inner harbor intertidal area).

1.2.7 Ecology Memorandum Re: Comments on Proposed Feasibility Study Materials Presented in Technical Meetings in February, March, and April 2017 (Ecology 2017b)

In this memorandum, Ecology provided feedback relative to the draft FS materials previously submitted by the WPAH Group to Ecology. The comments focused on the range of alternatives proposed and requested additional alternatives that had a greater emphasis on addressing areas with greater concentrations of contaminants and further evaluation of the effectiveness and appropriateness of enhanced monitored natural recovery (EMNR). Additionally, Ecology agreed with the weighted-benefit criteria the WPAH Group proposed to be used in the DCA, but noted that capital improvement costs should be separated from cleanup costs during the DCA.

1.3 OBJECTIVES OF THE REMEDIAL INVESTIGATION/FEASIBILITY STUDY

The overall objective of this RI/FS is to provide a comprehensive evaluation supporting the recommendation of a preferred cleanup remedy for the SCU that meets MTCA and SMS criteria and is consistent with the current and future uses of this working Harbor.

This RI/FS report is designed to meet the following objectives:

- Provide an overview of the history, land use, ownership, and environmental setting and resources within the Harbor.
- Complete the characterization of sediment quality, sediment transport mechanisms, and comprehensive exposure pathways within the Harbor.
- Prepare a Conceptual Site Model (CSM) that identifies the IHSs and SMAs within the SCU.
- Define Remedial Action Objectives (RAOs), Applicable or Relevant and Appropriate Requirements (ARARs), and cleanup standards appropriate to the SCU.
- Define and evaluate remedial action alternatives for comprehensive cleanup of the SMAs appropriate for implementation.
- Identify a preferred cleanup remedy for the SCU that will achieve MTCA and SMS compliance based on multiple lines-of-evidence and that will meet current and anticipated uses of the Harbor.

1.4 DOCUMENT ORGANIZATION

This RI/FS report is organized into the following sections:

- **Section 2.0—Harbor Description and Setting.** Provides information on the Harbor's environmental setting and aquatic resources.
- **Section 3.0—Historical and Current Uses of the Harbor.** Describes historical and current uses of the Harbor, including Native American uses and treaties, industrial and commercial land development, and current land use and ownership.
- **Section 4.0—Previous Environmental Investigations and Identification of Data Gaps.** Describes the scope of previous environmental investigations conducted within the Harbor since 2002. Also describes the identification of data gaps for the RI/FS and an overview of the activities required to address these data gaps.
- **Section 5.0—Remedial Investigation/Feasibility Study Activities.** Discusses the scope of the 2013/2014 RI/FS field investigations conducted in the WPAH Study Area by the WPAH Group, including chemical analyses, bioassays, bioaccumulation testing, SPME testing, and SPI/PV analyses.
- **Section 6.0—Development of Preliminary Indicator Hazardous Substances and Cleanup Criteria.** Summarizes the outcomes of the screening level human health and ecological risk assessments conducted by Ecology (Ecology 2012), which resulted in identification of the preliminary IHSs for the SCU. Also describes the process by which preliminary SCOs and CSLs were derived by Ecology (NewFields 2013, Ecology 2015a, and Ecology 2016c).

- **Section 7.0—Nature and Extent of Preliminary Indicator Hazardous Substances and Wood Debris.** Describes physical characteristics, current chemical contamination extent in surface and subsurface sediments, extent of wood debris and benthic habitat quality, sediment toxicity bioassay results, and bioaccumulation testing conducted for dioxins/furans and PCBs.
- **Section 8.0—Final Indicator Hazardous Substances and Development of Sediment Cleanup Standards.** Presents the screening process used to derive the final IHSs, which are protective of either benthic invertebrates or human health and are advanced for consideration in the FS. Also presents the final sediment cleanup standards including the SCLs and points of compliance.
- **Section 9.0—Remedial Investigation Conclusions and Conceptual Site Model.** Describes the conceptual understanding of the SCU; identifies sources of hazardous substances, how they were released, the types and concentrations of chemicals detected, transport pathways, exposure pathways, and receptors.
- **Section 10.0—Feasibility Study Introduction.** Describes RAOs for the proposed cleanup action and identifies applicable laws and regulations relevant to implementing a cleanup action in the SCU.
- **Section 11.0—Identification of Sediment Management Areas, Remedial Action Levels, and Remediation Areas.** Describes the Harbor-specific conditions that impact remedy application in areas of the SCU, and divides the SCU into SMAs based on those factors and contamination extent.
- **Section 12.0—Description and Screening of Remedial Technologies.** Identifies and describes potentially applicable technologies to address the IHSs in the SCU.
- **Section 13.0—Development of Remedial Alternatives.** Evaluates the retained technologies described in Section 12.0 based on the Harbor-specific conditions and constraints. Retained technologies are then aggregated into SCU cleanup alternatives.
- **Section 14.0—Evaluation of Remedial Alternatives.** Evaluates the SCU remedial alternatives proposed in Section 13.0 according to the MTCA and SMS requirements and evaluation criteria for a cleanup action. Summarizes the evaluation in a DCA and identifies a preferred cleanup remedy based on this analysis.
- **Section 15.0—Preferred Cleanup Remedy.** Describes in greater detail the preferred cleanup remedy for the SCU based on the results of the Section 14.0 evaluation.
- **Section 16.0—References.** Provides a list of materials cited in the RI/FS.

Supplemental materials are provided in the following appendices:

- **Appendix A— Western Port Angeles Harbor: RI/FS Approach White Paper.** Presents the White Paper described in Section 1.2.5 and the associated Ecology memoranda.
- **Appendix B—Estimated Net Sedimentation Rates and Watershed Loading Evaluation.** Presents back-up information used in the calculation of overall net sedimentation rates in the Harbor and in the determination of the watershed loading of the bioaccumulative IHSs.
- **Appendix C—Data Tables.** Presents all surface sediment data collected within the WPAH Study Area from 2002 to present.
- **Appendix D—Terminal Coring Data Report.** Presents the results of the sediment core sampling conducted by the WPAH Group at the Port's Terminal 5 and Terminal 7 in September 2014.
- **Appendix E—Source Control Evaluation.** Identifies ongoing sources that have the potential to result in sediment recontamination, per the RI/FS Work Plan.
- **Appendix F—Settlement Agreement and LEKT Monitoring and Discovery Plan.** Presents the Settlement Agreement between the State of Washington, Lower Elwha Klallam Tribe (LEKT), the Port, and the City from 2006 (State of Washington 2006), and the LEKT Monitoring and Discovery Plan (MDP), which establishes protocols for monitoring and reporting discoveries of cultural resources and/or human remains.
- **Appendix G—Detailed Cost Estimate Information.** Presents all back-up cost estimate information for the remedial alternatives.
- **Appendix H—Enhanced Monitored Natural Recovery Case Studies.** Presents EMNR case studies that are particularly relevant to this RI/FS, summarizing applications of EMNR throughout the Pacific Northwest.
- **Appendix I—Construction Quality Assurance and Adaptive Management Plan (CQAAMP) Framework.** Presents the framework for the CQAAMP that will be used to verify protectiveness and optimize sediment cleanup actions within the WPAH SCU. The CQAAMP will be finalized during remedial design.
- **Appendix J—Operations, Maintenance, and Monitoring Plan (OMMP) Framework.** Presents the framework for the post-construction OMMP that describes long-term performance monitoring of the constructed remedial actions within the WPAH SCU. The OMMP will be finalized during remedial design.
- **Appendix K—Preliminary Cap Design Evaluation.** Describes the preliminary cap design developed based on consideration of chemical isolation and bioturbation, and erosion protection.

Section 1.0: Introduction

Figures

WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor
Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 1.1
Vicinity Map

I:\GIS\Projects\WPAHG-RIFS\MXD\RIFS Final 2020\Figure 1.1 Vicinity Map.mxd
10/29/2020

WPAHG

Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 1.2
Location Map

I:\GIS\Projects\WPAHG-RIFS\MXD\RIFS Final 2020\Figure 1.2 Site Map.mxd
10/29/2020

Section 2.0:
Harbor Description and Setting

- Port Angeles Harbor is a naturally large, deep (depths up to 170 feet), and relatively flat-bottomed harbor. The Harbor is partially enclosed by Ediz Hook, a 2.5-mile-long sand spit that extends eastward from the Harbor's west end. Steep slopes are present along approximately 60 percent of the Harbor's shoreline.
- The Harbor is a sediment depositional area, and the majority of sediments are not subject to resuspension except in shallow nearshore zones, near actively used docks, or in the lagoon channel connected to the inner harbor. Fine-grained sediments tend to accumulate in the western portion of the Harbor, a low energy area. Overall, net sedimentation rates within the Harbor are very low, approximately 0.17 cm per year. The primary inputs of sediment to the Harbor currently include creeks and human activities.
- A variety of marine aquatic species and wildlife are observed in the Harbor, including a functional and relatively stable benthic community, macroalgae, more than 60 species of fish, a number of shellfish, birds, and marine mammals.
- The Harbor is fished recreationally by sportfishers and subsistence (tribal) fishers. Species targeted include salmon, Dungeness crab, and shellfish.
- There are five health advisories related to seafood consumption currently in effect that apply to the Harbor, including a Puget Sound-wide advisory for mercury and polychlorinated biphenyls and the periodic Harbor-wide closure of shellfish harvesting due to the presence of the Paralytic and Diarrhetic Shellfish Poison biotoxin and bacterial pollution.

2.0 Harbor Description and Setting

2.1 ENVIRONMENTAL SETTING

This section describes the natural environmental setting of the Harbor. The physical characteristics of the Harbor summarized in this section include regional geology and hydrogeology, bathymetry, circulation within the Harbor, drainage to the Harbor, and sediment stability and deposition.

As described earlier, the Harbor is a natural deep-water port located on the northern coast of Washington's Olympic Peninsula and along the southern shoreline of the Strait of Juan de Fuca (Figure 1.1). The Harbor is bounded to the west and south by the City and to the north by Ediz Hook, a 2.5-mile-long sand spit that extends eastward from the Harbor's west end (Figure 1.2). Ediz Hook protects the Harbor from the open-ocean waves within the Strait of Juan de Fuca. The Harbor contains approximately 26 miles of marine shoreline with water depths as great as 52 meters (170 feet) near Ediz Hook (Ecology 2012).

2.1.1 Regional Geology and Hydrogeology

The section of Olympic Peninsula coastline where the Harbor is located is underlain by glacial drift deposits, which are present in the area at thicknesses up to 300 feet. The glacial deposits consist predominantly of Vashon till commonly observed as a massive, compacted, pebbly sandy clay, and Vashon outwash pebble to cobble gravels with lenses of sand and clayey, sandy silt. These glacial deposits generally form lower sections of the bluffs that parallel the shoreline in the Harbor uplands area. Glacial deposits in the bluffs are capped in places by sand deposits younger than Vashon age. Localized landslide deposits are also widespread along the bluffs (Brown et al. 1960, Tabor and Cady 1978). Beneath the glacial deposits are southwardly tilted beds of mudstone with lesser amounts of thin-bedded sandstone.

Along the shoreline, recent alluvium and marine deposits—including unconsolidated beach, stream, and delta deposits—overlie the glacial drift. These are generally up to 30 feet thick and are characterized as pebbly or cobbly gravel and sand. These recent deposits form Ediz Hook, are mapped at the ground surface in the Ennis Creek drainage area, and are generally present along the pre-development shoreline (Brown et al. 1960, Tabor and Cady 1978). Ediz Hook itself was formed by the transport of sediment eastward from the delta of the Elwha River, along with the erosion of bluffs located along the southern shoreline of the Harbor (Larson 2006, Herrera 2011a). As this sand spit tip advanced eastward over time, Ediz Hook began to enclose and form the modern Harbor.

Hydraulic fill material dredged from the Harbor was placed in the shoreline area from approximately 1890 to 1955, which extended the Harbor's southern shoreline northward from the steep bluffs. The placement of this fill material has disconnected the bluffs from the nearshore area of the Harbor. This dredged fill material generally consists of loose to very dense sand, silty sand, and sandy silt with abundant shell fragments, and extends to depths of up to approximately 20 feet below ground surface (Shannon & Wilson 1993). A large amount of fill material from the bluffs was sluiced into the main business district during the Port Angeles Regrade project that began in 1914 (Martin and Brady 1983).

An unconfined aquifer is generally present in the shallow fill material and unconsolidated recent deposits along the Port Angeles shoreline. The aquifer is recharged by upgradient groundwater, infiltrating precipitation, and losing streams (stream that loses water via infiltration as it flows downstream) channelized through the fill. The groundwater flow direction is generally northerly toward the Harbor at a horizontal hydraulic gradient ranging from approximately 0.01 to 0.001 feet per foot. Groundwater near the shoreline is tidally influenced, which results in changes in groundwater level elevation and localized gradient reversals. The aquifer is generally considered non-potable based on elevated specific conductivity due to tidal influence (Shannon & Wilson 1993, Floyd|Snider 2013).

The Harbor area enclosed by Ediz Hook is a sediment depositional area (NewFields 2012). Prior to approximately 1900, erosion of soils from the southern shoreline bluffs was a significant source of sediment to the Harbor (Herrera 2011a). However, as the Harbor shoreline was extended northward with the placement of fill material, the shoreline bluffs were eliminated as a significant source of sediment to the Harbor. Currently, the main sources of sediment to the Harbor include creeks that drain into the Harbor, algal (phytoplankton) production within the Harbor, and human activities (Herrera 2011a). Further information regarding these current inputs of sediment to the Harbor is described in the following sections. The historical fill material placed along the southern shoreline of the Harbor has resulted in the displacement of the mouths of four of the creeks that enter the Harbor (Tumwater, Valley, Peabody, and Ennis Creeks) approximately 500 to 1,000 feet northward from their pre-development locations (Herrera 2011a).

Periodic dredging has occurred over the past 100 years, primarily at dock facilities and the mouths of creeks.

2.1.2 Bathymetry

The Harbor is a large (approximately 2,000 acres), deep, and relatively flat-bottomed harbor with steep slopes present along a significant portion (approximately 60 percent) of the shoreline. The steepest slopes within the Harbor are present along the length of Ediz Hook. Steep slopes are also present along the southern shoreline in the western portion of the Harbor. Generally, water depths in the Harbor range from 10 to 50 meters (33 to 165 feet) below mean lower low water (MLLW) with water depths increasing from south to north. The deepest portion of the Harbor is located to the north, near Ediz Hook, where water depths in this area are approximately 52 meters (170 feet) deep. The southern portion of the Harbor has a subtidal bench area, approximately 5 to 15 meters (16 to 50 feet) deep, which widens to the east. Figure 2.1 presents the Harbor's bathymetry recorded between 2001 and 2018, as compiled and provided to the WPAH Group by the LEKT[3] and collected by eTrac, Inc., on behalf of the WPAH Group in 2018.

2.1.3 Drainage

Five creeks currently discharge into the Harbor: Tumwater Creek, Valley Creek, Peabody Creek, Ennis Creek, and Lees Creek (creeks are listed in order moving from west to east along the southern shoreline of the Harbor). Tumwater Creek, Valley Creek, and Peabody Creek all discharge into the eastern portion of the WPAH Study Area. Ennis Creek and Lees Creek discharge east of the WPAH study area and east of the former Rayonier Mill. The locations of the three creeks discharging into the WPAH Study Area are shown in Figure 1.2. The size of the drainage basins for these three creeks ranges from approximately 2,400 to 7,200 acres (Herrera 2011b). The land use in the drainage basin for the creeks is 75 percent forest and field (refer to Appendix B). Based on an analysis performed by Herrera Environmental Consultants, the total estimated rate of sediment discharged from these creeks into the Harbor ranges between 1.35 and 5.69 kilograms per second on an average annual basis (Herrera 2011a). As stated in Section 2.1.1, the creeks discharging into the Harbor are currently a primary source of sediment input to the Harbor, along with algal production within the Harbor.

2.1.4 Harbor Circulation

The Strait of Juan de Fuca area experiences semi-diurnal tides, normally resulting in one major and one minor ebb and flood tide and resulting tidal currents each day. Based on the range of daily tidal prisms compared to the volume of water in the Harbor, total water replacement in the Harbor has been calculated to occur every 5 to 9 days (Floyd Snider McCarthy and Evans-Hamilton 2002). However, hydraulic modeling and empirical evaluation of water residence times using sulfite mixed liquor water quality data (collected in the 1960s) revealed that the residence time of surface waters in the Harbor is shorter, on the order of 2 to 4 days (Floyd Snider McCarthy and Evans-Hamilton 2002). The shorter observed residence time compared to the residence time calculated based on tidal flushing alone is due to eddies and related mixing processes that contribute to mixing of the waters of the Harbor with the Strait of Juan de Fuca, resulting in greater circulation and flushing of the Harbor than tides alone can generate.

As a result of relatively rapid circulation and water exchange, water quality characteristics of the Harbor closely reflect source waters within the Strait of Juan de Fuca. For example, dissolved oxygen (DO) concentrations in source waters to the Harbor seasonally decline to less than 6 milligrams per liter (mg/L) during late summer to early fall. Additionally, low DO conditions are observed in the Harbor particularly in the fall, largely attributable to natural seasonal upwelling of low DO waters from the Strait of Juan de Fuca (Floyd Snider McCarthy and Evans-Hamilton 2002).

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3 The bathymetry dataset for all of the Harbor with the exception of the lagoon was compiled by Randall McCoy of the LEKT and provided to the WPAH Group via the National Oceanic and Atmospheric Administration (NOAA) in April 2017.

2.1.5 Sediment Transport, Deposition, and Stability

The circulation and hydrodynamic characteristics of the Harbor cause it to act as a long-term sink for depositional sediments, particularly within the western portion of the Harbor. The distribution of fine-grained sediments (clay and silt grain size fractions) reflects the balance between sediment supply and energy at the seabed at different locations within the Harbor. The western portion of the Harbor has more fine-grained sediments, reflecting the lower energy in this area. The finest-grained sediments (greater than 70 percent fines) are located toward the western portion of the Harbor (NewFields 2012). Based on sediment grain size trends, GeoSea Consulting Ltd., identified an approximate sediment transport front, characterized by little to no east-west sediment transport, located approximately 0.6 to 1.2 miles from the Harbor's western shoreline (GeoSea 2009).

Net sedimentation rates in the Harbor have been measured using two methods: (1) radioisotope dating of core sections (Ecology 2012), and (2) SPI observations of the depth of buried pulp material in the Harbor. Discharges of pulp to the Harbor ceased between 1964 and 1970, providing a useful "marker" to estimate net sedimentation rates over the last 50 years (Integral et al. 2014). Combined, there are 14 independent estimates of contemporary net sedimentation rates in the western portion of the Harbor that have been performed using one or both of these methods (refer to Appendix B for individual estimates). All of these estimates yield very similar results, with an overall average net sedimentation rate in the western portion of the Harbor of 0.17 ± 0.03 cm per year, equivalent to roughly 9 cm of recent sediment deposition over the last 50 years (primarily clay and silt grain size fractions), excluding wood debris accumulations.

Once sediments deposit in the western portion of the Harbor, the relatively weak currents in most of the Harbor are not sufficient to resuspend even the finest sediment material (Herrera 2011a). However, during extreme wind events, waves with heights up to approximately 3 feet and periods of approximately 3.6 seconds may move into the Harbor, based on a 100-year return period storm from the east with a fetch distance of 32 miles (Appendix K). As these extreme waves pass over the seabed, they produce oscillatory water velocities near the seabed. These near-bed velocities impart a force on the surface sediments parallel to the seabed called shear stress. When this force exceeds the critical shear stress value of the in situ surface sediment, sediments deposited in the Harbor can be resuspended. The greater the critical shear stress value of the in situ sediment, the larger the velocity needed to resuspend the material.

For this RI/FS, an evaluation was conducted to estimate the approximate water depth above which significant sediment resuspension could occur during extreme wind-driven wave conditions throughout the Harbor. Herrera (2011a) estimated the maximum water depth of significant wind wave influence (i.e., the closure depth) to be 55 feet for areas influenced by the east-northeasterly (ENE) winds. The innermost portion of the Harbor and the south shore of Ediz Hook are less impacted by ENE waves; therefore, the local closure depth is expected to be shallower. Building on the findings of this work, a preliminary assessment of bottom shear stress and stable sediment grain size was performed (Appendix K) to assess sediment stability within the water depth range expected to represent the closure depth in the innermost portion of the

Harbor. The results indicate that waves generated by the most extreme wind events would not cause movement of sediment composed of particles approximately 5 millimeters in diameter in water depths below approximately -15 feet MLLW.

In addition to providing information on sedimentation rates, radioisotope analyses of core sections also provide empirical confirmation of sediment stability in depositional environments (Magar et al. 2009). For example, the lead-210 profile measured to a depth of 4 feet below mudline at Station WPAH030 (MA06), located toward the middle of the western portion of the Harbor, exhibits the characteristic exponential decay of this radioisotope (half-life of 22 years), further confirming the long-term stability of these deep sediments (Figure 2.2).

Based on the weight-of-evidence of the information provided in this section, including radioisotope analyses, SPI observations (refer to additional information in Section 7.2), and hydrodynamic calculations, the vast majority of sediments in the Harbor are highly stable and are not subject to resuspension even under worst-case hydrodynamic conditions. In addition to the shallow nearshore zone, there are localized areas of the Harbor that are subject to periodic scour and resuspension. These areas are either proximal to actively used docks and associated vessel propeller wash or to areas of higher energy hydrodynamic environments such as the lagoon channel connected to the inner harbor (Figure 2.3) that can generate higher velocity currents during peak ebb and flood tidal flows. Based on radioisotope analyses and SPI observations, sediment sampling locations in the inner harbor that are adjacent to these features exhibit evidence of periodic sediment resuspension and mixing.

2.2 AQUATIC RESOURCES

This section describes marine species likely to be present in the Harbor, endangered and threatened species, and the human consumption of seafood from the Harbor.

2.2.1 Benthic Community

In 2013, Ecology's Puget Sound Ambient Monitoring Program (Ecology 2015b) evaluated benthic communities at 11 stations within the WPAH Study Area. The benthic community samples collected were processed to the lowest practical taxonomic level, generally to species. In addition, total abundance, total richness (i.e., number of species), and the abundance and richness of polychaete worms, mollusks, and arthropods were determined. Although the benthic community in the WPAH Study Area had a similar total abundance and total richness as other stations in the Strait of Juan de Fuca, it had fewer arthropods and mollusks than other stations in the Strait of Juan de Fuca. The sediment triad index, which characterizes sediment conditions based on chemistry, toxicity, and benthic community, indicated that 10 of the 11 stations were "likely unimpacted." The remaining station was located in the inner harbor in an area of elevated chemical contamination and classified as "possibly impacted."

Additional qualitative information on the benthic community was generated using SPI in 2013 and is described in detail in Section 7.2. Benthic community successional stages, which vary from

Stage 1 (the community is dominated by small surface-dwelling species indicative of recently physically, chemically, or biologically disturbed habitats) to Stage 3 (the community is dominated by large head-down deposit feeders indicative of stable habitats), were measured at these SPI stations. Of the 92 stations evaluated, only 2 lacked evidence of deep-dwelling Stage 3 organisms. These two stations were located at the mouth of the Port Angeles Boat Haven marina where sediments were very coarse, and between the McKinley Paper Company facility and the active log rafting area along Ediz Hook. The presence and depth of the apparent redox potential discontinuity (aRPD) was also evaluated using SPI. The aRPD is the line separating the lighter-colored surface sediment from the darker sediment below. The depth to the aRPD generally reflects the thickness of the surface oxygenated layer of sediment and generally corresponds to the depth to which the sediments are highly mixed by benthic organisms. Deeper aRPDs suggest deeper dwelling benthic infauna, which are indicative of stable habitats. The SPI survey indicated that the station located at the mouth of the Port Angeles Boat Haven marina did not exhibit an aRPD, while the station between the McKinley Paper Company facility and the log rafting had a relatively thick aRPD layer (3.27 cm). Only one additional station along Ediz Hook exhibited no aRPD. Overall, this indicates that biological sediment mixing was occurring at nearly all WPAH stations. These results show the presence of a functional benthic community[4] characterized by diverse surface and subsurface-dwelling infaunal assemblages throughout the WPAH Study Area, and indicate that the benthic community is relatively undisturbed.

2.2.2 Aquatic Species and Wildlife

A variety of marine aquatic species and wildlife are observed in the Harbor, including both migratory and resident species. This section provides a broad overview of aquatics species in the Harbor grouped into the following categories: marine plants, fish, shellfish, birds, and mammals.

2.2.2.1 Marine Plants

Macroalgae, primarily sea lettuce *(Ulva sp.)*, occurs throughout the Harbor in shallow intertidal areas (Shea et al. 1981). In their 2012 sediment investigation, Ecology documented macroalgae including both *Ulva sp.* and bull kelp *(Nereocystis luetkeana)* along Ediz Hook (Ecology 2012).

Seagrass is also present within the Harbor, with the majority of seagrass being eelgrass *(Zostera marina)*. Eelgrass mapping conducted on behalf of Clallam County and by Washington State Department of Natural Resources (DNR) found two eelgrass beds: one in shallow water inside Ediz Hook, and one extending east of the City Pier (Marine Resources Consultants 2009 and DNR 2015). An additional healthy eelgrass bed is known to occur along the eastern side of the lagoon. Figure 2.4 depicts approximate eelgrass bed locations.

4 A functional benthic community refers to the presence of higher-order successional stages (Stage 3 and/or 1 on 3; discussed further in Section 7.2.4), characterized by longer-lived, subsurface, deposit-feeding organisms, which indicate that the benthic community is relatively undisturbed and/or not recently disturbed (i.e., stable).

2.2.2.2 Fish

More than 60 species of marine fish have been observed in the Port Angeles area (Shea et al. 1981). Salmon, bottomfish, and forage fish in the area are important for sport, commercial, and tribal harvests.

Salmon are anadromous species and typically migrate to the open ocean through the Harbor as juveniles for maturation before returning to freshwater tributaries to spawn. There are five primary species of salmon that may be present in the Harbor, including Chinook, Coho, chum, pink, and sockeye (WDFW 2017a and 2017b). If forage fish are available, Chinook and Coho salmon may be present year-round rather than migrate to the ocean (Malcolm Pirnie 2007a). Additionally, coastal cutthroat and steelhead trout may be present in the Harbor or in creeks during migratory periods (Malcolm Pirnie 2007a, WDFW 2017a). In-water work activities may occur in the Harbor only from July 16 to February 15 in order to protect sensitive species, including salmon, during migration (USACE 2012).

The important bottomfish species for commercial, tribal, or sport fishing within the Harbor include lingcod, Pacific halibut, spiny dogfish, Pacific cod, rockfish, English sole, Dover sole, rock sole, starry flounder, sanddab, and perch (Shea et al. 1981 and WDFW 2017a).

Forage fish are small pelagic fish such as herring, smelt, and sand lance. They are primary prey fish for higher-trophic-level fish (salmon, bottomfish, etc.), birds, and marine mammals. Schools of herring and sand lance may be seasonally abundant in the Harbor, but likely migrate through the area to feed (Malcolm Pirnie 2007a). According to the Washington State Department of Fish & Wildlife's (WDFW's) Forage Fish Spawning Map, no documented herring or smelt spawning areas occur in the Harbor, and one small sand lance spawning area is present in the vicinity of Harborview Park, located on the end of Ediz Hook (WDFW 2017c).

2.2.2.3 Shellfish

A variety of shellfish are present in the Harbor. These shellfish include a number of species of hardshell clams (native littleneck, butter, horse, and geoduck), softshell clams (Macoma, Eastern, and truncate), mussels, urchins, sea cucumbers, Pacific oyster, crab (Dungeness, red rock), and shrimp (dock [coonstripe], pink, and others; Bishop and Devitt 1970, Shea et al. 1981).

The Harbor, along with other areas along the Strait of Juan de Fuca from Cape Flattery eastward to the Jefferson County line, is periodically closed for all shellfish harvest (clams, geoducks, scallops, mussels, oysters, snails, and other invertebrates), excluding crab and shrimp. This periodic closure is due to the presence of the Paralytic and Diarrhetic Shellfish Poison marine biotoxin produced by algae (WDOH 2017). Additionally, the Washington State Department of Health (WDOH) lists shellfish harvest along the majority of the Harbor shoreline and some relatively deep subtidal areas of the Harbor (down to approximately 20 meters [70 feet]) as closed due to pollution, with the primary cause identified as bacterial contamination from the wastewater treatment plant (WWTP) outfall (WDOH 2017). The WWTP outfall is described further in Section 3.3.2.8.

2.2.2.4 Birds

The Ediz Hook Reservation for Native Birds within the Harbor and the Dungeness Wildlife Refuge in the Dungeness County Park located approximately 30 miles from the Harbor provide important habitat for wintering and migrating birds. The sheltered waters along Ediz Hook in the Harbor support wintering populations of great blue herons, Barrow's goldeneye, Western grebe, common goldeneyes, and harlequin ducks (Audubon 2017). Species observed year-round include cormorants, alcids, gulls, and sea ducks. The Harbor also supports populations of Heermann's gulls, Thayer's gulls, common loon, and common murre (Audubon 2017). Shorebirds observed in the Dungeness Wildlife Refuge that are likely to be seen along Ediz Hook include the black oystercatcher, sanderling, dunlin, and least sandpiper (USFWS 2014). The Audubon-designated Port Angeles Important Bird Area for marbled murrelets is present within the Harbor (Audubon 2017), but the closest known occupied nesting stands are located approximately 6 miles south of the Harbor in the Olympic National Forest (Malcom Pirnie 2007a). Small numbers of brown pelicans are noted to occur in the Strait of Juan de Fuca and Puget Sound (WDFW 2013).

2.2.2.5 Mammals

Twenty species of marine mammals are found in Puget Sound and the Strait of Juan de Fuca (NOAA 1979). Seals and sea lions include the California sea lion, Northern (Steller) sea lion, Pacific harbor seal, Northern elephant seal, and the Northern fur seal (NOAA 1979). Cetaceans include the gray whale, minke whale, fin whale, humpback whale, Risso's dolphin or whitehead grampus, pacific white-sided dolphin, short-beaked or saddleback dolphin, false killer whale, shortfin pilot whale, pygmy sperm whale, Cuvier's beaked whale or the goose-beaked whale, Baird's beaked whale or North Pacific giant bottlenose whale, orca, Dall's porpoise, and harbor porpoise (NOAA 1979). Short-beaked dolphins, which generally occupy warmer water, were sighted near Port Angeles for the first time in the summer of 2016 (Lee 2016). According to local whale watching groups, species commonly seen near Port Angeles include orcas, minke whales, humpback whales, gray whales, Steller sea lions, elephant seals, harbor seals, Dall's porpoises, and harbor porpoises (Island Adventures Whale Watching 2017). River otters are also commonly seen in the Harbor (WDFW 2017d).

2.2.3 Special Status Species

Information regarding federal- and state-listed sensitive and candidate species under the Endangered Species Act was obtained from the WDFW and U.S. Fish & Wildlife Service (USFWS) websites (WDFW 2017e; USFWS 2017), which include those species listed by the state, as well as species listed or proposed for listing by the USFWS or the National Marine Fisheries Service. The following list provides known species in the Harbor that are state- or federally-listed as of concern (WDFW 2017f):

Animal	Listing	Animal	Listing
Birds			
Brown pelican	SE, FCo	Brandt's cormorant	SC
Marbled murrelet	SE, FT	Western grebe	SC
Common loon	SS	Bald eagle	FCo
Common murre	SS	Peregrine falcon	FCo
Marine Mammals			
Fin whale	SE, FE	Gray whale	SS
Humpback whale	SE, FE	Harbor porpoise	SC
Orca	SE, FE	Stellar sea lion	FCo
Fish			
Puget Sound Chinook salmon	SC, FT	Bull trout	SC, FT
Hood Canal summer-run chum salmon	SC, FT	Puget Sound steelhead salmon	FT

Abbreviations:
FCo Federal species of concern
FE Federal endangered
FT Federal threatened
SC State candidate
SE State endangered
SS State sensitive

2.2.4 Human Consumption of Seafood

The Harbor is fished recreationally by sportfishers and subsistence (Tribal) fishers. Sportfishers in Port Angeles primarily target salmon species with cod caught less frequently, based on Puget Sound Creel Reports released by WDFW (WDFW 2017b). Dungeness crab and other shellfish (oysters, mussels, clams) are targeted by Tribal fishers in the Tribal Usual & Accustomed (U&A) fishing areas, which extend beyond the Harbor. The U&A Tribal fishing areas for the LEKT include the Harbor, large geographic areas to the north of the Harbor and south of the Harbor (i.e., rivers and creeks in portions of the Olympic Peninsula), selected areas of Hood Canal, and the Strait of Juan de Fuca (Section 3.2). These areas are also U&A fishing areas for other area tribes.

The tribal fish consumption rate for the LEKT, selected to evaluate potential risk posed by seafood consumption, was established by Ecology based on fish consumption surveys conducted by the LEKT (Table 32 of Ecology 2013a). The LEKT used the Suquamish Tribal data (The Suquamish Tribe 2000) to help derive their tribal specific fish consumption rate because the Suquamish Tribe has comparable high-quality harvestable shellfish habitat and comparable fish-consuming habits and rates. Ecology selected a LEKT tribal fish consumption rate of 583 grams per day, assuming that a significant portion of the tribal diet is seafood from the Harbor. The 583 grams per day consumption rate assumes 498 grams per day of shellfish consumption, 56 grams per day of pelagic fish consumption, and 29 grams per day of bottom fish consumption.

During the RI for the former Rayonier Mill site (Malcolm Pirnie 2007a), elevated concentrations of PCBs and dioxins were detected in sediment at that site. The LEKT responded by implementing a moratorium on commercial fishing in the Harbor. At that time, the Clallam County Health Department and WDOH also issued a health advisory against the consumption of Dungeness crab and bottom fish in the Harbor. While the health advisory has since been rescinded by the WDOH and Clallam County, it has remained in place by the LEKT.

There are a number of additional health advisories related to the consumption of seafood currently in effect within the Harbor:

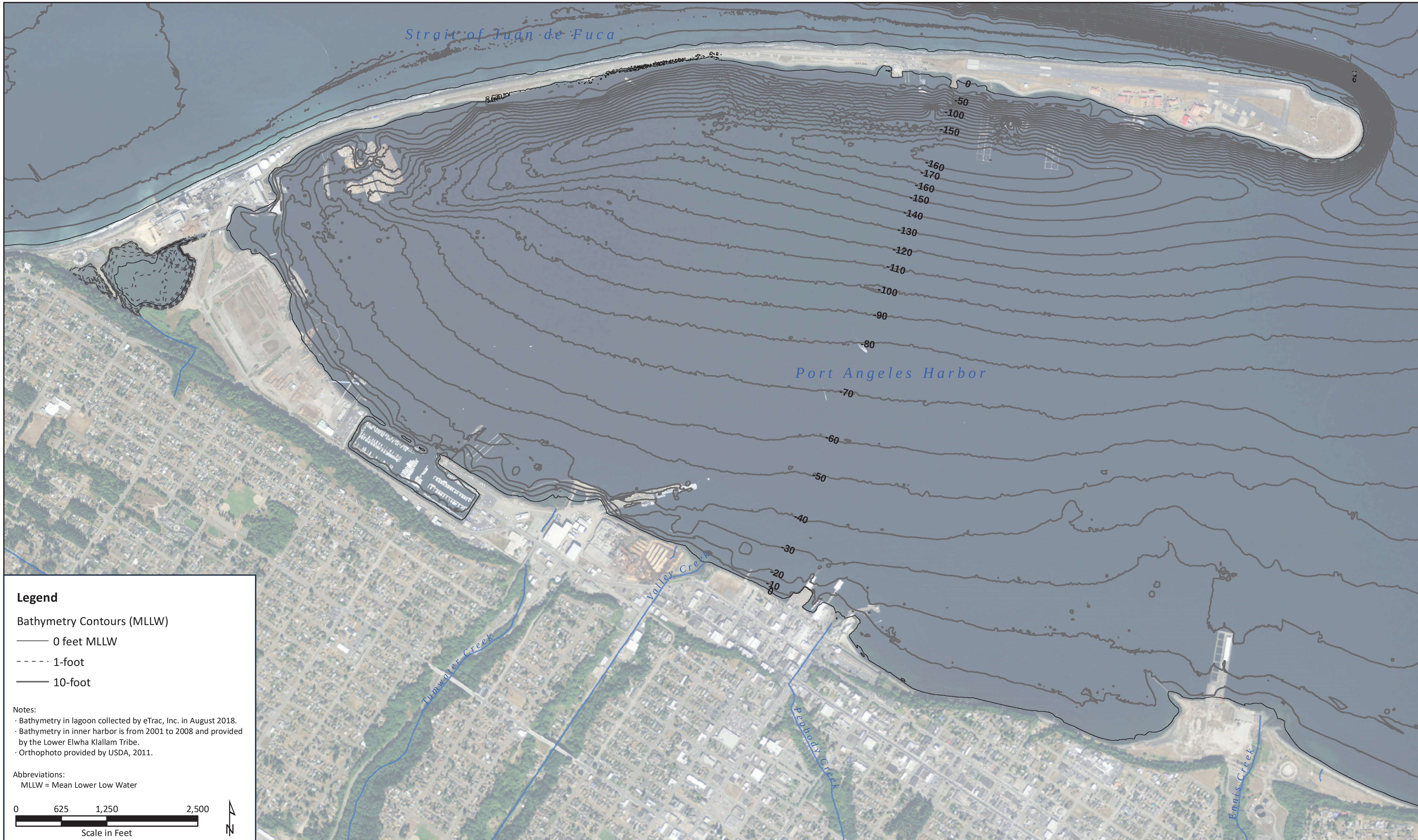
- There is currently a Puget Sound-wide advisory for mercury and PCBs. WDOH recommends the following for the Port Angeles area: no more than one meal per week of Chinook salmon, or no more than two meals per month of resident Chinook (blackmouth) salmon (WDOH 2018).
- Recreational and commercial harvesting of clams, geoducks, scallops, mussels, oysters, snails, and other invertebrates is periodically closed Harbor-wide due to the Paralytic and Diarrhetic Shellfish Poison biotoxin, as described in Section 2.2.2.3 (WDOH 2017).
- The majority of the Harbor shoreline and some subtidal areas of the Harbor (up to approximately 20 meters [70 feet] deep) are currently closed to shellfish harvests due to bacterial pollution (WDOH 2017).
- Although crab harvesting is not closed, WDOH recommends no more than four meals per month of crab, and warns against eating the hepatopancreas (digestive gland) of crabs caught within the Harbor (WDOH 2018).

Section 2.0:
Harbor Description and Setting

Figures

Western Port Angeles Harbor
Sediment Cleanup Unit

Remedial Investigation/Feasibility Study



WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 2.1
Port Angeles Bathymetry

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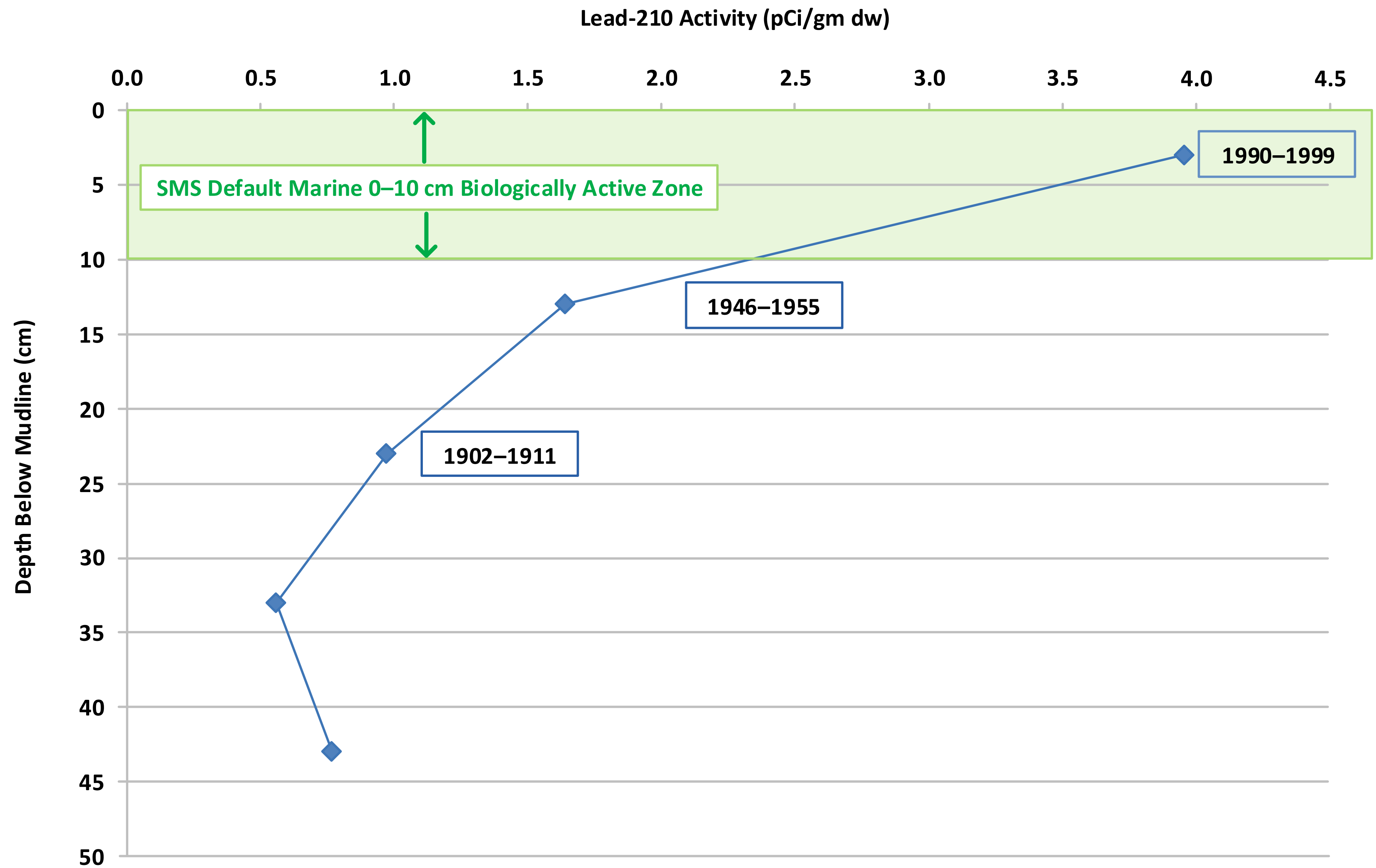
10/29/2020

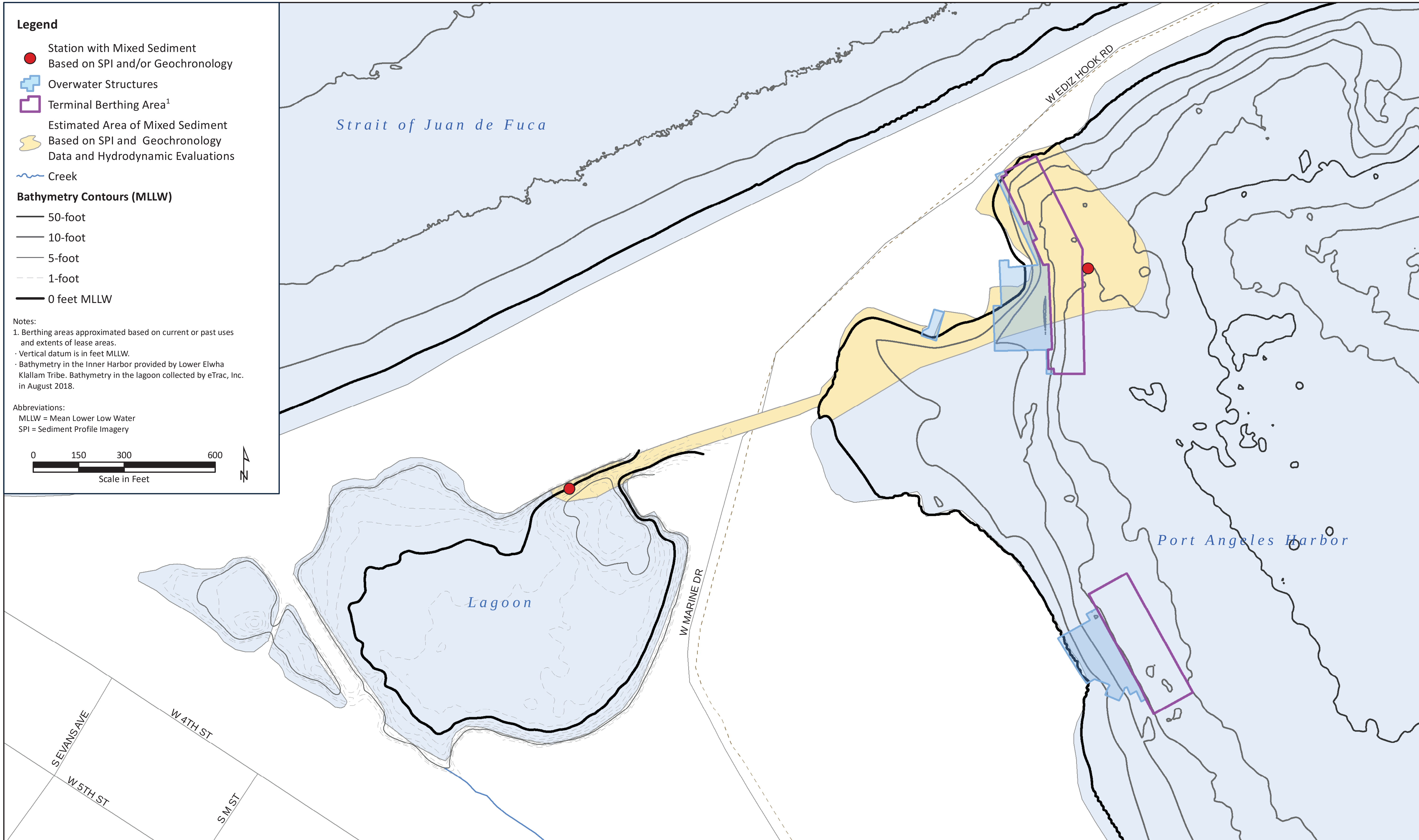


Abbreviations: cm = Centimeters, dw = Dry weight, pCi/gm = Picocuries per gram, SMS = Sediment Management Standards

WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor
Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 2.2
Lead-210 Activity Profile, Port Angeles Harbor Core WPAH030 (MA06)



WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 2.3
Estimated Extent of Mixed Sediment

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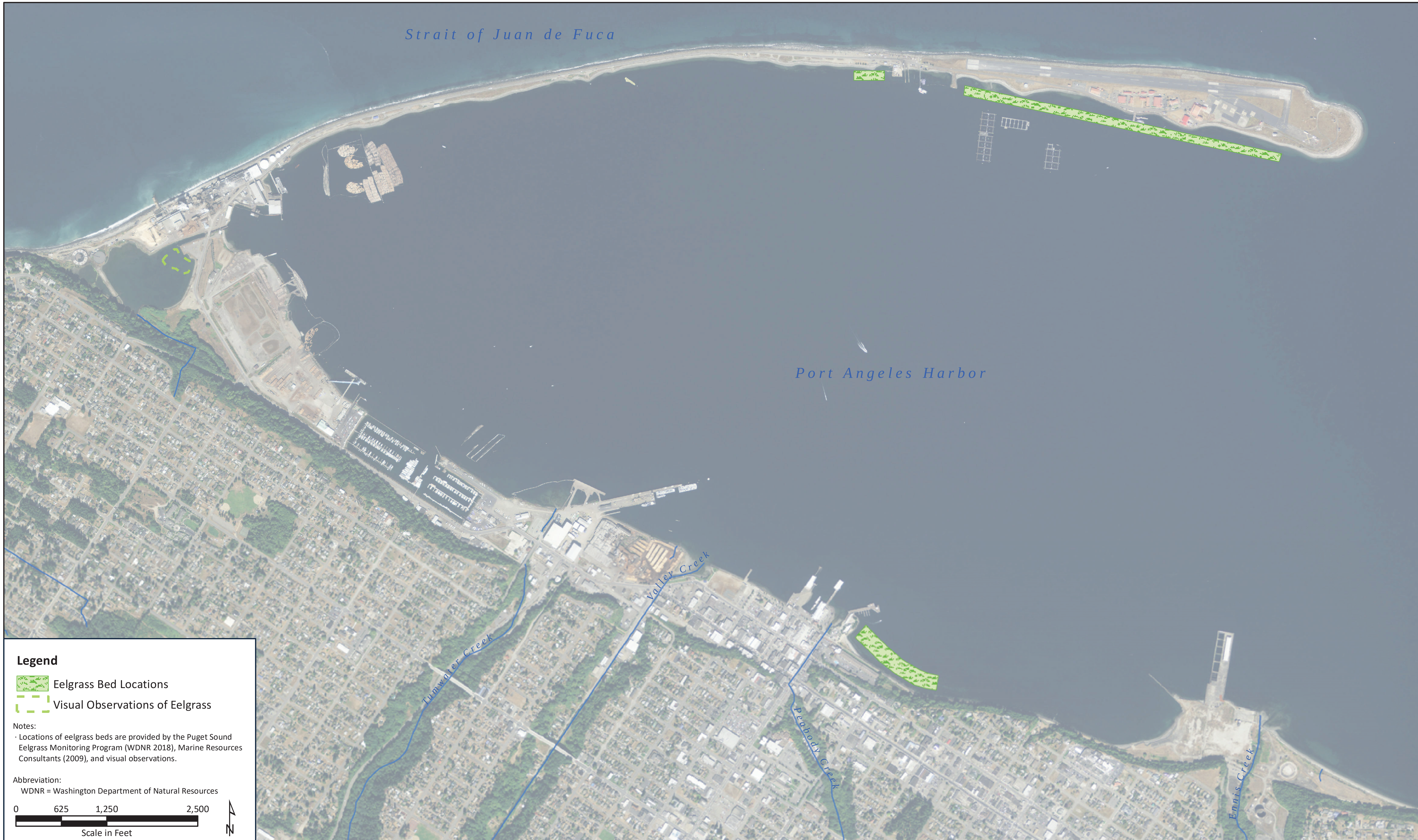
10/29/2020



WPAHG

Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 2.4
Eelgrass Bed Locations

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10/29/2020

Section 3.0: Historical and Current Uses of the Harbor

- Port Angeles Harbor is located within the traditional territory of the Lower Elwha Klallam Tribe (LEKT), an important stakeholder in the cleanup process. Based on the long history of Tribal presence in the Harbor, there is a high probability that archeological materials will be encountered during cleanup activities.
- Over the past 100 years, industrial operations along the Harbor's shoreline or within the Harbor have included sawmills, plywood manufacturing, pulp and paper production, wood handling, fish packing, marine shipping and transport, boat building, bulk fuel facilities, marinas, and commercial fishing. Some of these industrial operations have resulted in the accumulation of wood debris in log handling areas of the Harbor.
- Discharges to the Harbor have included the City of Port Angeles' sanitary and storm sewer systems. Additionally, private entities historically discharged industrial effluents and stormwater into the Harbor. Stormwater continues to be discharged into the Harbor through permitted outfalls.
- Currently, the shoreline areas in the western portion of the Harbor are primarily owned by the City, the Port of Port Angeles, McKinley Paper Company, the LEKT, and the federal government. The Port owns two sites on the Harbor shoreline under cleanup through the Model Toxics Control Act, one of which has been largely remediated (the K Ply Site).
- Current in-water activities are conducted under active Washington State Department of Natural Resources leases, including aquatic land currently leased to the Port managed under a Port Management Agreement. The Port currently conducts log handling and rafting and other maritime activities along the shoreline and in-water.

3.0 Historical and Current Uses of the Harbor

3.1 PRE-INDUSTRIAL HARBOR HISTORY AND CULTURAL RESOURCES

Historically, much of the northern Olympic Peninsula and southern Vancouver Island was territory of the Klallam Tribe, and more than 30 Klallam villages were scattered throughout this region. Today the Klallam Tribe is divided into three federally recognized tribes: the Port Gamble S'Klallam Tribe, the Jamestown S'Klallam Tribe, and the LEKT. The LEKT is the tribal community in Port Angeles (Oldham 2007). The Harbor is located within the traditional territory of the LEKT.[5]

The Harbor area was historically inhabited by two major Klallam villages: I'e'nis and Tse-whit-zen (Ecology 2012). These villages shared the Harbor area. I'e'nis was located on the east side of the Harbor, at the mouth of Ennis Creek. In the mid- to late 1800s, I'e'nis was fortified with a double stockade and was variously reported to have 200 to 1,500 residents. Tse-whit-zen was located in the western portion of the Harbor, on the former Washington State Department of Transportation graving dock property, now owned by the LEKT. Archeological investigations in 2003 documented six longhouses in this village, along with a stockade similar to that observed at I'e'nis. Beginning over two thousand years ago, the LEKT utilized Tse-whit-zen in the traditional practices of sea mammal hunting, ocean fishing, and the burial of its members. At Tse-whit-zen, artifact deposits underlying historical fill have been identified and include artifact-bearing middens containing shell, stone, and bone artifacts, projectile points, lithic debitage, and human remains (Oldham 2007). A third, unnamed village was historically noted as being located at the mouth of Tumwater Creek (Tingwall and Rust 2009). This village was depicted on the 1853 Coast and Geodetic Survey map of the Harbor; however, no further evidence of this village has been found. There is a high probability that archaeological materials associated with ethnographic- to historic-period Native American residential activities, as well as resource procurement, could be identified within the Harbor area.

Based on a review Washington State Department of Archaeology and Historic Preservation's (DAHP's) WISAARD database, two properties located along the shoreline area of the Harbor are listed on the National Register of Historic Places (NRHP): the Tse-whit-zen village site and the Ediz Hook Light Station (DAHP 2018). Three properties along the Harbor shoreline were listed on the Washington Heritage Register (WHR), including the Ediz Hook Light Station, located at the tip of Ediz Hook, the I'e'nis Klallam village site located just east of the City Pier on Hollywood Beach, and the Puget Sound Cooperative Colony, located at the mouth of Ennis Creek. The Puget Sound

5 Klallam tribal history was compiled from multiple sources including tribal and other relevant historical-related websites, and cultural resources surveys and inventories that have been completed in the Port Angeles area, as referenced herein. Specific information relative to historical property use in the Harbor was sourced from DAHP's Washington Information System for Architectural and Archaeological Records Data (WISAARD) database. A secure database is available to credentialed professionals, and a public version can be accessed on DAHP's website.

Cooperative Colony has since been subsumed by the former Rayonier Mill, and the lighthouse complexes at Ediz Hook have all been removed (DAHP 2018).

Historic Property Inventories documented in WISAARD have been completed for six other properties within the Harbor, including: the former Rayonier Mill jetty (outside the SCU), the Merrill & Ring timber warehouse located along Marine Drive, railroad spurs along Tumwater Creek, and the U.S. Coast Guard (USCG) Air Station hangar and barracks/administration building located on Ediz Hook. The eligibility status for listing in the WHR or NRHP has not been determined for the former Rayonier Mill jetty or the Merrill & Ring timber warehouse. The rail spurs at Tumwater Creek were determined not to be eligible. The two USCG buildings were determined to be eligible for listing on the WHR and NRHP (DAHP 2018).

3.2 POINT NO POINT TREATY AND TRIBAL USE

In 1855, the Klallam Tribe was a signatory to the Treaty of Point-No-Point between Isaac Stevens, the Governor of Washington Territory, and leaders of the Klallam, Chimakum, and Skokomish Tribes. Under this treaty, tribes ceded land ownership in exchange for small reservations and hunting and fishing rights. The LEKT did not obtain land until 1937. Trust lands were acquired by the U.S. during that time to establish a reservation. Federal recognition and establishment of the reservation did not occur until 1968 (LEKT 2014).

The case of *United States v. Washington*, commonly known as the Boldt Decision, affirmed the rights of Washington's tribes to fish in U&A places (*United States v. Washington*, 384 F. Supp. 312 [*aff'd* 520 F.2d 676 [Ninth Circuit 1975]). The Boldt Decision allocated 50 percent of annual catch to treaty tribes. A 1978 court decision held that the U&A fishing areas for the LEKT includes the Harbor, large geographic areas to the north and south of the Harbor, selected areas of Hood Canal, and the Strait of Juan de Fuca (*United States v. Washington*, 459 F. Supp. 1020 [W.D. Wash. 1978]).

Following the discovery of Tse-whit-zen in 2003, and the high probability of encountering archaeological materials between the bluff and the shoreline areas of the Harbor, certain sediment cleanup actions in the Harbor and adjacent upland areas (depending on the nature of the activity) may be subject to the conditions imposed by the Settlement Agreement between the LEKT and the State of Washington, the Port, and the City dated August 14, 2006, as well as the relevant Monitoring and Discovery Plan (MDP; refer to Appendix F). The 2006 Settlement Agreement requires consultation with the LEKT and review of ground-disturbing work to prevent disturbance of potential archaeological and cultural artifacts. The MDP includes established protocols for monitoring and reporting discoveries of cultural resources and/or human remains. These or comparable protocols will be used during future investigation and remediation activities that have the potential to disturb artifacts.

3.3 HARBOR HISTORY

3.3.1 Harbor Industrial Development Timeline

The Harbor's industrial history began with the development of sawmills and fish packing operations in the late 1800s. Table 3.1 summarizes by year the various significant shoreline or nearshore operations present within the Harbor from the late 1800s to today. Typical operations over time have included sawmills, fish packing, bulk fuel facilities, pulp and paper mills, and other wood processing-related operations. Other uses included the USCG Station and marine shipping. Figures 3.1, 3.2, and 3.3 show changes to the historical waterfront operations over time, for the periods of 1910 to 1929, 1930 to 1949, and 1950 to 1964, respectively. In general, waterfront industrial operations within the Harbor peaked in the 1950s and 1960s (Figure 3.3). Of note, several mills operated hog fuel boilers that burned salt-laden wood as a portion of the fuel source.

3.3.2 Historical Shoreline Facilities within the Harbor

As described in the AO, there have been shoreline facilities located within the western portion of the Harbor that have been associated with historical releases of hazardous substances and/or wood debris to sediments, based on the scale, nature of operations, and years of operation (State of Washington 2013a). These industrial, commercial, and other facilities are briefly summarized in the following sections.

3.3.2.1 Commercial Fishing and Shellfish Harvesting

Commercial fishing activities commenced in the late 1800s along the waterfront in the Harbor (Johnson 2013, Port Angeles Evening News 1967, Campbell 1976). In 1891, the first cannery in the Harbor, the National Packing Company, was built east of the future location of the Fibreboard Paper Products Corporation (Fibreboard) facility, near the current location of the Port's Boat Haven marina. This cannery was primarily a salmon- and clam-packing facility. In 1917, the cannery was renamed Anacortes Fish Packing Company (Figure 3.1). In 1919, the Union Fishermen's Fish & Packing Company built a cold storage facility and cannery on the central inner side of Ediz Hook (west of the USCG Air Station) to process catch from its fleet of fishing boats. Currently, large salmon fish pens owned by Cooke Aquaculture Pacific LLC are present in the Harbor near this location (Figure 3.4).

By the 1930s, much of the region's commercial fishing industry had diminished due to over-fishing and the canneries were dismantled. While the main canneries had all been removed, a fish packaging and cold storage facility was still located on the former Angeles Gravel and Supply Co. wharf located in the Port Angeles business district (currently the Landing Mall) for a short period of time in the mid-1960s.

3.3.2.2 Former Rayonier Mill and Log Dump

ITT Rayonier, Inc. (ITT Rayonier) operated a pulp mill in Port Angeles from 1930 until 1997, when ITT Rayonier closed the mill and dismantled the mill buildings. The mill was located in the southeast corner of the Harbor on both sides of Ennis Creek. The former Rayonier Mill is now undergoing investigation and remedial activities under a separate AO (AO No. DE 6815). In March 2018, ITT Rayonier submitted the *Public Review Draft of the Agreed Order Task 4d Deliverable Interim Action Report Volume III, Alternatives Evaluation* (Tetra Tech and Windward 2018), which functionally serves as an FS for contaminated sediment, soil, and groundwater at the Rayonier Mill Site.

ITT Rayonier also operated a log dump facility that included rafting and log storage in the northern Harbor along Ediz Hook, within the WPAH Study Area. This is separate from the mill itself, located within the former Rayonier Mill SCU. The log dump facility was a pile-supported trestle that extended out into the Harbor where the logs were dropped from a significant elevation. The locations of this historical log dump, rafting areas, and log storage are shown in Figures 3.2 and 3.3. The DNR removed the former Rayonier Mill log dump debris and pilings in January 2008.

3.3.2.3 In-Water and Nearshore Wood Handling Operations

Wood debris identified in the Harbor includes logs, large wood pieces, small wood pieces or chips, very fine wood particles and/or fibers, and pulp-like material. Historically, various mills and timber-related industries have operated along the shoreline of the Harbor. These facilities have, at one time or another, transported and stored logs, wood chips, and/or sawdust in nearshore areas or on barges in the Harbor. Releases of wood debris occurred during these operations. The western portion of the Harbor was historically utilized for extensive log rafting by a variety of entities, resulting in the release of wood debris in the rafting areas. Additionally, releases of wood debris resulted from the operation of log dumps by a variety of entities, including ITT Rayonier. Wood debris, in the form of very fine wood particles and/or fibers, was released to the Harbor in the process effluent from mills, including the Crown Zellerbach Corporation (Crown Zellerbach) and Fibreboard mills, resulting in wood debris layers within the Harbor.

3.3.2.4 Merrill & Ring

Merrill & Ring owned and operated a lumber mill located at 1608 Marine Drive near the base of Ediz Hook from 1958 through 1988 on property it leased from the Port. Merrill & Ring also owned and conducted operations on adjoining fee-owned property, which it purchased from Fibreboard in 1972. Merrill & Ring leased aquatic lands from the DNR for its operations and operated the existing Terminals 5, 6, and 7. These three terminals are now owned and operated by the Port. Prior to 1958, Merrill & Ring did not have any connection to the mills that operated on these properties or to the Harbor. Historical records indicate stormwater outfalls were situated on Merrill & Ring's property adjacent to the Harbor (Figure 3.5).

3.3.2.5 Nippon Paper Industries USA Co., Ltd. (formerly Daishowa America Co., Ltd.)

NPIUSA owned and operated a paper mill located at 1805 Marine Drive at the base of Ediz Hook from 1988 until 2017. NPIUSA's real property at this location included a lagoon, which is connected by a channel to the inner harbor. NPIUSA also leased aquatic lands within the inner harbor from the DNR for mill operations.

Prior owners of the paper mill, including Washington Pulp and Paper Corporation, Crown Zellerbach, and James River Corporation of Nevada, owned or operated the facility from approximately 1928 through 1988 and also leased aquatic lands from the DNR to facilitate mill operations. Georgia-Pacific is the successor to James River Corporation of Nevada. From 1928 through the late 1960s, process effluents, wood fiber, and stormwater were discharged from the paper mill through multiple outfalls to the Harbor and to the Strait of Juan de Fuca (Figure 3.5).

3.3.2.6 Fibreboard Corporation (formerly Fibreboard Paper Products Corporation and Fibreboard Products, Inc.)

Fibreboard and its predecessors were the operators of a paperboard plant located at or near 1313 Marine Drive from 1919 through 1970. The plant was sold in 1972 to Merrill & Ring. Fibreboard also leased Harbor areas contiguous with the Fibreboard plant site and Harbor areas and tidelands along Ediz Hook from the State of Washington. Owens Corning acquired Fibreboard in 1997. Historical records indicate that process effluents and stormwater were discharged from the plant into the Harbor via five outfalls (Figure 3.5).

3.3.2.7 Petroleum Storage Facilities

Petroleum storage and transport businesses have historically operated (and still operate) at various locations in the Harbor. A number of bulk fuel plants operated historically in the same general area, near the former Peninsula Plywood Co. (Figures 3.2 and 3.3).

3.3.2.8 City of Port Angeles Sanitary and Storm Sewer Systems

The City, with a population of 19,000 (2010 census), is served by a separated stormwater system and a combined sewer system. A waste water treatment plant (WWTP) discharges treated water through a deep-water diffuser outside of the WPAH Study Area. Combined sewers were first constructed in the downtown area in 1915. By the 1950s street improvement projects included replacement of drainage ditches with separate storm sewers (Heath, Hammond, Collier 1954) and installation of sediment traps and oil separation devices in catch basins (City of Port Angeles 2017a).

Major industries were located on the waterfront, but their wastewater did not enter the City's system. Nominal industrial inputs from smaller industrial facilities were discharged into the City's sanitary sewer conveyance system (Heath, Hammond, Collier 1954). An interceptor system and WWTP provided primary treatment by 1969 (CH2M Hill 1978) and secondary treatment by 1993.

Since 2007, the City has managed its Municipal Separate Storm Sewer System (MS4) under a National Pollutant Discharge Elimination System (NPDES) permit. Stormwater connections to the combined sewer have not been allowed since 1986, and about two-thirds of the City is drained by separate storm sewers (Ecology 2008).

The City recently completed a $46 million combined sewer overflow reduction program that included replacement of pump stations and the sewer force main along the waterfront, upgrades within the WWTP to eliminate bottle necks, retrofitting of a 5 million-gallon tank to hold excess combined waters during storm events, and repurposing of ITT Rayonier's deep water outfall in the Strait of Juan de Fuca. Four permitted CSOs remain; however, no overflow events have occurred since fall 2016, although the NPDES permit for the WWTP allows for one event per outfall per year (Bender 2018).

3.3.2.9 Port of Port Angeles Operations

The Port is a municipal corporation that was established in 1923. The Port owns a number of waterfront facilities in support of its mission of economic development and the provision of sustainable family wage jobs for Clallam County. Terminal facilities support an international ferry operation, commercial seafood industry, recreational boating, cargo movement, topside repair, yacht manufacturing, oil spill response vessels, aggregate import, and maritime security.

For its first several years, the Port acquired (and in other cases created) property along the Port Angeles waterfront. Part of this waterfront was made up of tidal flats and salt marshes unsuitable for development, and it was necessary to fill them with dredged mud from the Harbor before they could be developed. In 1927, the Port completed construction of a 550-foot-long pier known as Terminal 1. In 1971, the pier at Terminal 1 was extended and today is 950 feet long, the longest of the Port's terminals. The Port also built Terminal 3 for timber cargo movement, and it is located northwest of Terminal 1. Terminal 3 was renovated and replaced with a concrete dock and concrete piling in the late 1980s. Current activities at the Port's terminals are described in detail in Section 3.4.5.3.

The Port leased land upland of Terminals 1 and 3 to Peninsula Plywood Group, LLC (PenPly) and its successors for a plywood mill from 1941 through 2011. This mill is often referred to as the former K Ply mill and a detailed history of this site is described in Section 3.4.5.5. The K Ply Site is identified as a contaminated site under MTCA and was formerly included in the Marine Trades Area (MTA) Site, but was identified as a separate site in 2012. Between 1941 and 2011, various companies operated the plywood mill, including PenPly; ITT Rayonier; K Ply, Inc. (K Ply); and Peninsula Plywood Co. Remedial actions at the K Ply Site were completed by the Port in 2016 and are described in Section 3.4.5.5.

The Port owns a portion of the MTA Site, which is a contaminated site under MTCA located east of Tumwater Creek. Starting in the 1920s, the MTA Site was used for log storage, ship and logging truck repair, and bulk fuel facilities. The Port-owned portion of the property, north of

Marine Drive, is now used primarily for marine-related businesses. The MTA Site is described further in Section 3.4.5.5.

The Port bought Terminal 2 (commonly known as the Port Angeles ferry terminal) in 1959 and leased it to Black Ball Transport, Inc., which has since used it as part of its operations of the MV Coho ferry that runs daily between Port Angeles and Victoria, British Columbia. In 1931, the Port built a small boat basin consisting of a pile bulkhead, a small dock, and three floats, which provided moorage for about 50 boats. However, a bigger, more developed basin was needed, and construction of the Port Angeles Boat Haven began late in 1946. Upon completion, this marina, located west of Terminals 1 and 3, was capable of mooring more than 200 boats. The Port Angeles Boat Haven was expanded in 1958 and renovated in 2006 to include 442 moorage slips.

Historically, the Port has also provided facilities for handling logs transported from the Olympic Peninsula to Puget Sound, along the West Coast, and for export to Pacific Rim countries. The log yard was located east of the Port Angeles Boat Haven, as depicted on Figures 3.1 through 3.3. More recently, the Port has expanded its marine terminal services to handle a broad mix of bulk and break-bulk.

In 2004, the Port purchased upland NPIUSA parcels that were formerly owned and operated by Fibreboard and Merrill & Ring. With this purchase, the Port acquired the Terminal 7 Pier historically known as the Fibreboard dock or chip dock. The Port also leases or has leased, and manages or has managed under a Port Management Agreement (PMA), state-owned aquatic lands in the Harbor to facilitate Port operations. The Port's current lease agreements, and the terms of the PMA, are documented in DNR PMA No. 22-080013 and Lease Nos. 22-083897 and 22-074157 and are further described in Section 3.4.4.2. The Port has two facilities discharging under NPDES Stormwater General Permits.

3.3.3 Historical Documented Releases

Spill history information available back to 1990 from the USCG (USCG 2017) suggests that there have been numerous spills reported over the years in the Harbor. Reported spills typically have involved petroleum products of some kind, less commonly bilge water, garbage, batteries, or other miscellaneous objects or fluids. These spills have been reported at various locations throughout the Harbor. Precise release volumes are usually not available for these spills. The exception to this is an extremely large crude oil spill from the Arco Anchorage ship, which ran aground as it entered the Harbor in December 1985. Before the leak was stopped, 240,000 gallons of crude oil spilled into the Harbor (Callis 2010).

3.4 CURRENT LAND OWNERSHIP AND USE

3.4.1 Shoreline Parcel Ownership

Shoreline parcel ownership within the Harbor is dominated by the Port and the United States government (Figure 3.4). The Federal government owns the northeastern half of Ediz Hook. Other property owners on Ediz Hook include McKinley Paper Company at the base of the hook, the City, and the LEKT. The Port owns a large portion of the parcels along the southern shoreline of the Harbor, particularly the shoreline parcels west of Valley Creek. The remaining parcels along the southern shoreline of the Harbor are primarily owned by private entities located in Port Angeles' central business district and Rayonier Properties LLC (formerly Rayonier Inc., and ITT Rayonier).

3.4.2 Shoreline Zoning

The Harbor's southern shoreline west of Valley Creek and the base of Ediz Hook are primarily zoned for industrial land use (Figure 3.6). Adjacent to these industrial areas, but located farther south along the shoreline, are areas zoned for public buildings and parks and residential use. Zoning along the Harbor's southern shoreline east of Valley Creek is predominately commercial, along with some residential zoning near the shoreline farther eastward toward the former Rayonier Mill.

With the exception of the property leased by McKinley Paper Company from the City, Ediz Hook has been zoned for public buildings and parks land use.

The City's *Port Angeles Shoreline Master Program* (City 2014) presents shoreline classifications (i.e., environment designations) in the Harbor. Environment designations are based on "*existing use pattern, the biological and physical character of the shoreline, and the goals and aspirations of the community as expressed through comprehensive plans (WAC 173-26-211)*" and are intended to guide development and use of shorelines. Environment designations include high intensity uses (industrial, maritime, mixed use, urban uplands), residential, and conservancy (Figure 3.7).

3.4.3 Recreational Activities

The Harbor provides numerous recreational activities. Ediz Hook contains long stretches of public beaches, scenic viewpoints, and picnic areas. In addition to housing the Ediz Hook Reservation for Native Birds, two city parks are located on Ediz Hook: Harborview Park and Sail & Paddle Park. Additionally, the Harbor adjacent to Ediz Hook serves as a popular location for diving. The only portions of Ediz Hook not accessible to the public are the USCG Air Station, which is located at the end of Ediz Hook, and the western area where industrial activities take place.

An approximately 6.5-mile length of trail, referred to as the Waterfront Trail, extends along the waterfront of the Harbor. This trail runs the length of the USCG Air Station on Ediz Hook to just west of the former Rayonier Mill. The Waterfront Trail is a section of a larger trail system referred to as the Olympic Discovery Trail. Four City parks, located adjacent to the Harbor and within or near the City's downtown area, are located along this trail. These parks are called City Pier, Valley Creek Estuary Park, West End Park, and Francis Street Park.

Boating and kayaking are other popular activities within the Harbor. Public boat launches within the Harbor are located at the Port's Boat Haven marina and on Ediz Hook (near the USCG Air Station).

3.4.4 In-Water Aquatic Lease Areas

Subtidal aquatic lands within the Harbor owned and managed either by DNR or by the Port under a PMA with DNR are shown in Figure 3.8.

3.4.4.1 In-Water Washington State Department of Natural Resources Lease Areas

The majority of aquatic land under active leases in the Harbor is leased to the Port. Currently, the Port leases aquatic parcels from DNR on the inside of Ediz Hook (Harbor Area Lease 22-083897) and Terminal 4 (Harbor Area Lease 22-074157; Figure 3.8). The Ediz Hook lease area is used for the aquatic storage of logs and is approximately 28 acres in size. At this location, rafts are formed and towed to Puget Sound mills. The Terminal 4 lease area is the site of the Port Terminal 4 dock and is used by Port tenants for handling seafood and to support launch and freight services.

McKinley Paper Company also currently leases three aquatic parcels from DNR near the west end of Ediz Hook. Other larger aquatic parcels within the Harbor currently are being leased by Foss Maritime Company (along Ediz Hook), Cooke Aquaculture Pacific LLC[6] (along Ediz Hook), and ITT Rayonier. The remaining aquatic parcels being let by DNR are relatively small and leased by a number of entities including the City (for the City Pier and WWTP outfalls outside of the WPAH Study Area).

3.4.4.2 Port Management Agreement Areas and In-Water Log Handling Activities

The Port manages sub-tidal areas within the Harbor under a PMA with DNR. Operations within each PMA area must serve the public benefit and activities must be conducted in a manner that will comply with applicable laws and regulations, among other requirements. Several of the PMA areas are currently used to store, raft, or move logs. Although greatly reduced from historical levels, log handling and rafting are still economically important for the Port. The Port operates and maintains its PMA areas under best management practices (BMPs) for log storage, including loading logs into the water in such a way as to minimize abrasion of bark from the surface of logs, and cleanup and upland disposal of any debris that accumulates. Current log rafting areas are shown on Figure 3.9.

Activities at each of the PMA areas that are operated by the Port are described in the following paragraph. The PMA areas in the Harbor are used to both move and raft logs, and include multiple parcels. These parcels are referred to as PMA Parcels 1, 2, 3, and 4. Parcel 1 is located off of the Port's Terminal 5, which is used for log staging. Log trucks deliver logs to the Port's facility where metal bands are placed around the load to create a log bundle. The Port uses a transitional ramp and LeTourneau log stackers to place log bundles in the water and to transport logs for rafting or booming. Log rafting areas are located in PMA Parcel 2, which is located east of PMA Parcel 1. Log rafts are typically towed directly from the rafting areas to destinations in Puget Sound. Imported logs are transported to the Port via drop ramp barges and are offloaded at

6 In December 2017, DNR terminated the lease for Cooke Aquaculture Pacific LLC. Shutdown and removal of the Port Angeles facility is required.

PMA Parcel 1. PMA Parcel 3 covers the Port's Terminal 2. Terminal 2 consists of fill material and a pier used by Port tenant Black Ball Ferry Line for the operation of a ferry terminal.

3.4.5 Current Shoreline Facilities

3.4.5.1 City of Port Angeles

Properties owned by the City primarily include park land, riparian corridors, properties containing utility infrastructure, right-of-way properties, and the City Pier. The City Pier (Figure 3.9) is used for seasonal temporary mooring of USCG vessels, cruise ships, vessels moored for festival purposes, and recreational watercraft. The eastern side of the pier contains steel piles to support floating docks for seasonal mooring of transient vessels (i.e., vessels can be docked to allow boaters access to downtown). The City also owns eight lease lots on Ediz Hook, including a portion of the McKinley Paper Company property at the base of Ediz Hook. Historically, the City has not operated on these lots, but has leased them to industrial and recreational tenants (e.g., Crown Zellerbach, Foss Tug and Launch, Icicle Seafood, and Port Angeles Boat Club).

3.4.5.2 McKinley Paper Company

The McKinley Paper Company is located at the former NPIUSA paper mill facility and property at the base of Ediz Hook. It purchased the facility and property from NPIUSA in March of 2017.

3.4.5.3 Port Terminals

The Port currently owns seven marine terminals with a range of Port operations and tenants. The Port operations or current tenant operations are described in detail in Table 3.2 and are presented on Figure 3.9. Generally, these uses include yacht repair and fabrication, cargo berth, lay berths, log storage, boat moorage, and boat repair.

3.4.5.4 U.S. Coast Guard, Piloting Operations, and Marine Transport

The USCG began operations at the tip of Ediz Hook in 1862 and this area was declared a Federal Lighthouse Reservation in 1863. In 1935, the USCG Air Station on Ediz Hook was commissioned. The Air Station supports both helicopters and patrol boats.

The USCG's Vessel Traffic Center, located in Seattle, directs numerous vessels traveling through the Strait of Juan de Fuca seeking temporary anchor in the Harbor. There are six non-designated federal anchorages maintained by the USCG within the Harbor in support of vessels of up to 1,100 feet in length. At anchorage points 1 to 5, vessels may stay for up to 10 days. Anchorage point 6 allows a 1-day stay for inspection or other emergent needs during good weather. The Puget Sound Pilots are responsible for piloting the vessels in the Strait of Juan de Fuca and bringing them into anchor in the Harbor. Puget Sound Pilots are specially trained ship captains who board oil tankers, cargo vessels, and cruise ships to guide them safely through Puget Sound waters.

3.4.5.5 Shoreline MTCA Cleanup Sites

Two areas formerly comprised the MTA as part of a 2005 AO (AO No. DE 03TCPSR-5738) between Ecology, the Port, and Chevron USA, Inc., including:

1. The MTA, a portion of the Port property east of Tumwater Creek, where mostly marine-related trades, such as boat building or repair, currently occur (i.e., Westport and Platypus Marine, as mentioned in Table 3.2).
2. The former K Ply plywood mill (the AO was amended in 2012 to exclude the K Ply Site).

Marine Trades Area

The MTA Site is primarily of environmental concern due to legacy contamination from the large number of bulk fuel facilities with numerous pipelines and fuel storage tanks that historically occupied this area. Historical facility operations resulted in groundwater and soil hydrocarbon contamination, including light non-aqueous phase liquid (LNAPL). A total of eight bulk fuel plants operated in the general area between the 1940s and the late 1980s. The western portion of the MTA Site was formerly known as the Port of Port Angeles Log Sort Yard and was the subject of a now-closed 1994 AO with Ecology. The final RI/FS for the MTA Site was approved in August 2013 and the draft Cleanup Action Plan (CAP) was submitted to Ecology in October 2014. The final CAP is currently being developed. The location of the MTA Site is presented on Figure 3.4.

K Ply Mill

The K Ply Site was formerly part of the MTA under AO No. DE 03TCPSR-5738. However, a 2012 amendment to the AO excluded K Ply because the source and extent of the contamination at the K Ply Site was determined to be distinct from the contamination at the MTA Site. The K Ply Site was split off from the MTA AO so its cleanup could proceed independently under a separate AO (No. DE 11302).

The former K Ply mill produced plywood (location presented on Figure 3.4). Various companies operated the plywood mill between 1941 and 2011, including: PenPly; ITT Rayonier; K Ply; and Peninsula Plywood Co. Environmental contamination under the mill was first documented in the late 1980s and primarily consisted of groundwater and soil hydrocarbon contamination, including LNAPL. In 1990, a partial remedial action was conducted to recover spilled hydraulic oil and excavate pentachlorophenol-contaminated soil from beneath the facility. K Ply was permanently closed in 2011 and the former mill has recently been demolished by the Port as required under the AO to enable the Port to more effectively investigate and remediate site contamination. In the 2015 RI/FS, the Port documented impacts from residual hydraulic oil and releases from a gasoline pipeline operated by General Petroleum Corporation. In 2016, the Port remediated the K Ply Site by removing 54,000 tons of contaminated soil from the site.

Section 3.0:
Historical and Current Uses of the Harbor

Tables

Table 3.1
Port Angeles Harbor Development History

Year	Facility Present/Event	Reference
1888	First timber mill in Port Angeles opens at mouth of Ennis Creek	Paul Sadin and Dawn Vogel, *An Interpretive History of the Elwha River Valley and the Legacy of Hydropower on Washington's Olympic Peninsula* (Sadin and Vogel 2011)
1890	City of Port Angeles named as seat of government for Clallam County	Sadin and Vogel (2011)
1892	Port Angeles Packing Company, Cannery	Sadin and Vogel (2011)
1911	The Geist Thompson Co., Shingle, Saw, and Planing Mill later known as ("lka") Washington Mills Co., Mill later abandoned ("Abandoned Shingle Mill") and subsequently known post-abandonment as Foreman Mill Co., Shingle Mill and Crescent Logging Co., Shingle Mill	1911 Certified Sanborn Map (Environmental Data Resources 2012)
1914	Puget Sound Mill & Timber Co., Saw, Shingle, and Planing Mills ("The Big Mill") lka Charles Nelson Co., Saw and Planing Mills	1917 Certified Sanborn Map (Environmental Data Resources 2012)
1917	Anacortes Fish Packing Co. Cannery	1917 Certified Sanborn Map (Environmental Data Resources 2012)
1917	Standard Oil Co.	1917 Certified Sanborn Map (Environmental Data Resources 2012)
1917	People's Wharf Company	1917 Certified Sanborn Map (Environmental Data Resources 2012)
1919	The Parrafine Companies, Inc. d/b/a Crescent Boxboard Co., Paper and Boxboard Mill, lka Fibreboard Paper Products Corporation	1924 Certified Sanborn Map (Environmental Data Resources 2012); *Lehman Brothers Collection — Contemporary Business Archives* (Harvard Business School 2018)
1920s	Log yard operations begin in Port of Port Angeles Log Yard	*Historical Environmental Summary Report, Port of Port Angeles Marine Terminal Log Yard* (Shannon & Wilson 1993)
1920	Washington Pulp and Paper Corporation, lka Crown Zellerbach Corporation, begins pulp and paper mill operations	1924 Certified Sanborn Map (Environmental Data Resources 2012); *Making Pulp and Paper* (Crown Zellerbach 1968)
1923	Port of Port Angeles established	Port of Port Angeles website (online)
1924	Angeles Gravel and Supply Co.	1924 Certified Sanborn Map (Environmental Data Resources 2012)
1924	Port Angeles Cooperage Company lka Western Cooperage Co. and Port Angeles Shingle Co.	1924 Certified Sanborn Map (Environmental Data Resources 2012)
1924	Olympic Lumber Co. Saw Mill; P.A. Shingle, Inc.	1924 Certified Sanborn Map (Environmental Data Resources 2012)
1929	Olympic Forest Products Co. lka Rayonier, Inc./ITT Rayonier	*Port Angeles ¾ Thumbnail History* (Oldham 2007)
1930	Shell Oil Co.	1930 Certified Sanborn Map (Environmental Data Resources 2012)
1930	Associated Oil Co.	1930 Certified Sanborn Map (Environmental Data Resources 2012)
1930	Richfield Oil Co.	1930 Certified Sanborn Map (Environmental Data Resources 2012)
1930	Port of Port Angeles Municipal Wharf	1930 Certified Sanborn Map (Environmental Data Resources 2012)
1930	Port Angeles Western R.R. Co. Engine and Car Shops	1930 Certified Sanborn Map (Environmental Data Resources 2012)
1927	Crescent Boxboard, Co. becomes Fibreboard Products, Inc.	Martin, Port Angeles Washington: A History (1983)
1935	U.S. Coast Guard Air Station	*Port Angeles Harbor Sediment Characterization Study* (Ecology 2012)
1940	Charles Nelson Co. Mill destroyed by fire	Port Angeles Evening News (January 22, 1940)
1941	Peninsula Plywood Co.	Marine Trades Area Site Port Angeles, Washington Remedial Investigation/Feasibility Study (Floyd|Snider 2013)
1942	Olympic Shipbuilders Inc., barge construction	*Lockwood's Directory of the Paper and Allied Trades* (Lockwood 1943)
1946	Construction begins on Port Angeles Boat Haven	*Conquering the Last Frontier* (Aldwell 1950)
1949	General Petroleum Corp.	1949 Certified Sanborn Map (Environmental Data Resources 2012)
1949	Natural Gas Washington	1949 Certified Sanborn Map (Environmental Data Resources 2012)
1949	The Texas Co.	1949 Certified Sanborn Map (Environmental Data Resources 2012)
1949	Union Oil Co.	1949 Certified Sanborn Map (Environmental Data Resources 2012)
1949	Port Angeles Forest Products, Inc.	1949 Certified Sanborn Map (Environmental Data Resources 2012)

Table 3.1
Port Angeles Harbor Development History

Year	Facility Present/Event	Reference
1952	Port Angeles Shingle Co., is now Standard Shingle Co.	1952 Certified Sanborn Map (Environmental Data Resources 2012)
1958	Merrill & Ring Timber, Inc. (Merrill & Ring) purchases Western Lumber Co. sawmill	Peninsula Daily News (Ollikainen 2011)
1964	Fish Packing and Cold Storage	1964 Certified Sanborn Map (Environmental Data Resources 2012)
1964	Associated Oil Co., is now Tidewater Associated Oil Co.	1964 Certified Sanborn Map (Environmental Data Resources 2012)
1970	Fibreboard Paper Products Corporation Mill closes and mill dismantled, property purchased by Merrill & Ring in 1972	Memorandum re: Investigation of Reported Marine Invertebrate Kill at Old Fiberboard Dock, Port Angeles, Washington (Ecology 1973)
1980s	Majority of bulk fuel operations terminated	*Marine Trades Area Site Port Angeles, Washington Remedial Investigation/Feasibility Study* (Floyd|Snider 2013)
1988	Daishowa America Co., Ltd. buys Crown Zellerbach Corporation Mill (owned in 1988 by James River Corporation of Nevada) and it later becomes Nippon Paper Industries USA Co., Ltd. (NPIUSA)	*Sampling and Analysis Report Sediment Grab Sampling and Log Density Survey; Nippon Paper Industries USA Pulp and Paper Mill Port Angeles Facility (Anchor 2005)*
1989	Peninsula Plywood Co., is now K Ply	*Marine Trades Area Site Port Angeles, Washington Remedial Investigation/Feasibility Study* (Floyd|Snider 2013)
1997	ITT Rayonier Mill ceases production	*Current Situation/Site Conceptual Site Model Report, Rayonier Port Angeles Mill Site* (Malcolm Pirnie 2007a)
2003	Graving dock construction begins; Tse-whit-zen, an important Klallam village site, is discovered during construction, and therefore construction is ceased in 2004	Settlement Agreement, State of Washington, Lower Elwha Klallam Tribe, City of Port Angeles, Port of Port Angeles, August 14, 2006
2008	K Ply ceases plywood and veneer manufacturing operations	*Marine Trades Area Site Port Angeles, Washington Remedial Investigation/Feasibility Study* (Floyd|Snider 2013)
2010	K Ply operations restart under new management, Peninsula Plywood Group, LLC (PenPly)	*Marine Trades Area Site Port Angeles, Washington Remedial Investigation/Feasibility Study* (Floyd|Snider 2013)
2011	PenPly ceases operations	*Marine Trades Area Site Port Angeles, Washington Remedial Investigation/Feasibility Study* (Floyd|Snider 2013)
2017	McKinley Paper Company purchases NPIUSA Mill	Clallam County Assessor Records (Olympic Peninsula Title Company 2017)

Table 3.2
Summary of Port of Port Angeles Current Terminal Operations

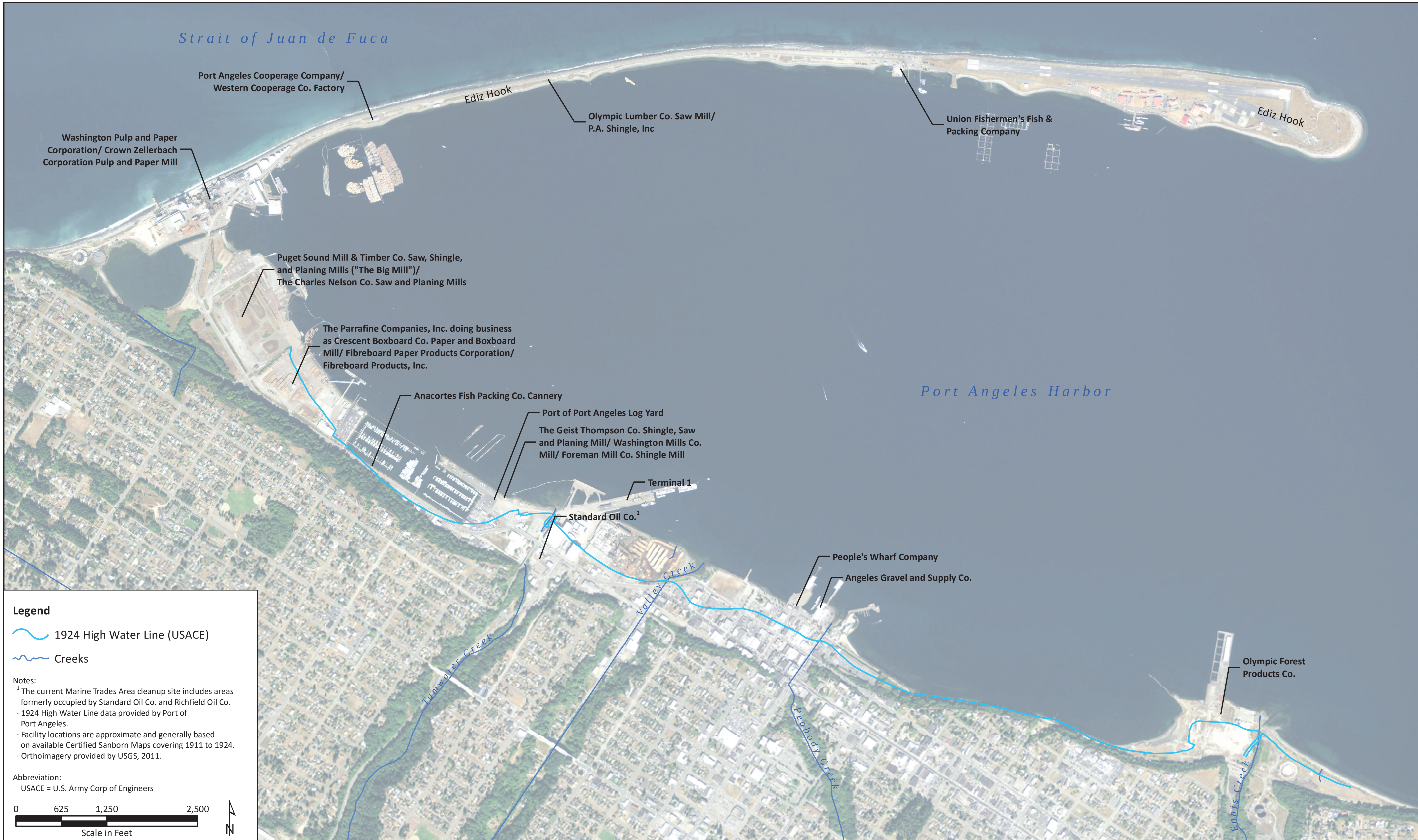
Marine Terminal	Current Tenants or Port Operation	Nature of Operations	Overwater Operations
1	Finger Pier and South Berth—Marine Spill Response Corporation	Lay berth	• Lay berth of two barges and two vessels for oil spill response.
	North Berth—Topside repair companies utilize terminal for ship repair	Lay berth	• Topside repair of vessels ~130 days/year (primarily Trans-Alaska Pipeline tank vessel fleet, Articulated Tug Barges and barges. ~120 days/year other vessel repair. Vacant between repair or lay berth days. • Some outside hull work (e.g., U.S. Coast Guard inspection of screws) but no paint removal or scraping. • Transfer of slops (sewage, grey water, oil storage tank cleaning waste). No spills or releases to date. • Internal repair conducted (e.g., welding, painting, etc.).
	Westport Shipyard (not a Port tenant, Westport owns land)	Yacht fabrication	• Westport utilizes the Port of Port Angeles' (Port's) travel lift pier on the south side of Terminal 1.
	Platypus Marine (leases uplands)	Yacht repair and fabrication	• Platypus Marine utilizes the Port's travel lift pier on the south side of Terminal 1.
2	Black Ball Ferry Line	Ferry terminal	• Terminal building, vehicle staging. Operates MV Coho Ferry that runs between Port Angeles and Victoria, British Columbia.
3	Cargo (logs), Lay Berth, and Topside Repair	Cargo berth	• Terminal 3 is currently used for the dockside and water loading of export logs ~85 days/year. • Dockside loading—trucks drive onto terminal, loader transfers logs to bunks (racks), then to logship. Waterside loading—logs transferred to the water at Terminals 5 or 7 and round boomed to Terminal 3 waterside.

Table 3.2
Summary of Port of Port Angeles Current Terminal Operations

Marine Terminal	Current Tenants or Port Operation	Nature of Operations	Overwater Operations
4	Arrow Marine Services & High Tides Seafoods	Cargo berth	• Supports marine logistic/freight services and commercial fishing cargo movement.
5	Port Log Yard	Log storage, land/water log transfer via ramp and easy letdown	• Land/water log transfer via ramp and easy letdown. Terminal 5 pier structure not utilized at this time.
6	Port Log Yard	Log storage (upland)	• Terminal 6 pier structure not utilized at this time.
7	Port Log Yard	Log storage, land/water log transfer via ramp and easy letdown	• Land/water log transfer via ramp and easy letdown—LeTourneau log stacker lowers logs into water without dropping. • Logs lowered both into and out of water. Logs from water go to sawmills. These logs are from Canada most frequently, and are still barked. Terminal 7 pier utilized as lay berth for oil response barges.
Port Angeles Boat Haven	Open public facility	Boat moorage	• Moorage for boats, 20 to 164 feet in length.
Port Angeles Boat Yard	Port and Port Agent Operated	Repair and maintenance of boats less than 65 feet	• 75-ton travel lift for transfer of boats to and from water.

Section 3.0:
Historical and Current Uses of the Harbor

Figures



WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.1
Historical Waterfront Operations Map
1910–1929

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WPAHG

Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.2
Historical Waterfront Operations Map
1930–1949

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Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.3
Historical Waterfront Operations Map
1950–1964

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Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.4
Shoreline Parcel Ownership and Current Facilites

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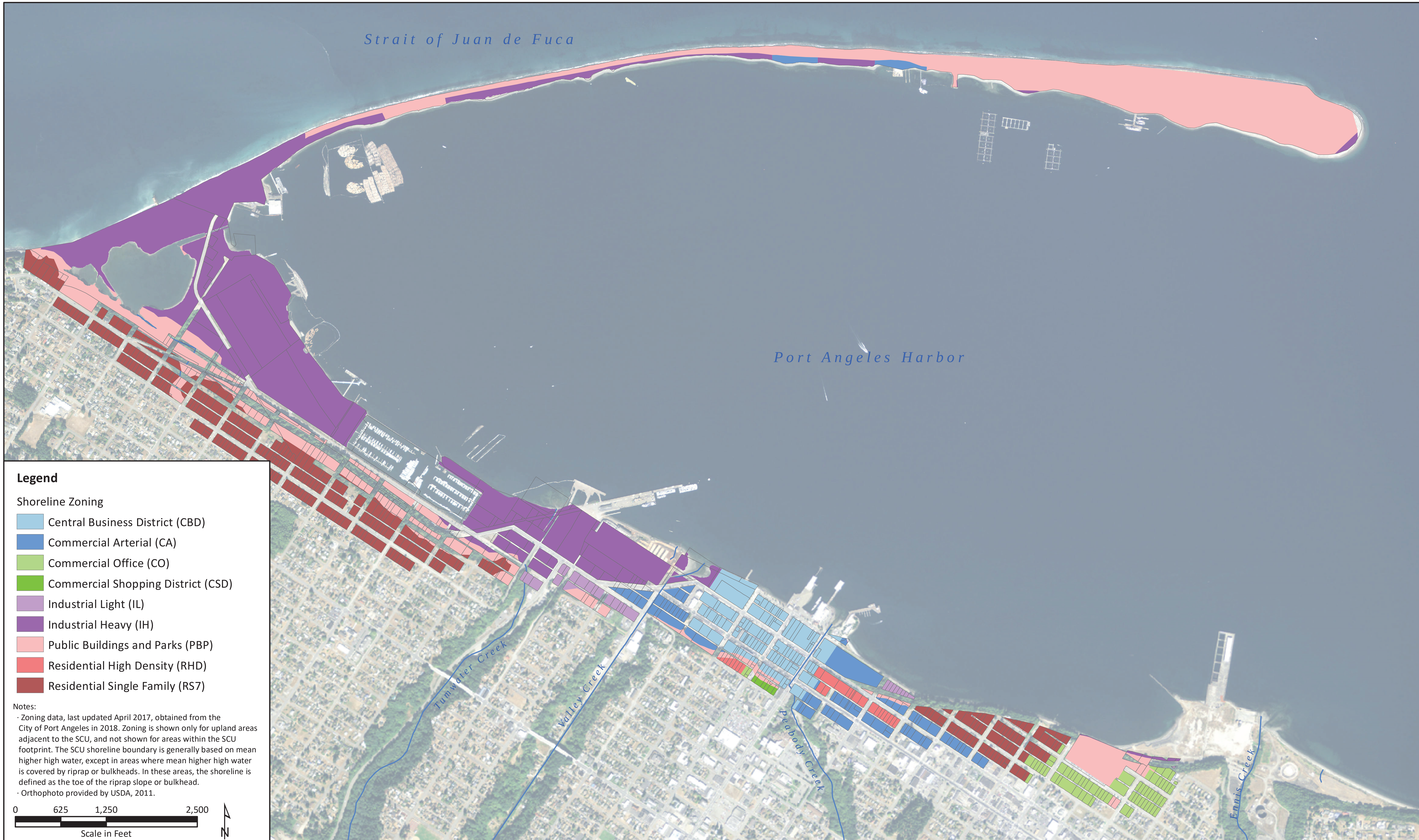
WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.5
Current and Historical Outfalls



WPAHG

Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.6
Shoreline Zoning

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WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.7
Port Angeles Shoreline Master Program
Environment Designations

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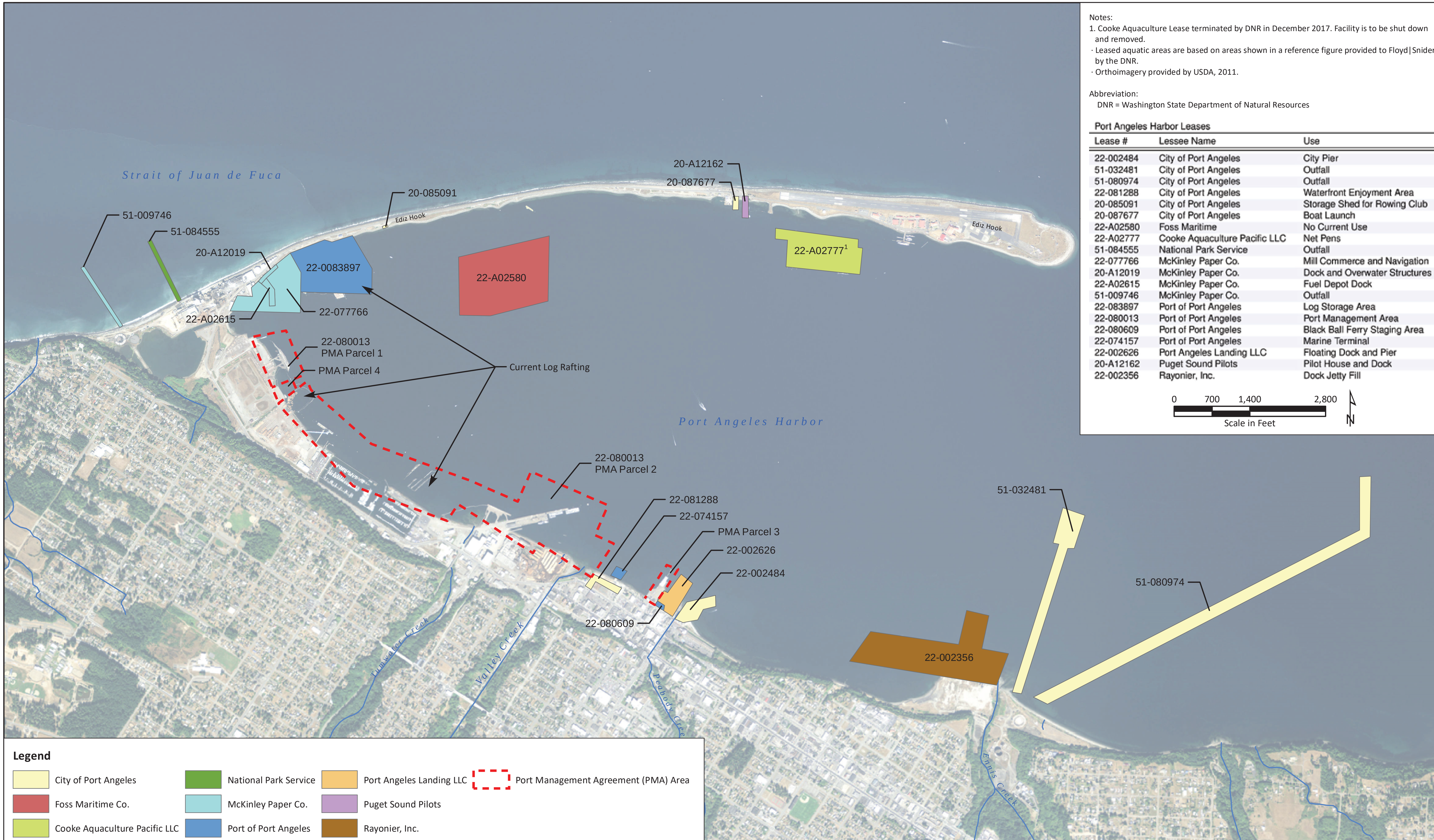

Notes:
1. Cooke Aquaculture Lease terminated by DNR in December 2017. Facility is to be shut down and removed.
· Leased aquatic areas are based on areas shown in a reference figure provided to Floyd|Snider by the DNR.
· Orthoimagery provided by USDA, 2011.

Abbreviation:
DNR = Washington State Department of Natural Resources

Port Angeles Harbor Leases

Lease #	Lessee Name	Use
22-002484	City of Port Angeles	City Pier
51-032481	City of Port Angeles	Outfall
51-080974	City of Port Angeles	Outfall
22-081288	City of Port Angeles	Waterfront Enjoyment Area
20-085091	City of Port Angeles	Storage Shed for Rowing Club
20-087677	City of Port Angeles	Boat Launch
22-A02580	Foss Maritime	No Current Use
22-A02777	Cooke Aquaculture Pacific LLC	Net Pens
51-084555	National Park Service	Outfall
22-077766	McKinley Paper Co.	Mill Commerce and Navigation
20-A12019	McKinley Paper Co.	Dock and Overwater Structures
22-A02615	McKinley Paper Co.	Fuel Depot Dock
51-009746	McKinley Paper Co.	Outfall
22-083897	Port of Port Angeles	Log Storage Area
22-080013	Port of Port Angeles	Port Management Area
22-080609	Port of Port Angeles	Black Ball Ferry Staging Area
22-074157	Port of Port Angeles	Marine Terminal
22-002626	Port Angeles Landing LLC	Floating Dock and Pier
20-A12162	Puget Sound Pilots	Pilot House and Dock
22-002356	Rayonier, Inc.	Dock Jetty Fill

0 700 1,400 2,800
Scale in Feet
N

Legend

City of Port Angeles
Foss Maritime Co.
Cooke Aquaculture Pacific LLC
National Park Service
McKinley Paper Co.
Port of Port Angeles
Port Angeles Landing LLC
Puget Sound Pilots
Rayonier, Inc.
Port Management Agreement (PMA) Area

WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.8
DNR Leased Aquatic Parcels and Port Management Areas

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10/29/2020

WPAHG
Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 3.9
Current Overwater Structures and Log Operation Areas

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10/29/2020

Section 4.0: Previous Environmental Investigations and Identification of Data Gaps

- The Harbor has been extensively sampled over the last 15 years, including a number of environmental investigations where sediment and/or tissue samples were collected. For this RI/FS, only historical data from 2002 to 2014 (when the last data were collected in the Harbor) have been used to help document the current environmental conditions in the Harbor.
- Based on data collected between 2002 and 2013, the Western Port Angeles Harbor Group (WPAH Group) identified data gaps and developed five Data Quality Objectives (DQOs) to guide additional data collection for the RI/FS. The DQOs included the following:
  1. Evaluate benthic conditions
  2. Evaluate risks to human health
  3. Evaluate risks to ecological receptors
  4. Evaluate ongoing sources of hazardous substances to sediments
  5. Prioritize sediment areas to address potential bioaccumulation exposures
- RI/FS sampling was conducted by the WPAH Group in 2013 and 2014 to meet these DQOs and to support development of this RI/FS.

4.0 Previous Environmental Investigations and Identification of Data Gaps

A number of environmental investigations in the Harbor have occurred to date, with the first investigations occurring in the early 1970s. Consistent with SMS guidance (Ecology 2017d) and consultations with Ecology, for this RI/FS, only historical data from 2002 to 2014 (when the last data were collected in the Harbor) are used to document current environmental conditions in the Harbor. This section briefly describes the various environmental investigations performed in the Harbor between 2002 and the 2013, excluding the RI/FS work completed in 2013 and 2014 by the WPAH Group, which is described separately in Section 5.0. The findings from these previous environmental investigations, as well as the recent RI/FS activities, are integrated and discussed in Section 7.0.

4.1 SUMMARY OF PREVIOUS ENVIRONMENTAL INVESTIGATIONS

This section summarizes the previous environmental investigations conducted in the Harbor between 2002 and the present, where sediment or tissue samples, or both, were collected and analyzed. The summaries in the following sections provide a brief description of each investigation's scope, objectives, and methods. Table 4.1 provides a list of these previous environmental investigations and a summary of the types of analyses performed during these investigations. Data collected during these previous environmental investigations have been incorporated into a project database for use in tables and figures and are presented in Appendix C.

The data from many of these previous environmental investigations are mapped and discussed in further detail in multiple documents (Ecology and Environment 2008, Ecology 2012, NewFields 2012). Surface sediment locations for previous environmental investigations are shown in Figure 4.1.

4.1.1 Former Rayonier Mill Site[7] Remedial Investigation for the Marine Environment

In 2002, sediment and tissue sampling was conducted throughout the Harbor, with the majority of the samples collected in the Rayonier Study Area, to support the preparation of the Remedial Investigation for the Marine Environment near the Former Rayonier Mill Site (Malcolm Pirnie 2007a). The 2002 sampling was performed to supplement previously collected sediment data near the former Rayonier Mill. A total of 54 surface sediment samples (0 to 10 cm) and 13 sediment cores were collected in the Rayonier Study Area (primarily surrounding the former Rayonier Mill's dock, log pond, and deep-water outfall), 8 surface sediment samples were collected farther out into the Harbor, and 3 reference surface sediment samples were collected in Sequim Bay. These sediment samples were generally analyzed for metals, semivolatile organic compounds (SVOCs), dioxins/furans, PCBs, pesticides, resin acids, fatty acids, guaiacols, and conventional parameters (sediment grain size, total organic carbon [TOC], ammonia, and

[7] The former Rayonier Mill Site is identified as the Rayonier Study Area in this document, as the Rayonier Mill Sediment Cleanup Unit has not yet been defined by Ecology.

sulfides). Sediment bioassays were also conducted at 15 of the surface sediment sampling locations in the Rayonier Study Area, based on where SMS benthic chemical criteria exceedances occurred, as well as at 3 reference sediment sampling locations in Sequim Bay. Bioassay testing included an acute 10-day amphipod test, an acute 48-hour bivalve larval test, and a chronic 20-day juvenile polychaete test. Additionally, tissue samples, including samples of coonstripe shrimp, Dungeness crab, geoduck clam, horse clam, rock sole, and starry flounder tissues, were collected from areas near the former mill, within the Harbor, and from regional background locations (Freshwater Bay and Dungeness Bay). The tissue samples were generally analyzed for metals, SVOCs, dioxins/furans, PCBs, and pesticides.

A second phase of sediment and tissue sampling was conducted in 2006, with the investigation described in the Phase 2 Addendum Remedial Investigation for the Marine Environment near the Former Rayonier Mill Site (Malcolm Pirnie 2007b). This second phase of the RI was performed to further characterize PCBs and dioxins/furans in surface sediment, as well as in horse clam and Dungeness crab tissues, in the Rayonier Study Area and farther into the Harbor. A total of 32 surface sediment samples (0 to 10 cm) were collected in the Rayonier Study Area (primarily surrounding the former Rayonier Mill's dock and log pond), 22 surface sediment samples were collected farther out into the Harbor, and 22 reference surface sediment samples were collected in Freshwater Bay and Dungeness Bay. Horse clam and Dungeness crab tissue samples were collected from the Rayonier Study Area as well as from reference locations (Freshwater Bay and Dungeness Bay). Geoduck tissue samples were also collected for analysis from Freshwater Bay. The surface sediment and tissue samples collected were generally analyzed for PCBs, dioxins/furans, and conventional parameters (sediment grain size, TOC, total solids, total volatile solids (TVS), and sulfides). Eleven sediment cores within Rayonier's log pond area were also collected as part of this second phase of sampling, but these cores were used for making physical observations and were not chemically analyzed.

4.1.2 Ecology's Port Angeles Harbor Sediment Investigation Study

The Harbor was identified by Ecology as a priority cleanup and restoration site under the Puget Sound Initiative based on the findings from previous environmental studies conducted on the Harbor. Using Puget Sound Initiative funding, Ecology and Environment, Inc., conducted a Harbor-wide sediment investigation study with the objective of characterizing the nature and distribution of chemical contamination and wood debris within the Harbor (Ecology 2012). Sediment and tissue samples were collected in 2008 within the Rayonier Study Area, to supplement previous sediment data collection efforts in this area, as well as in the WPAH Study Area. In the WPAH Study Area, a non-random sampling design was used with a tiered laboratory analysis scheme to characterize sediment conditions. The first tier of analyses included sediment toxicity tests, the analysis of sediment samples for chemicals with short laboratory holding times, and bioaccumulative compound analysis in marine tissue. With the exception of select stations where the full suite of chemicals was analyzed immediately, the remaining sediment samples were archived for potential additional analyses. The second tier of analyses involved further analytical testing of archived sediment samples that had bioassay toxicity test failures. Additionally, samples located near samples with bioassay toxicity test failures were examined to determine whether additional analyses should be conducted on these samples as well. Sediment sampling conducted in the Rayonier Study Area was designed to fill data gaps and more clearly define the horizontal and vertical distribution of contaminants and wood debris in this area of the Harbor.

Sediment sampling included the collection of 113 surface (0 to 10 cm) sediment grab samples and 45 subsurface sediment cores in the Harbor. Additionally, three surface sediment samples were collected from Dungeness Bay to use as reference samples. The sediment samples were generally analyzed for metals, SVOCs, dioxins/furans, PCBs, pesticides, resin acids and guaiacols, and conventional parameters (sediment grain size, TOC, total solids, ammonia, and sulfides). Bioassay tests were conducted on 55 of the surface sediment samples from the Harbor and 3 of the surface sediment samples from Dungeness Bay. These bioassay tests included an acute 10-day amphipod test, an acute 48-hour larval test, and a chronic 20-day juvenile polychaete test. Biota tissue samples were also collected in the Harbor for chemical analysis and included the collection of horse clams, geoducks, lingcod, eelgrass, and bull kelp. Horse clam and geoduck tissue samples were also collected from Dungeness Bay to use as background tissue concentrations. The tissue samples collected were generally analyzed for metals, SVOCs, dioxins/furans, PCBs, and pesticides.

To help understand the fate of chemicals within the Harbor, this sediment investigation also included an evaluation of currents and sediment transport within the Harbor, which is briefly described in Section 2.1. A Screening Level Human Health and Ecological Risk Assessment was also conducted in association with this sediment investigation study (Appendix G of Ecology 2012). Refer to Section 6.0 for a summary of this risk assessment.

4.1.3 NPIUSA Environmental Investigations Associated with Leased State Aquatic Lands

Two environmental investigations were previously conducted by NPIUSA, per DNR lease requirements, on state-owned aquatic lands leased by NPIUSA within the WPAH Study Area. In 2005, NPIUSA and Georgia-Pacific conducted surface sediment sampling and a survey to characterize the distribution and density of sunken logs/woody debris on state aquatic lands that NPIUSA previously leased from DNR (Anchor 2005). These former lease areas (Harbor Area Lease Nos. 22-002697 and 20-012614), covering approximately 85.7 acres, were located in the western portion of the Harbor along Ediz Hook. This sampling and survey work was performed by NPIUSA and Georgia-Pacific as part of NPIUSA's lease termination process. Four surface sediment samples (0 to 10 cm) were collected from the lease areas using a van Veen-type grab sampler. These samples were analyzed for selected metals and conventional parameters (TOC, total solids, TVS, and sulfides). The log/woody debris survey was performed using side scan sonar.

In 2008, an environmental baseline characterization investigation was conducted by NPIUSA on and in the vicinity of a new 18-acre lease area located immediately adjacent to their pulp and paper mill (Harbor Area Lease No. 22-077766; Exponent 2008). This baseline investigation included the characterization of sediments within and around this lease area as well as sediment within NPIUSA's on-site lagoon. Surface sediment samples (0 to 10 cm) were collected from nine sampling locations within the WPAH Study Area and six sampling locations within the lagoon using van Veen-type grab samplers. Four subsurface sediment cores were also collected within the WPAH Study Area (including one within the lagoon), using a vibracorer. Surface and subsurface sediment samples were generally analyzed for metals, SVOCs, dioxins/furans, PCBs, and conventional parameters (sediment grain size, TOC, total solids, and sulfides). The subsurface samples were also analyzed for Pb-210 and Cs-137 to provide data on sediment accumulation rates. In addition to the sediment sampling activities, a bathymetric survey and side-scan sonar survey were performed within the lease areas and the lagoon.

4.1.4 Sediment Monitoring Performed per NPDES Permit Requirements

The City and American Gold Seafoods LLC have been issued NPDES permits authorizing discharges within the Harbor that require these entities to conduct sediment monitoring to meet specific permit conditions. The sediment sampling events performed by these entities since 2002 in accordance with their NPDES permit requirements are briefly described in this section.

In accordance with the City's NPDES permit, the City conducted sediment monitoring in 2004 near their main WWTP outfall and their four CSO outfalls. The surface sediment samples (0 to 2 cm) collected near these outfalls were analyzed for metals, SVOCs, PCBs, and conventional parameters (sediment grain size, TOC, total solids, and sulfides). Bioassay testing was also performed in 2004 on the sediment samples collected near three of the CSO outfalls (CSO-7, CSO-8, and CSO-10; Herrera 2011c). NPDES-related sediment monitoring was also performed by the City in 2010 near two of their CSO outfalls (CSO-6 and CSO-7) at Ecology's request. For the 2010 monitoring, two surface sediment grab samples (0 to 10 cm) were collected near these CSO outfalls for chemistry and bioassay testing (Herrera 2011c). Additionally, in 2010 the City performed baseline sediment monitoring near the former Rayonier WWTP outfall. This sediment monitoring was required by DNR as a condition for the transfer of use of this outfall to the City and followed Ecology's sediment monitoring requirements (Herrera 2011d). Sediment monitoring near the former Rayonier WWTP outfall included the collection of six surface sediment samples (0 to 10 cm) for chemical analysis. Bioassay testing was also performed on one of these surface sediment samples. All the 2010 sediment samples were analyzed for metals, SVOCs, PCBs, and conventional parameters; however, the sediment samples collected near the former Rayonier WWTP outfall were also analyzed for dioxins/furans. Bioassay testing conducted on the two sediment samples collected near the City's CSOs and one of the samples near the former Rayonier WWTP outfall included an acute 10-day amphipod test, an acute 48-hour bivalve larval test, and a chronic 20-day juvenile polychaete test. A reference sediment sample from Sequim Bay was also included in the bioassay testing.

American Gold Seafoods LLC has conducted sediment sampling periodically near their Atlantic salmon net pen rearing areas within the Harbor in accordance with their NPDES permit. Sediment monitoring was performed at five sampling locations near their rearing areas in 2007 and 2010 to assess the concentrations of TOC, copper, and zinc in the surface sediments (0 to 2 cm). Up to five field replicates were collected at each of the sampling stations during these monitoring events. Surface sediment (0 to 2 cm) monitoring was also conducted in 2003 under prior ownership, by Cypress Island, Inc. Up to six field replicates were collected in September 2003 at each of the five sampling locations and analyzed for grain size (percent gravel and sand only), TOC, copper, and zinc.

4.1.5 K Ply Remedial Investigation/Feasibility Study

Three surface sediment grab samples were collected off shore of the K Ply Site (described in Section 3.4.5.5) in 2013, with results presented in the K Ply Site RI/FS (Floyd|Snider 2015). Surface samples were collected from the 0 to 10 cm interval and analyzed for metals, SVOCs, butyltins, gasoline- and oil-range hydrocarbons, PCBs, dioxins/furans, and conventional parameters (sediment grain size, TOC, total solids, moisture content, ammonia, and sulfides). Bioassay testing was performed on these surface sediment samples, including an acute 10-day amphipod test, an acute 48-hour bivalve larval test, and a chronic 20-day juvenile polychaete test. SPI monitoring was also conducted at the three locations to evaluate and delineate the extent of wood debris and provide information on benthic habitat quality.

4.2 WESTERN PORT ANGELES HARBOR GROUP DATA QUALITY OBJECTIVE PROCESS

As discussed in the previous section and shown in Table 4.1, the Harbor has been sampled extensively over the past 15 years. The available data from the previous environmental studies described above constitute the majority of the data needed for this RI/FS. However, a final defined RI/FS data collection effort was completed to fill several remaining RI/FS data gaps in the WPAH Study Area. To help guide the data collection and analysis to support development of the RI/FS and fill the remaining data gaps, the WPAH Group used the U.S. Environmental Protection Agency's (USEPA's) Guidance on Systematic Planning Using the Data Quality Objective Process (USEPA 2006). USEPA's DQO process is a tool used to determine the type, quantity, and quality of data to be collected and analyzed. It is a seven-step process that establishes performance and acceptance criteria to ensure that data collected support the goals of the RI/FS. The DQO process is shown graphically in Figure 4.2.

As described in USEPA's guidance, one of the primary benefits of using the DQO process is that it "helps to focus studies by encouraging data users to clarify vague objectives and document clearly how scientific theory motivating this project is applicable to the intended use of the data" (USEPA 2006). The process is also intended to lead "to efficient and effective expenditure of resources; consensus on the type, quality, and quantity of data needed to meet the project goal; and the full documentation of actions taken during the development of the project" (USEPA 2006).

4.3 RI/FS DATA QUALITY OBJECTIVES AND DESIGN RATIONALE

The results from the previous environmental investigations summarized in Section 4.1 were used by the WPAH Group, in consultation with Ecology, to identify the remaining RI/FS data gaps. The RI/FS activities needed to address these data gaps, including data collection, analysis, and evaluation, were then defined using the USEPA 2006 DQO process. The USEPA's DQO process is briefly described later in this section, and is explained more fully in the Work Plan (WPAH Group 2013). The specific DQOs that were identified to fill the remaining data gaps and complete the RI/FS are also described later in this section.

This section describes the specific remaining RI/FS data gaps that were identified and an overview of the focused RI/FS activities that were determined to be necessary to address them using USEPA's DQO process per the Work Plan (WPAH Group 2013). For further details on the RI/FS activities performed in 2013, refer to Section 5.0.

4.3.1 DQO 1: Evaluate Benthic Conditions

The evaluation of benthic conditions encompasses the presence of IHSs in surface sediments and the potential for associated biological impacts (i.e., whether concentrations of IHSs exceed SMS benthic criteria), as well as the potential for wood debris to influence benthic habitat quality. To address DQO 1, data from 2002 to present were reviewed and data gaps identified. The new RI data collected to address the identified data gaps for this DQO included:

- Bivalve larval bioassays conducted using the Ecology-accepted resuspension modified-endpoint protocol at stations west of the Rayonier Study Area where the echinoderm larval bioassay previously exceeded SCO chemical criteria (potentially false positive test results) during previous bioassay testing (Ecology 2012), described further in Section 5.1.2.
- Amphipod, larval, and polychaete bioassays at locations in the WPAH Study Area where one or more SCO or CSL chemical value was exceeded, between some stations where SCO chemical values were exceeded, or in specific areas lacking bioassay data.
- Porewater ammonia, porewater sulfides, and conventional parameter (sediment grain size, TOC, total solids, TVS, black carbon, and moisture content) analyses at all stations where bioassays are performed.
- SMS chemical analyses at bioassay stations where sediment chemical data are not already available.
- Limited SMS chemical analyses at stations where some sediment chemical data are available such that data will be available for all SMS chemicals.
- SPI/PV images at a subset of the stations sampled by Science Applications International Corporation in 1998 (SAIC 1999), at all stations sampled for bioassays, and at other representative locations to evaluate and delineate (to the extent practicable) wood debris deposits.

A decision tree to evaluate benthic conditions is presented in Figure 4.3.

4.3.2 DQO 2: Evaluate Risks to Human Health

A screening level human health assessment for the Harbor was completed by Ecology in 2012 (summarized in Section 6.0) to address potential risks to human health from exposure to bioaccumulative and SMS chemicals. Preliminary bioaccumulative IHSs and their respective SCOs have also been developed by Ecology (NewFields 2013, summarized in Section 6.0). The extent to which alternative cleanup remedies address unacceptable risks to human health and/or achieve background concentrations is used as a line-of-evidence in the evaluation of remedial alternatives in this RI/FS.

Because adequate data existed in the Harbor to evaluate the potential for unacceptable human health risks, no additional new data were collected by the WPAH Group to address this DQO. However, data describing background conditions were lacking. To address DQO 2, regional background data were collected by Ecology using the sampling approach described by NewFields (Ecology 2013b). As set forth by Ecology, regional background concentrations represent local concentrations that are influenced by broadly distributed non-point sources in the region such as atmospheric deposition or stormwater, but that are not attributable to a specific source or release (Ecology 2017d). The regional background concentrations for the bioaccumulative chemicals based on Ecology’s study were finalized in 2016 (Ecology 2016c).

4.3.3 DQO 3: Evaluate Risks to Ecological Receptors

A screening level ecological risk assessment for the Harbor was completed by Ecology in 2012 (summarized in Section 6.0) to address potential risks from exposure to bioaccumulative and other SMS chemicals of potential concern. Overall, the ecological risk assessment concluded that wood debris appeared to be the most significant stressor to ecological receptors in the Harbor. Based on the results of the ecological risk assessment, it was determined that additional lines-of-evidence related to ecological risk to be evaluated in the RI/FS would be limited to those described in DQO 1 (Section 4.3.1). Thus, new data collected to address DQO 1 were also used to address DQO 3.

4.3.4 DQO 4: Evaluate Ongoing Sources of Hazardous Substances to Sediments

DQO 4 focused on identifying ongoing sources that have the potential to result in sediment recontamination at levels greater than prospective sediment cleanup standards. To address this DQO, the WPAH Group evaluated spatial gradients of IHSs in surface sediments and conducted a shoreline survey to identify areas of interest relative to source control. This source evaluation is discussed in detail in Appendix E. Areas where surface sediments contain elevated concentrations may indicate an ongoing source. For these areas, potential sources to those areas (e.g., upland activities, overwater operations, upland soil/bank erosion, spills, stormwater, creeks, and NPDES-permitted outfalls) have been identified. Building on the Appendix E evaluation, Ecology will use state regulatory authorities (outside of the RI/FS AO) to follow up with the appropriate parties to control these sources. Recommended next steps and data gaps are identified in Appendix E.

4.3.5 DQO 5: Prioritize Sediment Areas to Address Potential Bioaccumulation Exposures

As discussed in DQO 2 (Section 4.3.2), the extent to which cleanup remedies address unacceptable risks to human health and/or achieve background concentrations is used as a line-of-evidence in the evaluation of remedial alternatives in the FS presented herein. Information on the bioavailability of IHSs that drive the risks to human health help focus the FS on high priority areas and contribute to the lines-of-evidence evaluation. To address DQO 5, additional data collected in the RI/FS field investigations included the following:

- Black carbon, an indicator of soot (additionally, black carbon was collected at all bioassay stations discussed in DQO 1).
- Tissue concentrations of PCB and dioxin congeners derived via laboratory bioaccumulation testing.
- PCB and dioxin/furan congener sediment data.
- Sediment grain size, total solids, TVS, and TOC.
- Porewater concentrations of PCB and dioxin congeners derived via SPME.

These data are used as lines-of-evidence in the evaluation of remedial alternatives in the FS presented herein.

Section 4.0:
Previous Environmental Investigations and Identification of Data Gaps

Table

Table 4.1
Previous Environmental Investigations in Port Angeles Harbor, 2002–2013

Study Name and Reference	Ecology EIM Study ID1	Year Sampled	Sample Type(s)	Sediment Collection Depths Described	Number of Sediment Samples Analyzed[2]	Sediment Analyte Groups					
						Metals	PCBs	Pesticides[3]	SVOCs	Dioxins/ Furans	Bioassay
Remedial Investigation for the Marine Environment near the Former Rayonier Mill Site (Malcolm Pirnie 2007a)	RAYONR05	2002	Sediment and Tissue	0–3.8 ft (variable)	104	X	X	X	X	X	X
Cypress Ediz Hook Smolt 2003 NPDES Monitoring (data reported to EIM only)	CIPA2003	2003	Sediment	0–2 cm	18	X					
City of Port Angeles 2004 NPDES Permit Sediment Characterization (Herrera 2011c)	PA_STP04	2004	Sediment	0–2 cm	13	X	X		X		X
Nippon Sampling and Analysis Report, Sediment Grab Sampling and Log Density Survey (Anchor 2005)	NIPPON PAPER MILL05	2005	Sediment	0–10 cm	4	X					
Phase 2 Addendum Remedial Investigation for the Marine Environment near the Former Rayonier Mill Site (Malcolm Pirnie 2007b)	PAMILLRI	2006	Sediment and Tissue	0–10 cm	76		X			X	
American Gold Seafoods 2007 NPDES Sampling at Puget Sound Salmon Net Pens (data reported to EIM only)	AGS_NPDES_2007	2007	Sediment	0–2 cm	9 (5 reps each)	X					
Port Angeles Harbor Sediment Characterization Study, Sediment Investigation Report (Ecology 2012)	PASED08	2008	Sediment and Tissue	0–302 cm (variable)	201	X	X	X	X	X	X
Nippon Environmental Baseline Investigation, DNR Lease 22-077766 (Exponent 2008)	PORT ANGELES DNR08	2008	Sediment	0–52 inches (variable)	43	X	X		X	X	
NPDES Sampling during 2010: American Gold Seafoods Net-Pen Sites in Puget Sound (data reported to EIM only)	AGS_NPDES_2010	2010	Sediment	0–2 cm	8 (2 to 5 reps each)	X					
City of Port Angeles 2010 NPDES Permit Sediment Baseline Monitoring (Herrera 2011c)	PA_STP10	2010	Sediment	0-–10 cm	2	X	X		X		X
City of Port Angeles Former Rayonier WWTP Outfall Sediment Baseline Monitoring (Herrera 2011d)	RAYSED09	2010	Sediment	0–10 cm	6	X	X		X	X	X
K Ply Site Remedial Investigation/Feasibility Study (Floyd|Snider 2015)	AODE9546	2013	Sediment	0–10 cm	3	X	X		X	X	X

Notes:

Blank cells indicate that sediment samples were not analyzed for that analyte group.

1 Source: Ecology EIM System database.

2 Sediment sample number reflects the number of sample IDs, and includes surface, subsurface, and reference samples as applicable; not all samples were analyzed for all analyte groups indicated.

3 Organochlorine pesticides.

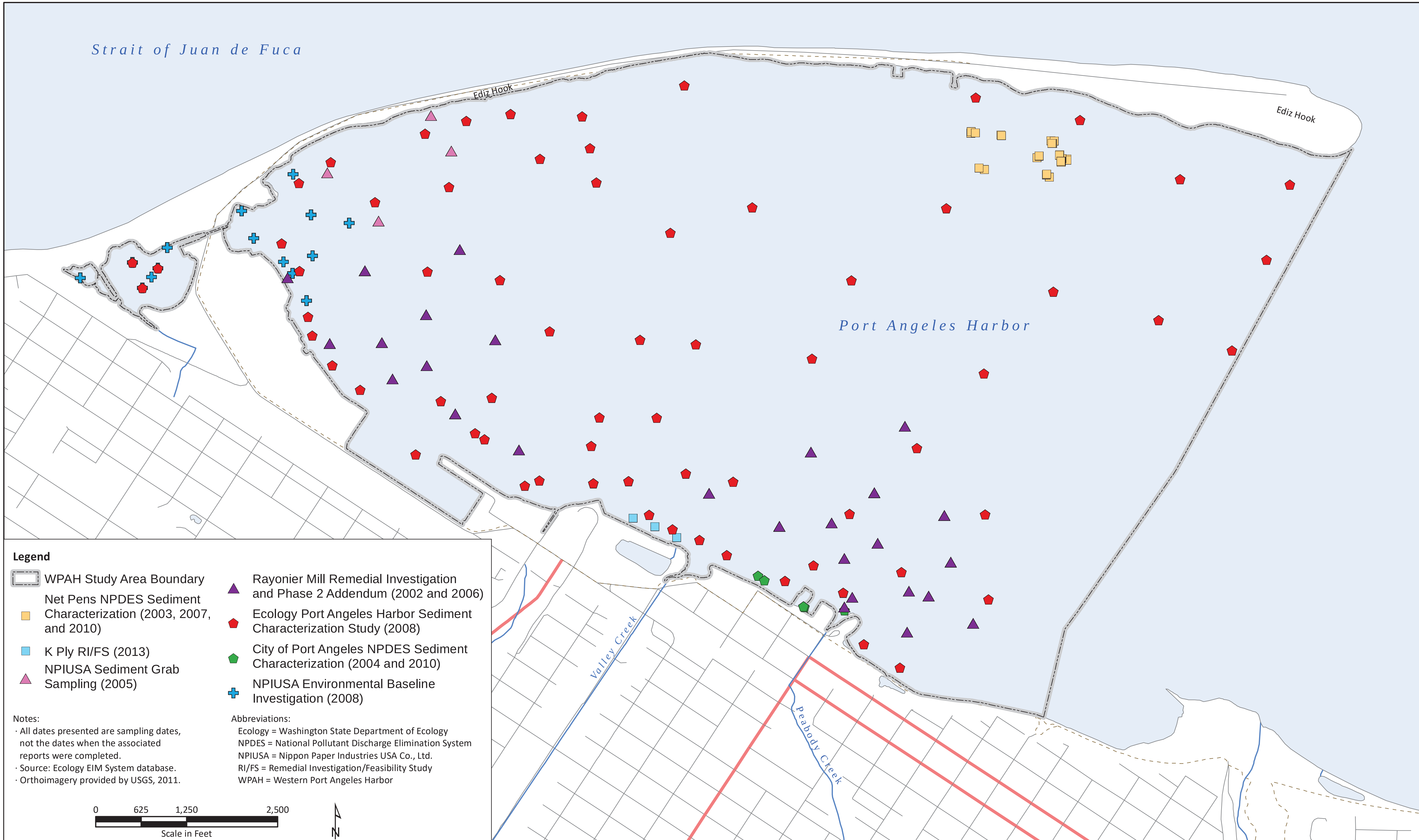
Abbreviations:

cm Centimeters
Ecology Washington State Department of Ecology
EIM Environmental Information Management
ft Feet
PCB Polychlorinated biphenyl
SVOC Semivolatile organic compound

–

Section 4.0:
Previous Environmental Investigations and Identification of Data Gaps

Figures



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Port Angeles, Washington

Figure 4.1
Surface Sediment Locations Sampled
For Previous Environmental Investigations

I:\GIS\Projects\WPAHG-RIFS\MXD\RIFS Final 2020\Figure 4.1 Surface Sediment Sample Locations from Previous Environmental Investigations.mxd
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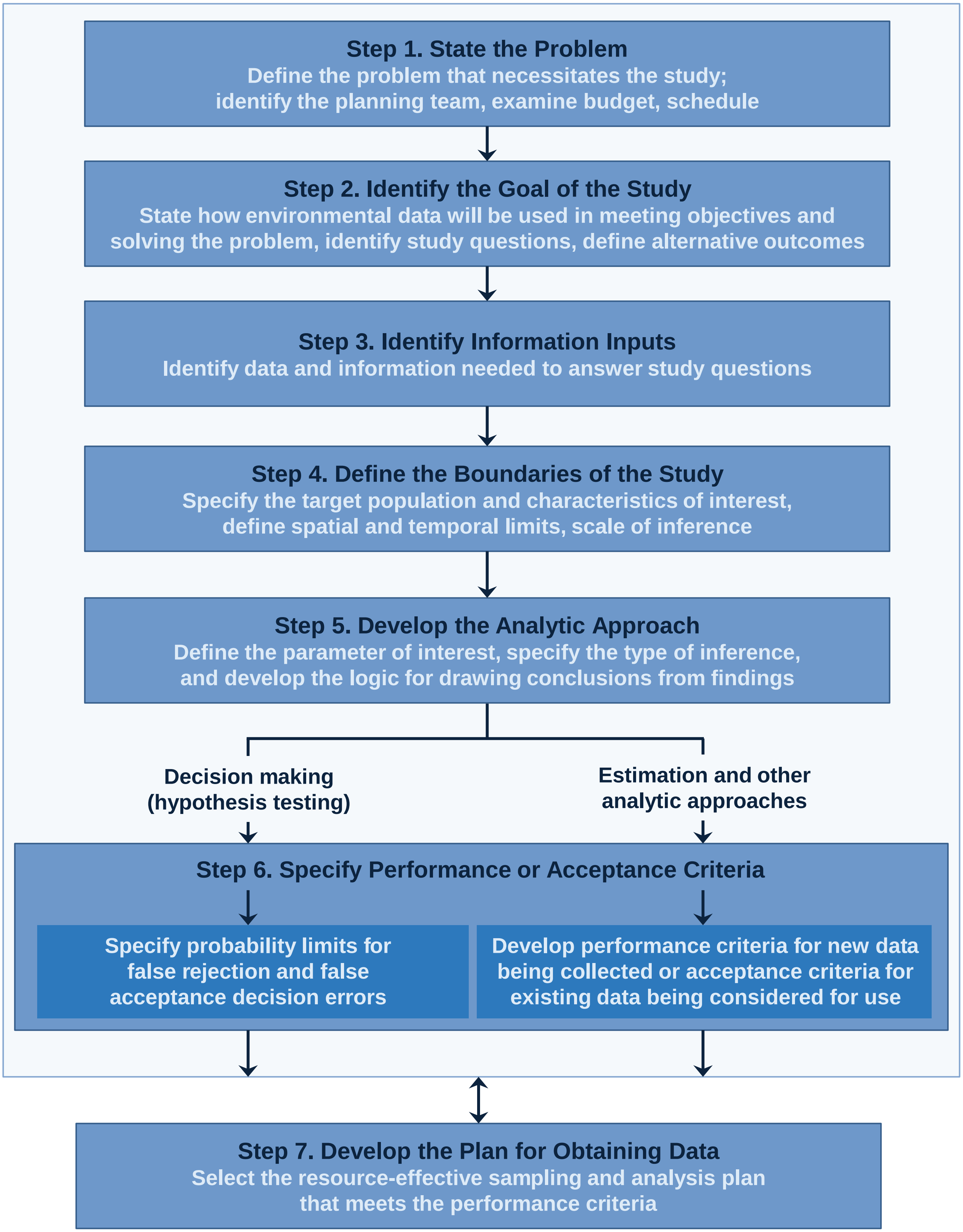

Source: USEPA 2006

WPAHG Western Port Angeles Harbor Group	**Western Port Angeles Harbor** **Sediment Cleanup Unit** **Remedial Investigation/Feasibility Study** **Port Angeles, Washington**	Figure 4.2 USEPA's (2006) Data Quality Objective Process

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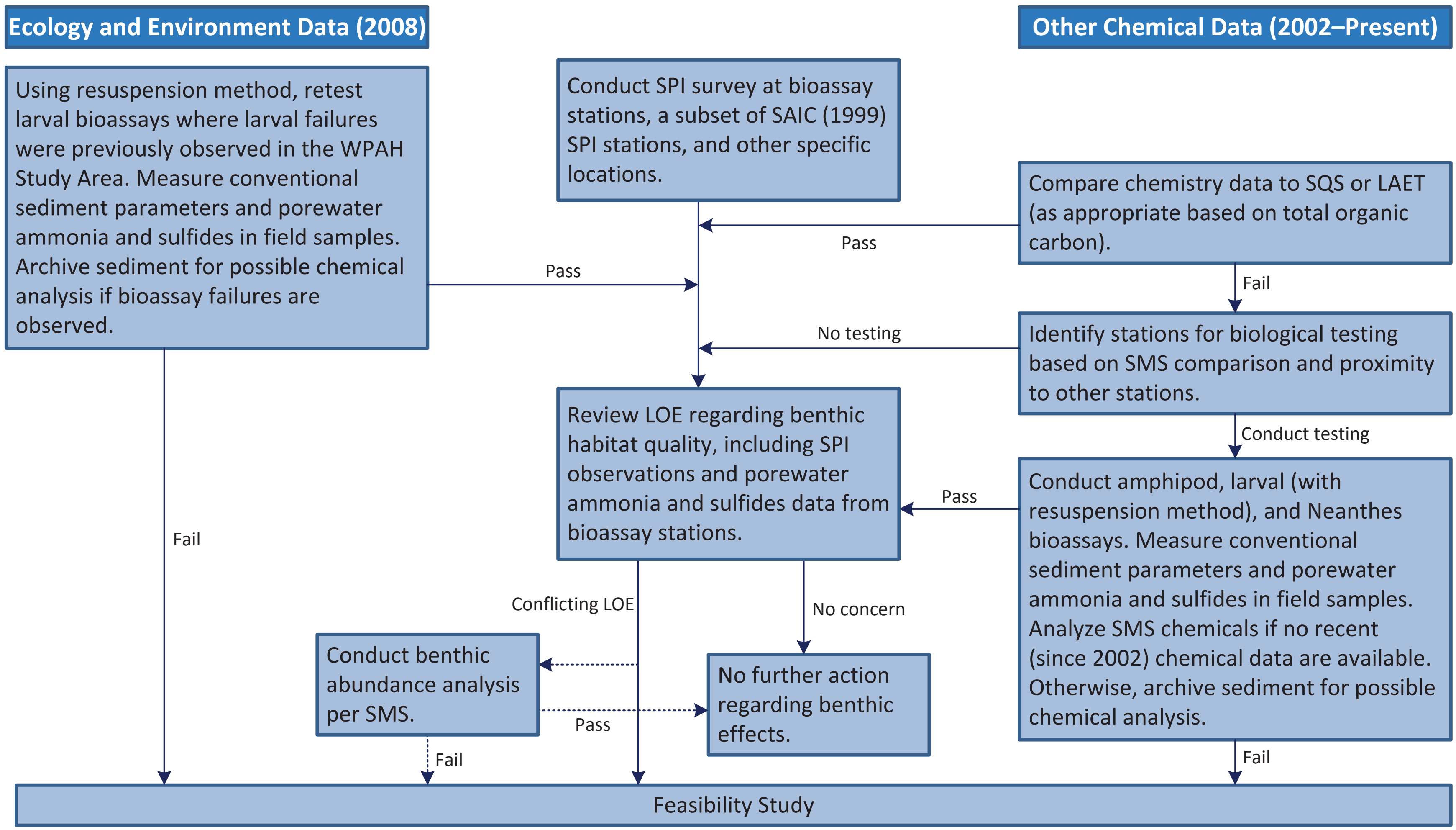
11/27/2017



Source: WPAH Group 2013

Note:

1. Dashed lines indicate options for consideration.

Abbreviations: LAET = Lowest Apparent Effects Threshold; LOE = Lines of evidence; SAIC = Science Applications International Corporation; SMS = Sediment Management Standards; SPI = Sediment Profile Imagery; SQS = Sediment quality standards; WPAH = Western Port Angeles Harbor

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Figure 4.3
Decision Tree for Benthic Conditions in Western Port Angeles Harbor

Section 5.0: Remedial Investigation/ Feasibility Study Activities

- The Western Port Angeles Harbor Group RI/FS sampling occurred in 2013 and 2014, and included the collection and analysis of field samples for the following:
    - Surface sediment chemistry
    - Subsurface sediment chemistry
    - Surface sediment bioassays (sediment toxicity)
    - Bioaccumulation testing (to evaluate the uptake of polychlorinated biphenyls [PCBs] and dioxins/furans into the tissue of benthic organisms)
    - Solid-Phase Microextraction Testing (to evaluate porewater concentrations of PCBs and dioxins/furans)
    - Sediment Profile Imagery and Plan View Survey (to map the distribution of wood debris and the quality of benthic habitat)
- The RI/FS data are used in conjunction with the historical data collected between 2002 and 2013 to evaluate the need and approach for cleanup actions in the Western Port Angeles Harbor Study Area.

5.0 Remedial Investigation/Feasibility Study Activities

The previous environmental investigations within the Harbor, described in Section 4.1, constitute the majority of the data used for this RI/FS. Remaining data gaps were identified early in the RI/FS process, as presented in Section 4.3. These data gaps were addressed by RI/FS field investigations conducted in the summer of 2013, which included surface sediment sampling for chemistry, bioassays, bioaccumulation, and microextraction testing, and a SPI/PV survey. The 2013 field investigations and testing were conducted in accordance with the Ecology-approved SAP (Integral et al. 2013). In 2014, a SAP Addendum was completed (Floyd|Snider et al. 2014) to describe supplemental RI/FS data collection that included the collection and analysis of subsurface sediment cores near Terminal 5 and Terminal 7.

The 2013 and 2014 field investigations and testing are summarized in this section. Detailed descriptions of the 2013 field program, analyses, and data are provided in the RI/FS Data Report for the 2013 Field Program (Integral et al. 2014). Detailed descriptions, analyses, and data for the 2014 supplemental field program are presented in Appendix D. A summary of the results from the 2013 and 2014 RI/FS field investigations, as well as the previous environmental investigations, is presented in Section 7.0.

5.1 SURFACE SEDIMENT SAMPLING AND LABORATORY TESTING IN 2013

Surface sediment grab samples (0 to 10 cm) were collected from 52 stations in the WPAH Study Area from June 25 through July 9, 2013. Samples were analyzed for sediment and porewater chemistry, sediment toxicity (bioassay testing), and/or bioaccumulation (bioaccumulation testing and SPME testing) depending on the sample location. Surface sediment grab samples were also collected from two stations at the bioassay reference area (Carr Inlet) on June 25, 2013. Actual station locations and the types of analyses conducted at each station in the WPAH Study Area are shown on Figure 5.1.

5.1.1 Chemistry

Conventional parameters, including sediment grain size, total solids, TVS, TOC, and black carbon, were analyzed in all of the sediment samples collected. Porewater ammonia and porewater sulfides were also analyzed at all bioassay stations. Metals, SVOCs, polycyclic aromatic hydrocarbons (PAHs), PCB congeners, and dioxin/furan congeners were analyzed in sediment collected from a subset (20) of the stations to fill in sediment chemistry data gaps from previous sampling events. Grain size, total solids, and TOC were analyzed in the two Carr Inlet bioassay reference samples. Analytical results are summarized in Section 7.0 and in the RI/FS Data Report (Integral et al. 2014).

5.1.2 Bioassays

Full suite bioassay testing included the 10-day amphipod test using *Eohaustorius estuarius,* the larval development bioassay with the resuspension protocol (Kendall et al. 2012) using the mussel *Mytilus galloprovincialis,* and the 20-day *Neanthes sp.* growth test. This full suite bioassay testing was conducted on sediments collected from 20 stations in the WPAH Study Area and at the 2 reference stations in Carr Inlet. The testing occurred at stations with previous chemical data that exceeded a SCO chemical criteria and in locations identified as lacking bioassay data. In addition, the larval bioassay test with the resuspension protocol was performed at an additional 27 stations within the WPAH Study Area that had previous larval bioassay testing.

As noted by Ecology in the Sediment Characterization Study, performance of the 2008 larval bioassay testing across the Harbor was highly inconsistent, with widespread failures in areas with an absence of SMS chemical exceedances and wood debris, as well as in samples collected from reference areas (Ecology 2012). Improved laboratory resuspension methods using bivalve larvae were subsequently developed and accepted for use in SMS and Dredged Material Management Program (DMMP) evaluations during the 2012 Sediment Management Annual Review Meeting that address the potential for entrainment of larvae by flocculent particulate material in tested sediments (Kendall et al. 2012). This potential laboratory artifact may have resulted in false positive echinoderm larval test results in previous samples collected from the WPAH Study Area. Stations previously sampled by Ecology in 2008 with possible false positive echinoderm larval test results were therefore retested in 2013 using the Ecology-accepted bivalve larvae resuspension method to provide more reliable confirmatory bioassay data for comparison with SMS biological criteria.

Sediment toxicity data were evaluated according to SMS (WAC 173-204 Table IV) to determine whether each sediment sample exceeded SMS criteria. Evaluation results are provided for each bioassay test in the RI/FS Data Report (Integral et al. 2014) and are summarized in Section 7.1.

5.1.3 Bioaccumulation Testing

Bioaccumulation testing was performed at 15 stations in the WPAH Study Area to evaluate the potential uptake of PCBs and dioxins/furans from the sediment samples into adult bivalve *(Macoma nasuta)* and adult polychaete *(Nephtys caecoides)* tissue over 45 days. The resulting tissue samples were analyzed for dioxin/furan and PCB congeners and for percent lipids. Bioaccumulation exposures were conducted a second time on sediments collected from two of the stations, WPAH050 and WPAH051, after activated carbon (AC) was mixed into the sediment at a concentration of approximately 4 percent by dry weight, 48 hours prior to organism exposure. The goal of this treatability testing was to evaluate whether AC affected the uptake of dioxin/furan and PCB congeners into the tissue. Tissue concentrations from the bioaccumulation tests and tissue concentrations following AC treatment are summarized in Section 7.4.1 and in the RI/FS Data Report (Integral et al. 2014).

5.1.4 Solid-Phase Microextraction Testing

SPME fibers were installed concurrently with the 45-day bioaccumulation testing to measure porewater concentrations of dioxins/furans and PCBs congeners. These data were then used to estimate porewater concentrations following the procedure described in the RI/FS Data Report

(Integral et al. 2014). Calculated porewater concentrations of dioxin/furan TEQ and total PCB congeners, including concentrations for the two samples where AC was mixed into the sediment, are summarized in Section 7.4.1 and in the RI/FS Data Report (Integral et al. 2014).

5.2 SEDIMENT PROFILE IMAGING AND PLAN VIEW SURVEY IN 2013

A SPI/PV survey was conducted in the WPAH Study Area from July 15 through 18, 2013. SPI is a photographic technique used to measure and infer physical, geochemical, and benthic ecological conditions in surface (0 to 20 cm) sediments (Germano et al. 2011). The primary objective of the 2013 SPI/PV survey was to map the distribution of wood debris and the associated benthic habitat quality throughout the WPAH Study Area (WPAH Group 2013). A similar SPI/PV survey of this area was conducted by Ecology in 1998 (SAIC 1999) and many of the stations occupied in 1998 were reoccupied in 2013, allowing for an evaluation of temporal changes.

In 2013, SPI/PV images (at least three replicate images per station) were collected at 97 stations in the WPAH Study Area. The 97 stations surveyed included the 92 proposed in the RI/FS SAP (Integral et al. 2013) plus 5 stations that were added as a result of a preliminary review of the images conducted with Ecology during the SPI/PV survey. Because the SAP specified analysis of images from a total of 92 stations only, images from 5 stations (WPAH029, WPAH040, WPAH041, WPAH044, and WPAH072) were not fully analyzed. These stations were selected by Integral and Ecology scientists based on a post-survey review of the preliminary SPI/PV results mapped during the preliminary image review.

The original 92 target stations consisted of those stations sampled for surface sediments in 2013 and many of the SPI stations originally surveyed in 1998 by SAIC (SAIC 1999). A map of the 2013 SPI/PV stations is provided in Figure 5.2 and tabulated station coordinates are included in the RI/FS Data Report (Integral et al. 2014). Results from the SPI/PV survey are further discussed in Section 7.0.

The following information was reported for each SPI image:

- Grain size major mode (i.e., distribution)
- aRPD
- Presence of wood debris
- Infaunal successional stage

Additional information tallied during the SPI/PV review included the presence of algae, methane gas bubbles, and bacterial mats.

PV images were reviewed for the presence of wood debris and epifauna.

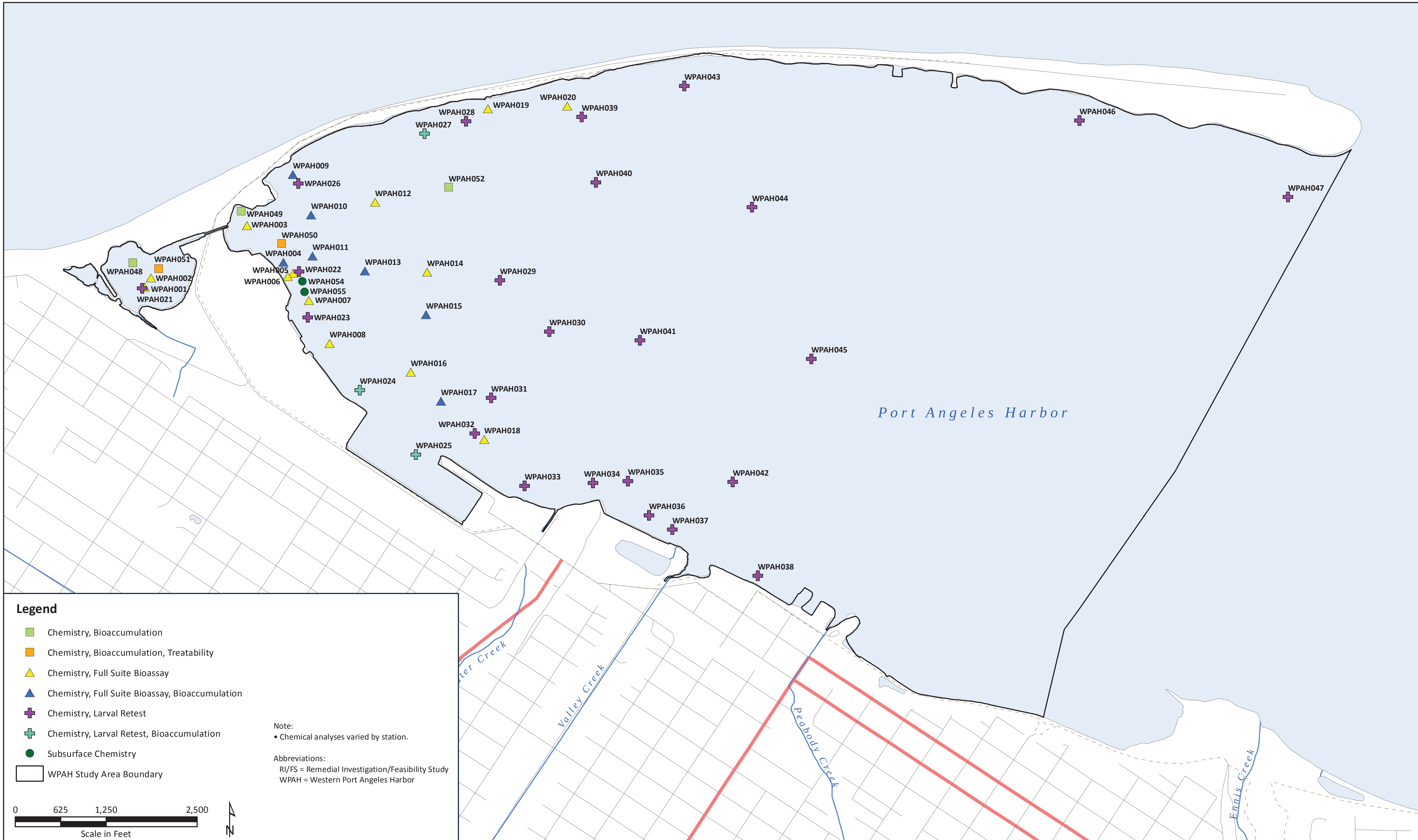
5.3 SUBSURFACE SEDIMENT SAMPLING AND LABORATORY TESTING IN 2014

Sediment cores were collected from eight stations in the WPAH Study Area on September 3 and September 4, 2014. A total of 10 samples were collected, with two of the samples and a sample duplicate analyzed for sediment chemistry only. The core locations are shown on Figure 5.1.

Conventional parameters (sediment grain size, total solids, moisture content, and TOC), metals, SVOCs, PAHs, PCB congeners, and dioxin/furan congeners were analyzed in the three sediment samples. Analytical results are summarized in Section 7.3.2 and in Appendix C.

Section 5.0:
Remedial Investigation/
Feasibility Study Activities

Figures



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Port Angeles, Washington

Figure 5.1
Sediment Locations Sampled during WPAH RI/FS Field Investigations

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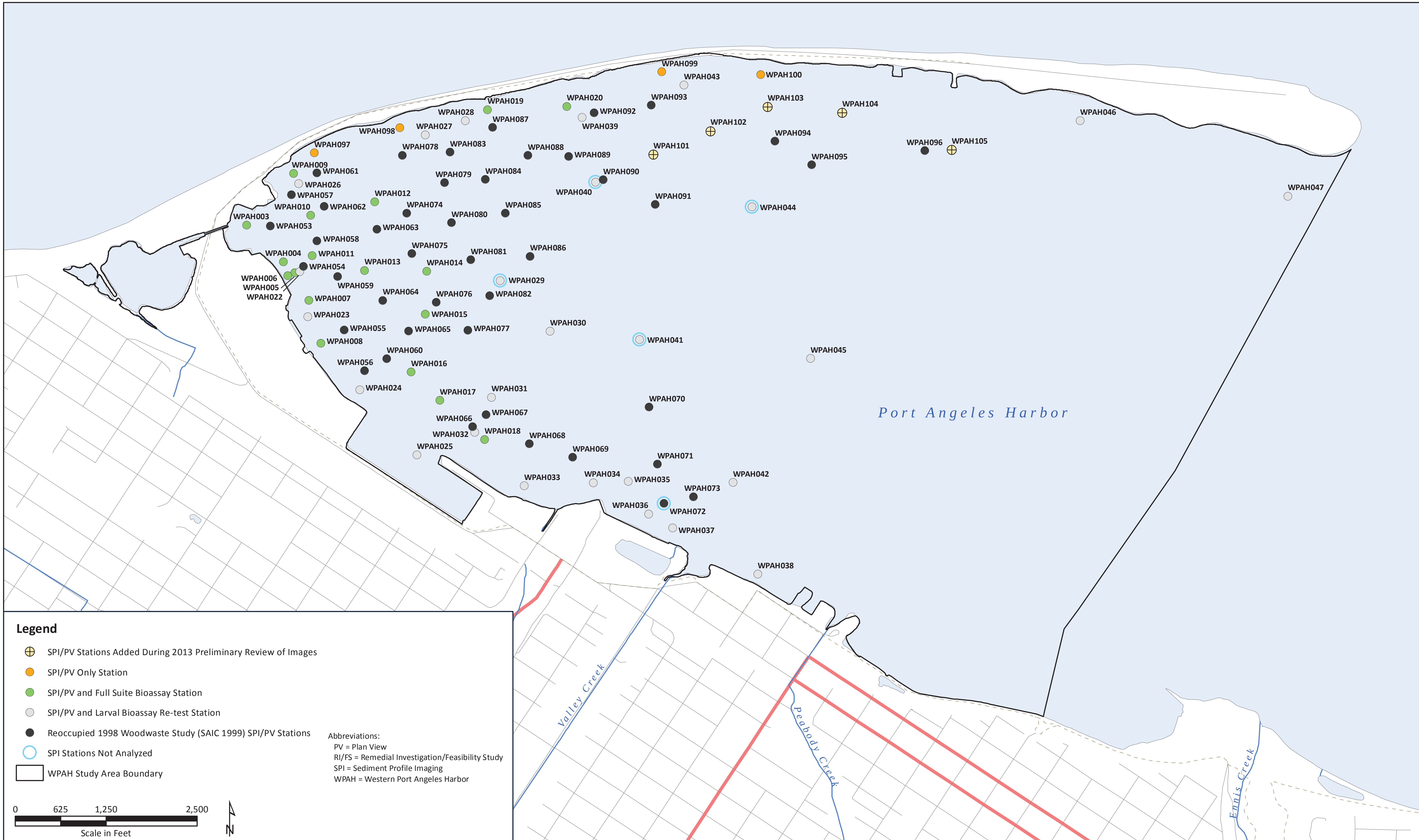

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Figure 5.2
SPI/PV Locations Occupied during WPAH RI/FS Field Investigations

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3/21/2018

Section 6.0: Development of Preliminary Indicator Hazardous Substances and Cleanup Criteria

- In 2012, Ecology published screening level human health and ecological risk assessments that evaluated Port Angeles Harbor-wide data collected through 2008. The risk assessments determined chemicals that may pose unacceptable human health and/or ecological risk. The chemicals identified by Ecology are referred to as preliminary indicator hazardous substances (IHSs) in this RI/FS.
  - For human health, potential risk posed by seafood consumption and direct contact with sediment was evaluated for subsistence fishers (the Lower Elwha Klallam Tribe), recreational fishers, residential users, and recreational users.
  - For ecological risk, potential risks posed to benthic invertebrates, marine plants and macroalgae, fish, and wildlife were evaluated.
- Dioxins/furans and polychlorinated biphenyls (PCBs) were both determined to pose a risk to human health. However, because dioxin/furan and PCB congeners used to calculate their respective toxic equivalents (TEQs) act through a common toxicological mechanism, Ecology determined that, for Port Angeles Harbor, dioxin/furan TEQ and PCB TEQ should be treated as a combined human health IHS: "Total TEQ."
- Once the preliminary IHSs were determined, corresponding Sediment Cleanup Objectives (SCOs) and Cleanup Screening Levels (CSLs) for these chemicals were derived in follow-up documents published on behalf of Ecology. Generally, the CSLs selected for the preliminary human health IHSs are based on regional background concentrations as presented in the *North Olympic Peninsula Regional Background Sediment Characterization, Data and Evaluation Report.*
- Ecology's preliminary IHSs and their SCOs and CSLs were carried forward to Section 7.0 to evaluate the nature and extent of contamination in the Western Port Angeles Harbor Study Area.

6.0 Development of Preliminary Indicator Hazardous Substances and Cleanup Criteria

This section describes Ecology's approach to development of preliminary human health and benthic IHSs and their associated SCOs and CSLs for the entire Harbor and the Rayonier Study Area. These IHSs, SCOs, and CSLs provide the basis for the final IHSs and SCLs identified in Section 8.0 and the rationales and derivations are described in detail here. It is important to note that Ecology's preliminary human health and benthic IHSs are based on the previous environmental data collected throughout the Harbor, including the Rayonier Study Area. Final IHSs are defined after additional IHS screening was performed incorporating newer data from the 2013 RI/FS sampling. Final IHSs are based on the WPAH Study Area data only.

6.1 DEVELOPMENT OF PRELIMINARY INDICATOR HAZARDOUS SUBSTANCES

Under MTCA, chemicals that pose a small percentage of the overall health risk to human and ecological receptors at a site may be eliminated from further consideration. Any remaining chemicals are identified as IHSs and are the focus of remedial actions at a site. The Ecology-led screening to determine preliminary IHSs in the Harbor was conducted in two steps:

- Chemicals of potential concern (COPCs) for both human health and ecological risk for the Harbor were identified in 2008 based on previously collected environmental data and historical and current activities and land uses within the Harbor (Ecology and Environment 2008).
- Following the initial screening process and identification of COPCs, screening level human health and ecological risk assessments were performed by Ecology (Appendix G to Ecology 2012) to select the list of preliminary IHSs for the Harbor that have the potential to pose unacceptable human health and/or ecological risk.

An overview of the outcomes of Ecology's human health and ecological risk assessments is presented in the following sections.

6.1.1 Screening Level Human Health Risk Assessment

Potential exposures to chemicals in fish and shellfish tissue and sediment were evaluated for subsistence fishers, recreational fishers, residential users, and recreational users. The exposures included both risk posed by seafood consumption and risk from direct contact with sediments (ingestion and dermal contact). The risk for consumption of seafood by subsistence fishers was based on the most highly exposed group, the LEKT.

Both reasonable maximum exposure (RME) and central tendency (CT) exposures were evaluated for the subsistence fisher and recreational fisher. The RME is the greatest amount of exposure that is reasonably expected to occur and likely overestimates exposure for many individuals (i.e., is greater than the average exposure level). CT risk estimates were calculated to reflect average exposures as compared to the RME (and therefore the CT scenario may underestimate exposure for some individuals). CT estimates provide a measure of the range of uncertainty associated with exposure and risk and an estimate of exposure for most individuals within a population.

6.1.1.1 Seafood Consumption

COPCs based on the seafood consumption pathway evaluated by Ecology generally included those listed by USEPA as persistent, bioaccumulative toxic chemicals (USEPA 2017a). COPCs that were retained as preliminary IHSs after the initial screening included those that generally met the following conditions: (1) were not essential human nutrients; 2) had a frequency of detection greater than 5 percent; and 3) had concentrations exceeding the area reference concentration (defined as concentrations detected in Dungeness Bay).

Additionally, USEPA's Regional Screening Calculator was used to develop fish tissue risk-based concentrations (RBCs). Chemicals with tissue concentrations greater than the tissue RBCs were retained for further analysis.

Ecology's threshold of 1 in 100,000 (1 x 10-5) potential excess cancer risks for multiple hazardous substances or pathways was exceeded for both the subsistence and recreational fishers. Subsistence and recreational fishers are assumed to consume seafood and be exposed to sediments during clamming and other beach activities. Arsenic, dioxins/furans, PCBs, alpha-hexachlorocyclobenzene (alpha-BHC), and cPAHs accounted for 58 percent, 23 percent, 11 percent, 4 percent, and 3 percent, respectively, of the subsistence fisher RME seafood consumption excess cancer risk (Figure 3-5 in Appendix G of Ecology 2012). However, it should be noted that the alpha-BHC risk was based on elevated detection limits rather than detected concentrations.

Non-cancer hazards exceeded Ecology's threshold of 1.0 for the RME subsistence fishers seafood consumption scenario for a number of chemicals, including: metals (arsenic, cadmium, cobalt, copper, iron, selenium, silver, vanadium, zinc, and methylmercury), PCBs, and dioxins/furans. The threshold of 1.0 was also exceeded for arsenic and PCBs in the RME recreational fishers seafood consumption scenario.

In the risk assessment, the preliminary human health IHSs were selected if the risk posed by the chemical exceeded 1 percent of the overall risk. Additionally, although zinc did not qualify as an IHS based on exceedance of the relative percent risk threshold, it was still identified as a preliminary IHS by Ecology because there are known or potential sources of zinc within the Harbor and measured concentrations of zinc in sediment exceeded SMS criteria. Cobalt and iron exceeded the relative percent risk threshold, but were not further evaluated by Ecology "as they are considered naturally occurring and not cause for concern" (NewFields 2013a), have no known industrial sources, and have limited data availability.

Therefore, the preliminary human health IHSs identified included: arsenic, cadmium, copper, selenium, mercury, zinc, alpha-BHC, cPAHs, PCBs, and dioxins/furans TEQ.

6.1.1.2 Direct Contact

The direct contact (ingestion and dermal contact) exposure pathway was evaluated for recreational activities in intertidal sediments. All preliminary human direct contact IHSs were identified by comparing concentrations against preliminary risk-based screening values, including MTCA Method A or MTCA Method B levels for unrestricted land use for human health risk when available, or USEPA Regional Screening Levels Tables when other criteria were not available.

Preliminary Bioaccumulative and Direct Contact Indicator Hazardous Substances:

Arsenic	Mercury	alpha-BHC
Cadmium	Selenium	cPAH TEQ
Copper	Zinc	Total TEQ

Sediment direct contact risk posed by arsenic and dioxins/furans was identified for subsistence and recreational fishers only. Cancer and non-cancer risks for residential and recreational users were less than Ecology's thresholds and therefore no analytes were identified as preliminary IHSs for these receptors. Based on Ecology's evaluation of health risks posed by direct contact with contaminated sediments, arsenic and dioxins/furans were identified as preliminary IHSs and will be further evaluated in Section 8.0. Additionally, though cPAH TEQ was not identified by Ecology as a preliminary IHS for direct contact, Ecology requested evaluation of cPAHs in the intertidal areas (Ecology 2017a). Therefore, cPAH TEQ is also evaluated relative to direct contact in Section 8.0.

6.1.2 Screening Level Ecological Risk Assessment

Risks to the following ecological receptor groups were evaluated by Ecology: benthic invertebrates, marine plants and macroalgae, fish, and wildlife.

6.1.2.1 Benthic Invertebrates

Three measures were used to assess potential risks to benthic invertebrates in the Harbor:

- **Surface sediment chemical concentrations.** Chemical concentrations were compared against the SCO or lowest apparent effects threshold (LAET) chemical criteria and the CSL or second lowest apparent effects threshold (2LAET) chemical criteria. Thirty-five surface sediment samples collected throughout the Harbor exceeded the SCO/LAET or CSL/2LAET for one or more chemicals.
- **Bioassay testing.** Surface sediment samples from 29 of the 56 sampling stations submitted for bioassay testing in 2008 failed SMS SCO or CSL biological criteria. The majority of these 2008 failures were based on the performance of the echinoderm larval bioassay, which was highly inconsistent, with widespread failures noted in samples from areas with an absence of chemical exceedances and wood debris. Samples collected from reference areas also exhibited toxicity.
- **Evaluation of sediment habitat quality.** Wood debris investigations indicated that about 20 to 25 percent of the Harbor is affected by wood debris, mostly in the inner

> harbor (Ecology 2012, NewFields 2012, SAIC 1999). Wood debris may impair benthic habitat quality in a number of ways, including creation of a physical barrier at the sediment surface and anoxic conditions, and may contribute to the production of ammonias and sulfides.

According to Ecology, "All three measures suggest that the benthic invertebrate community may be impaired at the site [the Harbor]" (Ecology 2012). Seven chemicals were identified as preliminary Harbor-wide benthic IHSs: zinc, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, fluoranthene, 2,4-dimethylphenol, 4-methylphenol, and phenol.

Preliminary Benthic Indicator Hazardous Substances:

Zinc	Fluoranthene
bis(2-Ethylhexyl)phthalate	2,4-Dimethylphenol
Butyl benzyl phthalate	4-Methylphenol
Phenol	

Arsenic, cadmium, mercury, and PCB Aroclors also showed potential benthic invertebrate impacts and are identified as benthic IHSs. However, because they were identified as preliminary human health IHSs as well, they were not evaluated further by Ecology as benthic IHSs. Wood debris was also considered a potential concern relative to benthic habitat quality for the reasons described in this section.

6.1.2.2 Marine Plants and Macroalgae

For marine plants, there are no sediment quality criteria or tissue RBCs available; therefore, no preliminary IHSs were identified for marine plants. Instead, the evaluation of marine plant risk by Ecology was based on a qualitative evaluation of habitat quality, with wood debris noted as the primary impact.

6.1.2.3 Fish

The ecological risk assessment evaluated 10 chemicals measured in lingcod and rock sole tissue and compared their maximum concentrations with fish tissue RBCs. Arsenic in rock sole was the only chemical to exceed a tissue RBC. Ecology concluded "fish in Port Angeles Harbor are unlikely to be adversely affected by current levels of most contaminants, except perhaps by arsenic" (Appendix G of Ecology 2012). However, the arsenic sediment RBC for human health was determined to be four orders of magnitude less than the arsenic sediment RBC for the protection of fish. Therefore, arsenic was not considered separately as a preliminary IHS for fish.

6.1.2.4 Wildlife

Six wildlife species were evaluated in the risk assessment including: Brant's cormorant, double-crested cormorant, greater scaup, harbor seal, raccoon, and bald eagle. No unacceptable risks were determined for Brant's cormorant, double-crested cormorant, greater scaup, or bald eagle. For the raccoon, a hazard quotient (HQ) of 1 based on the no observable adverse effect level (NOAEL) was exceeded for arsenic, while the HQ lowest observed adverse effect level (LOAEL) was not exceeded; a HQ-NOAEL greater than 1.0 "doesn't necessarily indicate adverse effect"

(Appendix G of Ecology 2012). The arsenic sediment RBC for human health is considered protective of raccoons and, therefore, arsenic in raccoons was not considered separately as a preliminary IHS for wildlife. For the harbor seal, a HQ-NOAEL greater than 1.0 was observed but was based on elevated detection limits; Ecology concluded that risk is not posed to harbor seals.

6.1.3 Ecology Updates to Preliminary Indicator Hazardous Substances – Total TEQ

After the human health and ecological risk assessments summarized above were issued, Ecology revised the approach for development of the appropriate IHS to represent combined dioxin/furan and PCB exposure (Ecology 2016a). In the risk assessments, dioxin/furan TEQ and total PCBs were previously defined as separate preliminary IHSs. However, the regional background levels for dioxin/furan TEQ and PCB congener TEQ in North Olympic Peninsula Regional Background Sediment Characterization Report (Ecology 2016c) indicated that the dioxin/furan TEQ regional background value (i.e., the SCL) is greater than 20 times the PCB congener TEQ regional background level. Because dioxin/furan and PCB congeners used to calculate their respective TEQs act through a common toxicological mechanism, the use of a separate PCB congener TEQ SCL is not necessary. Instead, Ecology established the IHS "Total TEQ," which combines the dioxin/furan TEQ and PCB congener TEQ regional background values to establish an SCL representative of the combined regional background levels of dioxin/furan and PCB congeners. In the Harbor, dioxin/furan TEQ and total PCBs are therefore not considered separately as human health IHSs, but are combined as Total TEQ.

6.2 DEVELOPMENT OF PRELIMINARY SEDIMENT CLEANUP OBJECTIVES AND CLEANUP SCREENING LEVELS

This section describes the process by which SCOs and CSLs for the preliminary human health and benthic IHSs were derived by NewFields on behalf of Ecology (NewFields 2013, Ecology 2015a). The objective of the NewFields report was "to facilitate a framework for setting SCLs for cleanups in Port Angeles Harbor" (NewFields 2013). Under SMS, the SCL is the concentration or level of biological effects for a contaminant considered to be protective of both human health and the environment.

In accordance with the SMS, numeric criteria for sediment protective of benthic invertebrates, human health, and higher trophic level species are established using a two-tiered framework, which are bounded by the SCO and the CSL. The SCO is defined as the long-term sediment quality goal for protection of human health and the environment. The SCL is initially established as the SCO and may be adjusted upward as appropriate on a site-specific basis, based on technical possibility and evaluation of net adverse environmental impacts. The derivation of preliminary SCOs and CSLs for the Harbor by Ecology is described below.

6.2.1 Sediment Cleanup Objectives

Preliminary SCOs for the Harbor were identified in Port Angeles Harbor Preliminary Sediment Cleanup Objectives (NewFields 2013). These preliminary SCOs are described in the following sections.

6.2.1.1 Human Health Indicator Hazardous Substances

The human health preliminary SCOs are established as the greatest of the following levels in accordance with WAC 173-204-560(3):

- The lowest human health RBC for chemicals identified as preliminary IHSs:
  - The concentration of the contaminant based on protection of human health (at cancer risk of less than or equal to 1 in 1,000,000 [1 x 10-6] or a non-cancer risk of less than or equal to a HQ of 1, as specified in WAC 173-204-561(2))
- Natural background; or
- PQL

Ecology's approach to determination of the SCOs for the preliminary human health IHSs is presented below.

Risk-Based Concentrations

Human health RBCs are those chemical concentrations less than which risk to human health is considered acceptable. Ecology calculated human health sediment RBCs for the Harbor based on two exposure pathways: (1) the consumption of finfish and shellfish by the LEKT; and (2) direct contact (ingestion and dermal contact) with sediments (NewFields 2013):

- **Seafood consumption.** The risks associated with the consumption of seafood were calculated by Ecology based on a LEKT tribal RME scenario. Tissue RBCs were calculated for this scenario using equations and parameters presented in Appendix A of NewFields 2013. These tissue RBCs were calculated for all chemicals that were identified as preliminary human health IHSs in the human health risk assessment and determined separately for each of the following fish and shellfish species: lingcod, rock sole, geoduck, horse clam, coonstripe shrimp, and Dungeness crab.

  Sediment RBCs for seafood consumption were then derived from the tissue RBCs using biota-sediment accumulation factors (BSAFs) and bioaccumulation factors (BAFs). A BSAF is the ratio of the lipid-normalized contaminant concentration in the organism to the TOC-normalized contaminant concentration in the sediment and is used to predict the bioaccumulation of lipophilic chemicals in aquatic biota from sediment concentrations. BAFs are also a ratio of the contaminant concentration in biota to the contaminant concentration in sediment, but are not normalized for lipid content and organic carbon (OC) and are calculated for non-lipophobic chemicals. Harbor-specific BSAFs and BAFs were calculated using paired sediment and tissue data, generally collected in the same sampling event or a nearby location (Ecology 2012). Where limited Harbor data were available, literature sources for BSAFs and BAFs were also evaluated. A discussion of sediment and tissue data pairing, literature sources, and other details of the BSAF/BAF derivation approach is presented in NewFields 2013.

Of the sediment RBCs calculated using the Harbor-specific BSAF/BAF values, the lowest sediment RBC was chosen for each chemical and tissue type comparison. The bioaccumulative sediment RBCs for both cancer and non-cancer risks are presented in Table 6.1.

- **Direct contact.** The sediment RBCs based on the direct contact pathway for arsenic, cPAHs, and Total TEQ were calculated using equations and parameters presented in Appendix A of NewFields 2013 for a lifetime (child and adult combined) subsistence fisher exposure in intertidal areas. Intertidal areas are defined as all areas in the Harbor located between MLLW and MHHW. The direct contact sediment RBCs for both cancer and non-cancer risks are presented in Table 6.2.

Natural Background

Per the Sediment Cleanup User's Manual II (SCUM II; Ecology 2017d), natural background is the "concentration of a hazardous substance consistently present in the environment that has not been influenced by localized human activities." Natural background includes concentrations of chemicals that are naturally occurring, as well as concentrations of anthropogenic chemicals that are globally distributed at low levels.

To determine natural background concentrations, NewFields on behalf of Ecology used the "Port Angeles Proximal Area Background" dataset (Ecology 2016c). This dataset consists of data from sediment samples collected from the Strait of Juan de Fuca and around the San Juan Islands as part of the 2008 OSV Bold Sediment Survey and data from samples collected in Freshwater Bay and Dungeness Bay acquired from Ecology's Environmental Information Management (EIM) database in 2012 (as described in NewFields 2012). Ecology calculated the 90/90 upper tolerance limit (UTL; i.e., the 90 percent upper confidence limit [UCL] on the 90th percentile) to derive natural background concentrations, with non-detect results assigned a value of one-half the method detection level. The natural background concentrations for the Harbor are presented in Tables 6.1 and 6.2.

It is important to note that the grain sizes for the samples in the Port Angeles Proximal Area Background dataset were coarser-grained than the Harbor samples with less of a fine fraction containing organic materials. Many of the IHSs (e.g., PCB, dioxins/furans, cPAH) tend to concentrate in finer sediment containing organic materials. Therefore, using the Port Angeles Proximal Area Background dataset to determine the Harbor natural background concentrations likely underestimates natural background concentrations.

Practical Quantitation Limits

The PQL is defined in WAC 173-204-505(15) as "the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department approved methods." SMS allows consideration of the PQL in establishing the SCO to address circumstances in which a concentration determined to be protective cannot be reliably detected using state-of-the-art analytical instruments and methods.

PQLs selected for use are those presented in the *Memorandum Re: Site-Specific Sediment Cleanup Levels, Remediation Levels, and Sediment Management Areas for Bioaccumulative Chemicals: Western Port Angeles Harbor* (Ecology 2015a). These PQLs "were taken from the North Olympic Peninsula Regional Background Sediment Characterization sampling and analysis plan (Ecology 2013b), while additional PQLs were from a survey of laboratory capabilities conducted by Hart Crowser, Inc. (McGinnis 2011)" and are presented in Table 6.1. The cPAH and dioxin/furan PQLs are not true PQLs, but were modified by the toxic equivalent factor (TEF). A TEQ was calculated for cPAH and dioxins/furans using TEF values from MTCA (WAC 173-340-900).

6.2.1.2 Benthic Indicator Hazardous Substances

For those chemicals identified as benthic IHSs in Section 6.1.2.1, the preliminary SCOs are based on SCO/LAET criteria from Table 8.1 of the SCUM II (Ecology 2017d) and are presented in Table 6.3.

6.2.2 Cleanup Screening Levels

CSLs were identified in Ecology's initial comments on the White Paper (Ecology 2015a) and in the North Olympic Peninsula Regional Background Sediment Characterization (Ecology 2016c). These preliminary CSLs are described in the following sections.

6.2.2.1 Human Health Indicator Hazardous Substances

The human health preliminary CSLs for a contaminant are established as the greatest of the following levels in accordance with WAC 173-204-560(3):

- The lowest human health RBC for chemicals identified as preliminary IHSs:
  - o The concentration of the contaminant based on protection of human health (at cancer risk of less than or equal to 1 in 100,000 [1 x 10-5] or a non-cancer risk of less than or equal to a HQ of 1, as specified in WAC 173-204-561(3))
- Regional background; or
- PQL

Ecology's approach to determination of the CSLs for the preliminary human health IHSs is presented below.

Risk-Based Concentrations

For the determination of a potential CSL based on risk concentrations, WAC 173-204-561(3) allows for the upward adjustment to 1 in 100,000 (1 x 10-5) for the upper bound on the estimated excess cancer risk for individual carcinogenic chemicals. An upward adjustment above a HQ of 1 is not allowed for non-carcinogenic chemicals.

The RBCs based on cancer risk for arsenic, alpha-BHC, cPAH TEQs, and Total TEQ have, therefore, been increased by an order of magnitude from their SCO values. The RBCs based on non-cancer risk for cadmium, copper, mercury, selenium, and zinc have not been adjusted. The RBCs considered as potential CSLs are presented in Tables 6.1 and 6.2.

Regional Background

In WAC 173-204-505(16), regional background is defined as "the concentration of a contaminant within the department-defined geographic area that is primarily attributable to diffuse sources, such as atmospheric deposition or storm water, not attributable to a specific source or release."

In 2013, Ecology conducted a surface sediment characterization effort to support implementation of the SMS Rule and establish regional background concentrations for a select group of bioaccumulative chemicals in the North Olympic Peninsula region. Bioaccumulative chemicals selected for data collection in this sampling effort included: arsenic, cadmium, mercury, cPAHs, dioxins/furans, and PCB congeners. Ecology determined the study area that was representative of regional background for the North Olympic Peninsula included: Dungeness Bay, Sequim Bay, Discovery Bay, and Port Townsend Bay (Ecology 2013b). Samples were collected throughout these bays with a 500-meter (1,600-foot) buffer designated around any potential source areas identified by Ecology, which included all of the shoreline, outfalls, marinas, wharfs, and fish pens, and a restricted anchorage location in Port Townsend Bay.

Results for the investigation were presented in the North Olympic Peninsula Regional Background Sediment Characterization, Data and Evaluation Report, Port Angeles – Port Townsend, Washington (Ecology 2016c). After outliers were removed from the dataset (which included all samples from Dungeness Bay because concentrations were equal to or less than natural background), a regional background 90/90 UTL was calculated for each chemical. These regional background values are presented in Tables 6.1 and 6.2. cPAHs were treated as a special case because cPAH presence is correlated to population density in addition to historical point source contamination. For cPAHs, the regional background calculated from the dataset used for regional background calculations of other chemicals was 31 micrograms per kilogram (µg/kg). However, as described in *North Olympic Peninsula Regional Background Sediment Characterization, Data and Evaluation Report, Port Angeles – Port Townsend, Washington* (Ecology 2016c), Ecology determined that "…the cPAH regional background value of 31 µg/kg derived from less-industrialized and populated embayments is likely biased low relative to Port Angeles Harbor." To address this issue, Ecology determined that samples collected in the Harbor that were not directly associated with a point source could also be used in the calculation of a cPAH regional background concentration specific to the Harbor. Ecology identified 14 samples within the Harbor for use in the regional background dataset in addition to data from Sequim Bay, Discovery Bay, and Port Townsend Bay. The resulting Harbor-specific cPAH regional background concentration using this separate dataset was 64 µg/kg.

6.2.2.2 Benthic Indicator Hazardous Substances

For those chemicals identified as benthic IHSs in Section 6.1.2.1, the CSLs are based on CSL/2LAET criteria derived from Table 8.1 of the SCUM II (Ecology 2017d) and are presented in Table 6.3.

Section 6.0:
Development of Preliminary Indicator Hazardous Substances and Cleanup Criteria

Tables

Table 6.1
Sediment Cleanup Objectives and Cleanup Screening Levels for Preliminary Bioaccumulative Indicator Hazardous Substances[1]

Preliminary IHSs	Units	Risk-Based Concentrations (1×10^{-6} or HQ = 1)		Natural Background	PQL	Preliminary Bioaccumulative SCO	Risk-Based Concentrations (1×10^{-5} or HQ = 1)		Regional Background	Preliminary Bioaccumulative CSL
		Cancer	Non-Cancer				Cancer	Non-Cancer		
Arsenic	mg/kg	0.000071	--	12	0.5	12	0.00071	--	13.9	13.9
Cadmium	mg/kg	--	0.098	0.82	0.1	0.82	--	0.098	2.4	2.4
Copper	mg/kg	--	5.6	35	0.35	35	--	5.6	--	35
Mercury	mg/kg	--	0.055	0.11	0.025	0.11	--	0.055	0.13	0.13
Selenium	mg/kg	--	0.23	--	0.6	0.6	--	0.23	--	0.6
Zinc	mg/kg	--	55	77	1.6	77	--	55	--	77
alpha-BHC	µg/kg	0.0068	--	1.4	1.3	1.4	0.068	--	--	1.4
cPAH TEQ[2]	µg/kg	5.5	--	16	0.76	16	55	--	64	64
Total TEQ[3]	ng/kg	0.0059	--	1.3	2.3	2.3	0.059	--	5.2	5.2

Notes:

-- Not available.

1 All preliminary bioaccumulative IHSs, SCOs, and CSLs were provided in Attachment 1 of Ecology's *Memorandum Re: Site-Specific Sediment Cleanup Levels, Remediation Levels and Sediment Management Areas for Bioaccumulative Chemicals: Western Port Angeles Harbor* (Ecology 2015).

2 Since the cPAH TEQ risk calculations were completed by Ecology in 2012, the cancer slope factor for benzo(a)pyrene was updated in IRIS (USEPA 2017). The update decreased the cancer slope factor from 7.3 kg-day/mg to 1.0 kg-day/mg. In accordance with WAC 173-204-561(2)(c); toxicity factors available from IRIS shall be used in cleanup level calculations. Therefore, this revised cancer slope factor is applied in the calculation of cPAH TEQ cleanup levels, which are calculated as benzo(a)pyrene toxic equivalents.

3 Total PCBs and dioxin/furan TEQ were originally proposed by Ecology as separate IHSs in Port Angeles Harbor, with individual SCOs and CSLs (Ecology 2012). However, since then, Ecology decided to establish the IHS "Total TEQ," which combines the dioxin/furan TEQ and PCB congener TEQ regional background values to establish a CSL representative of the combined regional background levels of dioxins/furans and PCBs. Therefore, in Port Angeles Harbor, total PCBs and dioxin/furan TEQ are no longer considered separate IHSs.

Abbreviations:

alpha-BHC alpha-Hexachlorocyclohexane
cPAH Carcinogenic polycyclic aromatic hydrocarbon
CSL Cleanup screening level
HQ Hazard quotient
IHS Indicator Hazardous Substance
IRIS Integrated Risk Information System
kg-day/mg Kilograms per day per milligram
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
ng/kg Nanograms per kilogram
PQL Practical quantitation limit
SCO Sediment cleanup objective
TEQ Toxic equivalent
WAC Washington Administrative Code

Table 6.2

Sediment Cleanup Objectives and Cleanup Screening Levels for Preliminary Direct Contact Indicator Hazardous Substances[1,2]

Preliminary IHSs	Units	Risk-Based Concentrations (1 x 10^{-6} or HQ = 1)		Natural Background	PQL	Preliminary Direct Contact SCO	Risk-Based Concentrations (1 x 10^{-5} or HQ = 1)		Regional Background	Preliminary Direct Contact CSL[3]
		Cancer	Non-Cancer				Cancer	Non-Cancer		
Arsenic	mg/kg	0.47	1,200	12	0.5	12	4.7	1,200	13.9	13.9
cPAH TEQ[4]	µg/kg	250	--	16	0.76	250	2,500	--	64	250
Total TEQ[5]	ng/kg	3.9	--	1.3	2.3	3.9	31[3]	--	5.2	5

Notes:

-- Not available.

1 The preliminary direct contact IHSs of arsenic and Total TEQ are based on the outcomes of Ecology's *Screening Level Human Health Risk Assessment* from their *Port Angeles Harbor Sediment Characterization Study, Sediment Investigation Report* (Appendix G of Ecology 2012). Additionally, though cPAH TEQ was not identified by Ecology as a preliminary IHS for direct contact, Ecology requested evaluation of cPAHs in the intertidal areas (Ecology 2017a). Therefore, cPAH TEQ is also further evaluated as a preliminary direct contact IHS.

2 The sediment RBCs based on the direct contact pathway for arsenic, cPAHs, and Total TEQ were calculated using equations and parameters presented by NewFields (Appendix A of NewFields 2013) for a lifetime (child and adult combined) subsistence exposure in intertidal areas. Intertidal areas are defined as all areas in the Harbor located between MLLW and MHHW.

3 For the three carcinogenic analytes identified as direct contact IHSs, the sum of the risk posed may not exceed 1 x 10^{-5} cancer risk, consistent with MTCA. For arsenic, because the arsenic cleanup level is less than regional background, a nominal risk of 10^{-6} was assigned. For cPAH TEQ, the risk-based concentration protective of 10^{-6} risk was selected as the CSL. Therefore, a remaining risk of 8 x 10^{-6} is allowable for Total TEQ, which results in a risk-based concentration of 31 ng/kg. This concentration is applied as the CSL for protection of direct contact in intertidal areas. This approach is consistent with previous documents (WPAH Group 2014, Ecology 2015).

4 Since the cPAH TEQ risk calculations were completed by Ecology in 2012, the cancer slope factor for benzo(a)pyrene was updated in IRIS (USEPA 2017). The update decreased the cancer slope factor from 7.3 kg-day/mg to 1.0 kg-day/mg. In accordance with WAC 173-204-561(2)(c); toxicity factors available from IRIS shall be used in cleanup level calculations. Therefore, this revised cancer slope factor is applied in the calculation of cPAH TEQ cleanup levels, which are calculated as benzo(a)pyrene toxic equivalents.

5 Total PCBs and dioxin/furan TEQ were originally proposed by Ecology as separate IHSs in Port Angeles Harbor, with individual SCOs and CSLs (Ecology 2012). However, since then, Ecology established the IHS "Total TEQ," which combines the dioxin/furan TEQ and PCB congener TEQ regional background values to establish cleanup levels representative of the combined regional background levels of dioxins/furans and PCBs. Therefore, in Port Angeles Harbor, total PCBs and dioxin/furan TEQ are no longer considered separate IHSs.

Abbreviations:

cPAH Carcinogenic polycyclic aromatic hydrocarbon
CSL Cleanup screening level
Ecology Washington State Department of Ecology
HQ Hazard quotient
IHS Indicator Hazardous Substance
IRIS Integrated Risk Information System
kg-day/mg Kilograms per day per milligram
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
MHHW Mean higher high water
MLLW Mean lower low water
MTCA Model Toxics Control Act
ng/kg Nanograms per kilogram
PCB Polychlorinated biphenyl
PQL Practical quantitation limit
RBC Risk-based concentration
SCO Sediment cleanup objective
TEQ Toxic equivalent
WAC Washington Administrative Code
WPAH Group Western Port Angeles Harbor Group

Table 6.3
Sediment Cleanup Objectives and Cleanup Screening Levels for Preliminary Benthic Indicator Hazardous Substances[1,2]

Preliminary IHSs	SCO	CSL	LAET	2LAET
Metals	**mg/kg**			
Arsenic	57	93	--	--
Cadmium	5.1	6.7	--	--
Mercury	0.41	0.59	--	--
Zinc	410	960	--	--
Phthalate Esters	**mg/kg-OC**		**µg/kg**	
bis(2-Ethylhexyl)phthalate	47	78	1,300	1,900
Butyl Benzyl Phthalate	4.9	64	63	900
Polychlorinated Biphenyls	**mg/kg-OC**		**µg/kg**	
Total PCB Aroclors	12.0	65	130	1,000
Polycyclic Aromatic Hydrocarbons	**mg/kg-OC**		**µg/kg**	
Fluoranthene	160	1,200	1,700	2,500
Ionizable Organic Compounds	**µg/kg**			
2,4-Dimethylphenol	29	29	--	--
4-Methylphenol	670	670	--	--
Phenol	420	1,200	--	--

Notes:

-- Not applicable.

1 Preliminary benthic IHSs are based on the outcomes of Ecology's *Screening Level Ecological Risk Assessment* from their *Port Angeles Harbor Sediment Characterization Study, Sediment Investigation Report* (Appendix G of Ecology 2012).

2 SCOs, CSLs, LAETs, and 2LAETs are sourced from Table III of the Sediment Management Standards (WAC 173-204-562) and Table 8.1 of the Sediment Cleanup Users Manual II (Ecology 2017).

Abbreviations:

2LAET Second lowest apparent effects threshold
CSL Cleanup screening level
Ecology Washington State Department of Ecology
IHS Indicator Hazardous Substance
LAET Lowest Apparent Effects Threshold
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
OC Organic carbon normalized
SCO Sediment cleanup objective
WAC Washington Administrative Code

Section 7.0: Nature and Extent of Preliminary Indicator Hazardous Substances and Wood Debris

- The nature and extent of contamination within the Western Port Angeles Harbor Study Area (WPAH Study Area) is evaluated using Ecology's preliminary indicator hazardous substances (IHSs) and their Sediment Cleanup Objectives (SCOs) and Cleanup Screening Levels (CSLs). Key findings from this evaluation include the following:
  - Limited benthic toxicity was observed within the WPAH Study Area. Stations with benthic toxicity were primarily located in the inner harbor and generally associated with chemical contamination. Generally, a healthy benthic community is present.
  - Wood debris was observed throughout the WPAH Study Area. Estimated wood content of surface sediments exceeding 50 percent by volume were found along the southwestern shoreline and in historical and current log rafting areas.
  - The distribution of surface chemical contamination in the WPAH Study Area varies depending on the preliminary IHS:
    - Metals concentrations are primarily greater than the benthic SCOs (up to 9 times greater) in the inner harbor and lagoon.
    - Total toxic equivalent (TEQ) also shows elevated concentrations in the inner harbor and the lagoon (greater than 10 times the CSL).
    - Carcinogenic polycyclic aromatic hydrocarbons (cPAHs) are broadly distributed at elevated concentrations in the inner harbor, lagoon, and southern shoreline, with concentrations up to approximately 20 times the CSL.
    - Organic compounds other than Total TEQ and cPAHs tend to be found in greatest concentrations along the southern shoreline.
  - For subsurface chemical contamination, the spatial pattern is not consistent among chemicals, suggesting various historical sources, releases, and transport. The exception is cPAHs, where subsurface concentrations are less than surface concentrations at approximately 75 percent of locations, suggesting ongoing sources of contamination.
  - Based on porewater and bioaccumulation testing tissue data, dioxins/furans do not readily bioaccumulate in much of the western portion of the WPAH Study Area, likely due to the presence of high organic content in the sediments, with the exception of some areas within the inner harbor.

7.0 Nature and Extent of Preliminary Indicator Hazardous Substances and Wood Debris

This section discusses the nature and extent of contamination in the WPAH Study Area based on examination of the RI/FS sediment chemistry dataset for the preliminary bioaccumulative and direct contact human health and benthic IHSs identified in Section 6.0, the results of sediment toxicity bioassays, and the 1998 and 2013 SPI/PV surveys.

7.1 SEDIMENT TOXICITY BIOASSAYS

Acute and chronic bioassays have been conducted in the WPAH Study Area to evaluate whether sediments are toxic to benthic organisms. Bioassay data are available from five surveys conducted since 2003 (Table 7.1). The majority of the data were collected in 2008 (Ecology 2012) and in 2013 for this RI/FS. In total, data are available for 64 locations. Bioassay tests conducted at the majority of the stations include amphipod survival, larval development, and juvenile polychaete growth. Most tests were conducted on sediment collected from 0 to 10 cm below the sediment surface, although two samples at one location were collected in 2004 from a depth of 0 to 2 cm by the City as part of the testing required under their NPDES Permit. All data are considered useable for this RI/FS. Results for the bioassays are presented in Figure 7.1.

The 2013 RI/FS field program included 21 stations where bioassay testing had not been conducted previously and an additional 26 stations that were retested. These retested stations had been sampled by Ecology in 2008 and failures of the larval development test were observed.

Sediment toxicity data were evaluated according to the SMS (WAC 173-204-562 Table IV) to determine whether sediment exceeded SMS sediment toxicity criteria. Results are provided in Table 7.2. A total of 11 of the 61 stations evaluated for sediment toxicity exceeded either the SCO or CSL biological criteria. Results showed:

- No exceedances of the amphipod survival test
- One SCO-level exceedance of the polychaete growth test
- Nine SCO-level exceedances of the larval development test
- One CSL-level exceedance of the larval development test

Bioassay exceedances occurred in nearshore areas along the western portion of Ediz Hook, in the inner harbor, and along the southwestern shoreline (Figure 7.1). The 2013 larval bioassay test results at stations where there had been larval bioassay failures in 2008 (Ecology 2012) showed considerable improvement, with fewer exceedances of SMS criteria. These improved results primarily reflect use of the resuspension protocol (Kendall et al. 2012) that addressed possible larval entrainment/negative bias, but also may reflect improved sediment quality over the 5-year period between 2008 and 2013.

Factors potentially influencing bioassay (especially larval) test results were evaluated using correlation analyses. Larval response (i.e., percentage mean normal survivorship) in the 2013 RI/FS samples was compared to the following parameters: percent fine-grained sediment (i.e., silt plus clay), percent clay, TVS, TOC, porewater ammonia, porewater sulfides, and the following chemicals[8]: cadmium, mercury, zinc, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, fluoranthene, and phenol.

The conventional parameters with significant negative (P<0.05) correlations with larval development[9] included TVS and TOC (Table 7.3), which are measures of organic enrichment. A number of sources of organic enrichment may have influenced the larval test, including wood chips, historically released wood pulp, and macroalgae decay (such as *Ulva sp.*). The discussion of SPI results in Section 7.2 describes the distribution of these potential stressors. Station WPAH024, the location of the only larval test with a CSL exceedance, had significant organic enrichment. SPI work showed both dense macroalgae (specifically, *Ulva sp.*) and obvious *Beggiotoa sp.* (sulfur oxidizing bacteria) mats present (Figure 7.2) at this location. In addition, Ecology sampling in 2012 found up to 8 feet of wood chips in nearby Station IH06. Results are somewhat unclear, however, as macroalgae and wood were present in a number of stations that passed the larval test, as well as stations that failed the larval test.

Cadmium, mercury, zinc, and benzo(g,h,i)perylene had significant (P<0.05) negative correlations with larval response (Table 7.3). None of these negative correlations had correlation coefficients greater than 0.4. This indicates a significant but weak correlation with larval response. The distribution of cadmium, mercury, and zinc in surface sediments is similar throughout the WPAH Study Area (refer to Section 7.3.1), and these metals significantly correlate with one another with strong correlation coefficients greater than 0.7 (Table 7.3).

The larval test involves using a sensitive, planktonic life stage that can be susceptible to non-treatment factors (i.e., the test organism can be affected adversely by factors other than chemical composition of the test sediment). The significant correlation of 2013 larval survival to TVS and TOC suggest that non-treatment factors (wood chips, wood pulp, presence of macroalgae and bacteria) may be affecting test outcome. Metals are the most likely chemicals in sediment to affect the larval stage, although conclusions are unclear given the other confounding, non-treatment factors.

7.2 WOOD DEBRIS AND BENTHIC HABITAT QUALITY

The primary objective of the 2013 SPI/PV survey was to map the distribution of wood debris in surface sediments and the associated benthic habitat quality throughout the WPAH Study Area (WPAH Group 2013). The complete 2013 SPI/PV survey report (Germano & Associates 2014) is provided as Appendix I of the Western Port Angeles Harbor RI/FS Data Report (Integral et al.

8 These chemicals were selected because they occurred in WPAH Study Area sediment samples at concentrations greater than SCO/LAET screening levels in more than one sample.

9 That is, factors correlating to poor larval development.

2014). The key findings from this SPI/PV survey are summarized in Sections 7.2.1 through 7.2.4. The 2013 findings are compared with the results of the SPI/PV survey in the WPAH Study Area conducted in 1998 (SAIC 1999) in Section 7.2.5.

7.2.1 Distribution of Wood Debris in 2013

The distribution of estimated wood debris in the SPI/PV images in the WPAH Study Area from July 2013 is shown in Figure 7.3a. The presence of wood debris was evident in both the SPI and PV images, either as decomposed, individual fibers mixed in with the sediment or as larger pieces of intact wood chips/chunks/logs. Examples of intact wood debris versus wood fibers in SPI images are shown in Figure 7.3b.

To estimate the percentage of wood residue in cross-sections of the sediment column (SPI images) or on the sediment surface (PV images), petrographic estimators (a series of images that visually depict a range of composition percentages from 1 to 80 percent; Williams et al. 1982) were placed over or adjacent to the images and the corresponding percent area represented by wood fragments was estimated based on the following categories:

- None = No discernible wood material present
- Trace = <5 percent
- Low = 5–20 percent
- Medium = 21–50 percent
- High = >50 percent

Examples of low, medium, and high wood debris in SPI and PV images are shown in Figures 7.3c and 7.3d, respectively. The wood debris levels mapped in Figures 7.3a through 7.3d represent the greatest wood content measured in either the SPI or PV images from each location. At some stations, the wood debris was evident both on the sediment surface in the PV image and below the sediment-water interface in the SPI image. In contrast, some stations showed wood debris only at the surface or only buried below the sediment-water interface. Estimates of wood debris exceeding 50 percent of the area either on the sediment surface or in the sediment cross-section, or both, were observed in five areas within the WPAH Study Area (shown in dark brown [i.e., High = >50 percent] in Figures 7.3a through 7.3d), including:

- The industrial waterfront from approximately the lagoon channel to the Port Angeles Boat Haven (southwest shoreline of the Harbor)
- An area of active and historical log rafting just northeast of the Port Angeles Boat Haven
- Two former log rafting areas near the shoreline of Ediz Hook
- The current log storage area offshore and east of the McKinley Paper Company facility

During the 2013 sediment grab sampling effort, the field team estimated the amount of wood debris observed in each grab sample. The percentage of wood debris was appraised visually without the use of petrographic estimators. These observations are included in the RI/FS Data Report (Integral et al. 2014). The wood debris estimates from the grab samples are compared with both the SPI and PV image wood debris estimates in Table 7.4. The second column in Table 7.4 represents the visual wood debris estimates recorded in the field for the grab samples. These grab sample field percentages were converted to the SPI/PV categories listed above and are reported in column three of Table 7.4 to allow direct comparison of the rankings for grab sample, SPI, and PV wood debris estimates.

Two patterns are evident in Table 7.4. First, there is a large variability in the data, which likely reflects small-scale variations or patchiness in the distribution of wood debris on the bottom. Second, given that the wood debris was on the surface and not at depth in the sediment column at some locations and vice versa, a lack of correlation between the PV image results and both the grab sample and SPI image results is expected. Comparing the grab sample to the SPI image results, there is a reasonable amount of similarity. In 35 of the 40 paired estimates, the SPI wood debris classification is the same or within one category class of the grab sample estimate.

7.2.1.1 Buried Pulp Layer

Several stations in the western portion of the WPAH Study Area had buried pockets or layers of what appear to be wood pulp or high concentrations of semi-consolidated wood fibers that gave the appearance of a "cottage cheese" texture to the sediments. The appearance and distribution of this buried pulp material is noted in Figures 7.3a through 7.3d. Table 7.5 lists the 2013 SPI stations and replicate images in which the buried pulp was observed, as well as the estimated thickness of the sediment deposit overlying the pulp layer. The pulp material provides a subsurface datum from which to estimate sediment accumulation rates since pulp discharges to the Harbor ceased between 1964 and 1970. This accumulation rate is compared with radioisotope sedimentation rate estimates in Section 2.1.5 to corroborate sediment deposition rates.

7.2.2 Sediment Grain Size and Other Physical Characteristics in 2013

Sediments surveyed throughout the WPAH Study Area in 2013 were primarily muds (fine-grained, silt-clay sediments with a major mode of >4 ϕ [i.e., predominantly less than approximately 60 micrometers in diameter]), with the exception of 11 locations (Figure 7.4). Of these locations, 10 were located close to the shoreline in shallower waters where greater percentages of very fine to medium sands were generally observed. A poorly sorted mixed silty-sand and cobble bottom was evident at Station WPAH053 in the high-energy lagoon channel. A well-sorted fine sand bottom was evident at the eastern edge of the WPAH Study Area at Station WPAH047.

The majority of the area surveyed appears to be a low-energy, depositional environment. This is evidenced by the widespread cover of fine-grained sediment observed coating the wood debris present in PV images from the western portion of the WPAH Study Area (example PV images shown on Figure 7. 5). Also, the buried wood pulp/fiber layer noted in Section 7.2.1 indicates the long-term accumulation of fine-grained sediments and stability over time in the western portion of the WPAH Study Area.

7.2.3 Organic Loading and Apparent Redox Potential Discontinuity Depths in 2013

Aerobic, near-surface, fine-grained marine sediments are typically olive or tan because oxidized sediment particles are coated with ferric hydroxide, and contrast in color with the underlying hypoxic or anoxic, sulphidic sediments that are generally gray or black (Fenchel 1969; Lyle 1983). The boundary between the tan surface sediment and the underlying gray to black sediment is called the aRPD.

The depth of the aRPD is one of the key parameters measured in SPI images and is an important indicator of DO conditions within sediment porewaters. The aRPD depth is related to the supply rate of molecular oxygen from the overlying seawater into the bottom sediment by bioturbation and/or diffusion and the consumption of that oxygen by the sediment and associated microflora. High inputs of labile organic material (e.g., from algal deposits or anthropogenic sources such as wood deposits) increase sediment oxygen demand (SOD). In sediments that have very high SOD, the sediment may lack a surface oxidized layer or an aRPD even when the overlying water column is aerobic.

Figure 7.6 illustrates the benthic ecological paradigm that underlies SPI image analysis and interpretation. The theory states that in fine-grained estuarine and marine sediments, primary benthic ecological succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance" (Rhoads and Boyer 1982). This paradigm is presented in *Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment* (Pearson and Rosenberg 1978) and is further developed in later studies (Rhoads and Germano 1982, Rhoads and Boyer 1982).

The aRPD depth in Figure 7.6 is represented by the line separating the lighter colored surface sediment from the darker sediment below. The left end of each graphic represents the seafloor following a severe physical disturbance that eliminates the benthic macrofauna community (top panel) or chronic organic loading that does the same by creating very high SOD conditions (bottom panel). In the absence of chronic or renewed physical disturbance or organic loading, the benthic community will become re-established through recolonization or migration from adjacent areas and the aRPD depth will deepen over time, eventually reaching, in theory, an equilibrium depth that reflects the balance of labile organic matter input and benthic community organic matter processing/remineralization. In practice, at any one time, the seafloor is a mosaic of states that lie along the spectrum shown in Figure 7.6 over both small and large spatial scales.

Figure 7.7 shows the distribution of mean aRPD depths measured in July 2013 in the WPAH Study Area. The aRPD depths ranged from approximately 0 to 6.9 cm, with an average value of 2.7 cm. As shown in Figure 7.7, there are several limited areas, largely nearshore, which exhibit relatively shallow aRPDs depths (i.e., less than 1.5 cm). However, the majority of the WPAH stations (88 percent) show relatively deep station-averaged aRPD depths (i.e., greater than 1.5 cm), indicating widespread bioturbation and low SOD in surface sediment in most of the surveyed area. There were six nearshore locations shown on Figure 7.7 where shallow aRPD depths, less than 0.5 cm, appear to be the result of organic enrichment from decomposing wood debris and/or macrophytes (example SPI images shown on Figure 7.8). At three of these stations (WPAH024, WPAH025, and WPAH100), macroalgae *(Ulva sp.)* detritus and/or beds appear to be the major contributor to the sediment oxygen depression. There was also a decrease in the aRPD depths, from those in other deeper water locations, just west of the fish pen operations along outer Ediz Hook (i.e., Stations WPAH096, WPAH104, and WPAH105), which may be related to organic enrichment from the aquaculture operations.

7.2.4 Infaunal Successional Stage and Benthic Habitat in 2013

As a SPI interpretative framework, this continuum of change in animal communities after a disturbance has been divided into four successional stages (Figure 7.6): Stage 0, a sediment column visually devoid of macrofauna, occurs immediately following a major physical disturbance or in close proximity to an organic enrichment source; Stage 1 is the initial community of tiny, densely populated polychaete assemblages at the sediment-water interface; Stage 2 is the start of the transition to subsurface, head-down deposit feeders; and Stage 3 is characterized by the presence of longer-lived deep-dwelling, head-down deposit feeders. The infaunal successional stages are recognized in SPI images by the presence of various features characteristic of each stage (e.g., the dense assemblages of near-surface polychaetes in Stage 1 or the presence of subsurface feeding voids in Stage 3). It is important to note that Stage 1 infauna are often present at the sediment-water interface when deeper-dwelling Stage 3 infauna are present. This is termed Stage 1 on 3 and is indicative of on-going small-scale secondary succession. In terms of benthic habitat quality, Stage 3 and Stage 1 on 3 are comparable and both are considered high order successional stages.

The mapped distribution of infaunal successional stages in the WPAH Study Area in 2013 is shown in Figure 7.9. Notably, higher order successional stages (i.e., Stage 2 going to 3, Stage 3, Stage 2 on 3, or Stage 1 on 3) were found in SPI images from every station where the successional status could be determined, except for nearshore Stations WPAH025 and WPAH061. At five other nearshore locations, the successional stage was indeterminate because of limited camera prism penetration. This limited penetration can be due to coarse-grained sediments, such as gravel or cobbles, or large rocks or pieces of woody debris. It does not necessarily mean that Stage 3 taxa are absent from those locations but instead that not enough of the sediment column was imaged to make that determination. The concentration of these stations in shallow, nearshore areas reflects the greater likelihood of encountering large rocks or wood debris near the shoreline.

Substantial amounts of bark or wood waste can have deleterious effects on the marine ecosystem (Pearson 1972; Conlan and Ellis 1979; Kurau 1975; Freese et al. 1988). However, the results of the 2013 SPI/PV survey indicate the presence of advanced stages of infaunal succession in most of the WPAH Study Area, including areas with high wood content. This appears to be due to the apparently refractory (i.e., inert or very slowly decomposing) nature of the organics in the wood debris, as even locations with relatively high wood content of surface sediments showed evidence of Stage 3 assemblages (example SPI/PV images shown on Figure 7.10).

In addition, most of the locations also had evidence of secondary succession with Stage 1 polychaetes (or possibly Foraminifera) present (Figure 7.9), sometimes in rather dense assemblages at the sediment surface. This widespread secondary succession could reflect ongoing inputs of fine-grained sediments/labile organic matter to the seafloor and/or the physical disturbance of surface sediments by the biogenic sediment reworking of widespread subsurface deposit-feeding infauna. One of the more notable features in the PV images is high densities of shrimp in much of the WPAH Study Area, which are apparently foraging on the widespread prey items at the sediment surface (example PV images shown on Figure 7.11).

There are only two stations in the inner harbor (WPAH025 near the Boat Haven and WPAH061 in the inner harbor near Ediz Hook) that show low-order successional stages. Chemical concentrations exceed benthic SCOs for bis(2-ethylhexyl)phthalate in the area of WPAH025 and for several metals in the area of WPAH061 (refer to Section 7.3.1). Based on the SPI and PV imagery, organic loading from wood debris and decaying macroalgae may be a contributing, or possibly the main, stressor at WPAH025. There is no obvious impact from wood or other organic debris at WPAH061.

Overall, from the perspective of the SPI benthic interpretative framework (Rhoads and Germano 1982, 1986), most of the WPAH Study Area exhibits a high-order infaunal successional stage community with high apparent near-surface secondary production that supports epifaunal foragers. This benthic habitat condition is evident in areas that range from no to high wood debris cover.

7.2.5 Changes in WPAH Study Area Benthic Habitat Conditions from 1998 to 2013

As detailed in the Sampling and Analysis Plan (Integral et al. 2013), 44 of the SPI/PV stations occupied in July 2013 were locations that had been sampled with the same technology in November 1998 (SAIC 1999). Images from 43 of these stations were analyzed in 2013, allowing for the direct comparison of benthic conditions at these specific locations over a 15-year timeframe.[10] The key SPI parameters evaluated for change over time at these stations include:

- Wood Debris

[10] It is important to note that the 1998 SPI images were re-analyzed by a senior Germano & Associates' image analyst in 2013 to minimize measured differences that could result from analyst bias and/or different image analysis technology or protocols. The 1998 images were re-analyzed for the following parameters: grain size, penetration depth, aRPD depth, biogenic mixing depth, methane presence, sulfur bacteria presence, boundary roughness, mud clasts, infaunal successional stage, and organism-sediment index. The semi-quantitative wood debris estimates were not re-analyzed. The reported 1998 narrative results (e.g., none, trace, sparse, moderate) were compared directly with the 2013 wood debris estimates (none, trace, medium, high). A table listing SAIC's 1998 results (SAIC 1999) and the revised Germano & Associates' results used for the 1998 baseline values in this RI/FS is provided in Appendix C.

- aRPD Depth
- Infaunal Successional Stage
- Grain Size

7.2.5.1 Change in Wood Debris

The 1998 SPI/PV survey did not characterize wood debris in the same way that the 2013 survey data was characterized (as described in Section 7.2.1). Consequently, only a qualitative comparison between wood debris observed in 1998 and 2013 can be made. Table 7.6 shows the results of that comparison for each re-occupied SPI/PV location. Overall, there appear to be no major changes in the distribution of wood debris in most surface sediments. Of the 43 stations, 34 show comparable wood debris levels, while 6 stations appear to have more wood debris in 2013 than in 1998, and 3 stations exhibit less wood debris in 2013 than 1998. The mapped distribution of the changes in wood debris content are shown in Figure 7.12. The active log rafting area just outside the Port's Boat Haven marina may be the reason for some increased wood debris in that area.

7.2.5.2 Change in aRPD Depths

There was an increase in aRPD depths at 31 of the 43 SPI/PV stations surveyed in both 1998 and 2013. Table 7.7 lists aRPD depths for each collocated station in 1998 and 2013 as well as the change in depth over time. When replicate images were analyzed at a station, the aRPD depth is the station average. Figure 7.13 shows the change in aRPD depth at each station between 1998 and 2013. Most of the inner harbor area shows an increase of over 0.5 cm in the aRPD depth (i.e., an increase in porewater irrigation depth due to bioturbation), over this time period. Figures 7.14 and 7.15 show paired 1998 and 2013 images from two SPI/PV stations that illustrate an increase in aRPD depth over time, with one location without significant wood content (WPAH054) and another location with high wood debris content (WPAH068). In contrast to these changes that are characteristic of the nearshore locations, four locations away from the shoreline and heavy wood debris areas (WPAH070, WPAH071, WPAH077, and WPAH082) show minimal change in the aRPD depth over time (e.g., WPAH070, as shown in Figure 7.16), suggesting relatively minor changes in biogenic sediment reworking over time at these locations. The other two stations with minimal aRPD change are WPAH092 and WPAH096, which are located along the Ediz Hook side of the WPAH Study Area. This is a steeper-sloped and deeper environmental setting (Figure 2.1), well away from the working harbor area.

7.2.5.3 Change in Infaunal Successional Stages

Consistent with the marine benthic successional paradigm illustrated in Figure 7.6, the generally deeper aRPD depths in the WPAH Study Area in 2013 compared with 1998 are associated with a widespread increase in higher-order succession stages (i.e., Stage 3). Table 7.7 lists the successional stages observed at each SPI/PV station occupied in both 1998 and 2013. Where two replicates were analyzed, both successional stage values are listed in the table. While 18 of the

43 stations surveyed in 1998 showed azoic (no observed biota) or Stage 1 successional stage, only 3 of the re-occupied locations lack evidence of Stage 3 infauna in 2013. These are classified as Stage 2 going to Stage 3, indicating that the infaunal successional process is occurring (Table 7.7). The relative changes in successional stage between 1998 and 2013 are shown on Figure 7.17.

The temporal change in benthic conditions over the 15-year period between SPI surveys, as evidenced by the increased aRPD depths and the widespread distribution of deep-dwelling benthic infauna, is notable and indicates significant improvement in benthic habitat quality over time at many locations in the WPAH Study Area (Table 7.7).

7.2.5.4 Change in Grain Size

Although the WPAH Study Area was dominated by predominately fine-grained sediment (i.e., silts and clays) in both 1998 and 2013, a visual comparison of images from the re-occupied SPI/PV stations reveals a shift in the surface sediment texture that points to an increase in the percentage of fines in near-surface sediments. Figure 7.18 illustrates this visual shift in texture. This increase in the apparent percentage of finer-grained silts and clays was seen in many of the re-occupied locations throughout the WPAH Study Area. The cause of this apparent change in surface sediment texture is not clear, but could have been influenced by the placement of beach nourishment materials along inner Ediz Hook from the LEKT's restoration work.

7.3 DISTRIBUTION OF INDICATOR HAZARDOUS SUBSTANCES IN SEDIMENT

7.3.1 Surface Sediment

This section presents the distributions in surface sediment of the following parameters in the RI/FS dataset:

- **Conventional Parameters.** Sediment grain size (as percent fines), TVS, TOC, black carbon, and porewater ammonia and sulfides.
- **SMS Chemicals at Concentrations Greater than the Benthic SCO/LAET in More Than One Sample within the WPAH Study Area.** These include cadmium, mercury, zinc, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, fluoranthene, and phenol.[11] Dry weight LAETs were used when the OC content in a sample was outside the SMS-recommended range for OC normalization (0.5 to 3.5 percent OC). Likely due to the presence of wood debris, approximately 40 to 50 percent of the surface sediment samples collected had an OC content greater than 3.5 percent.
- **Preliminary Bioaccumulative IHSs Proposed by Ecology (Ecology 2015a).** These include arsenic, cadmium, copper, mercury, zinc, cPAH TEQ, and Total TEQ, alpha-BHC

[11] Although 2,4-dimethylphenol and 4-methylphenol were identified by Ecology as preliminary benthic IHSs because of SCO exceedances (refer to Section 6.1.2.1), they are not included here because all SCO exceedances were observed in the Rayonier Study Area.

and selenium were also preliminary bioaccumulative IHSs proposed by Ecology, but are not described in this section. This is because alpha-BHC is not present at concentrations greater than the preliminary SCO presented by Ecology (Ecology 2015a), and selenium has too few data points to contour.

The distributions of these analytes in surface sediment in the WPAH Study Area are shown as contour maps, in Figures 7.19 through 7.36. For the purposes of analyte contouring, U-qualified results (non-detects) were assigned a value of one-half the reported U-qualified concentration unless otherwise indicated, and co-located results (e.g., field duplicates) were averaged. Except where noted on the figures, analyte contouring followed the Inverse Distance Weighting interpolation approach (NewFields 2016). For the complete RI/FS dataset of analytical results, refer to Appendix C.

7.3.1.1 Conventional Parameters

Sediment grain size (as percent fines), TVS, TOC, black carbon, and porewater ammonia and sulfides results are presented in Figures 7.19 through 7.24.

The percentage of fine-grained sediment (i.e., silt and clay) in surface sediment samples ranged from 2.9 to 91 percent (Figure 7.19). With the exception of areas near the shoreline, fine-grained sediments (i.e., greater than 50 percent fines) generally dominated the western portion of the WPAH Study Area, and decreased eastward, indicating a strongly depositional environment.

TVS and TOC were found to be significantly negatively correlated with larval development in the bioassay data (Section 7.1), although the correlation coefficients were low (Table 7.3). TVS ranged from 1.6 to 55 percent and generally decreased from the west to east across the WPAH Study Area (Figure 7.20). The greatest concentrations (greater than 25 percent) were found in the western portion of the WPAH Study Area, including: in the lagoon, outside the mouth of the lagoon, and in the inner harbor and inner Ediz Hook areas. These areas have a history of log rafting.

TOC content in the WPAH Study Area showed a pattern generally similar to TVS (Figure 7.21). Overall, TOC content ranged from 0.31 to 24 percent. Areas of TOC content greater than 4 percent were found primarily in the northwestern portion of the WPAH Study Area, and in limited areas near the southern shoreline. Samples with TOC content greater than 10 percent were limited to isolated locations in the inner Ediz Hook area, within the lagoon, and near the mouth of the lagoon.

Detected concentrations of black carbon ranged from 0.01 to 2.3 percent (Figure 7.22). The greatest concentration was found inside the lagoon, and nearly all concentrations greater than 0.5 percent were limited to the lagoon and inner Ediz Hook areas.

Ammonia concentrations detected in sediment porewater ranged from 1.5 to 30 mg/L, although most locations showed concentrations of 13 mg/L or less (Figure 7.23). Samples with concentrations greater than 13 mg/L were limited to one location in the lagoon and a few locations near the southern shoreline.

Detected porewater sulfides concentrations ranged from 0.02 to 15 mg/L. The greatest concentrations (greater than 5.0 mg/L) occurred in the lagoon, in the inner Ediz Hook area, outside the mouth of the lagoon, and in the inner harbor area along the southern shoreline (Figure 7.24).

7.3.1.2 Metals

Cadmium, mercury, and zinc are retained as preliminary benthic IHSs based on both exceedances of SMS SCOs and negative correlation with the bioassay toxicity results (although the correlation coefficients were low [Table 7.3]) and are also included as preliminary bioaccumulative IHSs (Section 6.1). Arsenic showed only one exceedance of SMS criteria, but is a preliminary bioaccumulative IHS. These metals were detected in most or all (depending on the metal) of the surface sediment samples that were analyzed for them. The concentration distributions are depicted in Figures 7.25 through 7.28.

Detected arsenic concentrations were up to 69 mg/kg. As shown in Figure 7.25, concentrations exceeding the 12-mg/kg bioaccumulative SCO and the 13.9-mg/kg bioaccumulative CSL are limited to the westernmost portion of the WPAH Study Area. One occurrence of a concentration greater than the 57-mg/kg benthic SCO (69 mg/kg) is located in the inner harbor area; the color-coding for this concentration is obscured by the sample symbol on Figure 7.25.

Detected cadmium concentrations ranged up to 8.1 mg/kg. Concentrations exceeding the 0.82 mg/kg human health SCO occur primarily in the western third of the WPAH Study Area, in the lagoon, and in limited areas along the southern shoreline. Occurrences of cadmium exceeding the 2.4 mg/kg human health CSL, the 5.1-mg/kg benthic SCO, and the 6.7 mg/kg benthic CSL are limited to an area extending southward from the neck of Ediz Hook, and within the central portion of the lagoon (Figure 7.26).

Copper concentrations are shown in Figure 7.27. Detected concentrations range up to 95 mg/kg, much less than the 390-mg/kg benthic SCO. Concentrations greater than the 35-mg/kg human health SCO and CSL were found in the western half of the WPAH Study Area, in the lagoon, and in limited areas along the southern shoreline.

Mercury was detected at concentrations ranging up to 3.5 mg/kg. Similar to cadmium, mercury concentrations greater than the human health SCO (0.11 mg/kg) and CSL (0.13 mg/kg) occur throughout most of the western half of the WPAH Study Area, in the lagoon, and in limited areas off the southern shoreline (Figure 7.28). Concentrations exceed the 0.41 mg/kg benthic SCO in the inner harbor and lagoon. The concentrations exceeding the 0.59 mg/kg benthic CSL are limited to the inner harbor area.

Zinc was detected at concentrations ranging up to 1,700 mg/kg. Similar to cadmium, zinc concentrations greater than the 77-mg/kg human health SCO and CSL occur throughout a large portion of the WPAH Study Area. Concentrations greater than the 410-mg/kg benthic SCO and 960-mg/kg benthic CSL are located in an area extending southward from the neck of Ediz Hook; however, unlike cadmium, zinc concentrations in the lagoon do not exceed the benthic SCO or CSL (Figure 7.29).

7.3.1.3 Organic Compounds

Benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, fluoranthene, and phenol are benthic community preliminary IHSs present in the WPAH Study Area at concentrations greater than SCO/LAETs in more than one sample. Concentrations of these preliminary benthic IHSs, which are evaluated on a point-by-point basis, are shown in Figures 7.30 through 7.34. Concentration contours in these figures are based on OC-normalized values, where applicable, with dry weight values shown with different symbols for those samples with TOC concentrations outside the SMS-recommended 0.5- to 3.5-percent range. cPAHs TEQ, and Total TEQ are preliminary bioaccumulative IHSs that are evaluated on an area-wide basis. Interpolated contoured concentrations of these constituents are shown in Figures 7.35 and 7.36.

Benzo(g,h,i)perylene was found to be significantly negatively correlated with larval survival in bioassay tests, although the correlation coefficients were low (Table 7.3; Section 7.1). Concentrations are shown in Figure 7.30, and range up to 34 mg/kg-OC. Concentrations greater than the 31-mg/kg-OC benthic SCO are limited to a very small area near the southeastern shoreline, next to the Black Ball Ferry pier. Note that most of the SCO exceedance area on Figure 7.30 is hidden underneath the dots depicting OC-normalized sample locations (Station IDs: PA_STP04CSO-007 and PA_STP10-02). All dry weight concentrations, ranging up to 210 µg/kg, are less than the-670 µg/kg dry weight LAET.

Concentrations of bis(2-ethylhexyl)phthalate range up to an estimated 670 mg/kg-OC, exceeding the 47-mg/kg-OC benthic SCO in a sample along the central shoreline, and exceeding the 78-mg/kg-OC benthic CSL along the southeastern shoreline (Figure 7.31). Dry weight concentrations in samples with TOC values outside the OC normalization range vary up to an estimated 210 µg/kg, much less than the 1,300 µg/kg dry weight LAET.

Butyl benzyl phthalate concentrations are shown in Figure 7.32. This chemical was not detected in samples throughout much of the WPAH Study Area. Among OC-normalized concentrations, only the 13 mg/kg-OC U-qualified value in one sample along the southeastern shoreline exceeded the 4.9-mg/kg-OC benthic SCO. Consequently, the color contouring for this exceedance is difficult to see beneath the sample symbology. Dry weight concentrations in non-OC-normalized samples range up to 670 µg/kg and exceed the 63-µg/kg dry weight benthic LAET at one location in the lagoon and at two locations along the southwestern shoreline.

Concentrations of fluoranthene in surface sediment range up to 250 mg/kg-OC (Figure 7.33). Concentrations greater than the 160-mg/kg-OC benthic SCO occur in one sample along the southeastern shoreline. Concentrations in samples with TOC concentrations outside the OC normalization range vary up to 2,600 µg/kg; those exceeding the 2,500-µg/kg dry weight 2LAET or 1,700-µg/kg dry weight benthic LAET occur at two locations along the central downtown shoreline (Figure 7.33).

As shown in Figure 7.34, phenol concentrations range up to 740 µg/kg and are much less than the 420-µg/kg benthic SCO throughout most of the WPAH Study Area. Concentrations greater than the SCO are limited to small areas near the Port Angeles Boat Haven.

CPAHs are a preliminary bioaccumulative IHS on a cPAH TEQ basis. Per MTCA, cPAH TEQ values were calculated using benzo(a)pyrene TEFs for cPAHs provided by the California Environmental Protection Agency (Cal-EPA 2005). In cases where constituent cPAH concentrations were not detected, a value of ½ of the reported value for U-qualified (non-detect) results was used.[12] The resulting cPAH TEQ values are mapped in Figure 7.35. Values range up to an estimated 1,400 µg/kg and exceed the 16-µg/kg human health bioaccumulative SCO in all but a few locations (Figure 7.35). As shown in this figure, the greatest cPAH TEQ values are generally found closest to the western and southern shorelines, where concentrations greater than the 64-µg/kg human health CSL occur.

Dioxins/furans and dioxin-like PCB congeners are also a preliminary bioaccumulative IHS on a TEQ basis. Total TEQ values (the sum of dioxin/furan TEQ and PCB congener TEQ values) are mapped in Figure 7.36. Per MTCA, Total TEQ values were calculated using TEFs for dioxin/furan congeners and dioxin-like PCB congeners provided in the 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds (Van den Berg et al. 2006). Dioxin/furan TEQ values used half the reported value non-detect results, while PCB congener TEQ calculations used zero for non-detect results. For locations with dioxin/furan results but no available PCB congener results, PCB congener values were assumed to be equal to the regional background value of 0.21 nanogram per kilogram (ng/kg). As shown in Figure 7.36, the greatest total TEQ concentrations (up to 180 ng/kg) are present in the westernmost areas of the WPAH Study Area and generally decrease to the east. Concentrations exceed the 2.3-ng/kg human health SCO and the 5.2-ng/kg human health CSL throughout most of the Harbor, with the exceptions of isolated locations along the southeastern shoreline.

7.3.2 Subsurface Sediment

Available subsurface sediment data (i.e., collected from intervals beginning greater than 10 cm below the mudline) within the WPAH Study Area are more limited than surface data.

12 Note that the basis of reported non-detect values may not be clear in some historical datasets available through Ecology's EIM database.

In addition to data from two cores collected in 2014 as part of the RI/FS investigation (Study ID WPAH13), the data from the following studies were downloaded from Ecology's EIM database:

- Ecology's Port Angeles Harbor Sediment Characterization Study (Study ID PASED08, described in Section 4.1.2)
- Nippon Environmental Baseline Investigation, DNR Lease 22-077766 (Study ID PORT ANGELES DNR08, described in Section 4.1.3)[13]

Table 7.8 presents the subsurface core station samples and analytical results for the benthic and preliminary bioaccumulative IHSs, evaluated in comparison to SCOs and CSLs. Where available, surface data from these locations are provided in Table 7.8 for comparison to subsurface results. The locations of subsurface exceedances of benthic or bioaccumulative criteria are shown in Figure 7.37. The locations of exceedances and qualitative observations of concentration trends are summarized in the following bullets:

- The spatial pattern of subsurface chemistry is not consistent among chemicals, and the depth of contamination varies geographically, suggesting various historical sources, releases, and transport.
- Stations farthest from the shoreline that do not exceed benthic or bioaccumulative criteria in the subsurface (Stations BL08, FT06, IE16, and KP07) tend to have maximum concentrations in the surface (0 to 10 cm) layer, possibly suggesting low sedimentation rates at these locations (Table 7.8). As discussed in Section 2.1.5, the average net sedimentation rate in the western portion of Port Angeles Harbor is 0.17 ±0.03 cm per year, equivalent to roughly 9 cm of recent sediment deposition over the last 50 years.
- There are no exceedances of SCO chemical criteria for arsenic, benzo(g,h,i)perylene, fluoranthene, or phenol in the subsurface sample results (Table 7.8).
- Subsurface cadmium concentrations were detected up to 12 mg/kg (Table 7.8). Concentrations exceed the 0.82-mg/kg bioaccumulative SCO in nearshore areas in the WPAH Study Area (Stations BL02, FT04, IE01, IE05, IE09, IE12, KP02, and MA02), and in the lagoon (Station LA02; Figure 7.37). Subsurface concentrations exceed the 2.4-mg/kg bioaccumulative CSL at two nearshore locations (Stations IH06 and MA02). Subsurface concentrations exceed both the benthic and bioaccumulative CSLs at one location in the inner harbor (Station IH02) and at one location in the lagoon (Station NPI-L2; Table 7.8 and Figure 7.37).
- Copper concentrations in the subsurface samples were detected up to 130 mg/kg (Table 7.8). Copper exceeds the 35-mg/kg bioaccumulative SCO and CSL in the subsurface along the southern shoreline and the inner harbor (Stations BL02,

13 One station from this study, Station NPI-L2 LAGOON, SEDIMENT CORE, is excluded because it appears to be a reporting error; all sample IDs and results reported for this station are the same as those for Station NPI-L2 (Lagoon) and only the location coordinates differ.

FT04, IE05, IE09, IE12, IE14, IH02, IH06, KP02, KP03, and MA02), and in the lagoon (Station NPI-L2; Figure 7.37).

- Subsurface mercury concentrations were detected up to 8.9 mg/kg (Table 7.8), and exceed SCO chemical criteria in the subsurface in nearly all of the locations along the shoreline throughout the WPAH Study Area, and at one location in the lagoon (Figure 7.37). Subsurface concentrations exceeding only the 0.11-mg/kg bioaccumulative SCO occur in scattered areas of the Harbor (Stations FT04, IE14, and NPI-PA9). Concentrations exceeding the 0.13-mg/kg bioaccumulative CSL occur in areas along the Ediz Hook, inner harbor, and southeastern downtown shorelines (Stations BL02, FT04, IE01, IE05, IE09, IE12, IH02, IH06, KP02, KP03, and MA02), and in the lagoon (Station NPI-L2). Subsurface mercury exceeds the 0.41-mg/kg benthic SCO at IH06 and MA02, and the 0.59-mg/kg benthic CSL at Stations IE05, IH02, and NPI-L2 (Figure 7.37). Concentrations are greater in the subsurface than in the surface at several locations, primarily along the southern shoreline (Table 7.8), which suggests sediment recovery is occurring in these areas.

- Zinc concentrations in the subsurface were detected up to 2,000 mg/kg (Table 7.8). Concentrations exceed the 77-mg/kg human health SCO/CSL in nearly all the locations along the shoreline (Stations BL02, FT04, IE01, IE05, IE09, IE12, IE14, IH02, IH06, KP02, KP03, MA02, and NPI-PA4) and in the lagoon (Station NPI-L2; Figure 7.37). Lagoon Station NPI-L2 contains a zinc concentration exceeding the 410-mg/kg benthic SCO, and two stations in the inner harbor (Stations NPI-PA4 and IH02) contain subsurface zinc concentrations exceeding the 960-mg/kg benthic CSL. Overall, vertical patterns in zinc concentrations vary at core locations in the WPAH Study Area, although, as with surface concentrations (Figure 7.29), the greatest subsurface concentrations occur in the inner harbor.

- Bis(2-ethylhexyl)phthalate exceedances of the benthic criteria in the subsurface are limited to one station (Station IH06), where the concentration (an estimated 2,800 µg/kg) exceeds the 1,900-µg/kg dry weight 2LAET (Table 7.8).

- The estimated butyl benzyl phthalate concentration of 91 µg/kg at Station IE09 is the only subsurface exceedance of the benthic criteria for butyl benzyl phthalate (Table 7.8). This concentration exceeds that chemical's 63-µg/kg dry weight LAET.

- Subsurface cPAH TEQ concentrations range up to an estimated 250 µg/kg (Table 7.8), exceeding the 16-µg/kg human health SCO along Ediz Hook (Stations IE01, IE09, IE12, and IE14), and exceeding the 64-µg/kg human health CSL in several nearshore areas of the WPAH Study Area (Stations BL02, FT04, IE05, IH02, IH06, KP02, KP03, and MA02) and in the lagoon (Station NPI-L2; Figure 7.37). Concentrations in the subsurface are less than concentrations in the surface at the majority of locations (Table 7.8), suggesting one or more ongoing sources.

- Available data show Total TEQ concentrations in the subsurface samples ranging up to 120 ng/kg (Table 7.8). Concentrations exceed the 2.3-ng/kg human health SCO in areas of the lagoon and nearshore of the inner harbor (Stations LA02 and NPI-PA9) and exceed the 5.2-ng/kg human health CSL along Ediz Hook and areas of the inner harbor and southeastern shoreline (Stations BL02, IE01, IE05, IE09, IE12, IE14, IH02, IH06, KP02, KP03, and MA02), and lagoon (Station NPI-L2; Figure 7.37). Total TEQ concentrations are greater in the subsurface than in the surface layer in more than half the cores for which there are data (Table 7.8), including several in the inner harbor and inner Ediz Hook areas, suggesting sediment recovery is occurring.

7.4 BIOACCUMULATION TESTING AND POREWATER SAMPLING

7.4.1 Bioaccumulation Testing

As discussed in Sections 5.1.3 and 5.1.4, bioaccumulation testing and porewater sampling were conducted to characterize site-specific bioavailability of dioxins/furans and PCBs[14] and were also used as a weight-of-evidence evaluation to identify sediment areas within the WPAH Study Area that contribute disproportionately to bioaccumulation (Integral et al. 2013). The bioaccumulation and porewater data for dioxin/furan TEQ are summarized on Figure 7.38, and reveal that different areas of the Harbor contribute disproportionately to potential porewater exposures of Total TEQ (as represented by the dioxin/furan TEQ bioaccumulation and porewater data).

One metric that has proven useful in the evaluation of site-specific bioavailability is the BSAF, calculated as the ratio of a chemical concentration in tissue to the concentration in sediment. Because of their hydrophobic characteristics, nonpolar organic compounds such as dioxins/furans and PCBs tend to preferentially accumulate in lipid-rich tissues, and also associate more strongly with the TOC fraction of the sediment. Consequently, when calculating the BSAF, chemical concentrations in tissue and sediment are standardized to the lipid content and the TOC content of tissue and sediment, respectively (Exponent 1998, NewFields 2013). Figure 7.39 presents a summary of the dioxin/furan TEQ bioaccumulation data normalized in this fashion, illustrating the broad correlation between measured sediment and tissue concentrations in the dioxin/furan bioaccumulation tests.

Simple linear regression models of paired sediment and tissue concentrations are often used to estimate the site-specific BSAF (Exponent 1998). The site-specific linear regression relationship for dioxin/furan TEQ is summarized in Figure 7.40, and describe the site-specific relationship between sediment and tissue concentrations:

- Dioxin/furan TEQ BSAF = 0.25

At two locations, one in the inner harbor and one in the lagoon, bioaccumulation exposures were conducted a second time after AC was mixed into the sediment prior to organism exposure. The goal of this treatability testing was to evaluate whether AC addition affected the uptake of dioxins/furans into the test organisms. Applying AC amendments to a representative sample of

[14] Data described in this section are from WPAH Group evaluations performed prior to Ecology's designation of Total TEQ as the combined IHS for dioxins/furans and PCBs.

subtidal lagoon sediments with higher existing black carbon/soot levels did not markedly reduce the already relatively low bioavailability of these sediments (Integral et al. 2014). However, applying AC to a representative sample of subtidal inner harbor sediments with higher existing bioavailability was effective (e.g., 67-percent reduction in porewater dioxin/furan [and also Total TEQ] concentrations; Integral et al. 2014), suggesting that application of this remedial technology could reduce bioaccumulation within certain areas of the Harbor.

7.4.2 Solid-Phase Microextraction Testing

SPME fibers exposed to porewater during the 45-day bioaccumulation exposures were analyzed for dioxin/furan and PCB congeners. These data were then used to estimate porewater concentrations following the procedure described in the Data Report (Integral et al. 2014). Consistent with the bioaccumulation test data discussed in Section 7.4.1, different areas of the WPAH Study Area contribute disproportionately to potential porewater exposures of dioxin/furan TEQ (refer to Figure 7.38).

Section 7.0:
Nature and Extent of Preliminary Indicator Hazardous Substances and Wood Debris

Tables

Table 7.1
Bioassay Data Used in the WPAH Study Area for the RI/FS

Survey	Ecology EIM Study ID	Sampling Date	Sample Depth	Number of Bioassay Samples	Amphipod Survival	Juvenile Polychaete Growth	Larval Development
Port Angeles NPDES Sediment Analysis	PA_STP04	2003–2004	0–2 cm	2	X	X	X
Port Angeles Harbor Sediment Investigation	PASED08	2008	0–10 cm	36	X	X	X[1]
City of Port Angeles 2010 NPDES Permit WA-0023973 Sediment Characterization	PA_STP10	2010	0–10 cm	2	X	X	X
K-Ply Site RI/FS Investigation	AODE9546	2013	0–10 cm	3	X	X	X[2]
Western Port Angeles Harbor RI/FS Investigation	WPAH2013	2013	0–10 cm	21	X	X	X[2]
Western Port Angeles Harbor RI/FS Investigation	WPAH2013	2013	0–10 cm	26[1]	NT	NT	X[2]

Notes:

1 As noted by Ecology (Ecology 2012), performance of the larval bioassay test across the Harbor was highly inconsistent, with widespread failures in areas with an absence of SMS chemical exceedances and wood debris, as well as in samples collected from reference areas. Therefore, 26 stations sampled by Ecology in 2012 with larval development failures were retested during the Western Port Angeles Harbor RI/FS investigation using the resuspension protocol (Kendall et al. 2012). The resuspension protocol address the potential for entrainment of larvae by flocculent particulate material in tested sediments, which may have resulted in false positive larval test results.

2 The larval development test was conducted using resuspension protocol (Kendall et al. 2012).

Abbreviations:

cm Centimeters
Ecology Washington State Department of Ecology
EIM Environmental Information Management
NT Not tested
RI/FS Remedial Investigation/Feasibility Study
SMS Sediment Management Standards

Table 7.2
SMS Screening Results for Bioassay Samples in the WPAH Study Area

Ecology EIM Study ID	Station ID	Historical Larval Retest Station, if Applicable[1]	Amphipod Survival	Polychaete Growth	Larval Development
WPAH2013	WPAH001	NA	Pass	Pass	Pass
	WPAH002	NA	Pass	Pass	Pass
	WPAH003	NA	Pass	Pass	**Fails SCO**
	WPAH004	NA	Pass	Pass	**Fails SCO**
	WPAH005	NA	Pass	Pass	Pass
	WPAH006	NA	Pass	Pass	**Fails SCO**
	WPAH007	NA	Pass	Pass	Pass
	WPAH008	NA	Pass	Pass	Pass
	WPAH009	NA	Pass	Pass	**Fails SCO**
	WPAH010	NA	Pass	Pass	**Fails SCO**
	WPAH011	NA	Pass	Pass	Pass
	WPAH012	NA	Pass	Pass	Pass
	WPAH013	NA	Pass	Pass	Pass
	WPAH014	NA	Pass	Pass	Pass
	WPAH015	NA	Pass	Pass	Pass
	WPAH016	NA	Pass	Pass	Pass
	WPAH017	NA	Pass	Pass	Pass
	WPAH018	NA	Pass	Pass	Pass
	WPAH019	NA	Pass	Pass	**Fails SCO**
	WPAH020	NA	Pass	Pass	Pass
	WPAH021	LA02A UV	NT	NT	Pass
	WPAH022	IH02A	NT	NT	**Fails SCO**
	WPAH023	IH03A	NT	NT	Pass
	WPAH024	IH06A	NT	NT	**Fails CSL**
	WPAH025	MA01A	NT	NT	Pass
	WPAH026	IE09A	NT	NT	**Fails SCO**
	WPAH027	IE07A UV	NT	NT	Pass
	WPAH028	IE06A	NT	NT	**Fails SCO**
	WPAH029	IE15A	NT	NT	Pass
	WPAH030	MA06A	NT	NT	Pass
	WPAH031	MA05A	NT	NT	Pass
	WPAH032	MA02A	NT	NT	Pass
	WPAH033	BL01A	NT	NT	Pass
	WPAH034	BL03A	NT	NT	Pass
	WPAH035	BL04A	NT	NT	Pass
	WPAH036	KP01A	NT	NT	Pass
	WPAH037	KP02A	NT	NT	Pass
	WPAH038	NA	NT	NT	Pass
	WPAH039	IE04A	NT	NT	Pass
	WPAH040	IE14A	NT	NT	Pass
	WPAH041	BL06A	NT	NT	Pass
	WPAH042	KP05A	NT	NT	Pass
	WPAH043	IE03A	NT	NT	Pass

Table 7.2
SMS Screening Results for Bioassay Samples in the WPAH Study Area

Ecology EIM Study ID	Station ID	Historical Larval Retest Station, if Applicable[1]	Amphipod Survival	Polychaete Growth	Larval Development
WPAH2013 (cont.)	WPAH044	BA01A	NT	NT	Pass
	WPAH045	KP06A	NT	NT	Pass
	WPAH046	FP01A	NT	NT	Pass
	WPAH047	EH02A	NT	NT	Pass
PASED08	EH02A	NA	Pass	Pass	Replaced[2]
	FP01A	NA	Pass	Pass	Replaced[2]
	BA01A	NA	Pass	Pass	Replaced[2]
	IE03A	NA	Pass	Pass	Replaced[2]
	IE04A	NA	Pass	Pass	Replaced[2]
	IE06A	NA	Pass	Pass	Replaced[2]
	IE07A UV	NA	Pass	Pass	Replaced[2]
	IE09A	NA	Pass	Pass	Replaced[2]
	IE14A	NA	Pass	Pass	Replaced[2]
	IE15A	NA	Pass	Pass	Replaced[2]
	LA02A UV	NA	Pass	Pass	Replaced[2]
	IH01A	NA	Pass	Pass	Pass
	IH02A	NA	Pass	Pass	Replaced[2]
	IH03A	NA	Pass	Pass	Replaced[2]
	IH05A	NA	Pass	Pass	Pass
	IH06A	NA	Pass	Pass	Replaced[2]
	MA01A	NA	Pass	Pass	Replaced[2]
	MA02A	NA	Pass	**Fails SCO**	Replaced[2]
	MA05A	NA	Pass	Pass	Replaced[2]
	MA06A	NA	Pass	Pass	Replaced[2]
	BL01A	NA	Pass	Pass	Replaced[2]
	BL02A	NA	Pass	Pass	Pass
	BL03A	NA	Pass	Pass	Replaced[2]
	BL04A	NA	Pass	Pass	Replaced[2]
	BL06A	NA	Pass	Pass	Replaced[2]
	KP01A	NA	Pass	Pass	Replaced[2]
	KP02A	NA	Pass	Pass	Replaced[2]
	KP03A	NA	Pass	Pass	Pass
	KP05A	NA	Pass	Pass	Replaced[2]
	KP06A	NA	Pass	Pass	Replaced[2]
	FT01A	NA	Pass	Pass	Pass
	FT04A	NA	Pass	Pass	Pass
	FT06A	NA	Pass	Pass	Pass
	FT11A	NA	Pass	Pass	Pass
	RL01A UV	NA	Pass	Pass	Pass
	RL02A UV	NA	Pass	Pass	Pass

Table 7.2
SMS Screening Results for Bioassay Samples in the WPAH Study Area

Ecology EIM Study ID	Station ID	Historical Larval Retest Station, if Applicable[1]	Amphipod Survival	Polychaete Growth	Larval Development
PA_STP04	PA_STP04CSO-007	NA	Pass	Pass	Pass
	PA_STP04CSO-008	NA	Pass	Pass	Pass
PA_STP10	PA_STP10-01	NA	Pass	Pass	Pass
	PA_STP10-02	NA	Pass	Pass	Pass
AODE9546[3]	KSS-1	NA	Pass	Pass	Pass
	KSS-2	NA	Pass	Pass	Pass
	KSS-3	NA	Pass	Pass	Pass

Notes:
1 Per the Sampling and Analysis Plan (Integral et al. 2013), the larval bioassay at 27 stations sampled by Ecology in 2008 (Ecology 2012) was re-run using the bivalve larval test with the resuspension protocol (Kendall et al. 2012).
2 The larval data collected in 2008 (Ecology 2012) were replaced by larval data collected in 2013 for this RI/FS (Integral et al. 2013).
3 Bioassay results provided in Floyd|Snider 2014.

Abbreviations:
CSL Cleanup screening level
Ecology Washington State Department of Ecology
EIM Environmental Information Management
NA Not applicable
NT Not tested in 2013; the amphipod and polychaete data collected at this station in 2008 are used in the RI/FS
RI/FS Remedial Investigation/Feasibility Study
SCO Sediment cleanup objective
SMS Sediment Management Standards

Table 7.3
Kendall's Tau-b Correlations between Larval Development Test Response and Chemical Parameters

		Mean Normal Survivorship (%)	bis(2-Ethylhexyl)phthalate (mg/kg)	Butyl Benzyl Phthalate (mg/kg)	Phenol (mg/kg)	Benzo(g,h,i)-perylene (mg/kg)	Fluoranthene (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	TOC (%)	TVS (%)	Fines (%)	Clay (%)	Ammonia-N (mg/L)	Sulfide (mg/L)
Mean Normal Survivorship (%)	Correlation Coefficient	1.000	0.014	-0.218	0.033	-0.314**	-0.199	-0.395**	-0.339**	-0.340**	-0.371**	-0.363**	0.084	-0.014	0.094	-0.191
	Sig. level (2-tailed)		0.903	0.070	0.795	0.006	0.075	0.000	0.001	0.002	0.000	0.000	0.404	0.891	0.350	0.065
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47
Bis(2-Ethylhexyl)phthalate (mg/kg)	Correlation Coefficient	0.014	1.000	0.396**	0.145	0.331**	0.337**	0.146	-0.007	0.064	0.108	0.084	0.014	0.055	0.229*	0.204
	Sig. Level (2-tailed)	0.903		0.001	0.259	0.004	0.003	0.206	0.952	0.578	0.343	0.459	0.903	0.627	0.044	0.081
	N	39	39	39	32	39	39	38	39	38	39	39	39	39	39	39
Butyl Benzyl Phthalate (mg/kg)	Correlation Coefficient	-0.218	0.396**	1.000	0.257	0.224	0.200	0.375**	0.181	0.267*	0.400**	0.364**	-0.002	0.190	0.055	0.271*
	Sig. Level (2-tailed)	0.070	0.001		0.063	0.068	0.098	0.002	0.134	0.029	0.001	0.002	0.990	0.115	0.648	0.028
	N	39	39	39	32	39	39	38	39	38	39	39	39	39	39	39
Phenol (mg/kg)	Correlation Coefficient	0.033	0.145	0.257	1.000	0.096	0.189	0.170	0.086	0.166	0.131	0.159	-0.016	0.016	-0.016	0.002
	Sig. Level (2-tailed)	0.795	0.259	0.063		0.459	0.134	0.184	0.495	0.195	0.298	0.205	0.897	0.897	0.897	0.987
	N	32	32	32	32	32	32	31	32	31	32	32	32	32	32	32
Benzo(g,h,i) perylene (mg/kg)	Correlation Coefficient	-0.314**	0.331**	0.224	0.096	1.000	0.648**	0.288*	0.167	0.177	0.208	0.213	-0.183	-0.100	0.308**	0.191
	Sig. Level (2-tailed)	0.006	0.004	0.068	0.459		0.000	0.013	0.144	0.128	0.068	0.062	0.108	0.380	0.007	0.104
	N	39	39	39	32	39	39	38	39	38	39	39	39	39	39	39
Fluoranthene (mg/kg)	Correlation Coefficient	-0.199	0.337**	0.200	0.189	0.648**	1.000	0.146	0.029	0.049	0.159	0.149	-0.243*	-0.102	0.254*	0.078
	Sig. Level (2-tailed)	0.075	0.003	0.098	0.134	0.000		0.199	0.799	0.669	0.157	0.183	0.030	0.364	0.024	0.500
	N	39	39	39	32	39	39	38	39	38	39	39	39	39	39	39
Cadmium (mg/kg)	Correlation Coefficient	-0.395**	0.146	0.375**	0.170	0.288*	0.146	1.000	0.714**	0.759**	0.653**	0.637**	0.101	0.376**	-0.128	0.174
	Sig. Level (2-tailed)	0.000	0.206	0.002	0.184	0.013	0.199		0.000	0.000	0.000	0.000	0.346	0.000	0.233	0.115
	N	42	38	38	31	38	38	42	42	42	42	42	42	42	42	42
Mercury (mg/kg)	Correlation Coefficient	-0.339**	-0.007	0.181	0.086	0.167	0.029	0.714**	1.000	0.821**	0.448**	0.415**	0.215*	0.444**	-0.113	0.064
	Sig. Level (2-tailed)	0.001	0.952	0.134	0.495	0.144	0.799	0.000		0.000	0.000	0.000	0.038	0.000	0.277	0.546
	N	45	39	39	32	39	39	42	45	42	45	45	45	45	45	45
Zinc (mg/kg)	Correlation Coefficient	-0.340**	0.064	0.267*	0.166	0.177	0.049	0.759**	0.821**	1.000	0.482**	0.475**	0.235*	0.477**	-0.175	0.050
	Sig. Level (2-tailed)	0.002	0.578	0.029	0.195	0.128	0.669	0.000	0.000		0.000	0.000	0.029	0.000	0.104	0.653
	N	42	38	38	31	38	38	42	42	42	42	42	42	42	42	42
TOC (%)	Correlation Coefficient	-0.371**	0.108	0.400**	0.131	0.208	0.159	0.653**	0.448**	0.482**	1.000	0.853**	-0.106	0.184	-0.168	0.401**
	Sig. Level (2-tailed)	0.000	0.343	0.001	0.298	0.068	0.157	0.000	0.000	0.000		0.000	0.292	0.068	0.095	0.000
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47
TVS (%)	Correlation Coefficient	-0.363**	0.084	0.364**	0.159	0.213	0.149	0.637**	0.415**	0.475**	0.853**	1.000	-0.122	0.176	-0.138	0.414**
	Sig. Level (2-tailed)	0.000	0.459	0.002	0.205	0.062	0.183	0.000	0.000	0.000	0.000		0.226	0.081	0.172	0.000
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47
Fines (%)	Correlation Coefficient	0.084	0.014	-0.002	-0.016	-0.183	-0.243*	0.101	0.215*	0.235*	-0.106	-0.122	1.000	0.576**	-0.148	-0.152
	Sig. Level (2-tailed)	0.404	0.903	0.990	0.897	0.108	0.030	0.346	0.038	0.029	0.292	0.226		0.000	0.142	0.141
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47
Clay (%)	Correlation Coefficient	-0.014	0.055	0.190	0.016	-0.100	-0.102	0.376**	0.444**	0.477**	0.184	0.176	0.576**	1.000	-0.165	-0.129
	Sig. Level (2-tailed)	0.891	0.627	0.115	0.897	0.380	0.364	0.000	0.000	0.000	0.068	0.081	0.000		0.103	0.211
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47
Ammonia-N (mg/L)	Correlation Coefficient	0.094	0.229*	0.055	-0.016	0.308**	0.254*	-0.128	-0.113	-0.175	-0.168	-0.138	-0.148	-0.165	1.000	0.027
	Sig. Level (2-tailed)	0.350	0.044	0.648	0.897	0.007	0.024	0.233	0.277	0.104	0.095	0.172	0.142	0.103		0.795
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47
Sulfide (mg/L)	Correlation Coefficient	-0.191	0.204	0.271*	0.002	0.191	0.078	0.174	0.064	0.050	0.401**	0.414**	-0.152	-0.129	0.027	1.000
	Sig. Level (2-tailed)	0.065	0.081	0.028	0.987	0.104	0.500	0.115	0.546	0.653	0.000	0.000	0.141	0.211	0.795	
	N	47	39	39	32	39	39	42	45	42	47	47	47	47	47	47

Notes:
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Bold Significantly correlated.

Abbreviations:
mg/kg Milligram per kilogram
mg/L Milligram per liter
N Sample size
TOC Total organic carbon
TVS Total volatile solids

Table 7.4
Comparison of Sediment Grab Samples and SPI/PV Image-Derived Wood Debris Estimates from 2013

2013 Station ID	Wood Debris Field Estimates In Grab Sample (%)[1]	Wood Debris Estimates in Grab Sample Converted to SPI/PV Categories[1]	Wood Debris Estimates in SPI Image	Wood Debris Estimates in PV Image
WPAH003	80	High	High	None
WPAH004	70	High	High	Low
WPAH005	5	Low	Trace	Low
WPAH006	5	Low	High	Low
WPAH007	< 5	Trace	High	Low
WPAH008	40	Med	Med, High[2]	Med
WPAH009	< 5	Trace	Trace, Med	Low, Med[2]
WPAH010	15	Low	Med	Med
WPAH011	< 5	Trace	Low	Med
WPAH012	30	Med	Low, High[2]	Med
WPAH013	< 5	Trace	None	Med
WPAH014	Trace	Trace	Low	Med
WPAH015	<5	Trace	Trace	Low
WPAH016	Trace	Trace	Trace	Med
WPAH017	0	None	None	Med
WPAH018	30	Med	Low	Low
WPAH019	50	Med	High	Low
WPAH020	70	High	Med	None
WPAH022	< 5	Trace	Low, Med[2]	Med
WPAH023	80	High	High	None
WPAH024	0	None	None	None
WPAH025	0	None	None	Low
WPAH026	10	Low	None	Low
WPAH027	50	Med	High	None, Low[2]
WPAH028	50	Med	High	None
WPAH030	< 5	Trace	None	Med
WPAH031	< 5	Trace	None	Med
WPAH032	20	Low	Med	Med
WPAH033	10	Low	Trace	Low
WPAH034	10	Low	Trace	Low
WPAH035	5	Low	None	Med
WPAH036	< 5	Trace	None	Med
WPAH037	< 5	Trace	Trace	High
WPAH038	0	None	None	Med
WPAH039	20	Low	None	Med
WPAH042	0	None	None	Med
WPAH043	40	Med	High	Med
WPAH045	< 5	Trace	None	Med
WPAH046	0	None	Med, Trace[2]	Med
WPAH047	< 3	Trace	None	Med

Notes:

None	0
Trace	< 5%
Low	5–20%
Med	21–50%
High	> 50%

1 The second column in this table represents the visual estimates of wood debris recorded in the field for the sediment grab samples. These percentages were converted to the SPI/PV categories (None, Trace, Low, Med, and High) and are reported in column three of the table to allow direct comparison of the rankings for grab sample, SPI, and PV wood debris estimates.

2 Two replicate images were analyzed at a subset of stations.

Abbreviations:

PV Plan View

SPI Sediment Profile Imaging

Table 7.5
Measured Depths of Buried Pulp Layers Observed in 2013 SPI Images

2013 Station	SPI Replicate Image Where Buried Pulp Observed	Depth of Sediment Above Buried Pulp (cm)
WPAH009	D	5.6
WPAH010	C	8.0
WPAH010*	F	4.7
WPAH011	B	7.8
WPAH011	D	7.8
WPAH014	A	10.3
WPAH014	B	6.0
WPAH026	A	9.7
WPAH026	B	9.2
WPAH054	C	9.7
WPAH057	B	4.7
WPAH057	C	3.8
WPAH057	F	3.9
WPAH057	H	5.4
WPAH058	C	11.2
WPAH058	F	9.9
WPAH064	A	7.1
WPAH064	C	6.7
WPAH065	B	8.5
WPAH075	B	7.7
WPAH075	E	8.9
WPAH076	B	9.4
WPAH076	D	10.8
WPAH081	A	6.8
Average Depth of Sediment Above Buried Pulp		**7.7**

Note:
* Image not analyzed by Germano Associates.

Abbreviations:
cm Centimeters
SPI Sediment Profile Imaging

Table 7.6
Qualitative Comparison of Wood Debris from 1998 and 2013 SPI/PV Images

2013 Station ID	2013 Wood Debris Estimate[1]	1998 Wood Debris Description	1998 Station Identifier (SAIC 1999)	Apparent Change in Wood Debris from 1998 to 2013[2]
WPAH053	None	Wood chips mixed in wood pulp	13	**-**
WPAH054	None	Trace pulp mixed in > 20 cm	92	**0**
WPAH055	None	Trace pulp mixed in > 8.6 cm	43	**0**
WPAH056	None	Sparse pulp mixed in > 16.8 cm	63	**0**
WPAH057	Low	Pulp	91	**0**
WPAH058	None	Pulp/bacterial mat	38	**0**
WPAH059	None	Trace pulp mixed in top 5 cm	14	**0**
WPAH060	Trace	Moderate pulp mixed with sediment	15	**0**
WPAH061	None, Trace[3]	Pulp/bacterial mat	12	**0**
WPAH062	None	Pulp/bacterial mat	39	**0**
WPAH063	None	Moderate pulp mixed with sediment	11	**-**
WPAH064	Trace	Sparse pulp mixed in top 4.8 cm	44	**0**
WPAH065	None, None[3]	Buried pulp layer	51	**0**
WPAH066	Med	Trace pulp mixed in top 7 cm	95	**+**
WPAH067	None	Trace pulp mixed in top 3 cm	16	**0**
WPAH068	High	Trace pulp mixed in 0.5 cm	67	**+**
WPAH069	Med	None	17	**+**
WPAH070	Low	None	72	**+**
WPAH071	Trace	None	82	**0**
WPAH073	None	None	18	**0**
WPAH074	Med, None[3]	Sparse wood chips mixed in trace pulp > 6.5 cm	41	**0**
WPAH075	Low	Buried pulp layer	45	**0**
WPAH076	None, None[3]	Buried pulp layer	30	**0**
WPAH077	Trace	Buried pulp layer	57	**0**
WPAH078	Trace	Trace pulp mixed in top 5 cm	40	**0**
WPAH079	None, Trace[3]	None	10	**0**
WPAH080	Trace, None	Sparse, scattered wood pieces on surface	46	**0**
WPAH081	None	Buried pulp layer	52	**0**
WPAH082	None	Sparse, scattered wood pieces on surface	58	**0**
WPAH083	Med	Trace pulp/bacterial mat	42	**+**
WPAH084	None, None[3]	Sparse, scattered wood pieces on surface	47	**0**
WPAH085	None	Pulp/bacterial mat	9	**0**
WPAH086	Trace	Sparse, scattered wood pieces on surface	59	**0**
WPAH087	Trace	Large wood piece on surface	8	**-**
WPAH088	None	Sparse, scattered wood pieces on surface	48	**0**
WPAH089	Trace	Sparse, scattered wood pieces on surface	7	**0**
WPAH090	None	Sparse, scattered wood pieces on surface	61	**0**
WPAH091	None	Sparse, scattered wood pieces on surface	6	**0**
WPAH092	High	Sparse pulp and wood pieces in top 3 cm	50	**+**
WPAH093	Low, None[3]	Sparse, scattered wood pieces on surface	5	**0**
WPAH094	None	Sparse, scattered wood pieces on surface	3	**0**
WPAH095	None	Sparse, scattered wood pieces on surface	2	**0**
WPAH096	None	Sparse, scattered wood pieces on surface	77	**0**
			Total Stations	**43**
			No Apparent Change	**34**
			Apparent Increase	**6**
			Apparent Decrease	**3**

Notes:

1 The presence of pulp was not considered in these comparisons; the focus was wood debris only. The descriptors none, trace, and sparse were considered to be comparable and representative of no or minimal wood debris content (i.e., < 5%). Changes between stations assigned any of these lowest level categories and descriptors (1998) or defined categories (2013) indicating higher wood content were considered a change in the direction indicated, i.e., more or less wood debris over time.

2013 wood debris estimate:

None	No discernible wood material present.
Trace	<5%
Low	5–20%
Medium	21–50%
High	> 50%

2 Apparent change in wood debris from 1998 to 2013:
- **+** Apparent increase.
- **0** No apparent change.
- **-** Apparent decrease.

3 Two replicate images were analyzed at a subset of stations.

Abbreviations:
- cm Centimeters
- PV Plan View
- SPI Sediment Profile Imaging

Table 7.7

Comparison of aRPD Depth and Infaunal Successional Stage Designations at SPI Stations Occupied in Both 1998 and 2013

2013 Station ID	1998 Station Identifier (SAIC 1999)	1998 aRPD Depth (cm)	2013 aRPD Depth (cm)	Change in aRPD Depth (cm)	Successional Stage in 1998	Successional Stage in 2013	Change in Successional Stage
WPAH053	13	NA	NA	NA	Indeterminate	Indeterminate	Indeterminate
WPAH054	92	0.00	2.95	2.95	Stage 3	Stage 1 on 3	None
WPAH055	43	0.00	1.80	1.80	Azoic (no observed biota)	Stage 2 → 3	Increase
WPAH056	63	1.94	4.27	2.33	Stage 1 on 3	Stage 1 on 3	None
WPAH057	91	0.00	2.00	2.00	Indeterminate	Stage 1 on 3	Indeterminate
WPAH058	38	NA	3.76	NA	Indeterminate	Stage 1 on 3	Indeterminate
WPAH059	14	NA	2.80	NA	Stage 3	Stage 1 on 3	None
WPAH060	15	1.38	3.27	1.89	Stage 1 on 3	Stage 1 on 3	None
WPAH061	12	0.00	3.27	3.27	Stage 1 on 3, Stage 1	Stage 1 on 2, Stage 1 on 2[1]	Decrease
WPAH062	39	1.39	2.61	1.22	Indeterminate, Stage 1	Stage 2 → 3	Increase
WPAH063	11	2.25	2.84	0.59	Stage 1 on 3	Stage 1 on 3	None
WPAH064	44	NA	2.73	NA	Stage 1	Stage 1 on 3	Increase
WPAH065	51	1.60	2.25	0.65	Stage 1 on 3	Stage 1 on 3, Stage 1 on 3[1]	None
WPAH066	95	0.00	2.25	2.25	Stage 1, Stage 1	Stage 1 on 3	Increase
WPAH067	16	1.97	3.38	1.41	Stage 1	Stage 1 on 3	Increase
WPAH068	67	0.50	3.35	2.85	Stage 1, Stage 1	Stage 1 on 3	Increase
WPAH069	17	1.37	3.31	1.94	Stage 1 on 3	Stage 1 on 3	None
WPAH070	72	2.63	2.26	-0.37	Stage 1 on 3	Stage 1 on 3	None
WPAH071	82	2.10	1.84	-0.26	Stage 1 on 3	Stage 1 on 3	None
WPAH073	18	0.42	3.49	3.07	Stage 1	Stage 1 on 3	Increase
WPAH074	41	2.39	2.90	0.51	Stage 1	Stage 1 on 3, Stage 1 on 3[1]	Increase
WPAH075	45	1.49	3.16	1.67	Stage 1 on 3, Stage 1	Stage 1 on 3	None
WPAH076	30	3.01	3.52	0.51	Stage 1 on 3, Stage 1 on 3	Stage 1 on 3, Stage 1 on 3[1]	None
WPAH077	57	2.65	2.44	-0.21	Stage 1 on 3, Stage 1 on 3	Stage 1 on 3	None
WPAH078	40	0.00	1.85	1.85	Stage 1	Stage 1 on 3	Increase
WPAH079	10	0.00	2.72	2.72	Azoic (no observed biota)	Stage 1 on 3, Stage 1 on 3[1]	Increase

Table 7.7
Comparison of aRPD Depth and Infaunal Successional Stage Designations at SPI Stations Occupied in Both 1998 and 2013

2013 Station ID	1998 Station Identifier (SAIC 1999)	1998 aRPD Depth (cm)	2013 aRPD Depth (cm)	Change in aRPD Depth (cm)	Successional Stage in 1998	Successional Stage in 2013	Change in Successional Stage
WPAH080	46	2.96	3.56	0.60	Stage 1 on 3	Stage 1 on 3, Stage 1 on 3[1]	None
WPAH081	52	2.22	4.34	2.12	Stage 1, Stage 1 on 3	Stage 1 on 3	None
WPAH082	58	2.69	3.12	0.43	Stage 1 on 3	Stage 1 on 3	None
WPAH083	42	0.00	2.60	2.60	Stage 1	Stage 1 on 3	Increase
WPAH084	47	2.22	3.02	0.80	Stage 1, Stage 1	Stage 1 on 3, Stage 1 on 3[1]	Increase
WPAH085	9	NA	2.99	NA	Stage 1	Stage 1 on 3	Increase
WPAH086	59	2.42	4.46	2.04	Stage 1 on 3	Stage 1 on 3	None
WPAH087	8	0.00	2.97	2.97	Azoic, Stage 3	Stage 1 on 3	None
WPAH088	48	NA	1.70	NA	Stage 1	Stage 1 on 3	Increase
WPAH089	7	1.83	2.71	0.88	Stage 1	Stage 1 on 3	Increase
WPAH090	61	NA	3.29	NA	Indeterminate	Stage 2 → 3	Indeterminate
WPAH091	6	3.43	4.05	0.62	Stage 1 on 3, Stage 1 on 3	Stage 1 on 3	None
WPAH092	50	2.34	2.73	0.39	Stage 1	Stage 1 on 3	Increase
WPAH093	5	1.94	3.42	1.48	Stage 1	Stage 1 on 3, Stage 1 on 3[1]	Increase
WPAH094	3	3.33	5.36	2.03	Stage 1, Stage 1	Stage 1 on 3	Increase
WPAH095	2	5.54	3.32	-2.22	Stage 1 on 3	Stage 1 on 3	None
WPAH096	77	3.24	2.86	-0.38	Stage 1	Stage 1 on 3	Increase

Notes:

1 Two replicate samples were analyzed at a subset of stations.

Stage 1 on 3	Stage 1 on Stage 3
Stage 2 on 3	Stage 2 on Stage 3
Stage 2 → 3	Stage 2 going to Stage 3

Abbreviations:

aRPD Apparent redox potential discontinuity
cm Centimeters
NA Not applicable
SPI Sediment Profile Imaging

Table 7.8
Subsurface Chemistry Data and Criteria Exceedances

				Metals					Aromatic Hydrocarbons					Phthalate Esters				Ionizable Organic Compounds	Other
			Preliminary IHSs[1]	Arsenic	Cadmium	Copper	Mercury	Zinc	Benzo(g,h,i)perylene		Fluoranthene		cPAH TEQ	bis(2-Ethylhexyl)phthalate		Butyl Benzyl Phthalate		Phenol	Total TEQ
			Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg	mg/kg-OC	µg/kg	mg/kg-OC	µg/kg	µg/kg	mg/kg-OC	µg/kg	mg/kg-OC	µg/kg	ng/kg
			Human Health SCO	12	0.82	35	0.11	77					16						2.3
			Human Health CSL	13.9	2.4	35	0.13	77					64						5.2
			Benthic Community SCO	57	5.1		0.41	410		31		160			47		4.9	420	
			LAET						670		1,700			1,300		63			
			Benthic Community CSL	93	6.7		0.59	960		78		1,200			78		64	1,200	
			2LAET						720		2,500			1,900		900			
Station ID	Sample ID	Sample Date	Sample Depth																
PASED08																			
BL02	BL02A	6/13/2008	0–10 cm	4.9	0.73	30	0.063	61	NA	0.96	NA	9.9	110	NA	2.5	NA	0.4 U	13 U	4.1 J
	BL02B	6/8/2008	3–4 ft	6.2	1.3	44	0.37	110	NA	0.2 U	NA	5.9	65 J	NA	1.1 J	NA	0.88 J	77	19 J
	BL02C	6/8/2008	5–6.5 ft	1.7	0.12 J	15	0.023 J	28	NA	0.61 U	NA	0.71 U	6.2 U	NA	1 U	NA	1 U	22	0.84 J
BL08	BL08A	6/9/2008	0–10 cm	6.8	0.34	30	0.13	77	NA	0.45 UJ	NA	4.7	13 J	23	1.6	NA	0.75 U	40	6.5 J
	BL08B	6/11/2008	1–2 ft	4.9	0.13 J	18	0.026 J	53	6.6 U	NA	16 J	NA	6.1 U	25	NA	11 U	NA	13 U	1.4 J
	BL08C	6/11/2008	3–4 ft	4.7	0.095 J	16	0.017 J	50	6.7 U	NA	7.8 U	NA	6.1 U	11 U	NA	11 U	NA	14 U	0.42 J
FT04	FT04A	6/17/2008	0–10 cm	7.2	0.47	24	0.077	69	NA	8.6	NA	62	400	NA	34	NA	0.98 U	13 U	3.5 J
	FT04B	6/7/2008	1–2 ft	7.1	0.38	34	0.13	78	NA	2.2	NA	29	160	NA	12	NA	0.79 U	31	--
	FT04C	6/7/2008	3–4 ft	7.9	0.89	46	0.33	130	NA	0.27 U	NA	11	100	NA	12	NA	0.45 U	27	--
FT06	FT06A	6/12/2008	0–10 cm	5.2	0.32 JQ	22	0.092	60	NA	1.4 J	NA	12	63 J	NA	1.7	NA	0.75 U	190	5.5 J
	FT06B	6/9/2008	1–2 ft	4	0.095 J	11	0.028	37	6.6 U	NA	7.8 U	NA	6.1 U	11 U	NA	11 U	NA	150	--
	FT06C	6/9/2008	3–4 ft	2.2	0.064 J	8.8	0.012 J	25	6.7 U	NA	7.8 U	NA	6.2 U	11 J	NA	11 U	NA	25	--
FT12	FT12A	6/11/2008	0–10 cm	--	--	--	0.03	--	--	--	--	--	--	--	--	--	--	--	1.8 J
	FT12B	7/18/2008	0.5–1 ft	3.5	0.089 J	14	0.042	39	NA	0.78 U	NA	0.91 U	6 U	NA	1.3 U	NA	1.3 U	40	--
	FT12C	7/18/2008	3–4 ft	3.5	0.11 J	18	0.048	47	NA	1.3 U	NA	1.5 U	6 U	NA	2.2 U	NA	2.2 U	28	--
IE01	IE01B	6/17/2008	2.5–3.5 ft	5.5	1.2	34	0.16	79	19 J	NA	120	NA	54 J	26	NA	11 U	NA	37	8.9 J
	IE01C	6/17/2008	4–5 ft	2.1	0.052 J	11	0.014 J	42	NA	0.95 U	NA	1.1 U	6 U	NA	1.6 U	NA	1.6 U	13 U	--
IE05	IE05A	6/7/2008	0–10 cm	12	1.8	45	0.13	90	6.7 UJ	NA	120	NA	34 J	24	NA	11 U	NA	24	10 J
	IE05B	6/13/2008	1–2 ft	7.6	1.7	50	0.86	130	35	NA	220	NA	100	11 U	NA	11 U	NA	38	24 J
	IE05C	6/13/2008	8.2–9.2 ft	5.4	0.2 J	24	0.037	57	NA	0.74 U	NA	1.3 J	6.1 U	NA	1.2 U	NA	1.2 U	13 U	--
IE09	IE09A	6/16/2008	0–10 cm	12	5	60	1.2	860	NA	1.5	NA	13	200 J	NA	0.66	NA	0.33 U	16 JQ	63 J
	IE09B	6/13/2008	3–4 ft	4.3	0.97 J	71	0.25	150	6.7 U	NA	490 J	NA	33 J	11 U	NA	91 J	NA	60	12 J
IE12	IE12A	6/9/2008	0–10 cm	11	1.2	45	0.15	110	--	--	--	--	--	--	--	--	--	--	5.8 J
	IE12B	6/20/2008	1–2 ft	9.9	1.2	40	0.2	110	18 J	NA	110	NA	55 J	16 J	NA	11 U	NA	49	11 J
	IE12C	6/20/2008	8.9–9.9 ft	5	0.17 J	17	0.026	54	NA	1.1 U	NA	1.2 U	6.1 U	NA	1.7 U	NA	1.7 U	13 U	--
IE14	IE14A	6/9/2008	0–10 cm	8.4	0.76	39	0.15	96	NA	0.24 UJ	NA	0.72	6.1 UJ	NA	0.39 U	NA	0.39 U	14 U	4.5 J
	IE14B	6/20/2008	1–2 ft	6.8	0.64	36	0.13	93	12 J	NA	95	NA	53 J	22	NA	11 U	NA	49	11 J
	IE14C	6/20/2008	5.2–6.2 ft	5.7	0.26 J	25	0.098	67	NA	1.2 J	NA	3.1	16 J	NA	1 U	NA	1 U	13 U	--
IE16	IE16A	6/9/2008	0–10 cm	9.7	2.4	53	1.3	290	6.7 UJ	NA	23	NA	6.2 UJ	11 U	NA	11 U	NA	14 U	--
	IE16B	6/12/2008	1–2 ft	5.1	0.4	16	0.035	55	NA	1 U	NA	1.2 U	6.2 U	NA	1.7 U	NA	1.7 U	18 J	0.56 J
	IE16C	6/12/2008	3–4 ft	4.7	0.17 J	17	0.029	53	6.7 U	NA	7.9 U	NA	6.2 U	11 U	NA	11 U	NA	14 U	--

Table 7.8
Subsurface Chemistry Data and Criteria Exceedances

				Metals					Aromatic Hydrocarbons					Phthalate Esters				Ionizable Organic Compounds	Other
			Preliminary IHSs[1]	Arsenic	Cadmium	Copper	Mercury	Zinc	Benzo(g,h,i)perylene		Fluoranthene		cPAH TEQ	bis(2-Ethylhexyl)phthalate		Butyl Benzyl Phthalate		Phenol	Total TEQ
			Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg	mg/kg-OC	µg/kg	mg/kg-OC	µg/kg	µg/kg	mg/kg-OC	µg/kg	mg/kg-OC	µg/kg	ng/kg
			Human Health SCO	12	0.82	35	0.11	77					16						2.3
			Human Health CSL	13.9	2.4	35	0.13	77					64						5.2
			Benthic Community SCO	57	5.1		0.41	410		31		160			47		4.9	420	
			LAET						670		1,700			1,300		63			
			Benthic Community CSL	93	6.7		0.59	960		78		1,200			78		64	1,200	
			2LAET						720		2,500			1,900		900			
Station ID	Sample ID	Sample Date	Sample Depth																
PASED08 (cont.)																			
IH02	IH02A	6/16/2008	0–10 cm	69	4.1	60	1.3	460	48	NA	290	NA	160	11 U	NA	11 U	NA	51	44
	IH02B	6/12/2008	1–2 ft	9.8	12	130	8.9	1,900	32 J	NA	120	NA	95 J	56	NA	11 U	NA	68	90 J
	IH02C	6/12/2008	5.8–6.8 ft	6.8	0.63	24	0.058	59	NA	0.3 U	NA	1.5	16 J	NA	0.49 U	NA	0.49 U	14 U	0.6 J
IH06	IH06A	6/16/2008	0–10 cm	8.1	1.5	32	0.19	91	NA	5.7	NA	96	570	NA	1.8	NA	0.57 JQ	86	12 J
	IH06B	6/10/2008	1–2 ft	7.8	3.1	53	0.53	310	22	NA	540	NA	110 J	2,800 J	NA	38 J	NA	34	74 J
	IH06C	6/10/2008	8.2–8.3 ft	3.9	0.51	11	0.021 J	35	NA	0.95	NA	1.1 U	6.1 U	NA	1.6 U	NA	1.6 U	13 U	0.55 J
KP02	KP02A	6/17/2008	0–10 cm	9.9	1.3	34	0.11	77	64	NA	240	NA	140 J	45	NA	11 U	NA	20	11 J
	KP02B	6/10/2008	1–2 ft	6	1.3	37	0.36	100	16 J	NA	240	NA	85 J	26	NA	11 U	NA	18 J	19 J
	KP02C	6/10/2008	4.5–5.5 ft	4.8	0.19	21	0.025	38	6.6 U	NA	7.7 U	NA	6.1 U	NA	3.3 U	NA	3.3 U	62	--
KP03	KP03A	6/17/2008	0–10 cm	3.9	0.22	24	0.036	58	NA	0.83 JQ	NA	6.7	63 J	NA	1.8	NA	0.61 U	14 U	2.7 J
	KP03B	6/10/2008	2–3 ft	4.9	0.32	28	0.063	57	NA	0.93	NA	9.6	250 J	NA	1.1	NA	0.35 U	18 J	7.2 J
	KP03C	6/10/2008	6.5–7.5 ft	8	0.75	42	0.17	87	31 J	NA	430 J	NA	170 J	11 U	NA U	11 U	NA	14 U	--
KP07	KP07A	6/11/2008	0–10 cm	6.2	0.42	22	0.065	67	NA	0.4 U	NA	3.2	22 J	NA	0.67 JQ	NA	0.67 U	15 JQ	3.7 J
	KP07B	6/21/2008	1–2 ft	5.2	0.12 J	18	0.035	56	NA	1.3 U	NA	1.5 U	6.2 U	NA	2.1 U	NA	2.1 U	14 U	0.72 J
	KP07C	6/21/2008	3–4 ft	4.9	0.12 J	15	0.014 J	50	NA	1.3 U	NA	1.5 U	6.1 U	NA	2.2 U	NA	2.2 U	16 J	--
KP08	KP08A	6/12/2008	0–10 cm	6.3	0.56	24	0.14	58	NA	1 J	NA	5.9	110 J	NA	1.1	NA	0.46 U	57	--
	KP08B	6/8/2008	3–4 ft	4.9	0.049 J	16	0.035	41	NA	0.88 U	NA	1 U	6.1 UJ	NA	1.5 U	NA	1.5 U	13 U	1.1 J
	KP08C	6/8/2008	4–5 ft	5.1	0.022 J	13	0.034	34	NA	1.1 U	NA	1.3 U	6.2 UJ	NA	1.8 U	NA	1.8 U	14 U	--
LA02	LA02A	7/23/2008	0–10 cm	--	--	--	0.59	--	16 JQ	NA	150	NA	66 J	39	NA	11 U	NA	41	55 J
	LA02B	7/23/2008	2–3 ft	5.4	1.7	27	0.083	64	6.6 U	NA	28	NA	6.1 UJ	11 U	NA	11 U	NA	13 U	2.7 J
	LA02C	7/23/2008	3–4 ft	3.3	0.51	18	0.028	44	NA	0.37 U	NA	0.44 U	6 UJ	NA	0.62 U	NA	0.62 U	13 U	0.8 J
MA02	MA02A	6/13/2008	0–10 cm	8.3	1.6	38	0.21	99	40 U	NA	47 UJ	NA	37 UJ	65 UJ	NA	66 U	NA	81 UJ	15 J
	MA02B	6/11/2008	0.5–1 ft	9.2	1.8	47	0.25	170	18 J	NA	340	NA	200 J	69	NA	23 J	NA	16 J	21 J
	MA02C	6/11/2008	1–2 ft	9.4	2.6	51	0.5	200	6.7 U	NA	21	NA	14 J	11 U	NA	11 U	NA	190	29 J
PORT ANGELES DNR08																			
NPI-L2 (Lagoon)	NPI-L2-01/LP-2	2/27/2008	0–10 cm	2.4	0.23	17	0.052	39	NA	1.7 J	NA	3.6 J	42 J	NA	3.3 U	NA	1.5 U	--	5.2 J
	NPI-L2-SC-01/LP2-SC	3/17/2008	3.1–4.1 ft	12	7.7	69	0.71	440	49 J	NA	360 J	NA	150 J	590 J	NA	12 U	NA	--	120
NPI-PA1 (Inner Harbor)	NPI-PA1-01/PA-1	2/28/2008	0–10 cm	14	4.5	52	0.54	240	170 J	NA	980 J	NA	410 J	210 J	NA	90 U	NA	--	57 J
	NPI-PA1-SC-01/PA1-SC	3/17/2008	2.9–3.8 ft	2.1	0.061	12	0.006	29	1.5 U	NA	3.4 J	NA	1.2 U	7 U	NA	3.2 U	NA	--	0.54
NPI-PA2 (Inner Harbor)	NPI-PA2-01/PA-2	2/28/2008	0–10 cm	11	2.9	32	0.43	140	65 J	NA	230 J	NA	130 J	150 U	NA	69 U	NA	--	29
	NPI-PA2-SC-01/PA2-SC	3/17/2008	2.4–3.3 ft	3.2	0.69	11	0.022	31	NA	0.14 U	NA	0.58 J	1.2 J	NA	1.2 J	NA	0.29 U	--	0.44 J

Table 7.8
Subsurface Chemistry Data and Criteria Exceedances

				Metals					Aromatic Hydrocarbons					Phthalate Esters				Ionizable Organic Compounds	Other
Preliminary IHSs[1]				Arsenic	Cadmium	Copper	Mercury	Zinc	Benzo(g,h,i)perylene		Fluoranthene		cPAH TEQ	bis(2-Ethylhexyl)phthalate		Butyl Benzyl Phthalate		Phenol	Total TEQ
Units				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg	mg/kg-OC	µg/kg	mg/kg-OC	µg/kg	µg/kg	mg/kg-OC	µg/kg	mg/kg-OC	µg/kg	ng/kg
Human Health SCO				12	0.82	35	0.11	77					16						2.3
Human Health CSL				13.9	2.4	35	0.13	77					64						5.2
Benthic Community SCO				57	5.1		0.41	410		31		160			47		4.9	420	
LAET									670		1,700			1,300		63			
Benthic Community CSL				93	6.7		0.59	960		78		1,200			78		64	1,200	
2LAET									720		2,500			1,900		900			
Station ID	Sample ID	Sample Date	Sample Depth																
PORT ANGELES DNR08 (cont.)																			
NPI-PA4 (Inner Harbor)	NPI-PA4-01/PA-4	2/28/2008	0–10 cm	11	**6.9**	**63**	**2.7**	**1,300**	NA	0.7 J	NA	1.3 J	**91 J**	NA	0.26 U	NA	0.13 U	--	**110**
	NPI-PA4-SC-01	3/17/2008	1–2.4 ft	--	--	--	--	**2,000**	--	--	--	--	--	--	--	--	--	--	--
NPI-PA9 (Tidelands)	NPI-PA9-01/PA-9	3/17/2008	0–10 cm	**14**	**4.3**	**46**	**1.1**	**330**	NA	0.66 J	NA	4.7 J	**280 J**	NA	1.3 U	NA	0.54 U	--	**48**
	NPI-PA9-SC-01/PA9-SC	3/17/2008	3.4–4.3 ft	4.9	0.71	23	**0.13**	67	NA	0.08 U	NA	1.1	1.8 J	NA	0.38 J	NA	0.17 U	--	**3.1**
WPAH13																			
WPAH054	SD0059	9/4/2014	6–7 ft	5.9	0.46	16	0.041	51	NA	0.39 U	NA	1.7	2.7 J	NA	7.9 U	NA	0.79 U	22 U	0.29 J
WPAH055	SD0057	9/3/2014	5.5–7 ft	6.4	0.51	17	0.036	56	NA	0.11 J	NA	0.98	2.1 J	NA	7 U	NA	0.7 U	22 U	0.67 J
	SD0058 (Field Dup)	9/3/2014	5.5–7 ft	6	0.51	19	0.033	57	NA	0.23 J	NA	2.4	6.6 J	NA	7.3 U	NA	0.73 U	21 U	0.67 J

Notes:

1 Analytes presented in this table include those identified in Section 7.3.1 as (1) chemicals occurring in sediment at concentrations greater than the benthic SCO/LAET screening levels in more than one sample within the WPAH Study Area or (2) bioaccumulative preliminary IHSs proposed by Ecology (Ecology 2015) and presented in Table 6.1. Although identified as bioaccumulative preliminary IHSs, selenium and alpha-BHC results are not included here because subsurface results are not available.

BOLD Detected concentration that exceeds the human health SCO.
BOLD Detected concentration that exceeds the human health CSL.
BOLD Detected concentration that exceeds either the SQS or LAET.
BOLD Detected concentration that exceeds either the CSL or 2LAET.
-- No data.
NA Not applicable, more appropriate result available in a different unit of measure.

Abbreviations:

BHC Hexachlorocyclobenzene
cm Centimeters
cPAH Carcinogenic polycyclic aromatic hydrocarbon
CSL Cleanup screening level
Ecology Washington State department of Ecology
ft Feet
IHS Indicator hazardous substance
LAET Lowest apparent effects threshold
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
mg/kg-OC Milligrams per kilogram organic carbon normalized
ng/kg Nanograms per kilogram
SCO Sediment cleanup objective
TEQ Toxic equivalent
2LAET Second lowest apparent effects threshold

Qualifiers:

J Analyte was detected, concentration is considered an estimate.
JQ Analyte was detected between the detection limit and reporting limit, concentration is considered an estimate.
U Analyte was not detected at the given reporting limit.
UJ Analyte was not detected at the given reporting limit, which is considered an estimate.

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Section 7.0:
Nature and Extent of Preliminary Indicator Hazardous Substances and Wood Debris

Figures

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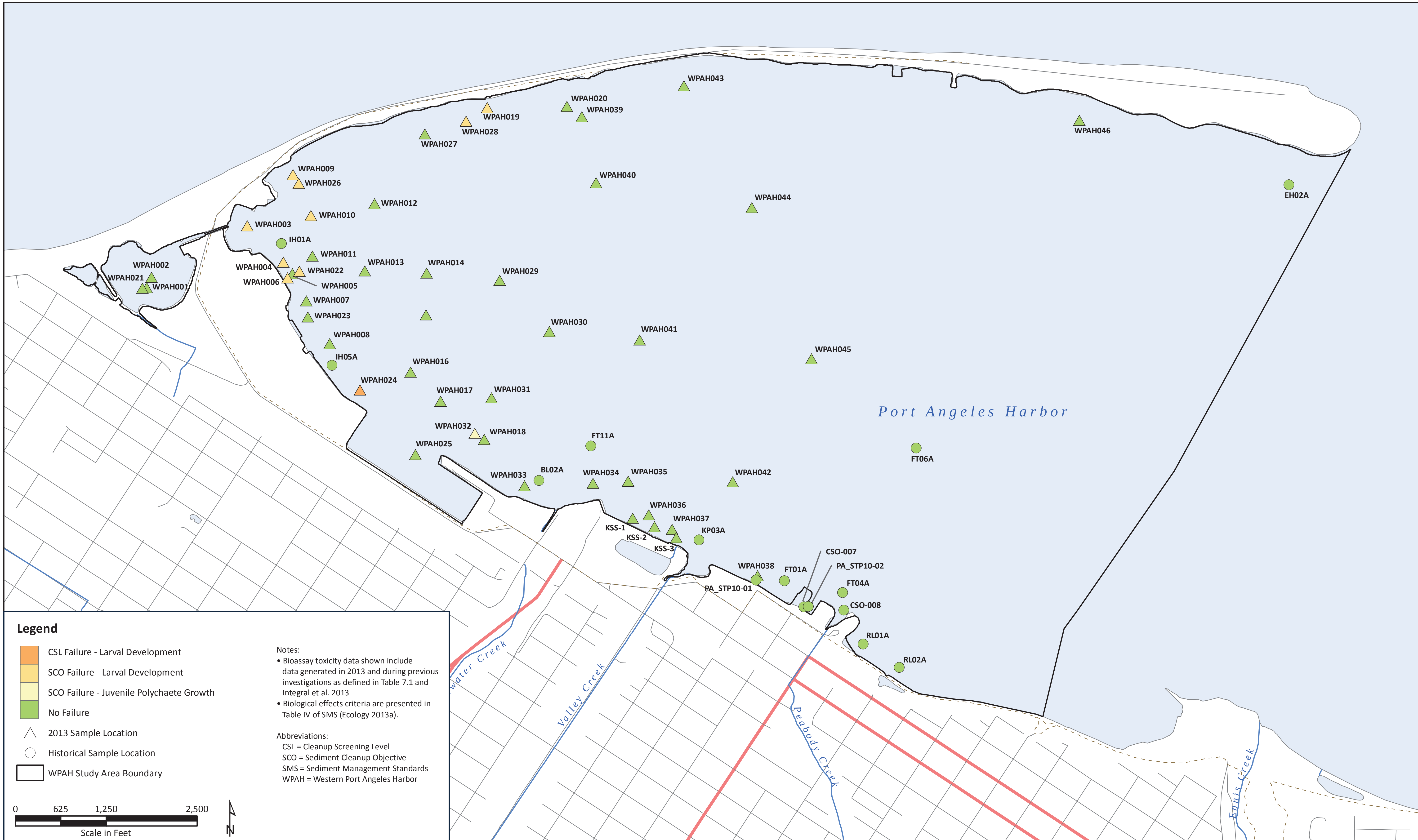

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Figure 7.1
Bioassay Toxicity Test Results

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9/18/2018

Abbreviation:
SPI = Sediment Profile Imaging

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Figure 7.2
SPI Image of Station WPAH024 in 2013
Showing Macroalgae and *Beggiotoa* sp.

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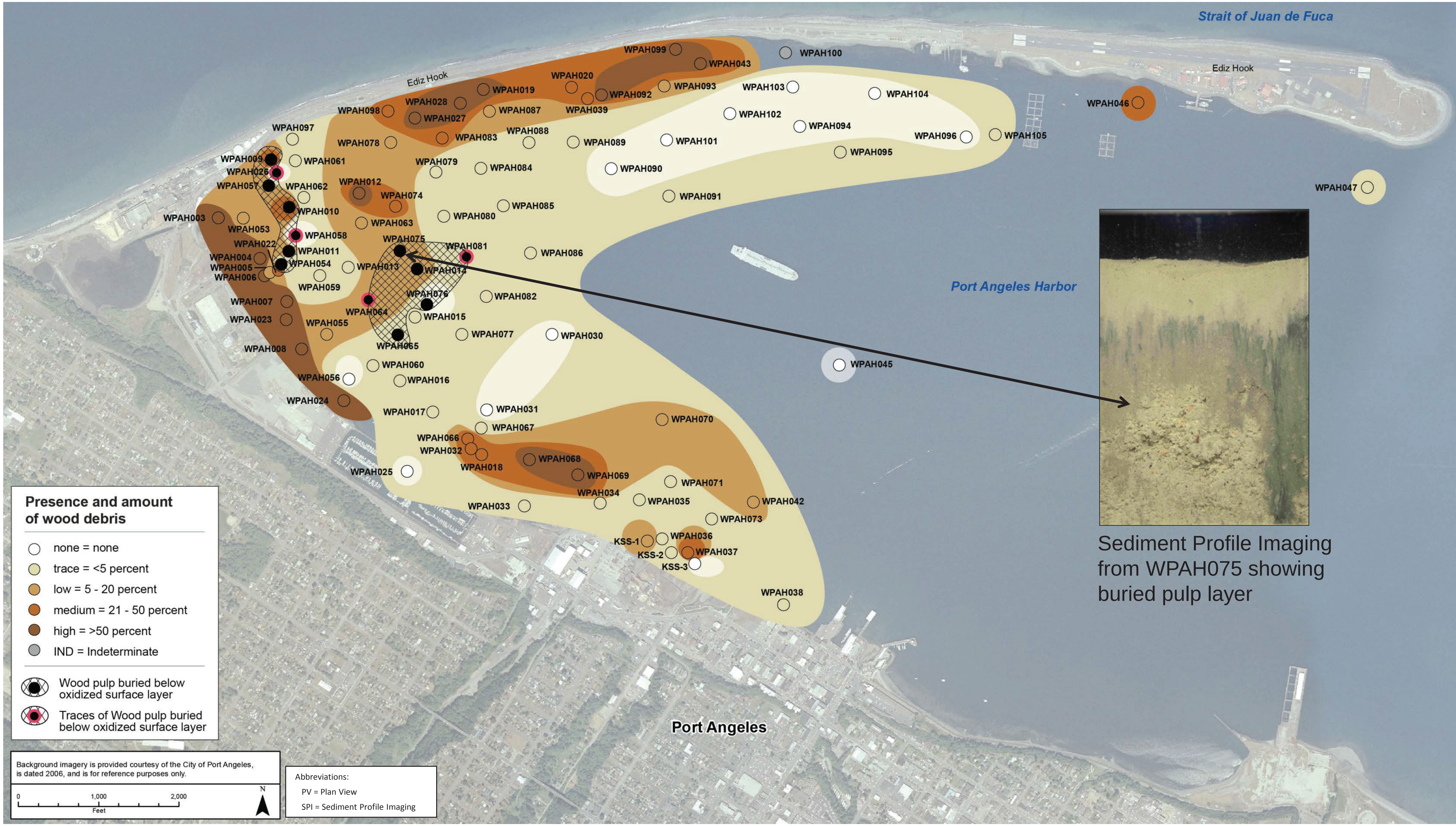
11/27/2017



Source: Adapted from Germano & Associates (2014)

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Figure 7.3a
Spatial Distribution of Wood Debris in SPI/PV Images
July 2013

WPAH023 B Intact Wood Debris

WPAH099 A Decayed Wood Fibers

Abbreviation:
SPI = Sediment Profile Imaging

Source: Germano & Associates (2014)

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Figure 7.3b
SPI Images Showing Intact Wood Debris and Decayed Wood Fibers

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08/29/2018

WPAH018 A Low

Low wood debris (5 - 20 percent)

WPAH020 B Medium

Medium wood debris (21 - 50 percent)

WPAH003 D High

High wood debris (>50 percent)

Abbreviation:
SPI = Sediment Profile Imaging

Source: Germano & Associates (2014)

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Figure 7.3c
SPI Images Showing Low (5–20%), Medium (21–50%), and High (>50%) Wood Debris

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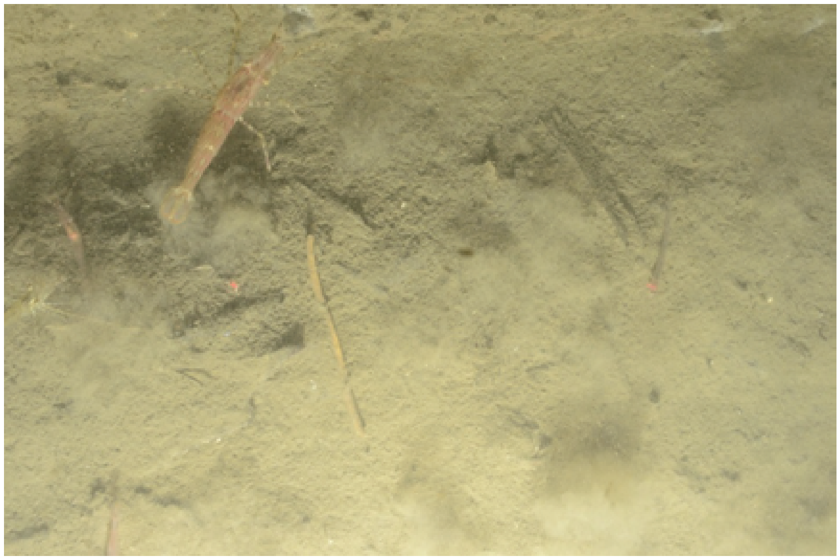
08/29/2018

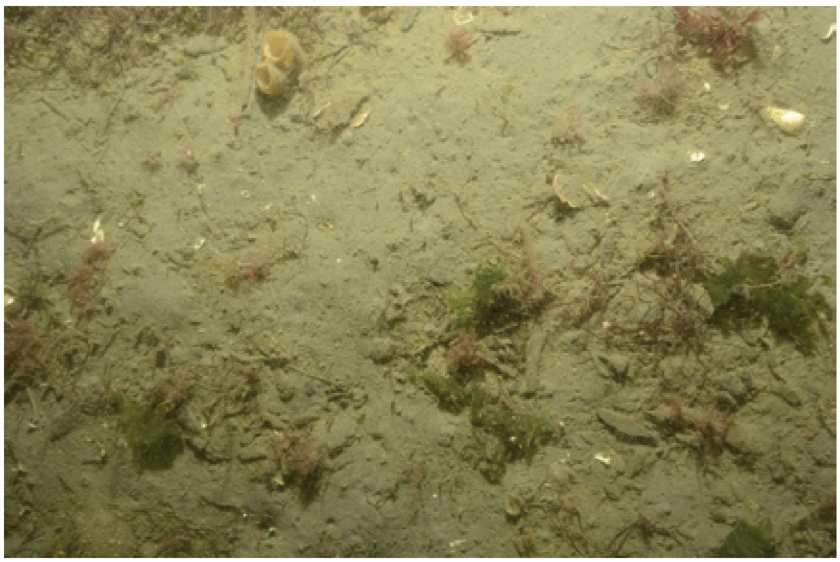
WPAH012 E Low

Low wood debris
coverage
(5 - 20 percent)



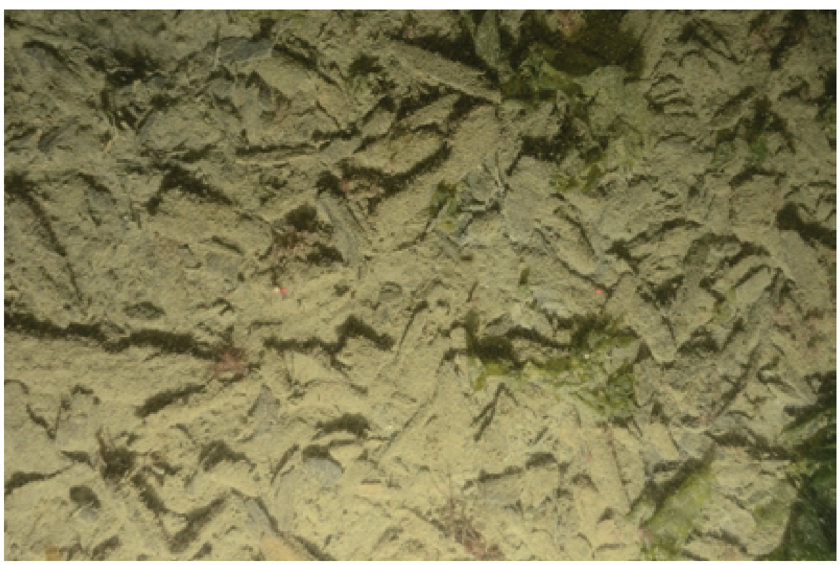
WPAH046 A Medium

Medium wood debris
coverage
(21 - 50 percent)



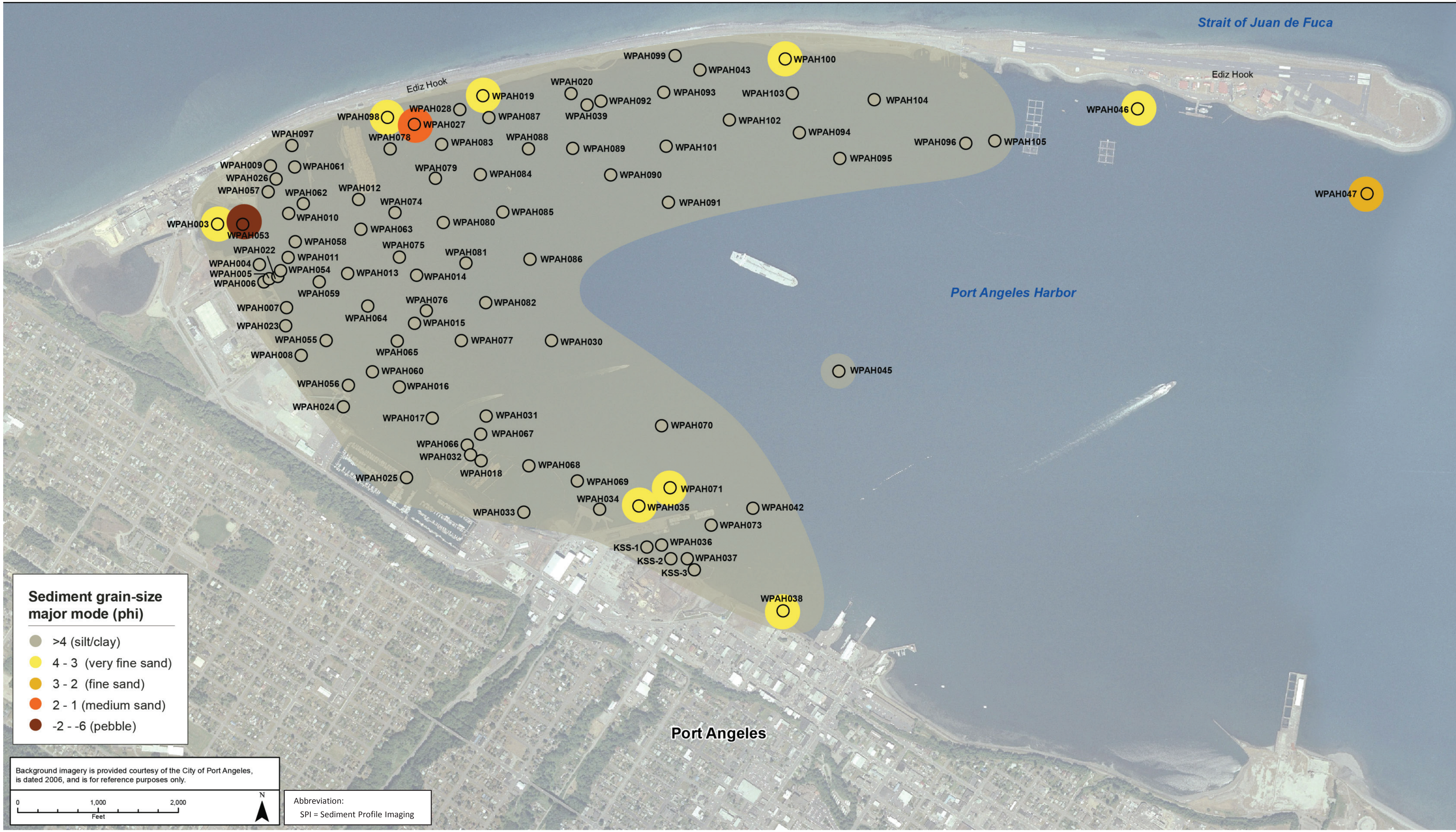
WPAH028 C High

High wood debris
coverage
(>50 percent)



Source: Germano & Associates (2014)

WPAHG Western Port Angeles Harbor Group	**Western Port Angeles Harbor Sediment Cleanup Unit Remedial Investigation/Feasibility Study Port Angeles, Washington**	Figure 7.3d Plan View Images Showing Low (5–20%), Medium (21–50%), and High (>50%) Wood Debris



Source: Germano & Associates (2014)

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Figure 7.4
Spatial Distribution of Grain Size Major Mode (phi Units) in SPI Images
July 2013

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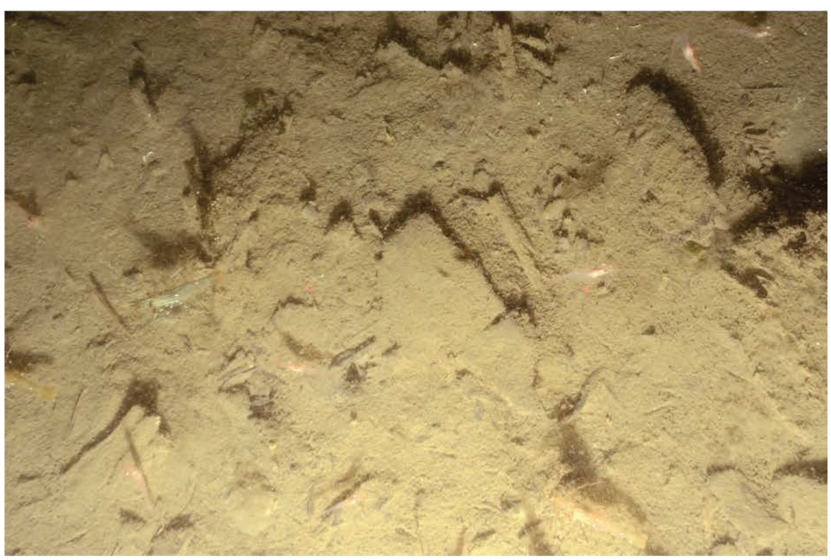
11/27/2017

WPAH006 C

High wood debris coverage (>50 percent)

WPAH068 A

Medium wood debris coverage (21 - 50 percent)



WPAH092 B

High wood debris coverage (>50 percent)

Source: Germano & Associates (2014)

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Figure 7.5
Plan View Images Showing Wood with Fine Sediment Natural Deposition

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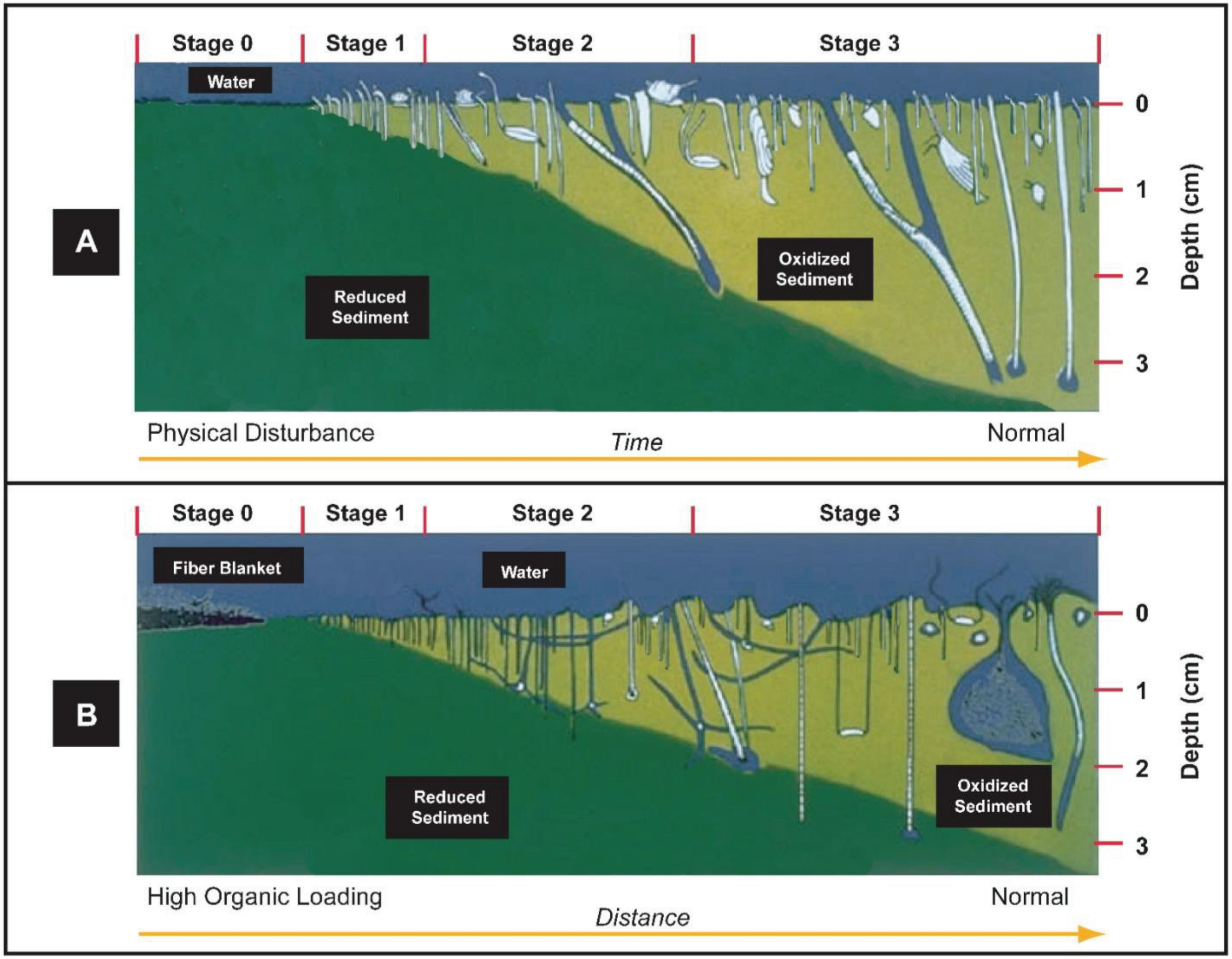
11/27/2017



Source: Rhoads and Germano (1982)

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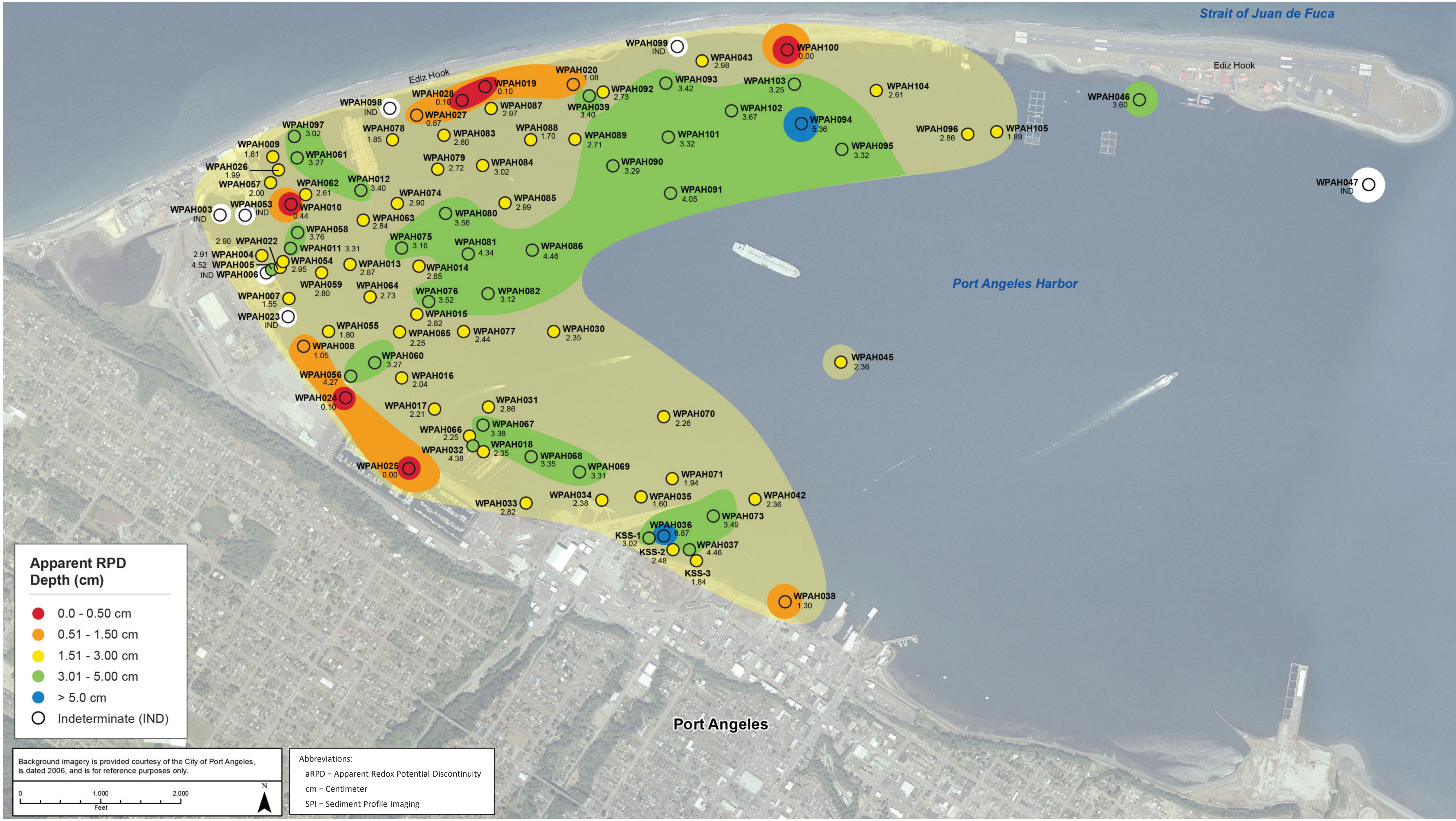
Figure 7.6
Soft-Bottom Benthic Community Response to Physical Disturbance (A) or Organic Enrichment (B)



Source: Germano & Associates (2014)

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Figure 7.7
Spatial Distribution of aRPD Depths in SPI Images
July 2013

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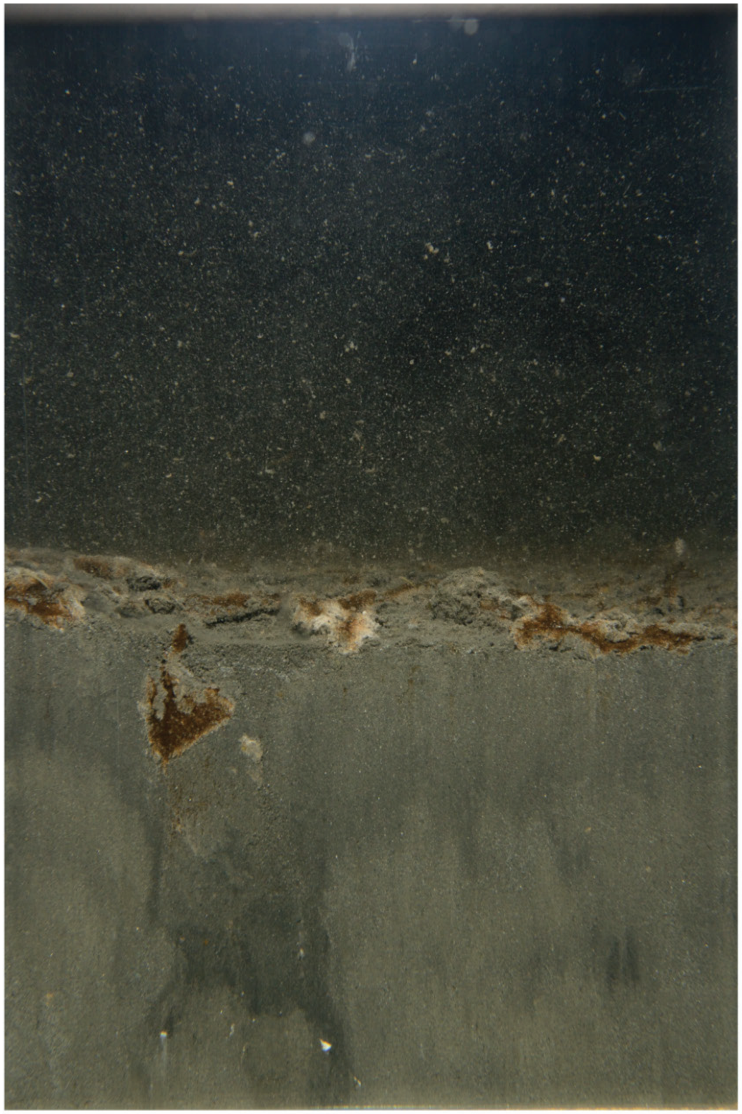
11/27/2017



WPAH025 A

WPAH100 A

Abbreviation:
SPI = Sediment Profile Imaging

Source: Germano & Associates (2014)

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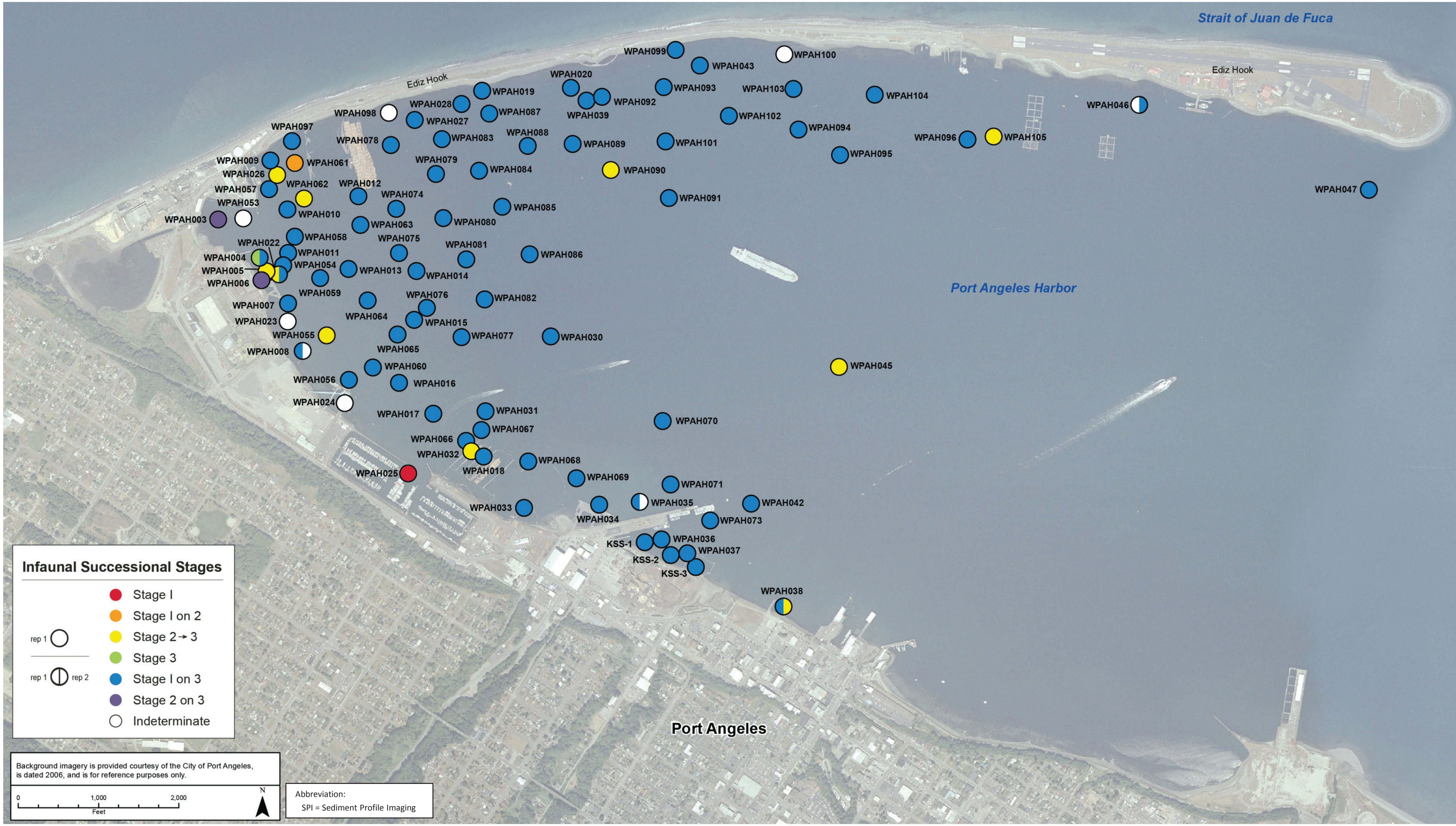
Figure 7.8
SPI Images of Decaying Macroalgae



Source: Germano & Associates (2014)

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Figure 7.9
Spatial Distribution of Infaunal Successional Stages in SPI Images
July 2013

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11/27/2017

Note:
• Even with significant levels of wood cover (~ 40% in this PV image), the presence of Stage 3 taxa and subsurface feeding voids (red arrows) was evident.

Abbreviations:
PV = Plan View
SPI = Sediment Profile Imaging

Source: Germano & Associates (2014)

WPAH068 A

WPAHG Western Port Angeles Harbor Group	**Western Port Angeles Harbor** **Sediment Cleanup Unit** **Remedial Investigation/Feasibility Study** **Port Angeles, Washington**	Figure 7.10 SPI/PV Images with Stage 3 Taxa and Subsurface Feeding Voids

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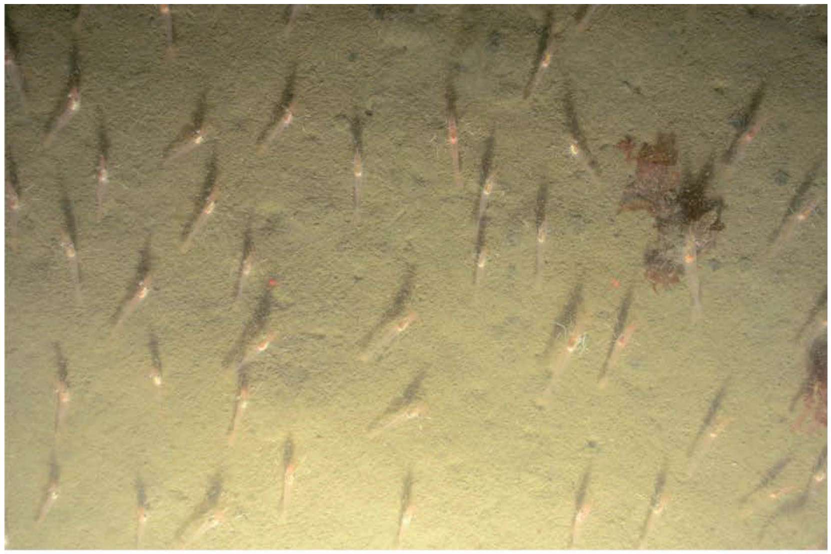
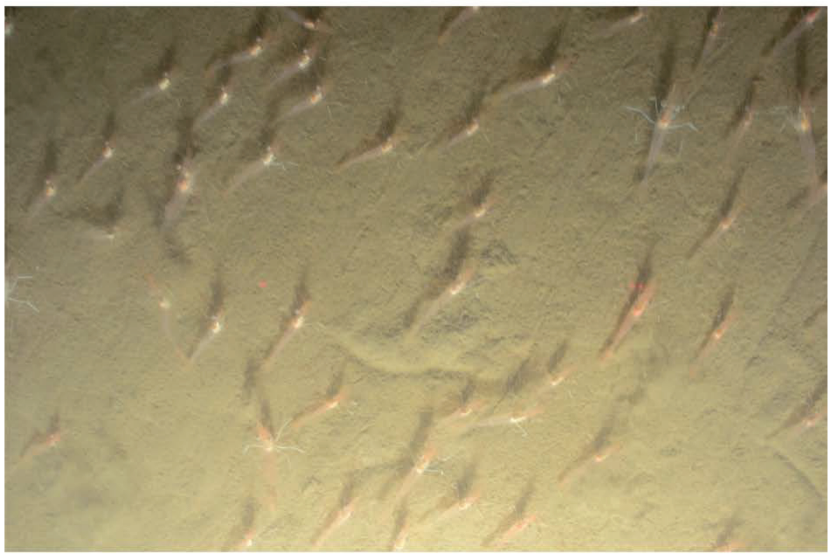
11/27/2017

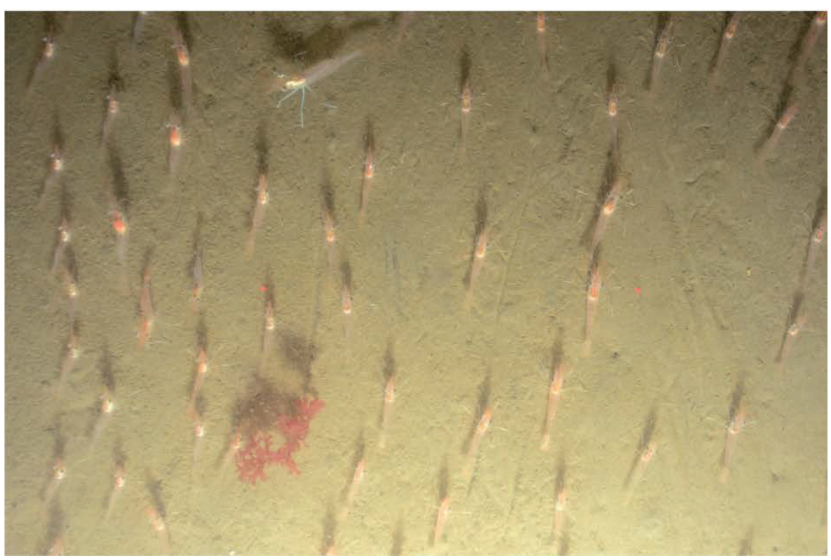
WPAH040E



WPAH044 C



WPAH095 B



Abbreviation:
PV = Plan View

Source: Germano & Associates (2014)

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Figure 7.11
PV Images Showing High Shrimp Density

\\Pfs1w\cf1100-cf1299\CF1102_Floyd_Snyder\Working_Files\RI_FS\2017_RIFS\Figures\Source Files for SPI Figures
11/27/2017

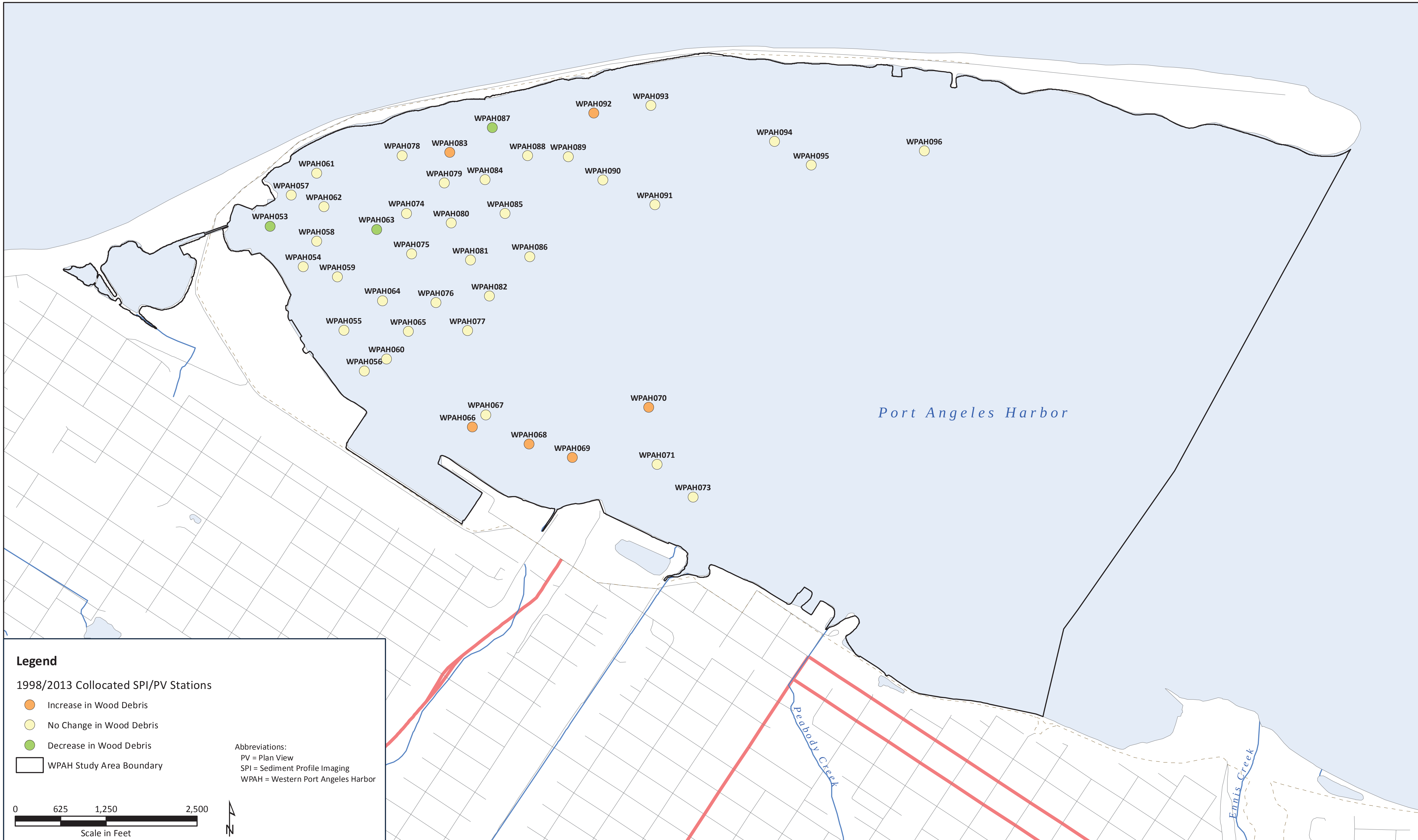

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Figure 7.12
Change in Wood Debris from 1998 to 2013

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_12_WoodContent.mxd
3/21/2018

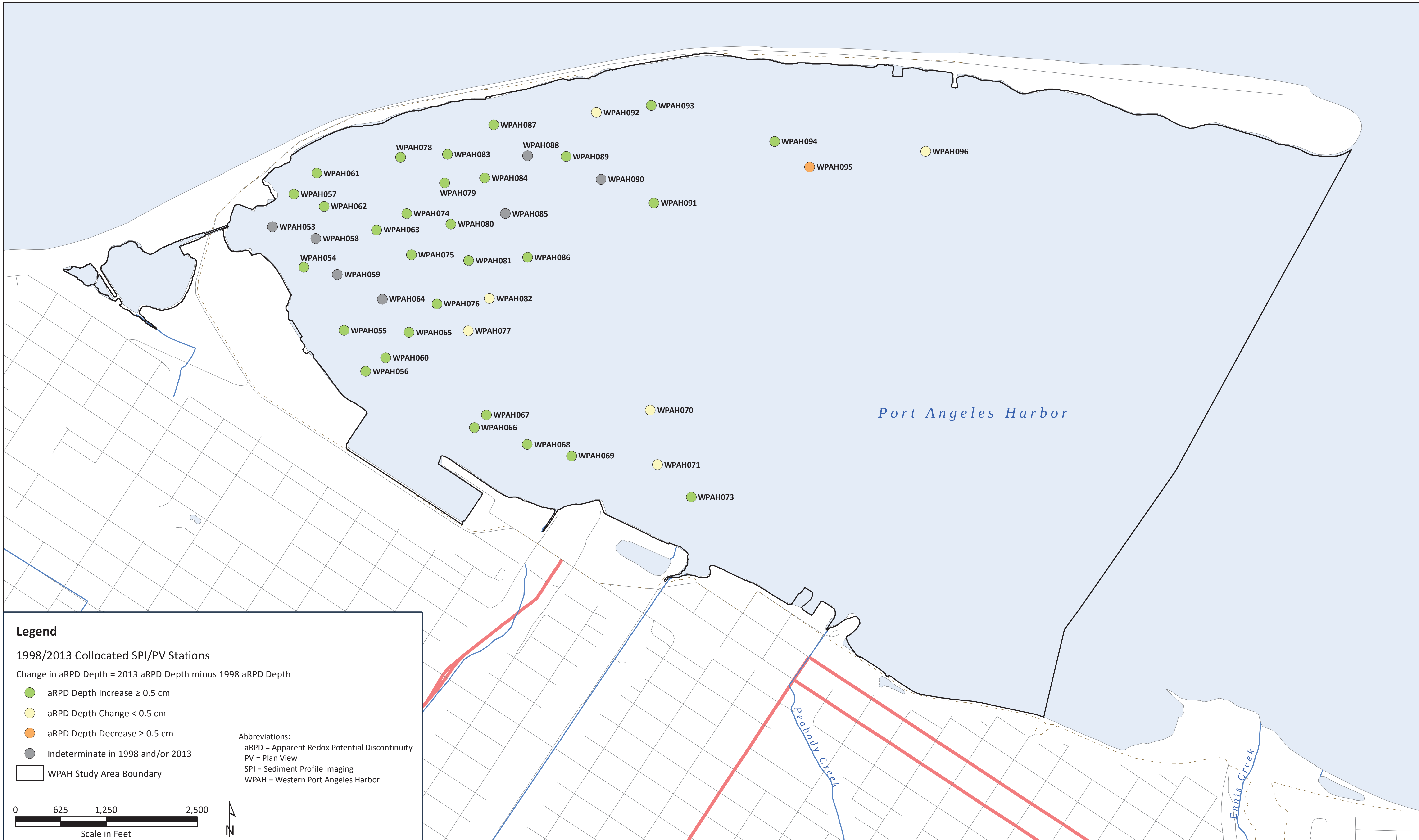

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Figure 7.13
Change in aRPD Depths from 1998 to 2013

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_13_DeltaaRPDs.mxd
3/21/2018

1998 (Successional Stage 3)

WPAH054 A

2013 (Successional Stage 1 on 3)

WPAH054 A

Abbreviation:
aRPD = Apparent Redox Potential Discontinuity

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Figure 7.14
Change in aRPD Depth from 1998 to 2013
at WPAH054

\\Pfs1w\cf1100-cf1299\CF1102_Floyd_Snyder\Working_Files\RI_FS\2018_RIFS_201807_Revisions Per Ecology Comments\Figures
08/30/2018

1998 (Successional Stage 1)

2013 (Successional Stage 1 on 3)

WPAH068 A

WPAH068 B

WPAH068 A

Abbreviation:
aRPD = Apparent Redox Potential Discontinuity

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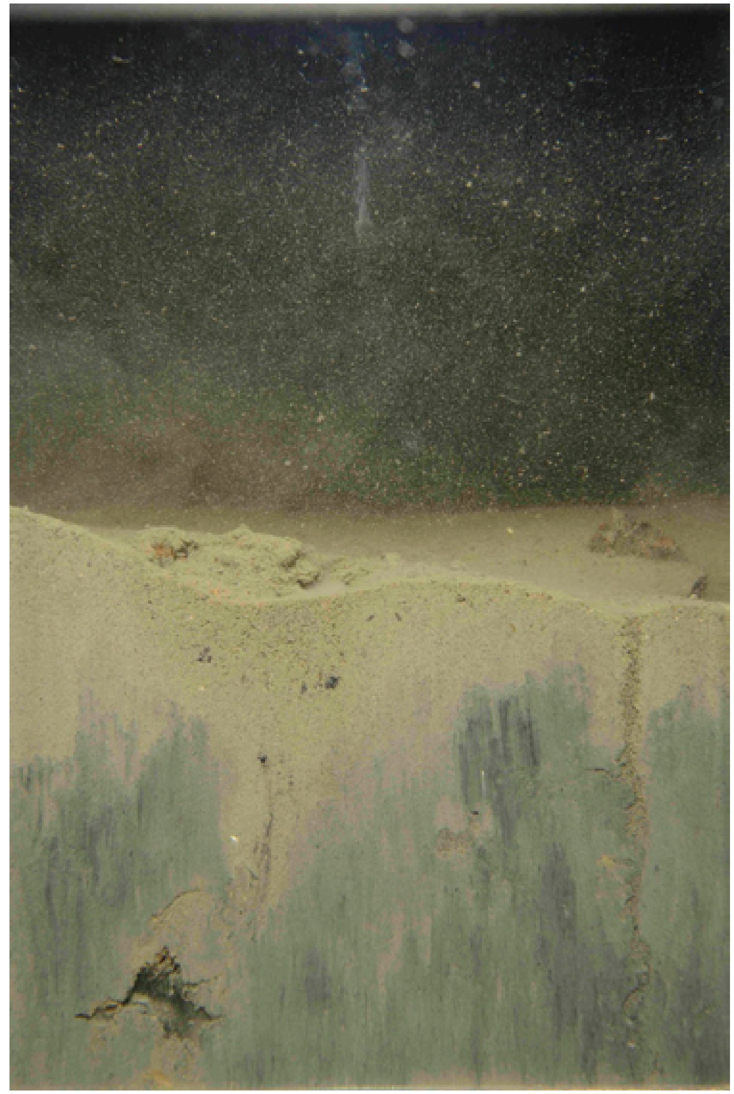
Figure 7.15
Change in aRPD Depth from 1998 to 2013 at WPAH068

1998 (Successional Stage 1 on 3)

WPAH070 A

2013 (Successional Stage 1 on 3)



WPAH070 A

Abbreviation:
aRPD = Apparent Redox Potential Discontinuity

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Figure 7.16
aRPD Depth at WPAH070 is Comparable in 1998 and 2013

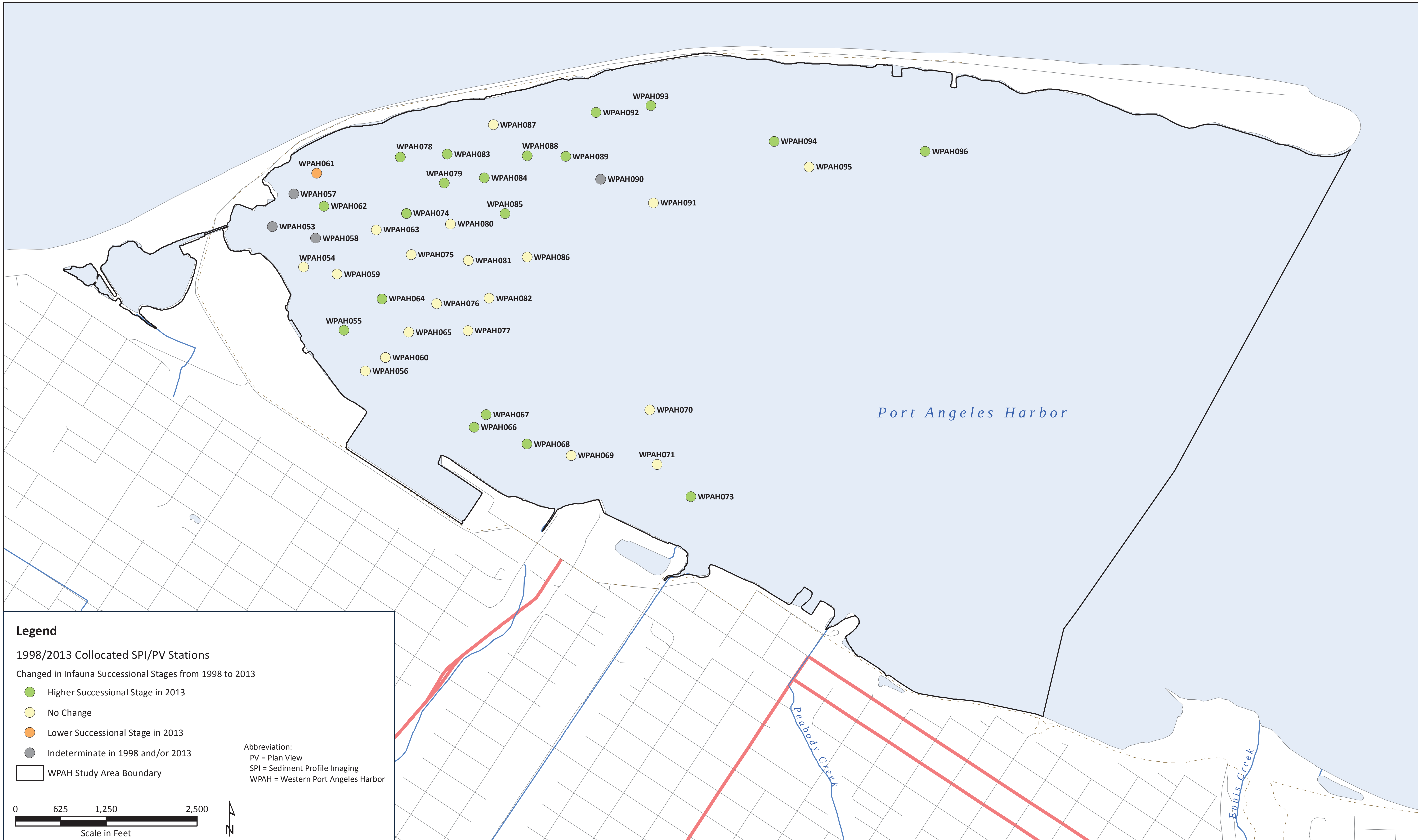

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Figure 7.17
Relative Change in Successional Stage from 1998 to 2013

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3/21/2018

1998

2013

WPAH080 B

WPAH080 B

WPAH080 A

Abbreviation:
SPI = Sediment Profile Imaging

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Figure 7.18
SPI Images from WPAH080 in 1998 and 2013
Showing Shift to Finer Grain Size

\\Pfs1w\cf1100-cf1299\CF1102_Floyd_Snyder\Working_Files\RI_FS\2017_RIFS\Figures\Source Files for SPI Figures
11/27/2017

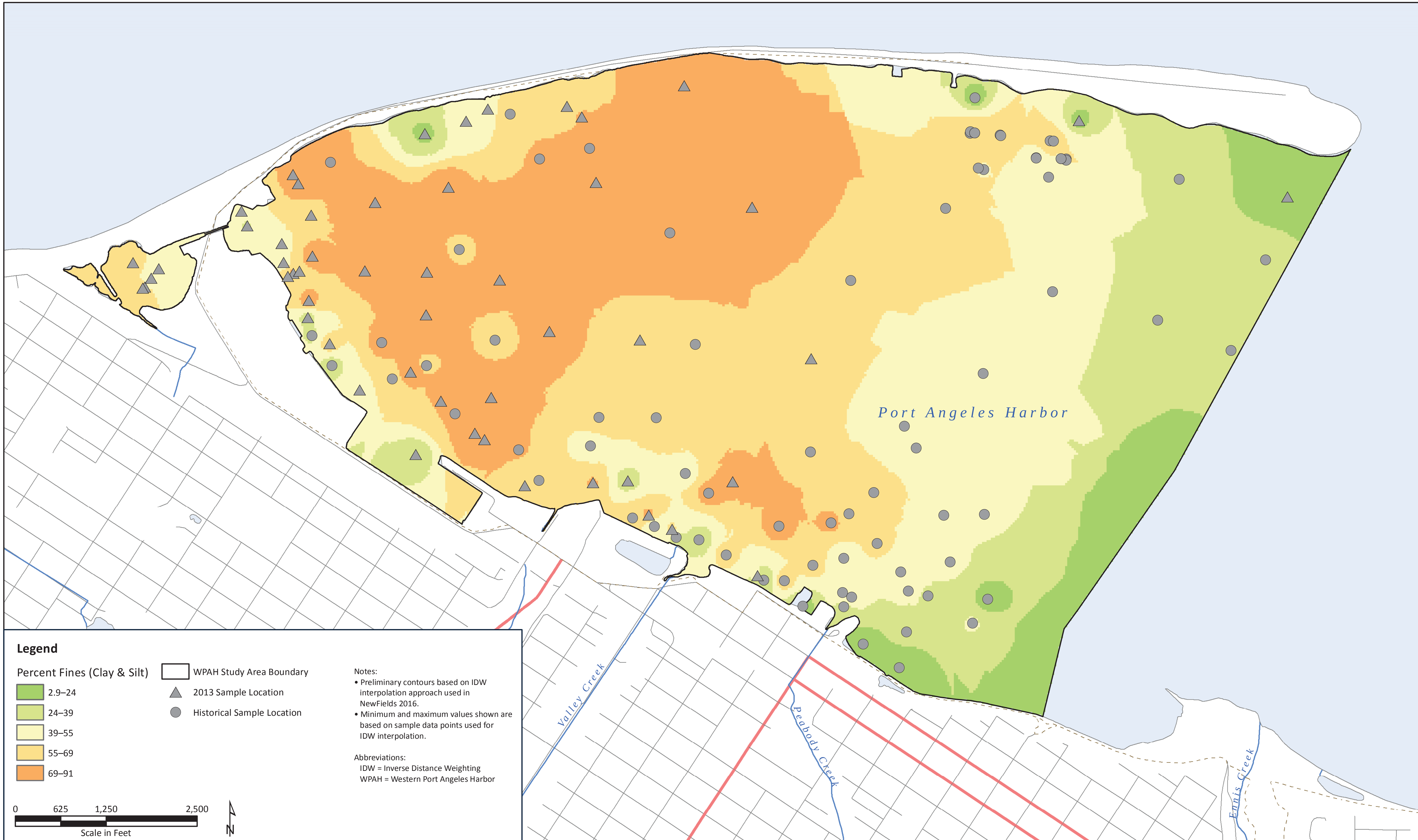

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Figure 7.19
Percent Fines (Clay & Silt) in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_19_PctFines.mxd
9/18/2018

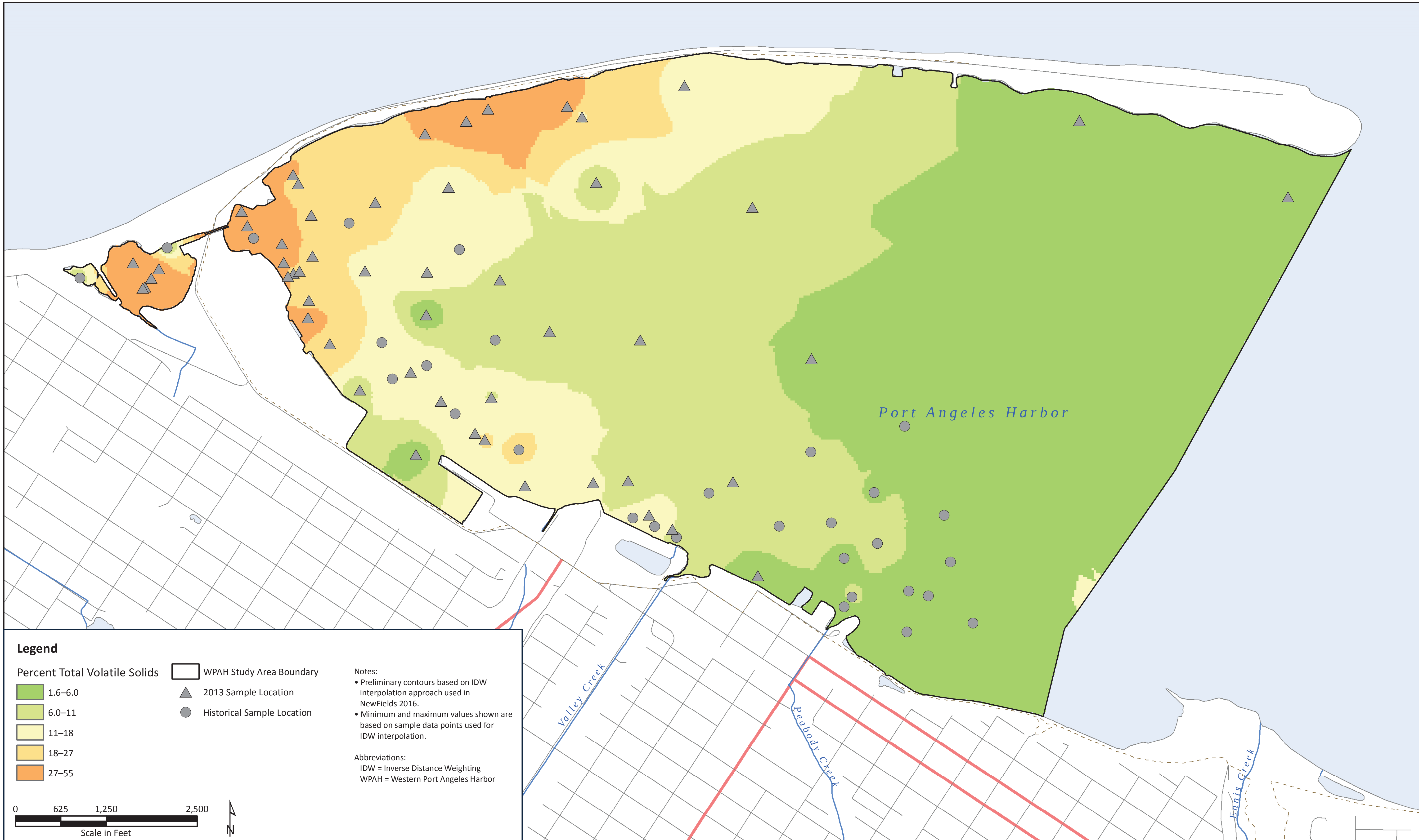

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Figure 7.20
Total Volatile Solids in Surface Sediment

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9/18/2018

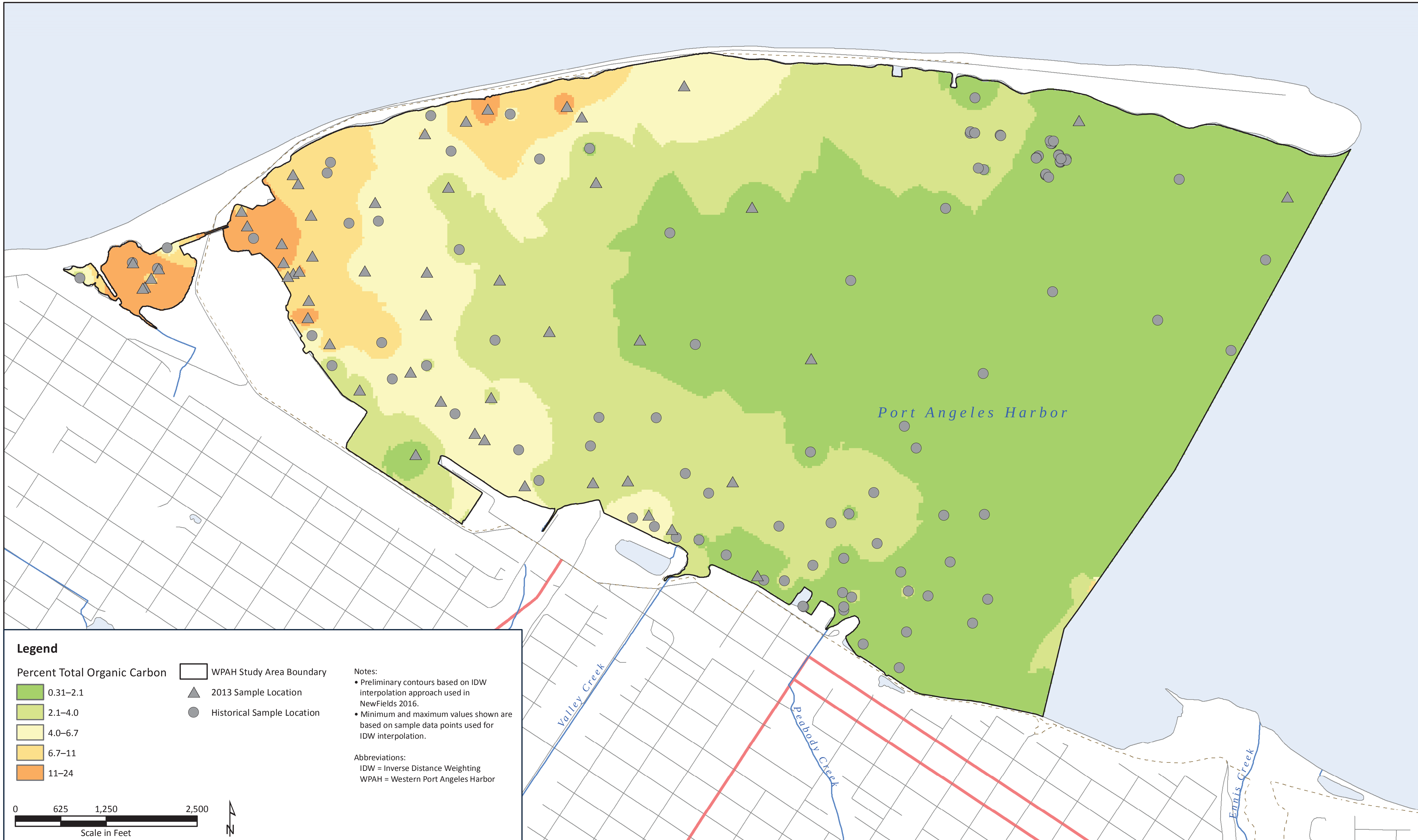

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Figure 7.21
Total Organic Carbon in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_21_TOC_rev.mxd
9/18/2018

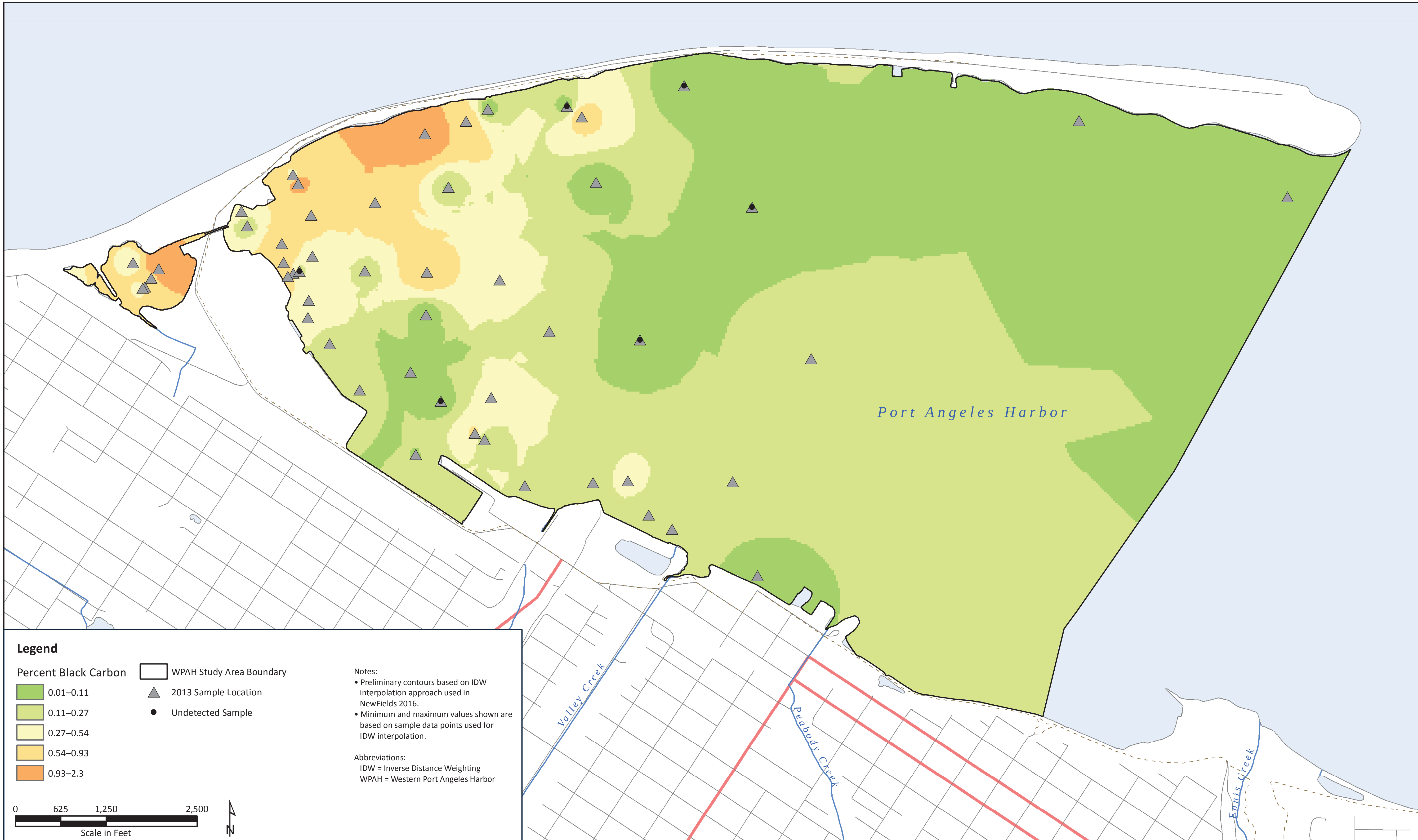

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Figure 7.22
Black Carbon in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_22_BlackCarbon.mxd
9/18/2018

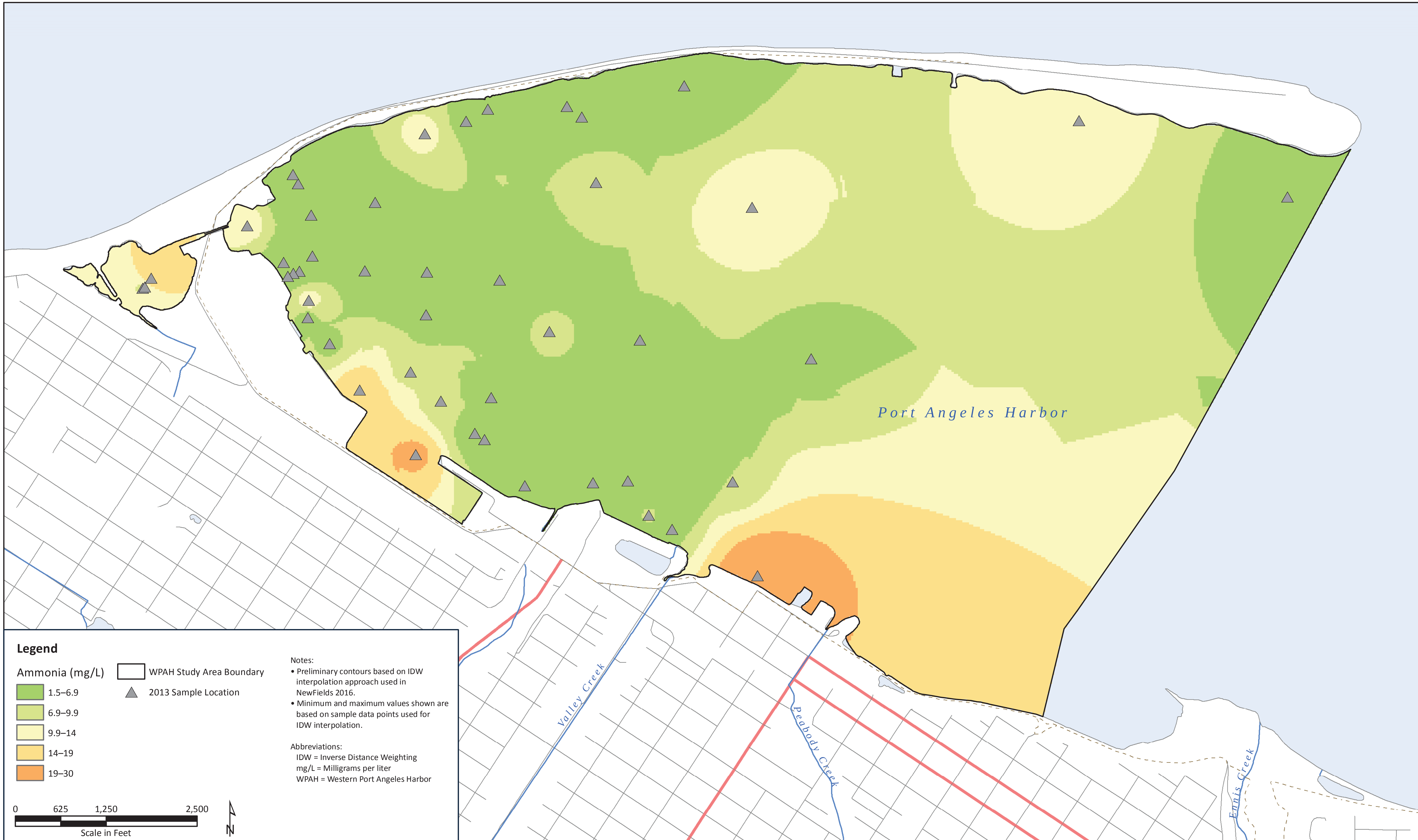

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Figure 7.23
Ammonia in Surface Sediment Porewater

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_23_AmmoniaPW.mxd
9/18/2018

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Figure 7.24
Sulfides in Surface Sediment Porewater

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Figure 7.25
Arsenic in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_25_Arsenic.mxd
9/18/2018

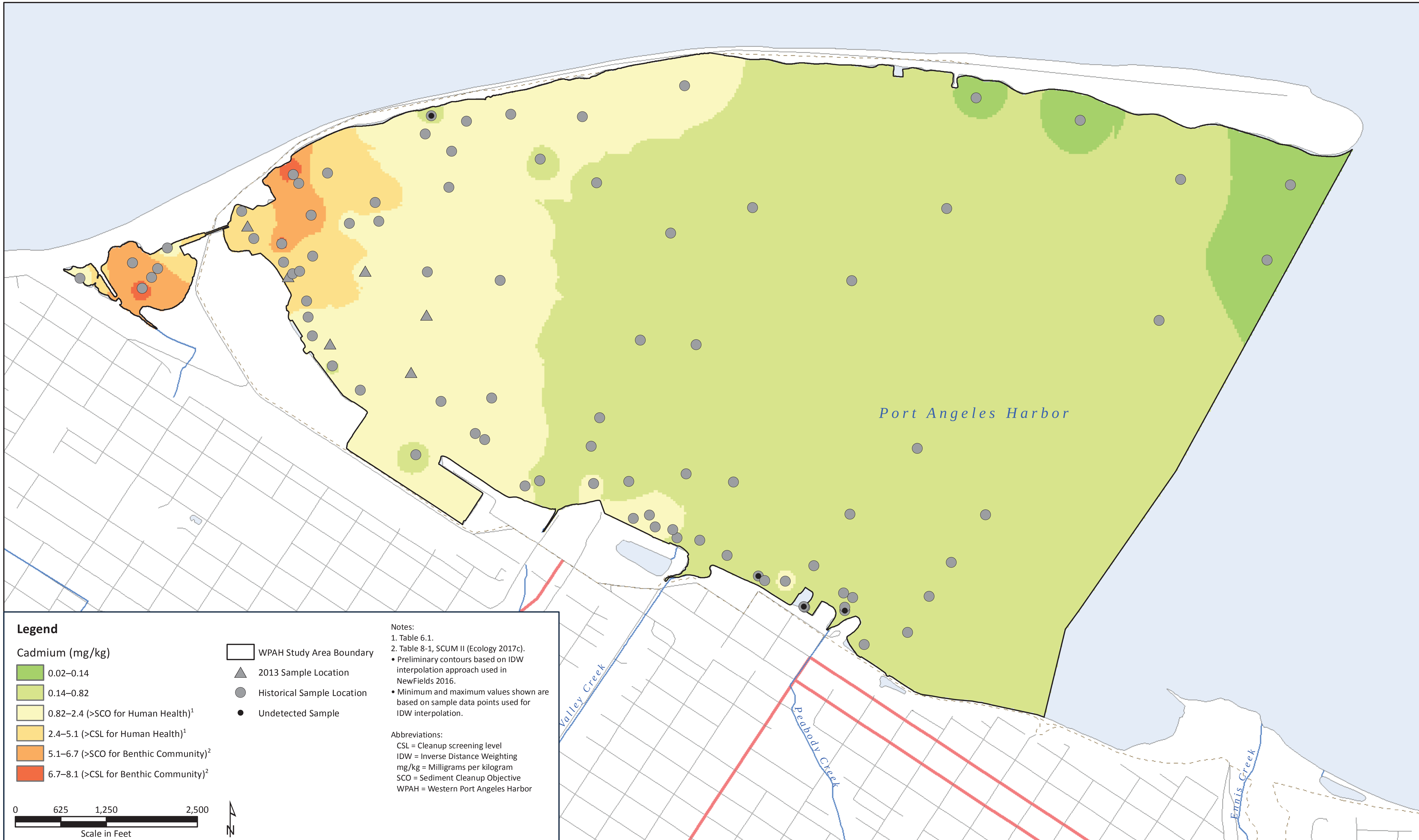

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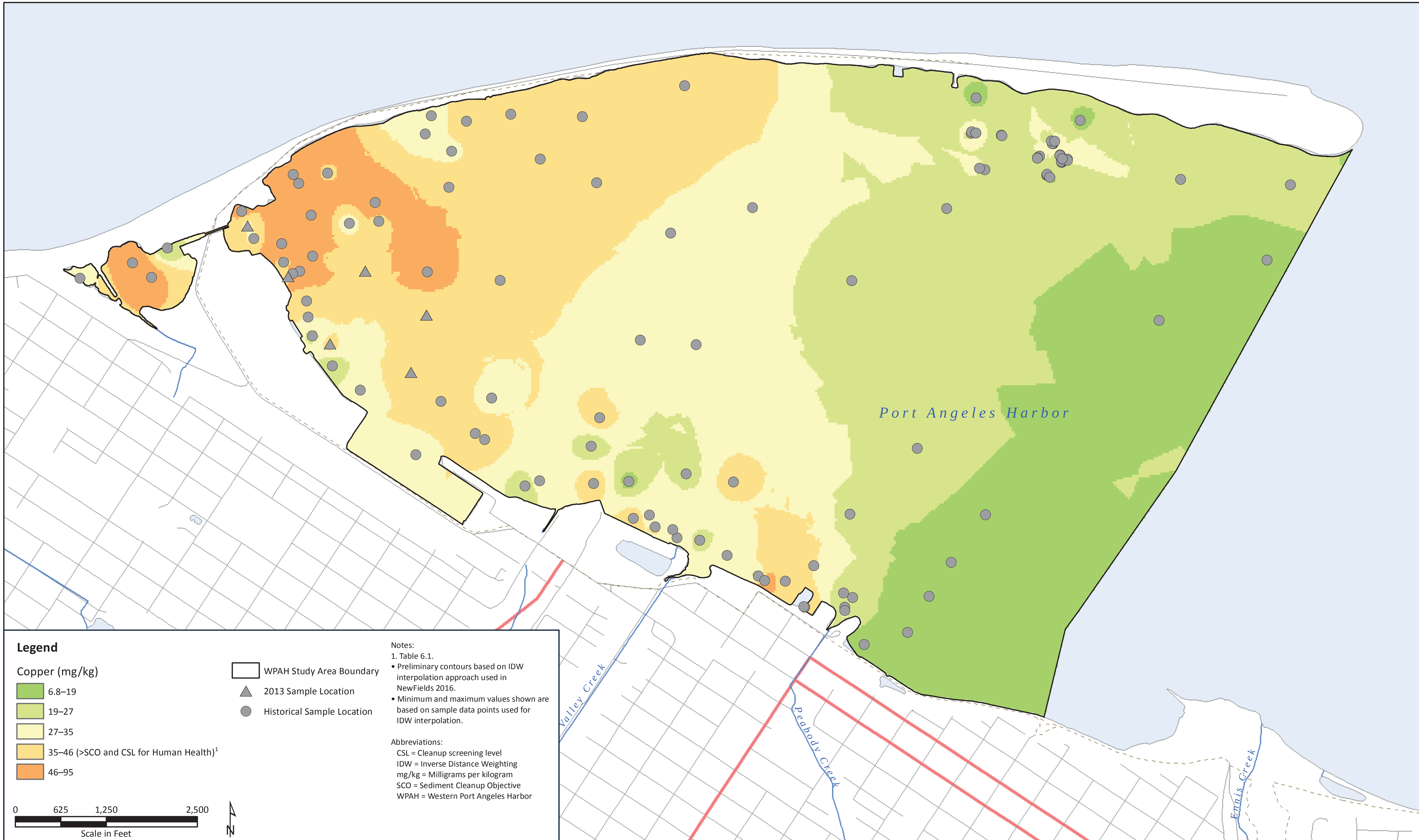
Figure 7.26
Cadmium in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_26_Cadmium.mxd
2/7/2019



Legend

Copper (mg/kg)
- 6.8–19
- 19–27
- 27–35
- 35–46 (>SCO and CSL for Human Health)[1]
- 46–95

- WPAH Study Area Boundary
- 2013 Sample Location
- Historical Sample Location

0 625 1,250 2,500
Scale in Feet

N

Notes:
1. Table 6.1.
- Preliminary contours based on IDW interpolation approach used in NewFields 2016.
- Minimum and maximum values shown are based on sample data points used for IDW interpolation.

Abbreviations:
CSL = Cleanup screening level
IDW = Inverse Distance Weighting
mg/kg = Milligrams per kilogram
SCO = Sediment Cleanup Objective
WPAH = Western Port Angeles Harbor

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Figure 7.27
Copper in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_27_Copper.mxd
2/7/2019

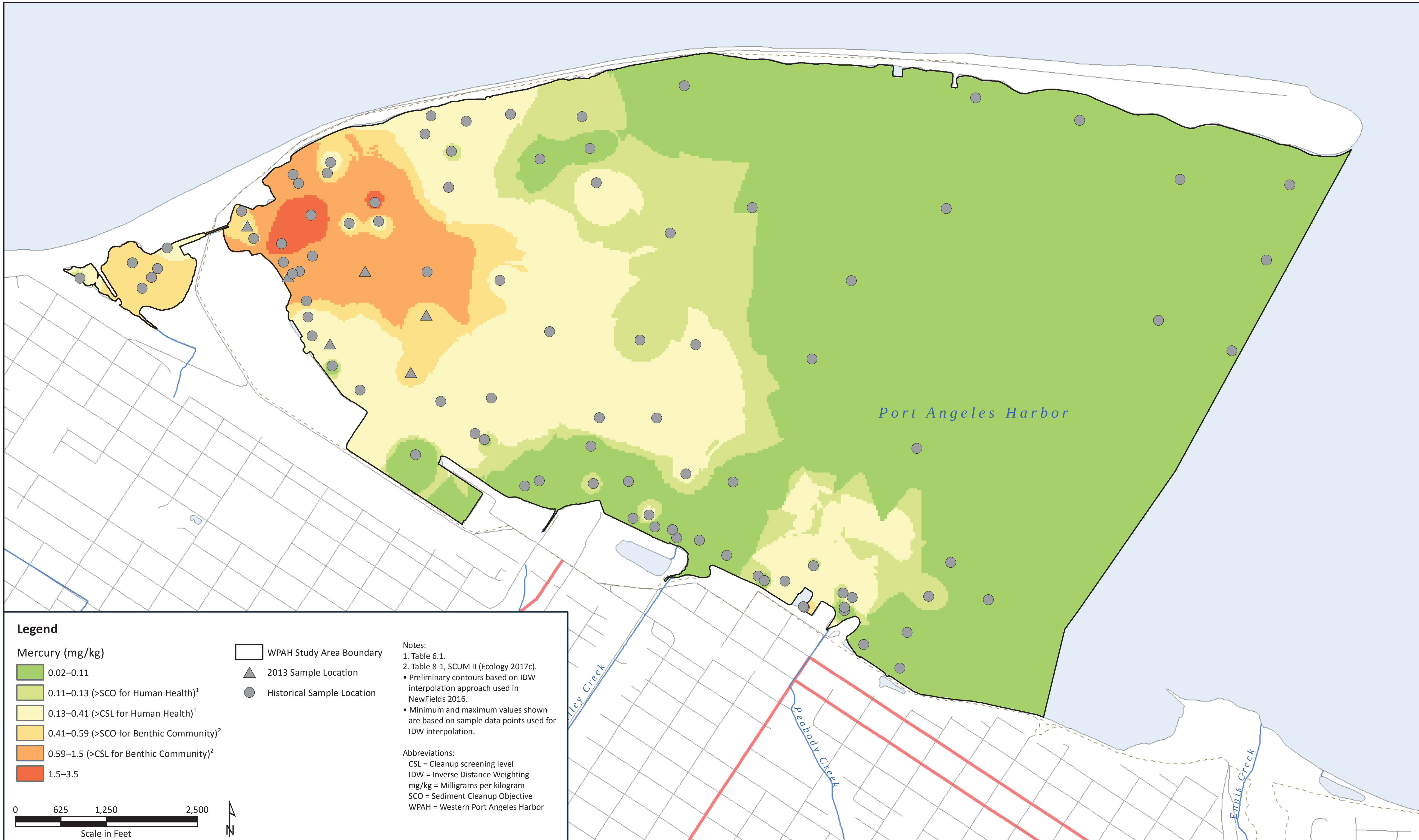

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Figure 7.28
Mercury in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_28_Mercury.mxd
2/7/2019

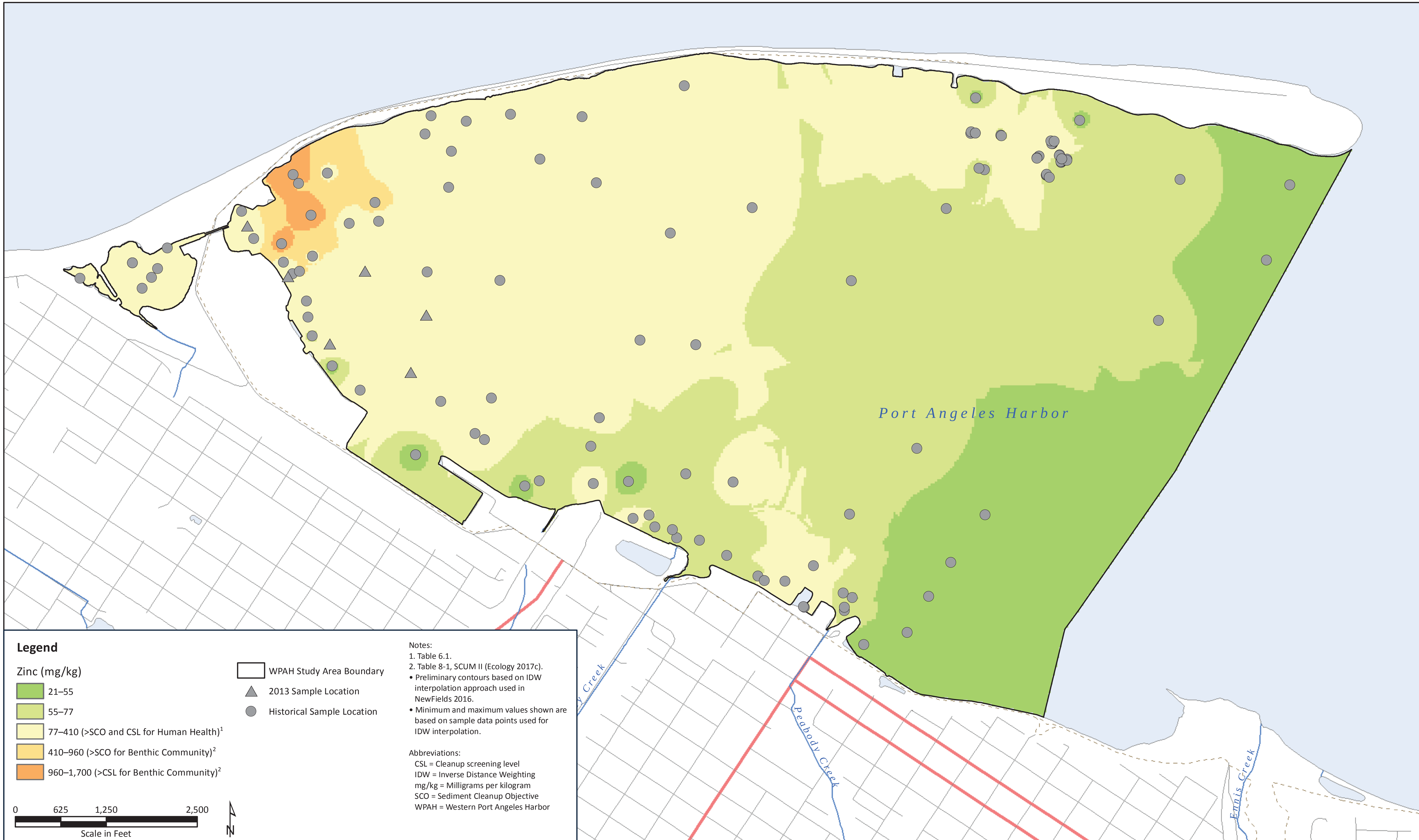

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Figure 7.29
Zinc in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_29_Zinc.mxd
2/7/2019

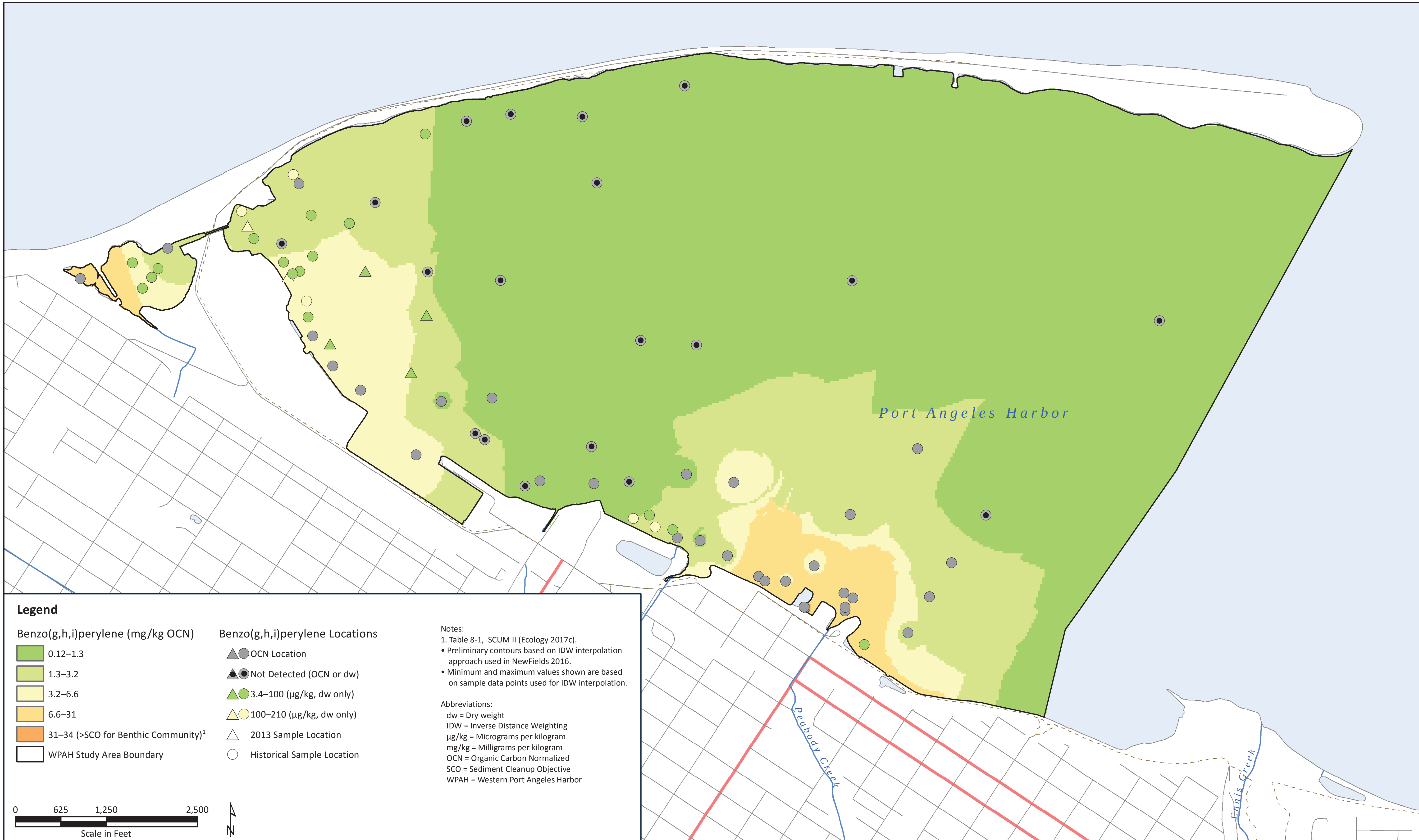

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Figure 7.30
Benzo(g,h,i)perylene in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Response_to_Ecology_2018\Fig7_30_BzGHIPerylene.mxd
9/18/2018

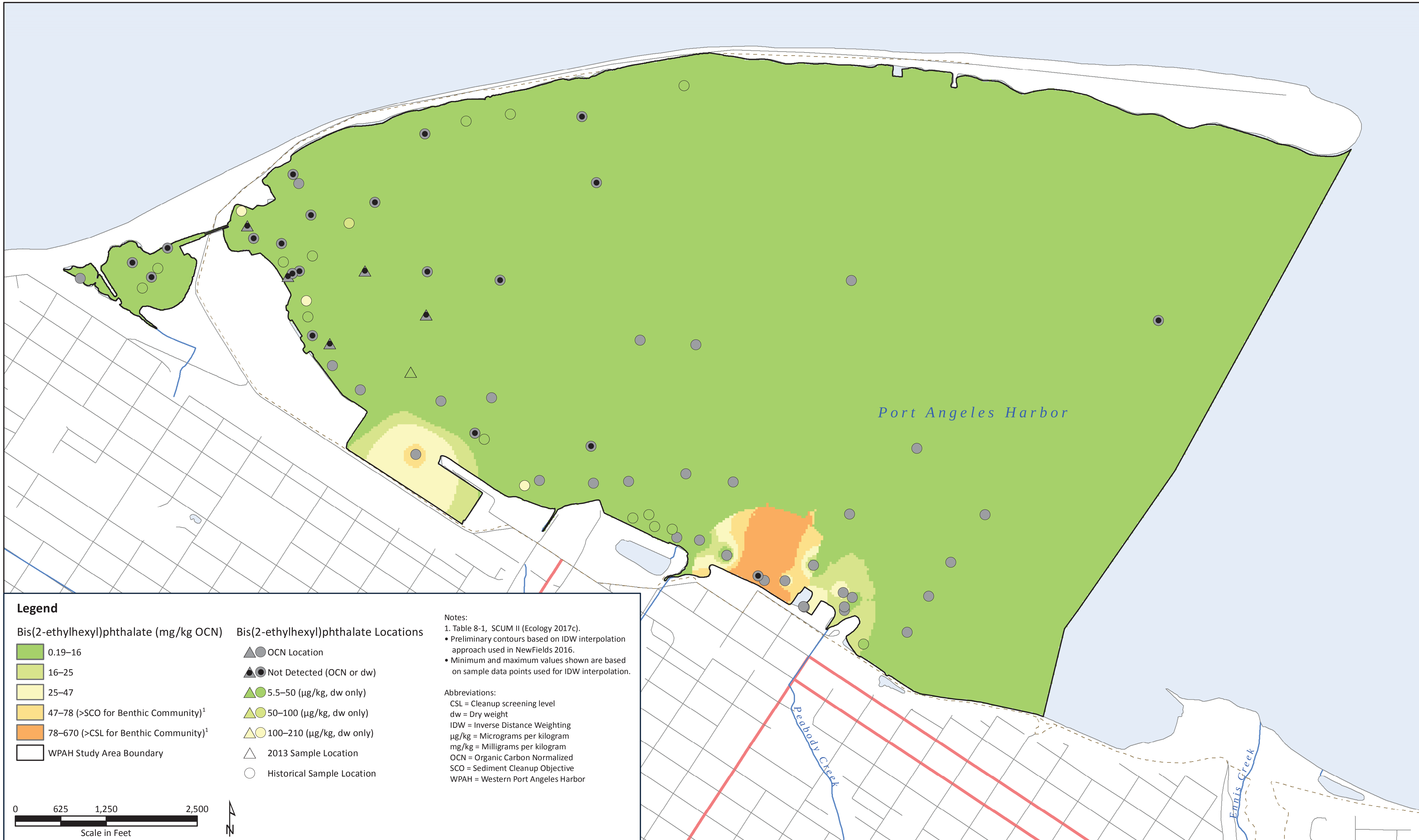

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Figure 7.31
Bis(2-ethylhexyl)phthalate in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Response_to_Ecology_2018\Fig7_31_BEHP.mxd
9/18/2018

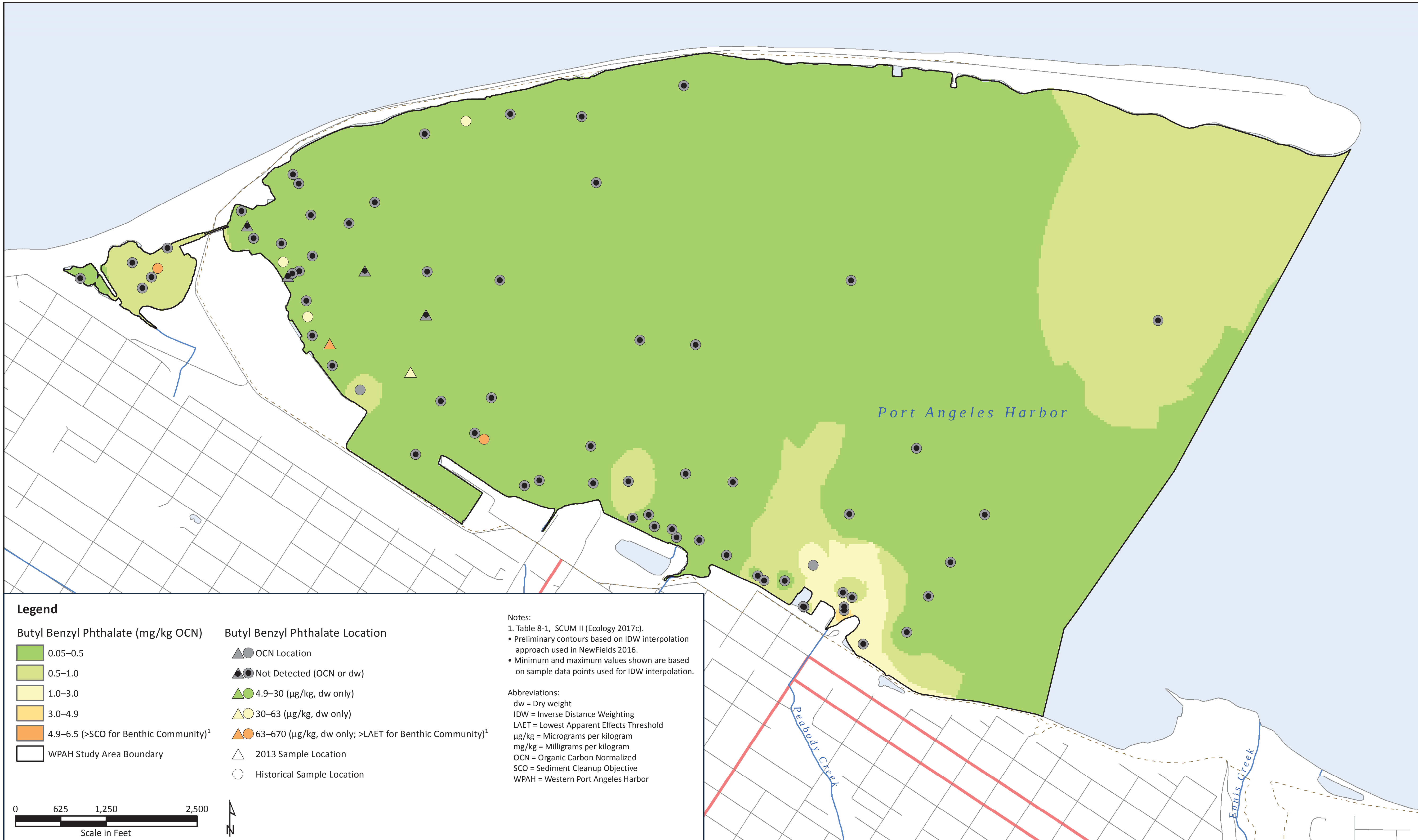

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Figure 7.32
Butyl Benzyl Phthalate in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Response_to_Ecology_2018\Fig7_32_BBP.mxd
9/18/2018

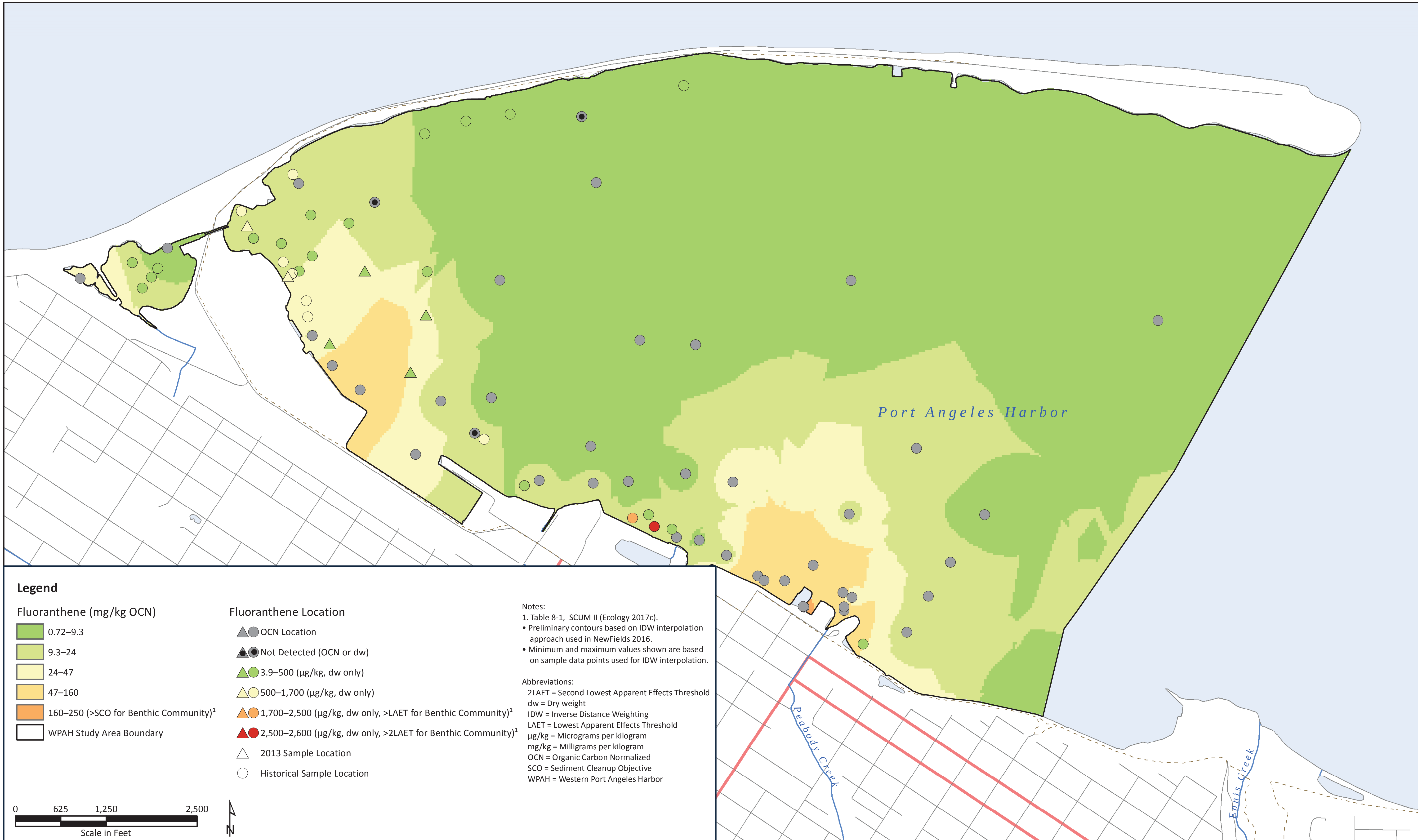

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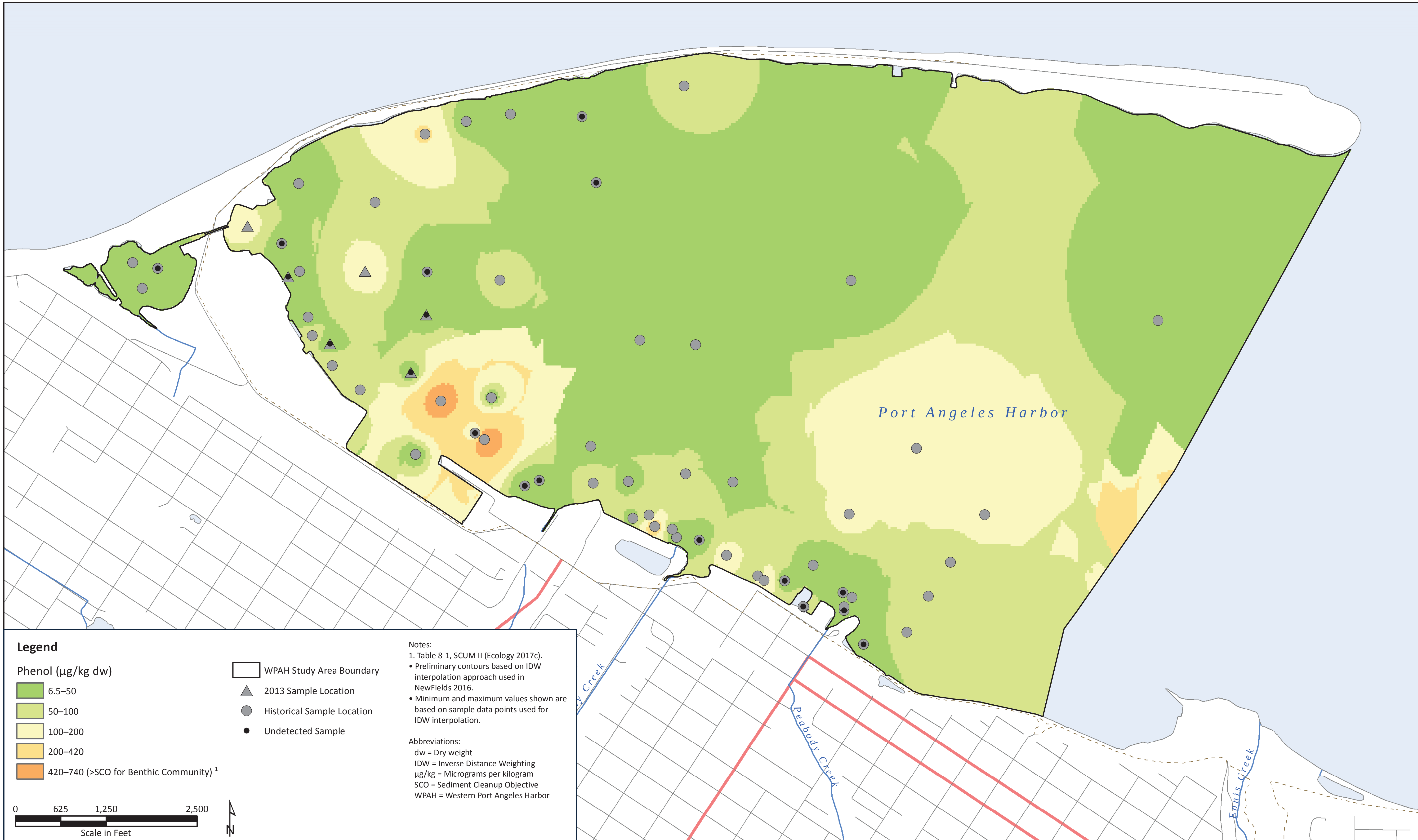
Figure 7.33
Fluoranthene in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Response_to_Ecology_2018\Fig7_33_Fluoranthene.mxd
9/18/2018



Legend

Phenol (µg/kg dw)
- 6.5–50
- 50–100
- 100–200
- 200–420
- 420–740 (>SCO for Benthic Community) [1]

- WPAH Study Area Boundary
- 2013 Sample Location
- Historical Sample Location
- Undetected Sample

0 625 1,250 2,500
Scale in Feet

N

Notes:
1. Table 8-1, SCUM II (Ecology 2017c).
- Preliminary contours based on IDW interpolation approach used in NewFields 2016.
- Minimum and maximum values shown are based on sample data points used for IDW interpolation.

Abbreviations:
dw = Dry weight
IDW = Inverse Distance Weighting
µg/kg = Micrograms per kilogram
SCO = Sediment Cleanup Objective
WPAH = Western Port Angeles Harbor

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Figure 7.34
Phenol in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_34_Phenol.mxd
9/18/2018

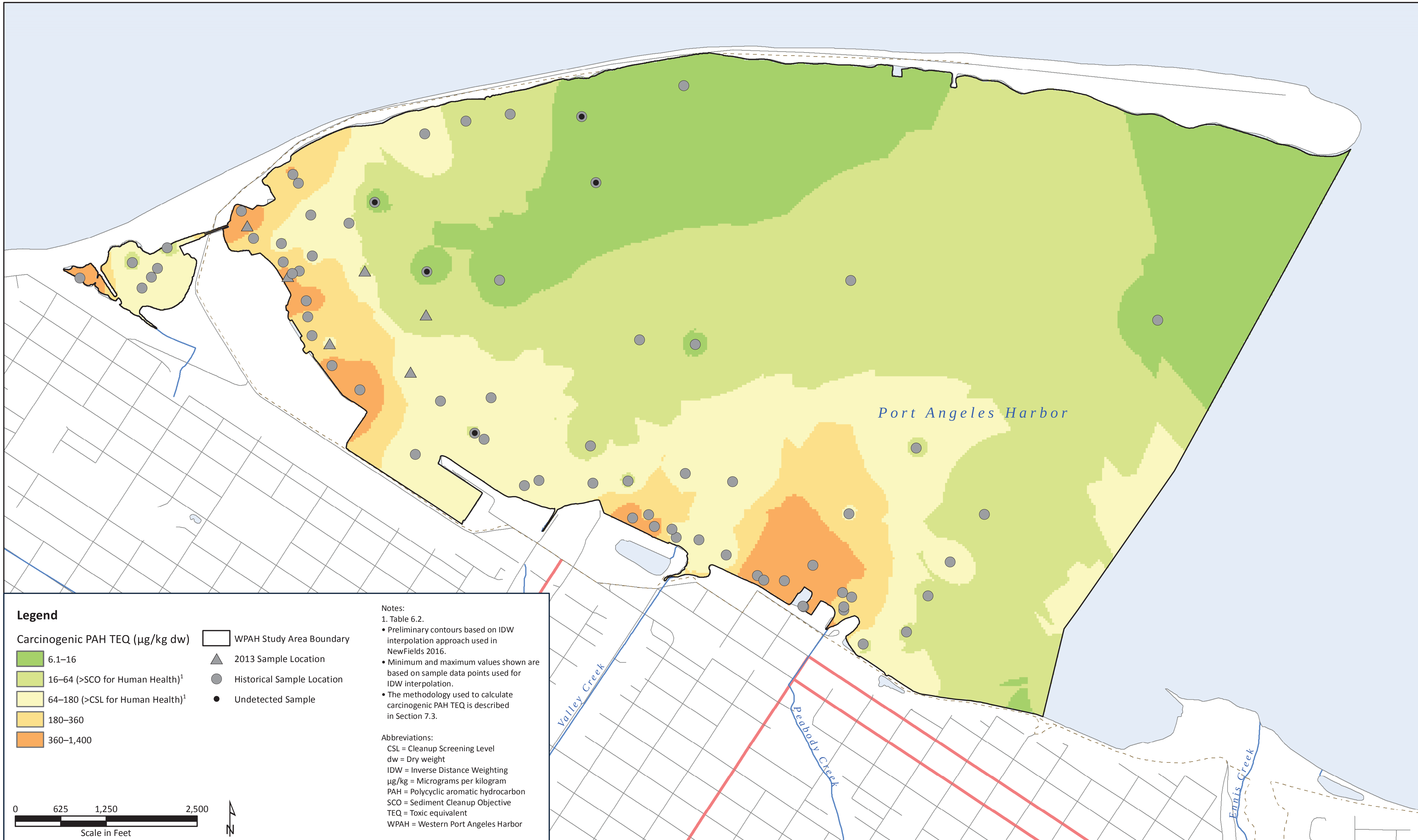

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Figure 7.35
Carcinogenic PAH TEQ in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2017\Fig7_35_cPAHTEQ.mxd
9/18/2018

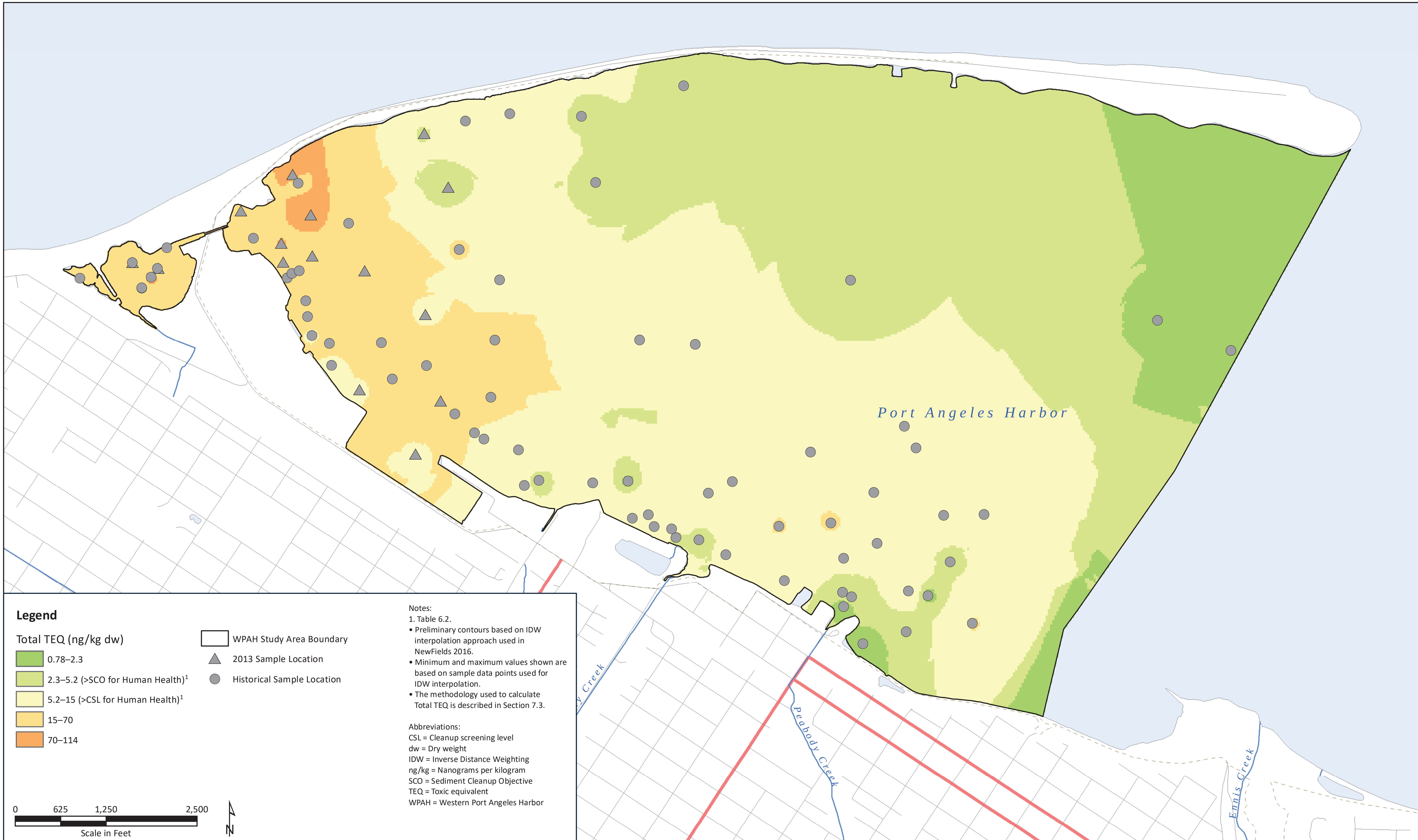

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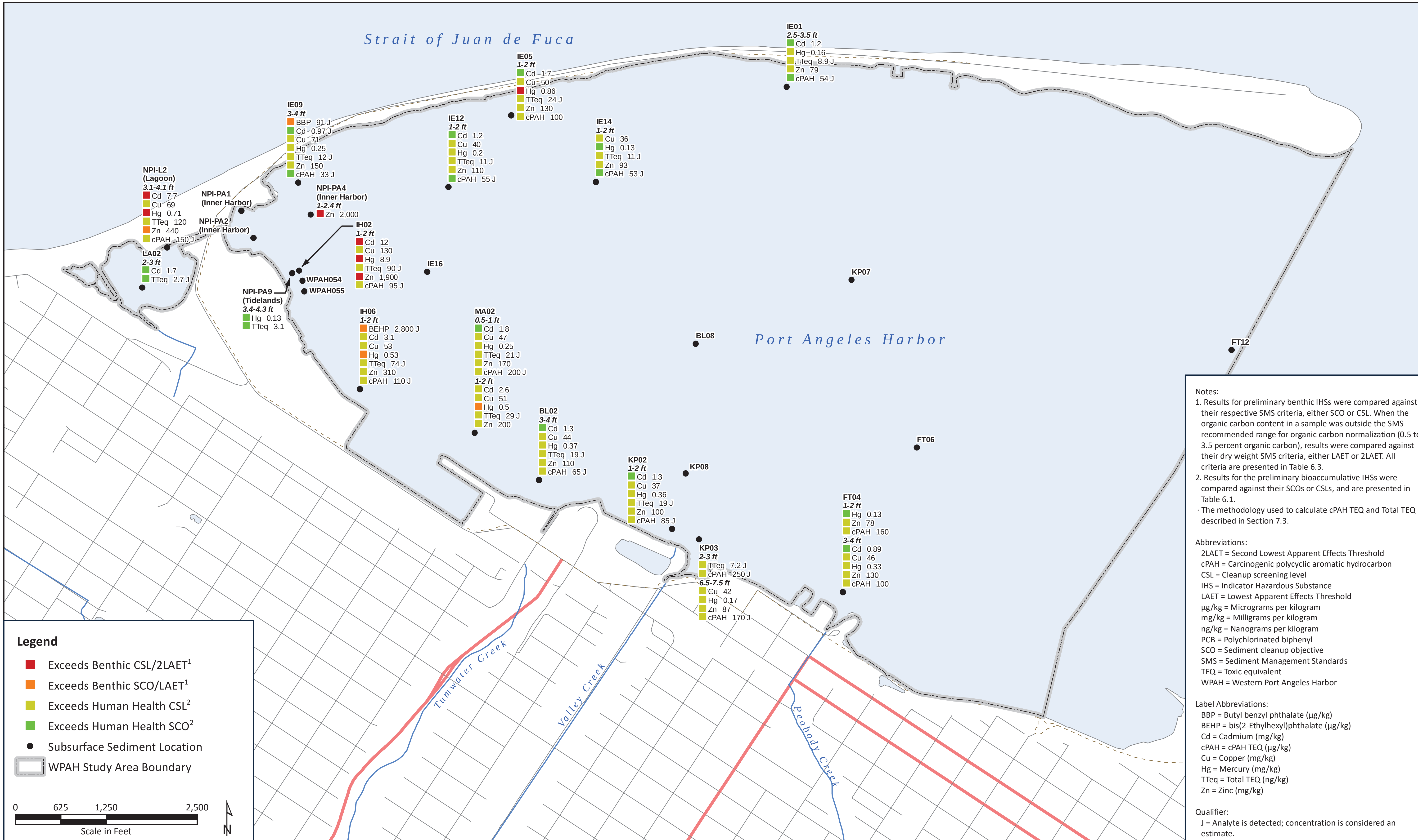
Figure 7.36
Total TEQ in Surface Sediment

N:\GIS\Projects\C1102_PAHarbor_WPAHG\Production_MXDs\RIFS\2019\Fig7_36_TotalTEQ_v2.mxd
6/25/2019



Notes:

1. Results for preliminary benthic IHSs were compared against their respective SMS criteria, either SCO or CSL. When the organic carbon content in a sample was outside the SMS recommended range for organic carbon normalization (0.5 to 3.5 percent organic carbon), results were compared against their dry weight SMS criteria, either LAET or 2LAET. All criteria are presented in Table 6.3.
2. Results for the preliminary bioaccumulative IHSs were compared against their SCOs or CSLs, and are presented in Table 6.1.

· The methodology used to calculate cPAH TEQ and Total TEQ is described in Section 7.3.

Abbreviations:

2LAET = Second Lowest Apparent Effects Threshold
cPAH = Carcinogenic polycyclic aromatic hydrocarbon
CSL = Cleanup screening level
IHS = Indicator Hazardous Substance
LAET = Lowest Apparent Effects Threshold
µg/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
ng/kg = Nanograms per kilogram
PCB = Polychlorinated biphenyl
SCO = Sediment cleanup objective
SMS = Sediment Management Standards
TEQ = Toxic equivalent
WPAH = Western Port Angeles Harbor

Label Abbreviations:

BBP = Butyl benzyl phthalate (µg/kg)
BEHP = bis(2-Ethylhexyl)phthalate (µg/kg)
Cd = Cadmium (mg/kg)
cPAH = cPAH TEQ (µg/kg)
Cu = Copper (mg/kg)
Hg = Mercury (mg/kg)
TTeq = Total TEQ (ng/kg)
Zn = Zinc (mg/kg)

Qualifier:

J = Analyte is detected; concentration is considered an estimate.

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Figure 7.37
Subsurface Locations and Chemical Exceedances

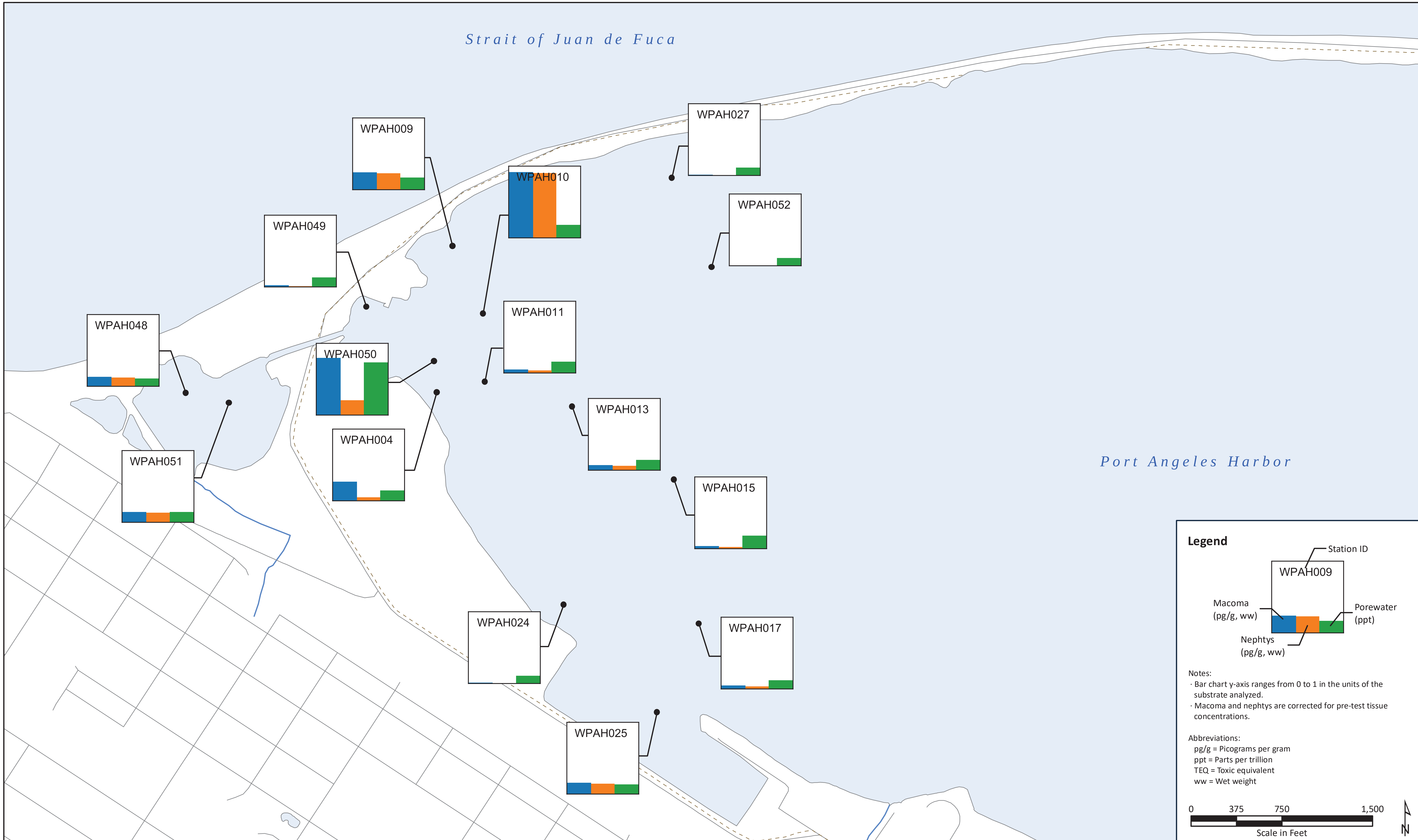

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Figure 7.38
Relative Bioaccumulation—Dioxin/Furan TEQ

I:\GIS\Projects\WPAHG-RIFS\MXD\RIFS Final 2020\Figure 7.38 Relative Bioaccumulation - Dioxin Furan TEQ.mxd
10/29/2020

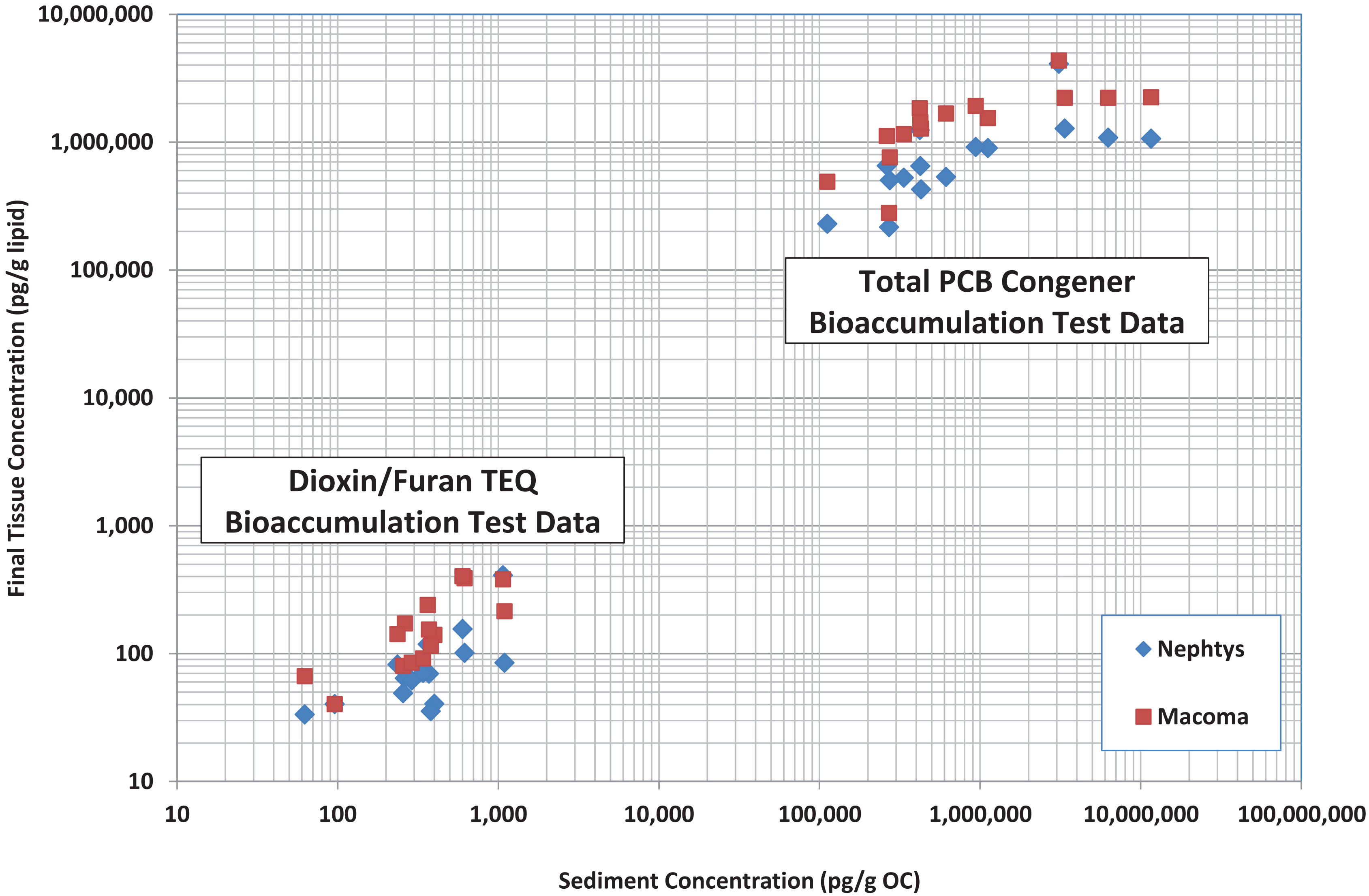

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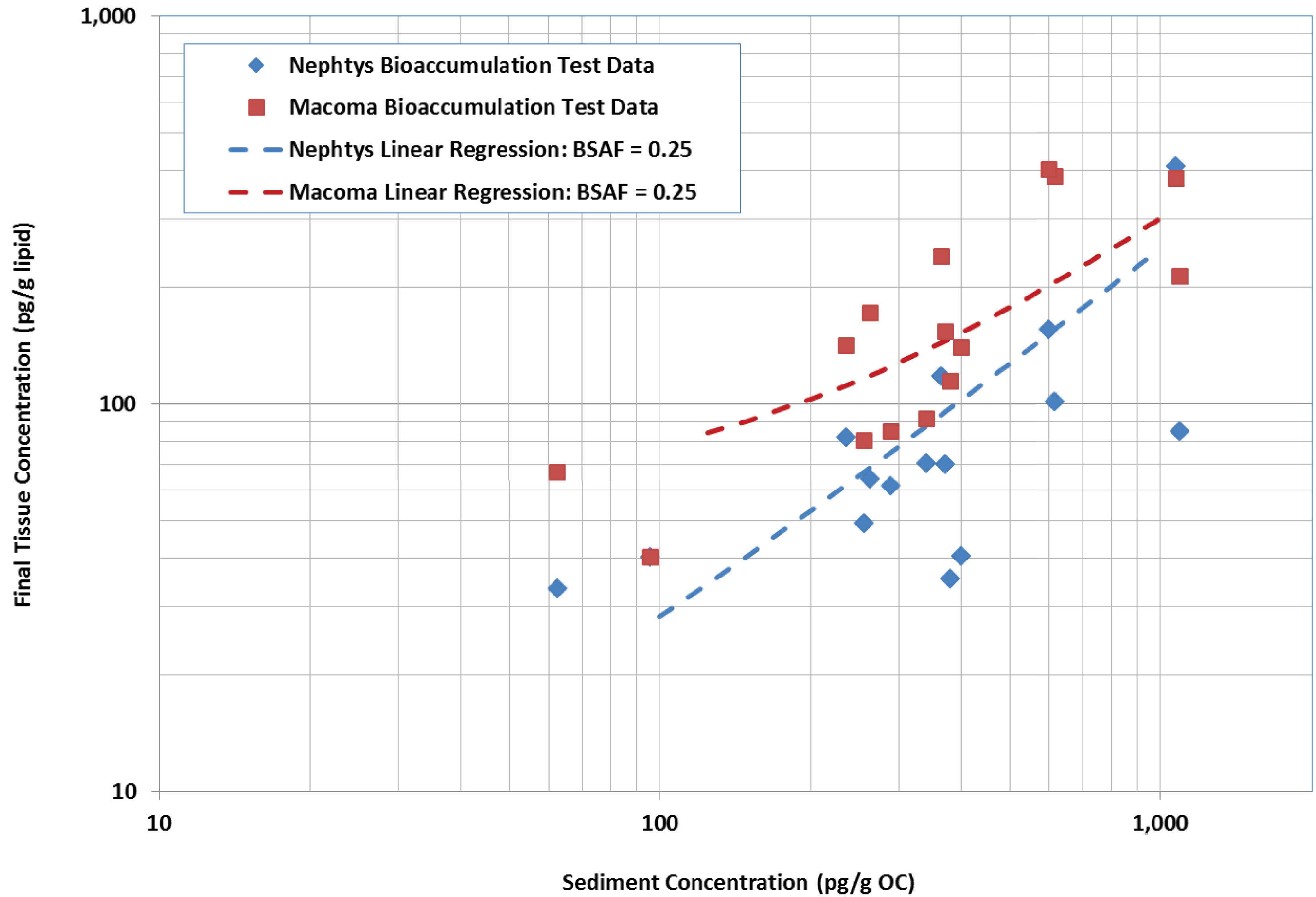
Figure 7.39
WPAH Study Area Bioaccumulation Test Data



Nephtys: Y = 3.5 + 0.25 X; r^2 = 0.49; P (slope) = 0.004
Macoma: Y = 60 + 0.25 X; r^2 = 0.47; P (slope) = 0.005

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Figure 7.40
Bioaccumulation Data—Dioxin/Furan TEQ

Section 8.0: Final Indicator Hazardous Substances and Development of Sediment Cleanup Standards

- Additional evaluation was conducted to determine final indicator hazardous substances (IHSs) and sediment cleanup standards. The results for each of the exposure receptors include:
    - Mobile seafood species (finfish, Dungeness crab):
        - Final IHSs: mercury, carcinogenic polycyclic aromatic hydrocarbon (cPAH) toxic equivalent (TEQ), and Total TEQ
        - Exposure area: the Sediment Cleanup Unit (SCU), based on the interpolated Cleanup Screening Level (CSL) exceedance areas of all the preliminary bioaccumulative IHSs and benthic toxicity test failures.
        - Sediment Cleanup Standards: the CSL to be met on a surface-weighted average concentration (SWAC) basis at a 10-cm point of compliance within the SCU.
    - Sessile seafood species (shellfish):
        - Final IHSs: cadmium, mercury, and cPAH TEQ
        - Exposure area: lagoon intertidal area and inner harbor intertidal area as identified by Ecology.
        - Sediment Cleanup Standards: the CSL to be met on a SWAC basis at a 45-cm point of compliance within the lagoon intertidal area and inner harbor intertidal area.
    - Human health direct contact (oral and dermal): No final IHSs were determined; therefore, no further evaluation was conducted.
    - Benthic species:
        - Final IHSs: cadmium, mercury, and zinc
        - Exposure area: the SCU
        - Sediment Cleanup Standards: the Sediment Cleanup Objective (SCO) to be met on a point-by-point basis at a 10-cm point of compliance within the SCU.

8.0 Final Indicator Hazardous Substances and Development of Sediment Cleanup Standards

The first objective of this section is to document the screening process used for each potential exposure pathway within the WPAH Study Area, consistent with SMS requirements (WAC 173-204-560), which results in the determination of the final bioaccumulative, direct contact, and benthic IHS list. After the final IHSs are determined, final sediment cleanup standards can be established for these substances. Per WAC 173-204-500(5)(a), "Sediment cleanup standards consist of SCLs for individual contaminants and the locations within the site or sediment cleanup unit where the SCLs must be met (points of compliance). Sediment cleanup standards may also include other regulatory requirements that apply to a cleanup action for contaminated sediment because of the type of action and/or location of the site (applicable laws)." The second objective of this section, therefore, is to document the process used to select final SCLs for each final bioaccumulative or direct contact IHS and each final benthic IHS.

8.1 HUMAN HEALTH INDICATOR HAZARDOUS SUBSTANCES

8.1.1 Preliminary Indicator Hazardous Substances Screening and Final Indicator Hazardous Substance Development

The first step in the bioaccumulative and direct contact IHS finalization process was re-screening of the preliminary human health IHSs proposed by Ecology (described in Section 6.1). The preliminary human health IHSs proposed by Ecology (Ecology 2012) include:

- Arsenic, cadmium, copper, mercury, selenium, zinc, alpha-BHC, cPAH TEQ, and Total TEQ for the seafood consumption exposure pathway. There are two potential exposure pathways for seafood consumption: consumption of mobile seafood species (finfish and crab) and consumption of sessile species (bivalves).
- Arsenic, cPAH TEQ, and Total TEQ for the direct contact exposure pathway.

After Ecology's preliminary IHS screening was completed, a supplemental RI/FS data collection effort was conducted in the WPAH Study Area to fill several remaining RI/FS data gaps. Because new data were available, re-screening of the preliminary human health IHSs was conducted for each of the three potential exposure pathways (consumption of mobile seafood species, consumption of sessile seafood species, and direct contact).

8.1.1.1 Consumption of Mobile Seafood Species Pathway Indicator Hazardous Substance Evaluation

Once the preliminary bioaccumulative IHS list was established, the following step-wise screening process was used to determine final bioaccumulative IHSs for mobile seafood species (finfish and crab). A flowchart detailing the final IHS screening process is presented in Figure 8.1, and a summary of the screening outcomes is presented in Table 8.1.

Comparison with Cleanup Screening Levels

The detected chemical concentrations of all preliminary bioaccumulative IHSs were compared against their respective preliminary CSLs. As presented in Table 6.1, these CSLs are all based on regional background levels or natural background levels where regional background values were not determined. The exception to this is selenium, where neither a natural nor regional background value was available, and the PQL was selected as the CSL.

If any sediment sample in the WPAH Study Area had a chemical concentration for a preliminary bioaccumulative IHS that exceeded the CSL, then those IHSs with exceedances were carried forward to the next step of the screening process. If the chemical concentration for a preliminary bioaccumulative IHS did not exceed the CSL in any samples, that preliminary IHS was eliminated from consideration as a bioaccumulative IHS. One of the preliminary IHSs, alpha-BHC, was not detected at concentrations greater than the CSL for protection of seafood consumption risk (1.4 µg/kg based on natural background) on a point-by-point comparison at any locations in the WPAH Study Area. It was, therefore, eliminated as a bioaccumulative IHS.

Evaluation of Essential Nutrients and Risk Contribution

Next, two additional lines-of-evidence were evaluated to determine if the preliminary IHS should be retained for further assessment. These lines-of-evidence included: (1) whether or not the preliminary IHS is considered an essential nutrient for human health, and (2) the overall contribution of the preliminary IHS to seafood consumption risk based on evaluation of the available tissue data collected in the Harbor (NewFields 2013).

After evaluating these lines-of-evidence, copper, selenium, and zinc were eliminated as bioaccumulative IHSs:

- **Copper.** Eliminated as a bioaccumulative IHS based on the following rationale:
    - Based on Ecology's evaluation of the available tissue data collected in the Harbor, copper resulted in maximum calculated HQs only marginally greater than the protective levels (i.e., 1.9 for the worst-case adult subsistence exposure scenario and 3.8 for the worst-case child subsistence exposure scenario; Appendix G, Table 3-14 of Ecology 2012).
    - Copper is an essential nutrient for human health.
- **Selenium.** Eliminated as a bioaccumulative IHS based on the following rationale:
    - Based on Ecology's evaluation of the available tissue data collected in the Harbor, selenium contributes less than 2 percent of the total human health risk (Table 2 of NewFields 2013).
    - Ecology's Port Angeles Harbor sediment characterization study did not identify selenium as a COPC in the Harbor (Ecology 2012), nor did the Western Port Angeles Harbor RI/FS Work Plan (WPAH Group 2013).
    - Selenium is an essential nutrient for human health.

- **Zinc.** Eliminated as a bioaccumulative IHS based on the following rationale:
  - Based on Ecology's evaluation of the available tissue data collected in Port Angeles Harbor, zinc contributes less than 1 percent of the total human health risk (Table 2 of NewFields 2013), with a calculated HQ only marginally greater than the protective levels (i.e., 1.1) and only for a worst-case child subsistence exposure scenario (Appendix G, Table 3-14 of Ecology 2012).
  - Zinc is an essential nutrient for human health.

Arsenic, cadmium, mercury, cPAH TEQ, and Total TEQ were retained as preliminary bioaccumulative IHSs for additional screening.

Determination of the Exposure Area for Mobile Seafood Species

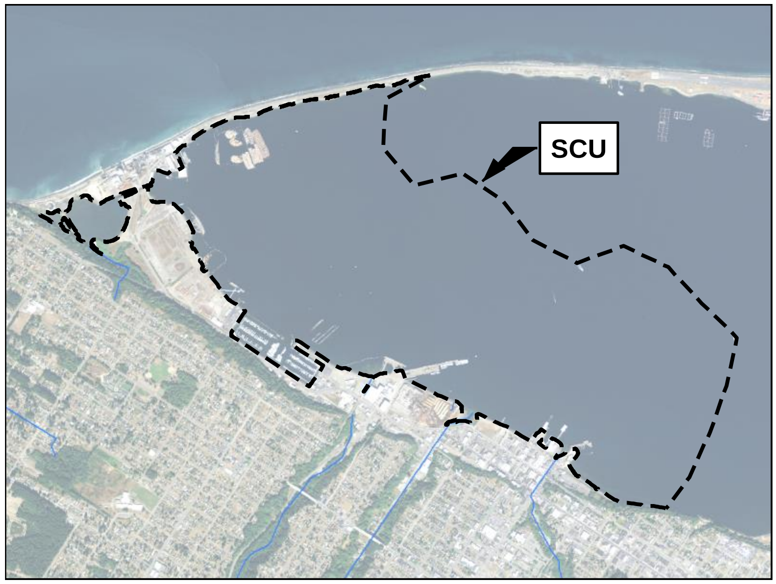
<u>Sediment Cleanup Unit Boundary</u>

Next, using the preliminary IHSs that were retained above, the appropriate area (the SCU) in which to calculate SWACs for the preliminary IHSs was determined. As per Ecology direction (Ecology 2016b), the SCU must encompass all exceedances of the preliminary IHS CSLs and areas exhibiting biological toxicity. Although species' home-ranges are much larger than the SCU, exposures for mobile seafood species are assumed to occur entirely inside the SCU, which is a very conservative assessment of potential exposure because it presumes species are not exposed to lower concentration areas outside of the SCU.

To generate the SCU boundary, the interpolated CSL exceedance areas of all the preliminary bioaccumulative IHSs[15] and benthic toxicity test failures were overlain. Interpolations were performed using the inverse-distance weighted algorithm from the ArcGIS Geostatistical Analyst extension with all of the selected parameters consistent with the Port Angeles Harbor – Sediment Interpolation and Recovery Modeling memorandum (NewFields 2016). The final boundary of the SCU encompasses all footprints of CSL exceedances for the preliminary bioaccumulative IHSs (arsenic, cadmium, mercury, cPAH TEQ, and Total TEQ) and benthic toxicity test failures. Consistent with the Work Plan (WPAH Group 2013), the shoreline of the SCU was based on MHHW, except in areas where this tidal level is covered by riprap or bulkheads. In this case, the SCU shoreline was defined as the toe of the riprap slope or bulkhead, consistent with the Work Plan (WPAH Group 2013).

[15] The two exceptions to this are the cPAH TEQ exceedance area located along the boundary of the WPAH Study Area, as shown in Figure 7.35 (the interpolation in this area was driven by data points within the Rayonier Study Area, and is not considered representative of true cPAH TEQ exceedances) and a single exceedance of mercury at 0.15 mg/kg adjacent to the SCU boundary, which drove a discontinuous contour interpolation along the northern extent of the SCU, as shown in Figure 7.28, that is not considered representative of true mercury exceedances in the interpolated area.

The SCU boundary, having been generated from interpolation contours, was originally defined by a line containing hundreds of vertices, creating a jagged boundary. To develop an accurate and consistent SCU boundary, vertices were selected on the boundary that were 1,000 feet apart starting at the north end of the SCU to draw the boundary, resulting in the final "simplified" and visually smoothed SCU boundary shown on the inset figure at right.



Point of Compliance

The point of compliance is the location at which the SCLs must be achieved. For bioaccumulative IHSs (as well as benthic IHSs) SCU-wide, SCLs apply to subtidal surface sediments within the top 10-cm (Ecology 2017a). This depth is consistent with SCUM II, which states that "for a typical subtidal, soft-bottom marine sediment, the biologically active zone is typically 10 cm" (Ecology 2017d), and the Work Plan (WPAH Group 2013), as well as the Ecology sediment investigation program (Ecology 2012). The point of compliance is therefore defined as the top 10-cm of subtidal sediments SCU-wide.

Within the SCU, compliance with the benthic SCLs is evaluated on a point-by-point basis, and compliance with the bioaccumulative SCLs is evaluated on a SCU-wide SWAC basis.

Comparison of Surface Weighted Average Concentrations with Cleanup Screening Levels

SWACs for the remaining preliminary bioaccumulative IHSs provided by Ecology (arsenic, cadmium, mercury, cPAH TEQ, and Total TEQ) were calculated within the SCU as the average of interpolated grid cell concentrations (using a cell size of 10 by 10 feet; NewFields 2016). All preliminary IHSs with resulting SWACs less than the CSL inside the SCU were eliminated as final bioaccumulative IHSs for the mobile seafood species exposure pathway, since that pathway assumes usage of the entire SCU by mobile species. Arsenic and cadmium were eliminated as final bioaccumulative IHSs on this basis. The SWACs for mercury, cPAH TEQ, and Total TEQ were greater than their respective preliminary CSLs. Refer to Table 8.1 for SWACs compared to preliminary CSLs.

Final Bioaccumulative Indicator Hazardous Substances for Mobile Seafood Species

The bioaccumulative IHS screening resulted in three final bioaccumulative IHSs for the mobile seafood consumption pathway, which will be evaluated further in the FS:

Final Bioaccumulative Indicator Hazardous Substances for Mobile Seafood Consumption:

Mercury	cPAH TEQ	Total TEQ

8.1.1.2 Consumption of Sessile Seafood Species Pathway Indicator Hazardous Substance Evaluation

The step-wise screening process used to determine final bioaccumulative IHSs for sessile seafood species (bivalves) is summarized in this section. A flowchart detailing the screening process is presented in Figure 8.1, and summary of the screening outcomes is presented in Table 8.1.

Preliminary Screening

This section includes the two initial screening evaluation steps identified for consumption of mobile seafood species, with identical outcomes: alpha-BHC, copper, selenium, and zinc are eliminated as bioaccumulative IHSs.

Additionally, Total TEQ is not identified as an applicable IHS for sessile seafood species (Ecology 2017a). Total TEQ is not a primary bioaccumulative risk driver for bivalves (i.e., 92 percent of bioaccumulation exposures to dioxin/furan TEQ and 96 percent of exposures to total PCBs are the result of ingestion of crab [WPAH Group 2014]) and, therefore, does not need to be considered further relative to sessile species.

Determination of the Exposure Area for Sessile Seafood Species

Lagoon Intertidal Area and Inner Harbor Intertidal Area Boundary

Ecology defined areas where future shellfishing is “likely” or “possible.” Ecology stated that these areas were defined based on consideration of industrial and operational areas in the Harbor, vessel traffic, and diver safety (Ecology 2017a). These areas are “limited to intertidal areas within the anticipated SCUs where there is, or may be in the future, reasonable access to the shoreline for shellfish harvest by the public.” These areas, as defined by Ecology within the WPAH Study Area, are termed the lagoon intertidal area and the inner harbor intertidal area.[16] The lagoon intertidal and inner harbor intertidal area is depicted on Figure 8.2.

16 These areas were modified slightly by the WPAH Group based on operational and shoreline characteristics such as the presence of bulkheads, riprap, and active industrial operations in the vicinity of McKinley Paper Company and including the dock.

Point of Compliance

Ecology considers 45 cm as "a typical depth from which clams would be collected during intertidal clam-digging" and, therefore, 45 cm is the point of compliance in the lagoon intertidal and inner harbor intertidal area (Ecology 2017a). Compliance with the bioaccumulative SCLs within this combined intertidal area is evaluated on a SWAC basis, with one SWAC calculated for the lagoon intertidal and inner harbor intertidal area depicted on Figure 8.2.

Importantly, the applicability of a 45-cm point of compliance in the intertidal areas was not identified by Ecology until August 2017, after preparation of the Work Plan (WPAH Group 2013) and subsequent data review (Integral et al. 2014). Therefore, very limited data exist in the intertidal areas identified by Ecology, and there are no 45-cm sample depth results from either Ecology investigations (Ecology 2012) or subsequent work performed by the WPAH Group. However, SWACs were estimated for these intertidal areas based on concentrations measured in adjacent subtidal sediments. These SWACs are based on chemical concentrations in samples proximate to the intertidal area.

Comparison of Surface Weighted Average Concentrations with Cleanup Screening Levels

Total TEQ is not considered relative to sessile species (Table 8.1). SWACs for all of the retained preliminary bioaccumulative IHSs (arsenic, cadmium, mercury, and cPAH TEQ) were calculated as the average of interpolated grid cell concentrations (using a cell size of 10 by 10 feet; NewFields 2016) within the intertidal areas. As in the mobile seafood species exposure pathway, all preliminary IHSs with resulting SWACs less than the preliminary CSL were eliminated as final bioaccumulative IHSs for the sessile seafood species exposure pathway. Arsenic was eliminated as a final IHS on this basis. The SWACs for cadmium, mercury, and cPAH TEQ were greater than the preliminary CSLs. Refer to Table 8.1 for SWACs compared to preliminary CSLs.

Final Bioaccumulative Indicator Hazardous Substances for Sessile Seafood Species

The bioaccumulative IHS screening resulted in three final bioaccumulative IHSs for the sessile seafood consumption pathway, which will be evaluated further in the FS:

Final Bioaccumulative Indicator Hazardous Substances for Sessile Seafood Consumption:

Cadmium Mercury cPAH TEQ

8.1.1.3 Direct Contact Pathway Indicator Hazardous Substance Evaluation

The step-wise screening process used to determine final direct contact IHSs for intertidal areas is summarized in the following sections. A flowchart detailing the screening process is presented in Figure 8.1, and a summary of the screening outcomes is presented in Table 8.1.

Comparison with Cleanup Screening Levels

The detected chemical concentrations of all preliminary direct contact IHSs identified by Ecology in their human health risk assessment (arsenic, cPAH TEQ, and total TEQ) were compared against their preliminary direct contact CSLs. These direct contact CSLs were calculated based on the exposure parameters defined in the human health risk assessment (Appendix G, Attachment C of Ecology 2012) and are presented in Table 6.2. All preliminary direct contact IHSs were eliminated from further consideration on this basis.

Determination of the Exposure Area

Direct Contact Intertidal Areas

Intertidal areas are any areas between the elevations of MHHW and MLLW within the SCU (Ecology 2017a). The intertidal areas within the SCU are presented on Figure 8.2.

Point of Compliance

Ecology requested a 45-cm depth point of compliance in these intertidal areas (Ecology 2017a). Compliance with the direct contact SCLs within the intertidal areas is evaluated on a SWAC basis, with one SWAC calculated for all direct contact intertidal areas depicted on Figure 8.2.

Comparison of SWACs with Cleanup Screening Levels

SWACs for Ecology's preliminary direct contact IHSs (arsenic, cPAH TEQ, and Total TEQ) were calculated for the intertidal areas (areas between MLLW and MHHW) based on data proximate to the intertidal areas. Preliminary IHSs with SWACs less than the CSL were eliminated as direct contact IHSs. Arsenic, cPAH TEQ, and Total TEQ were all eliminated as direct contact IHSs on this basis (Table 8.1).

Final Direct Contact Indicator Hazardous Substances

The human health IHS screening resulted in no IHSs for the direct contact pathway to be carried forward in the FS.

8.2 BENTHIC INDICATOR HAZARDOUS SUBSTANCES

Although Ecology previously identified preliminary benthic IHSs in their ecological risk assessment, the entire SMS chemical list was re-screened to determine final benthic IHSs. This re-screening incorporates the 2013 bioassay data as an additional line-of-evidence to determine the final IHS list, as described in this section. A flowchart detailing the benthic IHS screening process is presented in Figure 8.3. Unlike the consumption and direct contact exposure pathways, benthic exposures are evaluated on a point-by-point basis, not by SWACs, due to the generally sessile nature of the benthic community. Therefore, comparisons discussed herein are performed using available individual chemical data.

8.2.1 Determination of the Exposure Area for Benthic Species

The exposure area evaluated for benthic species was within the SCU, with a 10-cm point of compliance.

8.2.2 Comparison of Point-by-Point Concentrations with Sediment Cleanup Objectives and Cleanup Screening Levels

The frequency of SCO and CSL exceedances for each SMS chemical is presented in Table 8.2 (using only samples with the TOC range of 0.5 to 3.5 percent for the OC-normalized data). Table 8.3 shows the frequency of the dry weight LAET and 2LAET exceedances in the samples with TOC concentrations greater than 3.5 percent. If the chemical concentration exceeded the SCO/LAET in more than 1 percent of the samples, the chemical was carried forward to Step 2 of the screening process. If the chemical concentration exceeded the SCO/LAET in less than 1 percent of the samples, the chemical was eliminated from consideration as a benthic IHS. One percent was also the screening percentage used by Ecology in their ecological risk assessment (Ecology 2012).

8.2.3 Comparison of Bioassay Results with Biological Criteria

As described in Section 5.1.2, a full suite of SMS confirmatory bioassay testing was performed at a number of sample stations to more directly characterize potential sediment toxicity for benthic organisms. The sediment bioassays included: (1) the 10-day amphipod test (using *E. estuarius*); (2) the larval development bioassay with the resuspension protocol (using the mussel *M. galloprovincialis*); and (3) the 20-day polychaete growth test (using *Neanthes sp.*).

If the confirmatory bioassay results exceeded the SCO biological criteria, the corresponding chemical(s) in that sample were retained as benthic IHSs. Conversely, if the confirmatory bioassay results were less than the SCO biological criteria, the corresponding chemical(s) in that sample were eliminated as benthic IHSs. The results of the chemical screening and confirmatory bioassays within the SCU are summarized in Figure 8.4.

8.2.4 Final Benthic Indicator Hazardous Substances

The rationale for the elimination or retention of each SMS chemical as a final benthic IHS is summarized in Table 8.4. The chemical screening and confirmatory bioassay process resulted in three final benthic IHSs:

Final Benthic Indicator Hazardous Substances:

Cadmium Mercury Zinc

8.3 CONSIDERATIONS FOR PROSPECTIVE SEDIMENT CLEANUP STANDARDS

SMS recognizes that at certain sites additional factors should be considered when establishing SCLs. In accordance with SMS, the site-specific SCL can be adjusted upward from the SCO to a value no greater than the CSL on the basis of the following considerations:

- **Technical possibility.** Whether it is technically possible to achieve and maintain the cleanup level at the applicable point of compliance (WAC 173-204-560(2)(a)(ii)(A)).
- **Net adverse environmental impacts.** Whether achieving and maintaining the cleanup level will have a net adverse environmental impact on the aquatic environment (WAC 173-204-560(2)(a)(ii)(B)).

8.3.1 Technical Possibility

Technically possible is defined as "…capable of being designed, constructed and implemented in a reliable and effective manner, regardless of cost" (WAC 173-204-505(23)). Technical possibility depends on a variety of site-specific factors that include the ability to achieve the SCL using available technologies.

Achieving the SCOs is technically possible for a short post-construction period using large-scale EMNR and/or capping actions. However, these actions will not be effective at maintaining SCOs over time due to watershed loading. Estimates of watershed loading (discussed in Section 11.2.3) indicate diffuse ongoing sources of cPAHs (and potentially other bioaccumulative IHSs) that are projected to increase the post-construction cPAH TEQ SWAC to concentrations greater than the SCO of 16 µg/kg for cPAH TEQ. Therefore, although it is technically possible to design and construct a remedy that achieves the natural background SCO immediately following construction, long-term effectiveness (ability to maintain natural background-based SCOs for the bioaccumulative IHSs) is not technically possible under Ecology's definition (WAC 173-204-505(23)). In addition, the net adverse environmental impacts resulting from the selection of SCOs versus CSLs provide additional basis for adjusting the site-specific SCL upward from the SCO as allowed by SMS. This evaluation is discussed in the next subsection.

8.3.2 Net Adverse Environmental Impacts

The determination of net adverse environmental impacts is based on the short- and long-term positive and negative impacts of cleanup actions on natural resources, including shellfish, forage fish, and eelgrass beds; aquatic habitat; habitat restoration opportunities; and habitat enhancement opportunities (WAC 173-204-560(2)(a)(ii)(B)).

Construction of a large-scale subtidal remediation that will only temporarily achieve the SCOs for the bioaccumulative IHSs would extend over decades due to the size of the area to be addressed (approximately 1,780 acres). This extended construction period would result in extensive adverse environmental impacts on natural resources as well as on the harvest of such resources from the SCU. The SCOs and CSLs for the final bioaccumulative IHSs for mobile seafood species are summarized in Table 8.5, along with the approximate acreages within the SCU that have concentrations of these bioaccumulative IHSs that currently exceed the SCOs and CSLs. The SCOs for cPAH TEQ and Total TEQ are significantly lower than their respective CSLs and would result in roughly 1.5 to 2.5 times the acreage (of sediments exceeding the TEQ value) as compared to the CSLs. Moreover, because experience from regional sediment cleanup projects shows that sediment cleanup remedies can be constructed at a maximum production rate of approximately 50 acres per year (e.g., EMNR placement using two barges operating around regional fish windows), decades of construction and disruption would be required to achieve the SCOs for the bioaccumulative IHSs. Similarly, for intertidal areas with the potential for human exposure through direct contact, construction of a large-scale remedy throughout the intertidal areas of the Harbor to achieve the SCO as opposed to the CSL would result in temporary removal or disruption of existing ecological populations within intertidal beach areas.

Targeting subtidal areas with the greatest concentrations of bioaccumulative IHSs for remediation would reduce risks and meet the CSL more rapidly compared to remediating more widely distributed, lower-level contamination that would only temporarily achieve the SCO. Additionally, the duration of adverse impacts on natural resources and habitat associated with remedial construction would be more limited. Moreover, focusing sediment remediation on higher-concentration areas of the inner harbor, some of which have evidence of historical mixing (Figure 2.3), would reduce internal sources of IHSs, accelerating natural recovery of the rest of the SCU. Therefore, based on considerations of net adverse environmental impacts, the site-specific SCLs for the bioaccumulative and direct contact IHSs are appropriately set at the CSLs.[17]

Separate considerations of net adverse environmental impacts based on the short- and long-term positive and negative effects of cleanup actions on natural resources, as required under WAC 173-204-560(2)(a)(ii)(B), apply to benthic IHSs. For example, potential sediment toxicity impacts on natural resources resulting from setting site-specific benthic chemical criteria at levels greater than the SCO must be appropriately balanced with construction impacts during and after remediation. For benthic toxicity, the SCO is the criterion at which no adverse effects occur, including no acute or chronic adverse effects on biological resources. The CSL is the minor adverse effects level, which is the minimum level to be achieved in all cleanup actions under the SMS. Because of the far more localized exceedances of the benthic SCOs in the SCU (Figure 8.4) compared with the bioaccumulative IHSs as summarized above, the site-specific SCLs for the benthic IHSs are appropriately set at the SCOs, particularly because differences in extent (as well as associated disruption to ecological resources) are relatively minor between the benthic SCO and the CSL.

[17] For the direct contact exposure pathway, establishment of the CSL as the SCL results in the elimination of all preliminary direct contact IHSs as final direct contact IHSs, as described in Section 8.1.1.3; therefore, no further evaluation of the direct contact exposure pathway is required.

8.4 INDICATOR HAZARDOUS SUBSTANCES AND SEDIMENT CLEANUP STANDARDS

Sediment cleanup standards consist of SCLs for the human health and benthic IHSs, and their respective points of compliance. A summary of the final IHSs, their SCLs and points of compliance, and the basis for each of the SCLs is presented in Table 8.6.

Table 8.6
Final IHS SCLs and Points of Compliance

Final IHS	SCL	Point of Compliance	SCL Basis
SCU			
Bioaccumulative IHSs			
Mercury (mg/kg)	0.13	0 to 10 cm based on protection of human health via bioaccumulative exposures from mobile seafood consumption; SWAC of SCU	Regional Background
cPAH TEQ (µg/kg)	64		Regional Background
Total TEQ (ng/kg)	5.2		Regional Background
Benthic IHSs			
Cadmium (mg/kg)	5.1	0 to 10 cm based on protection of benthic toxicity; point by point within SCU	SMS SCO
Mercury (mg/kg)	0.41		SMS SCO
Zinc (mg/kg)	410		SMS SCO
Lagoon Intertidal and Inner Harbor Intertidal Area			
Bioaccumulative IHSs			
Cadmium (mg/kg)	2.4	0 to 45 cm based on protection of human health via bioaccumulative exposures from sessile seafood consumption; SWAC of lagoon intertidal and inner harbor intertidal area	Regional Background
Mercury (mg/kg)	0.13		Regional Background
cPAH TEQ (µg/kg)	64		Regional Background

WPAHG

Western Port Angeles Harbor Group

Section 8.0:
Final Indicator Hazardous Substances and Development of Sediment Cleanup Standards

Tables

Western Port Angeles Harbor
Sediment Cleanup Unit

Remedial Investigation/Feasibility Study

Table 8.1
Final Bioaccumulative and Direct Contact Human Health Indicator Hazardous Substances Screening Summary

Proposed Indicator Hazardous Substance	Retained as a Final IHS?	Rationale for Elimination or Retention
Preliminary Seafood Consumption Screening		
Copper	No	• Based on Ecology's evaluation of the available tissue data collected in the Harbor, copper resulted in maximum calculated hazard quotients only marginally greater than the protective levels (i.e., 1.9 for the worst-case adult subsistence exposure scenario and 3.8 for the worst-case child subsistence exposure scenario; Appendix G, Table 3-14 of Ecology 2012). • Copper is an essential nutrient for human health.
Selenium	No	• Based on Ecology's evaluation of the available tissue data collected in the Harbor, selenium contributes less than 2 percent of the total human health risk (Table 2 of NewFields 2013). • Ecology's Port Angeles Harbor sediment characterization study also did not identify selenium as a chemical of potential concern in the Harbor (Ecology 2012), nor did the Work Plan (WPAH Group 2013). • Selenium is an essential nutrient for human health.
Zinc	No	• Based on Ecology's evaluation of the available tissue data collected in the Harbor, zinc contributes less than 1 percent of the total human health risk (Table 2 of NewFields 2013), with a calculated hazard quotient only marginally greater than the protective levels (i.e., 1.1) and only for a worst-case child subsistence exposure scenario (Appendix G, Table 3-14 of Ecology 2012). • Zinc is an essential nutrient for human health.
α-BHC	No	None of the concentrations in samples collected within the WPAH Study Area were greater than the human health CSL (1.4 µg/kg).
Seafood Consumption – Mobile Species		
Arsenic	No	The current arsenic SWAC within the SCU (7.6 mg/kg) is less than the CSL (13.9 mg/kg).
Cadmium	No	The current cadmium SWAC within the SCU (1.0 mg/kg) is less than the CSL (2.4 mg/kg).
Mercury	Yes	The current mercury SWAC within the SCU (0.23 mg/kg) is greater than the CSL (0.13 mg/kg).
cPAH TEQ	Yes	The cPAH TEQ current SWAC within the SCU (144 µg/kg is greater than the CSL (64 µg/kg).
Total TEQ	Yes	The current Total TEQ SWAC within the SCU boundary (13.4 ng/kg) is greater than the CSL (5.2 ng/kg).

Table 8.1
Final Bioaccumulative and Direct Contact Human Health Indicator Hazardous Substances Screening Summary

Proposed Indicator Hazardous Substance	Retained as a Final IHS?	Rationale for Elimination or Retention
Seafood Consumption – Sessile Species		
Arsenic	No	The current arsenic SWAC within the lagoon and inner harbor intertidal areas (8.1 mg/kg) is less than the CSL (13.9 mg/kg).
Cadmium	Yes	The current cadmium SWAC within the lagoon and inner harbor intertidal areas (4.6 mg/kg) is greater than the CSL (2.4 mg/kg).
Mercury	Yes	The current mercury SWAC within the lagoon and inner harbor intertidal areas (0.47 mg/kg) is greater than the CSL (0.13 mg/kg).
cPAH TEQ	Yes	The cPAH TEQ current SWAC within the lagoon and inner harbor intertidal areas (246 µg/kg) is greater than the CSL (64 µg/kg).
Total TEQ	No	Per Ecology, Total TEQ is not identified as an applicable Indicator Hazardous Substance for sessile seafood species. Total TEQ is not a primary bioaccumulative risk driver for bivalves (i.e., 92 percent of bioaccumulation exposures to dioxin/furan TEQ and 96 percent of exposures to total PCBs are the result of ingestion of crab [WPAH Group 2014]) and therefore does not need to be considered further relative to sessile species (Ecology 2017a).
Direct Contact		
Arsenic	No	The current arsenic SWAC within the intertidal areas (7.56 mg/kg) is less than the CSL (13.9 mg/kg).
cPAH TEQ	No	The current cPAH TEQ SWAC within the intertidal areas (226 µg/kg) is less than the CSL (250 µg/kg).
Total TEQ	No	The current Total TEQ SWAC within the intertidal areas (31 ng/kg) is equal to the CSL (31 ng/kg).

Note:
Grey row indicates chemical retained as a final IHS for further evaluation.

Abbreviations:
α-BHC alpha-Hexachlorocyclohexane
cPAH Carcinogenic polycyclic aromatic hydrocarbon
CSL Cleanup Screening Level
Ecology Washington State Department of Ecology
IHS Indicator hazardous substance
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
ng/kg Nanograms per kilogram
PCB Polychlorinated biphenyl
SCU Sediment Cleanup Unit
SWAC Surface-weighted average concentration
TEQ Toxic equivalent

Table 8.2

Frequency of Exceedances of Sediment Management Standards Sediment Cleanup Objectives and Cleanup Screening Levels in Surface Sediment Samples[1]

			Information about Detections								Information about Exceedances							
Chemicals	**CAS No.**	**Units**	**Number of Results**	**Number of Detections**	**Percentage Detection**	**Minimum Detected Value**	**Maximum Detected Value**	**Location of Maximum Detections**	**Date of Maximum Detection**	**Depth of Maximum Detection**	**SMS SCO**	**Number of Detected Exceedances of SMS SCO**	**Percentage of Detected Exceedances of SMS SCO**	**Exceedance Factor**	**SMS CSL**	**Number of Detected Exceedances of SMS CSL**	**Percentage of Detected Exceedances of SMS CSL**	**Exceedance Factor**
Metals																		
Arsenic	7440-38-2	mg/kg dw	78	73	94%	1.7	69	PA_IH02A	06/16/2008	0–10 cm	57	1	1.3%	1.2	93	None	None	None
Cadmium	7440-43-9	mg/kg dw	81	77	95%	0.1	8.1	NPI-PA3	02/28/2008	0–10 cm	5.1	8	9.9%	1.6	6.7	4	4.9%	1.2
Chromium	7440-47-3	mg/kg dw	62	62	100%	11	45	PA_STP10-02	09/08/2010	0–10 cm	260	None	None	None	270	None	None	None
Copper	7440-50-8	mg/kg dw	78	78	100%	6.8	95	PA_IH01A	06/16/2008	0–10 cm	390	None	None	None	390	None	None	None
Lead	7439-92-1	mg/kg dw	62	62	100%	3.6	84	PA_LA01A	07/23/2008	0–10 cm	450	None	None	None	530	None	None	None
Mercury	7439-97-6	mg/kg dw	86	86	100%	0.022	3.5	PA_IH01A	06/16/2008	0–10 cm	0.41	24	28%	8.5	0.59	14	16%	5.9
Silver	7440-22-4	mg/kg dw	62	57	92%	0.027	0.24	PA_FT01A	06/17/2008	0–10 cm	6.1	None	None	None	6.1	None	None	None
Zinc	7440-66-6	mg/kg dw	81	81	100%	21	1,700	NPI-PA3	02/28/2008	0–10 cm	410	6	7.4%	4.1	960	3	3.7%	1.8
Polycyclic Aromatic Hydrocarbons (PAHs)																		
Total LPAH	--	mg/kg-OC	37	37	100%	2.1	180	PA_STP10-02	09/08/2010	0–10 cm	370	None	None	None	780	None	None	None
Naphthalene	91-20-3	mg/kg-OC	37	26	70%	0.3	10	RAYONR05HS-07	08/19/2002	0-10 cm	99	None	None	None	170	None	None	None
Acenaphthylene	208-96-8	mg/kg-OC	37	21	57%	0.34	8.5	PA_STP04CSO-006	09/23/2003	0–2 cm	66	None	None	None	66	None	None	None
Acenaphthene	83-32-9	mg/kg-OC	37	18	49%	0.4	8.6	PA_STP10-02	09/08/2010	0–10 cm	16	None	None	None	57	None	None	None
Fluorene	86-73-7	mg/kg-OC	37	25	68%	0.56	10	PA_STP10-02	09/08/2010	0–10 cm	23	None	None	None	79	None	None	None
Phenanthrene	85-01-8	mg/kg-OC	37	37	100%	1.2	140	PA_STP10-02	09/08/2010	0–10 cm	100	1	2.7%	1.4	480	None	None	None
Anthracene	120-12-7	mg/kg-OC	37	31	84%	0.73	17	PA_STP10-02	09/08/2010	0–10 cm	220	None	None	None	1,200	None	None	None
2-Methylnaphthalene	91-57-6	mg/kg-OC	37	13	35%	0.24	3.2	PA_STP04CSO-006	09/23/2003	0–2 cm	38	None	None	None	64	None	None	None
Total HPAH	--	mg/kg-OC	37	37	100%	5	860	PA_STP10-02	09/08/2010	0–10 cm	960	None	None	None	5,300	None	None	None
Fluoranthene	206-44-0	mg/kg-OC	37	37	100%	1.8	250	PA_STP10-02	09/08/2010	0–10 cm	160	1	2.7%	1.6	1,200	None	None	None
Pyrene	129-00-0	mg/kg-OC	37	37	100%	1.6	170	PA_STP10-02	09/08/2010	0–10 cm	1,000	None	None	None	1,400	None	None	None
Benzo(a)anthracene	56-55-3	mg/kg-OC	37	36	97%	1.1	66	PA_STP10-02	09/08/2010	0–10 cm	110	None	None	None	270	None	None	None
Chrysene	218-01-9	mg/kg-OC	37	37	100%	0.89	89	PA_STP10-02	09/08/2010	0–10 cm	110	None	None	None	460	None	None	None
Total Benzofluoranthenes	56832-73-6	mg/kg-OC	39	39	100%	0.81	140	PA_STP10-02	09/08/2010	0–10 cm	230	None	None	None	450	None	None	None
Benzo(a)pyrene	50-32-8	mg/kg-OC	37	35	95%	0.88	68	PA_STP10-02	09/08/2010	0–10 cm	99	None	None	None	210	None	None	None
Benzo(g,h,i)perylene	191-24-2	mg/kg-OC	37	31	84%	0.81	34	PA_STP10-02	09/08/2010	0–10 cm	31	2	5.4%	1.1	78	None	None	None
Indeno(1,2,3-cd)pyrene	193-39-5	mg/kg-OC	37	30	81%	0.73	36	PA_STP10-02	09/08/2010	0–10 cm	34	1	2.7%	1.1	88	None	None	None
Dibenzo(a,h)anthracene	53-70-3	mg/kg-OC	37	20	54%	0.35	11	PA_STP10-02	09/08/2010	0–10 cm	12	None	None	None	33	None	None	None
Chlorinated Benzenes																		
1,2-Dichlorobenzene	95-50-1	mg/kg-OC	35	None	None	None	None	None	None	None	2.3	None	None	None	2.3	None	None	None
1,4-Dichlorobenzene	106-46-7	mg/kg-OC	35	4	11.4%	0.19	6.8	PA_STP04CSO-007	09/23/2003	0–2 cm	3.1	1	2.9%	2.2	9	None	None	None
1,2,4-Trichlorobenzene	120-82-1	mg/kg-OC	35	None	None	None	None	None	None	None	0.81	None	None	None	1.8	None	None	None
Hexachlorobenzene	118-74-1	mg/kg-OC	37	1	2.7%	0.21	0.21	PA_STP04CSO-007	09/23/2003	0–2 cm	0.38	None	None	None	2.3	None	None	None
Phthalate Esters																		
Dimethyl phthalate	131-11-3	mg/kg-OC	37	2	5.4%	0.96	1.4	PA_STP04CSO-007	09/23/2003	0–2 cm	53	None	None	None	53	None	None	None
Diethylphthalate	84-66-2	mg/kg-OC	37	6	16%	0.84	1.8	PA_KP05A	06/12/2008	0–10 cm	61	None	None	None	110	None	None	None
Di-n-butyl phthalate	84-74-2	mg/kg-OC	37	8	22%	0.27	25	PA_STP10-02	09/08/2010	0–10 cm	220	None	None	None	1,700	None	None	None
Butyl benzyl phthalate	85-68-7	mg/kg-OC	37	2	5.4%	0.57	1.5	PA_FT02A	06/17/2008	0–10 cm	4.9	None	None	None	64	None	None	None
bis(2-ethylhexyl)phthalate	117-81-7	mg/kg-OC	37	32	86%	0.66	670	PA_STP10-01	09/08/2010	0–10 cm	47	3	8.1%	14	78	1	2.7%	8.6
Di-n-octyl phthalate	117-84-0	mg/kg-OC	37	2	5.4%	1.1	2	PA_STP04CSO-007	09/23/2003	0–2 cm	58	None	None	None	4,500	None	None	None

Table 8.2

Frequency of Exceedances of Sediment Management Standards Sediment Cleanup Objectives and Cleanup Screening Levels in Surface Sediment Samples[1]

Chemicals	CAS No.	Units	Information about Detections								Information about Exceedances							
			Number of Results	Number of Detections	Percentage Detection	Minimum Detected Value	Maximum Detected Value	Location of Maximum Detections	Date of Maximum Detection	Depth of Maximum Detection	SMS SCO	Number of Detected Exceedances of SMS SCO	Percentage of Detected Exceedances of SMS SCO	Exceedance Factor	SMS CSL	Number of Detected Exceedances of SMS CSL	Percentage of Detected Exceedances of SMS CSL	Exceedance Factor
Miscellaneous Nonionizable Organic Compounds																		
Dibenzofuran	132-64-9	mg/kg-OC	37	17	46%	0.26	6.3	PA_STP10-02	09/08/2010	0–10 cm	15	None	None	None	58	None	None	None
Hexachlorobutadiene	87-68-3	mg/kg-OC	37	None	None	None	None	None	None	None	3.9	None	None	None	6.2	None	None	None
N-Nitrosodiphenylamine	86-30-6	mg/kg-OC	35	2	5.7%	0.36	5.4	PA_STP10-02	09/08/2010	0–10 cm	11	None	None	None	11	None	None	None
Pesticides/Polychlorinated Biphenyls (PCBs)																		
PCBs (Total, Aroclors)	1336-36-3	mg/kg-OC	37	10	27%	0.28	2.1	PA_STP10-01	09/08/2010	0–10 cm	12	None	None	None	65	None	None	None
Ionizable Organic Compounds																		
Phenol	108-95-2	µg/kg dw	60	44	73%	12	740	PA_MA04A	06/12/2008	0–10 cm	420	2	3.3%	1.8	1,200	None	None	None
2-Methylphenol	95-48-7	µg/kg dw	60	2	3.3%	40	61	KSS-2	07/09/2013	0–10 cm	63	None	None	None	63	None	None	None
4-Methylphenol	106-44-5	µg/kg dw	60	40	67%	5.1	190	WPAH003	07/01/2013	0–10 cm	670	None	None	None	670	None	None	None
2,4-Dimethylphenol	105-67-9	µg/kg dw	60	2	3.3%	12	15	KSS-2	07/09/2013	0–10 cm	29	None	None	None	29	None	None	None
Pentachlorophenol	87-86-5	µg/kg dw	60	None	None	None	None	None	None	None	360	None	None	None	690	None	None	None
Benzyl alcohol	100-51-6	µg/kg dw	55	None	None	None	None	None	None	None	57	None	None	None	73	None	None	None
Benzoic acid	65-85-0	µg/kg dw	58	3	5%	150	180	RAYONR05HS-02	08/21/2002	0–10 cm	650	None	None	None	650	None	None	None

Notes:

1 The following notes pertain to the content of this table:

- Only locations within the SCU boundary are included.
- For sample/sample duplicate pairs, only the greatest detected concentration (or lowest reporting limit if both were not detected) has been reported for each chemical at each location.
- For samples in which multiple analytical methods resulted in reported concentrations for a single chemical, only the greatest detected concentration (or lowest reporting limit if none were detected) has been reported.
- Only surface samples (maximum depth of 10 cm) are included.
- All SMS chemicals are included. For organic chemicals with criteria that are OC-normalized, only samples with TOC values between 0.5 to 3.5 percent are included. For samples with TOC values outside this range, refer to Table 8.3.
- Only the most recent results from reoccupied stations are included.
- The exceedance factor is rounded to two significant figures.

Abbreviations:

CAS Chemical Abstracts Service
cm Centimeters
CSL Cleanup screening level
dw Dry weight
HPAH High molecular weight polycyclic aromatic hydrocarbon
LPAH Low molecular weight polycyclic aromatic hydrocarbon
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
OC Organic carbon normalized
SCO Sediment cleanup objective
SCU Sediment Cleanup Unit
SMS Sediment Management Standards
TOC Total organic carbon

Table 8.3

Frequency of Exceedances of LAET and 2LAET Criteria in Surface Sediment Samples[1]

			Information about Detections								Information about Exceedances							
Chemicals	CAS No.	Units	Number of Results	Number of Detections	Percentage of Detected Results	Minimum Detected Value	Maximum Detected Value	Location of Maximum Detection	Date of Maximum Detection	Depth of Maximum Detection	LAET	Number of Detected Exceedances of LAET	Percentage of Detected Exceedances of LAET	Exceedance Factor	2LAET	Number of Detected Exceedances of 2LAET	Percentage of Detected Exceedances of 2LAET	Exceedance Factor
Polycyclic Aromatic Hydrocarbons (PAHs)																		
Total LPAH	--	µg/kg dw	35	33	94%	26	3,200	KSS-2	07/09/2013	0–10 cm	5,200	None	None	None	5,200	None	None	None
Naphthalene	91-20-3	µg/kg dw	35	20	57%	10	1,100	KSS-2	07/09/2013	0–10 cm	2,100	None	None	None	2,100	None	None	None
Acenaphthylene	208-96-8	µg/kg dw	35	24	69%	7.6	430	KSS-2	07/09/2013	0–10 cm	1,300	None	None	None	1,300	None	None	None
Acenaphthene	83-32-9	µg/kg dw	35	22	63%	4.3	94	PA_MA02A	06/13/2008	0–10 cm	500	None	None	None	500	None	None	None
Fluorene	86-73-7	µg/kg dw	35	26	74%	8.9	280	NPI-PA10	03/17/2008	0–10 cm	540	None	None	None	540	None	None	None
Phenanthrene	85-01-8	µg/kg dw	35	33	94%	26	1,200	KSS-2	07/09/2013	0–10 cm	1,500	None	None	None	1,500	None	None	None
Anthracene	120-12-7	µg/kg dw	35	28	80%	22	1,500	NPI-PA10	03/17/2008	0–10 cm	960	1	2.9%	1.6	960	1	2.9%	1.6
2-Methylnaphthalene	91-57-6	µg/kg dw	35	17	49%	10	140	NPI-PA3	02/28/2008	0–10 cm	670	None	None	None	670	None	None	None
Total HPAH	--	µg/kg dw	35	33	94%	50	8,000	KSS-2	07/09/2013	0–10 cm	12,000	None	None	None	17,000	None	None	None
Fluoranthene	206-44-0	µg/kg dw	35	33	94%	23	2,600	KSS-2	07/09/2013	0–10 cm	1,700	2	5.7%	1.5	2,500	1	2.9%	1
Pyrene	129-00-0	µg/kg dw	35	33	94%	27	2,100	KSS-2	07/09/2013	0–10 cm	2,600	None	None	None	3,300	None	None	None
Benzo(a)anthracene	56-55-3	µg/kg dw	35	32	91%	20	670	WPAH006	06/27/2013	0–10 cm	1,300	None	None	None	1,600	None	None	None
Chrysene	218-01-9	µg/kg dw	35	32	91%	34	1,400	KSS-1	07/09/2013	0–10 cm	1,400	None	None	None	2,800	None	None	None
Total Benzofluoranthenes	56832-73-6	µg/kg dw	35	31	89%	48	1,400	WPAH006	06/27/2013	0–10 cm	3,200	None	None	None	3,600	None	None	None
Benzo(a)pyrene	50-32-8	µg/kg dw	35	31	89%	20	480	WPAH006	06/27/2013	0–10 cm	1,600	None	None	None	1,600	None	None	None
Benzo(g,h,i)perylene	191-24-2	µg/kg dw	35	27	77%	11	210	KSS-1 KSS-2	7/9/2013 7/9/2013	0–10 cm	670	None	None	None	720	None	None	None
Indeno(1,2,3-cd)pyrene	193-39-5	µg/kg dw	35	27	77%	14	260	KSS-1	07/09/2013	0–10 cm	600	None	None	None	690	None	None	None
Dibenzo(a,h)anthracene	53-70-3	µg/kg dw	35	21	60%	4.2	70	WPAH006	06/27/2013	0–10 cm	230	None	None	None	230	None	None	None
Chlorinated Benzenes																		
1,2-Dichlorobenzene	95-50-1	µg/kg dw	25	None	None	None	None	None	None	None	35	None	None	None	50	None	None	None
1,4-Dichlorobenzene	106-46-7	µg/kg dw	25	None	None	None	None	None	None	None	110	None	None	None	110	None	None	None
1,2,4-Trichlorobenzene	120-82-1	µg/kg dw	25	None	None	None	None	None	None	None	31	None	None	None	51	None	None	None
Hexachlorobenzene	118-74-1	µg/kg dw	25	None	None	None	None	None	None	None	22	None	None	None	70	None	None	None
Phthalate Esters																		
Dimethyl phthalate	131-11-3	µg/kg dw	35	1	2.9%	19	19	KSS-2	07/09/2013	0–10 cm	71	None	None	None	160	None	None	None
Diethylphthalate	84-66-2	µg/kg dw	35	7	20%	6.2	93	PA_IH01A	06/16/2008	0–10 cm	200	None	None	None	1,200	None	None	None
Di-n-butyl phthalate	84-74-2	µg/kg dw	35	2	5.7%	7.2	24	NPI-PA6	02/28/2008	0–10 cm	1,400	None	None	None	5,100	None	None	None
Butyl benzyl phthalate	85-68-7	µg/kg dw	35	7	20%	31	670	PA_MA04A	06/12/2008	0–10 cm	63	3	8.6%	11	900	None	None	None
bis(2-ethylhexyl)phthalate	117-81-7	µg/kg dw	35	18	51%	17	220	NPI-PA10	03/17/2008	0–10 cm	1,300	None	None	None	3,100	None	None	None
Di-n-octyl phthalate	117-84-0	µg/kg dw	35	None	None	None	None	None	None	None	6,200	None	None	None	6,200	None	None	None
Miscellaneous Nonionizable Organic Compounds																		
Dibenzofuran	132-64-9	µg/kg dw	32	14	44%	5.6	180	KSS-2	07/09/2013	0–10 cm	540	None	None	None	540	None	None	None
Hexachlorobutadiene	87-68-3	µg/kg dw	25	None	None	None	None	None	None	None	11	None	None	None	120	None	None	None
N-Nitrosodiphenylamine	86-30-6	µg/kg dw	25	None	None	None	None	None	None	None	28	None	None	None	40	None	None	None
Pesticides/Polychlorinated Biphenyls (PCBs)																		
PCBs (Total, Aroclors)	1336-36-3	µg/kg dw	29	14	48%	11	74	NPI-PA1	02/28/2008	0–10 cm	130	None	None	None	1,000	None	None	None

Notes:

1 The following notes pertain to the content of this table:

- Only locations within the SCU boundary are included.
- For sample/sample duplicate pairs, only the greatest detected concentration (or lowest reporting limit if both were not detected) has been reported for each chemical at each location.
- For samples in which multiple analytical methods resulted in reported concentrations for a single chemical, only the greatest detected concentration (or lowest reporting limit if none were detected) has been reported.
- Only surface samples (maximum depth of 10 cm) are included.
- Only chemicals where SMS SCO/CSL criteria are OC-normalized are included.
- Only samples with TOC values outside the 0.5 to 3.5 percent range for OC normalization are included.
- Only the most recent results from reoccupied stations are included.
- The exceedance factor is rounded to two significant figures.

Abbreviations:

2LAET Second Lowest Apparent Effects Threshold
CAS Chemical Abstracts Service
cm Centimeter
CSL Cleanup screening level
dw Dry weight
HPAH High molecular weight polycyclic aromatic hydrocarbon
LAET Lowest Apparent Effects Threshold
LPAH Low molecular weight polycyclic aromatic hydrocarbon
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
OC Organic carbon
SCO Sediment cleanup objective
SCU Sediment Cleanup Unit
SMS Sediment Management Standards
TOC Total organic carbon

Table 8.4
Final Benthic Indicator Hazardous Substances Screening Summary

Proposed Indicator Hazardous Substance	Retained as a Final IHS?	Rationale
Metals		
Arsenic	No	Result for only 1 of 78 samples (1.3% of results) exceeds the SCO.
Cadmium	Yes	Results for 8 of 81 samples (9.9% of results) exceed the SCO.
Chromium	No	No SCO exceedances.
Copper	No	No SCO exceedances.
Lead	No	No SCO exceedances.
Mercury	Yes	Results for 24 of 86 samples (28% of results) exceed the SCO.
Silver	No	No SCO exceedances.
Zinc	Yes	Results for 6 of 81 samples (7.4% of results) exceed the SCO.
Polycyclic Aromatic Hydrocarbons (PAHs)		
Total LPAH	No	No SCO or LAET exceedances.
Naphthalene	No	No SCO or LAET exceedances.
Acenaphthylene	No	No SCO or LAET exceedances.
Acenaphthene	No	No SCO or LAET exceedances.
Fluorene	No	No SCO or LAET exceedances.
Phenanthrene	No	Result for 1 of 72 samples (1.4% of results) exceeds the SCO or the LAET. This sample is co-located with bioassays that did not indicate benthic toxicity.
Anthracene	No	Result of 1 of 72 samples (1.4% of results) exceeds the SCO or the LAET. This sample is co-located with bioassays that did not indicate benthic toxicity.
2-Methylnaphthalene	No	No SCO or LAET exceedances.
Total HPAH	No	No SCO or LAET exceedances.
Fluoranthene	No	Results for 3 of 72 samples (4.2% of results) exceed the SCO or the LAET. These samples are co-located with bioassays that did not indicate benthic toxicity.
Pyrene	No	No SCO or LAET exceedances.
Benzo(a)anthracene	No	No SCO or LAET exceedances.
Chrysene	No	No SCO or LAET exceedances.

Table 8.4
Final Benthic Indicator Hazardous Substances Screening Summary

Proposed Indicator Hazardous Substance	Retained as a Final IHS?	Rationale
Polycyclic Aromatic Hydrocarbons (PAHs) (cont.)		
Total Benzofluoranthenes	No	No SCO or LAET exceedances.
Benzo(a)pyrene	No	No SCO or LAET exceedances.
Benzo(g,h,i)perylene	No	Results for 2 of 72 samples (2.8% of results) exceed the SCO or the LAET. These samples are co-located with bioassays that did not indicate benthic toxicity.
Indeno(1,2,3-cd)pyrene	No	Result for 1 of 72 samples (1.4% of results) exceeds the SCO or the LAET. This sample is co-located with bioassays that did not indicate benthic toxicity.
Dibenzo(a,h)anthracene	No	No SCO or LAET exceedances.
Chlorinated Benzenes		
1,2-Dichlorobenzene	No	No SCO or LAET exceedances.
1,4-Dichlorobenzene	No	Result for 1 of 60 samples (1.7% of results) exceeds the SCO or the LAET. This sample is co-located with bioassays that did not indicate benthic toxicity.
1,2,4-Trichlorobenzene	No	No SCO or LAET exceedances.
Hexachlorobenzene	No	No SCO or LAET exceedances.
Phthalate Esters		
Dimethyl Phthalate	No	No SCO or LAET exceedances.
Diethylphthalate	No	No SCO or LAET exceedances.
Di-n-butyl Phthalate	No	No SCO or LAET exceedances.
Butyl Benzyl Phthalate	No	Results for 3 of 72 samples (4.2% of results) exceed the SCO or the LAET. These samples are co-located with bioassays that did not indicate benthic toxicity.
bis(2-Ethylhexyl)phthalate	No	Results for 3 of 72 samples (4.2% of results) exceed the SCO or the LAET. These samples are co-located with bioassays that did not indicate benthic toxicity.
Di-n-octyl Phthalate	No	No SCO or LAET exceedances.
Miscellaneous Nonionizable Organic Compounds		
Dibenzofuran	No	No SCO or LAET exceedances.
Hexachlorobutadiene	No	No SCO or LAET exceedances.
N-Nitrosodiphenylamine	No	No SCO or LAET exceedances.

Table 8.4
Final Benthic Indicator Hazardous Substances Screening Summary

Proposed Indicator Hazardous Substance	Retained as a Final IHS?	Rationale
Pesticides/Polychlorinated Biphenyls (PCBs)		
PCBs (Total, Aroclors)	No	No SCO or LAET exceedances.
Ionizable Organic Compounds		
Phenol	No	Results for 2 of 60 samples (3.3% of results) exceed the SCO. These samples are co-located with bioassays that did not indicate benthic toxicity.
2-Methylphenol	No	No SCO exceedances.
4-Methylphenol	No	No SCO exceedances.
2,4-Dimethylphenol	No	No SCO exceedances.
Pentachlorophenol	No	No SCO exceedances.
Benzyl Alcohol	No	No SCO exceedances.
Benzoic Acid	No	No SCO exceedances.

Note:
Gray-shaded row indicates chemical retained as an indicator hazardous substance for further evaluation in the remedial investigation/feasibility study.

Abbreviations:
HPAH High molecular weight polycyclic aromatic hydrocarbon
LAET Lowest apparent effects threshold
LPAH Low molecular weight polycyclic aromatic hydrocarbon
SCO Sediment cleanup objective

Table 8.5
Approximate Acreage within the WPAH Study Area Exceeding SCO and CSL Chemical Criteria for Bioaccumulative Indicator Hazardous Substances

Bioaccumulative Indicator Hazardous Substance	SCO and CSL Chemical Criteria		Approximate Acres Exceeding SCO and CSL Chemical Criteria	
	SCO	CSL	SCO	CSL
Total TEQ	2.3 ng/kg	5.2 ng/kg	1,780 acres	1,110 acres
cPAH TEQ	16 µg/kg	64 µg/kg	1,540 acres	620 acres
Mercury	0.11 mg/kg	0.13 mg/kg	777 acres	563 acres

Abbreviations:
cPAH Carcinogenic polycyclic aromatic hydrocarbon
CSL Cleanup screening level
µg/kg Micrograms per kilogram
mg/kg Milligrams per kilogram
ng/kg Nanograms per kilogram
SCO Sediment cleanup objective
TEQ Toxic equivalent

WPAHG

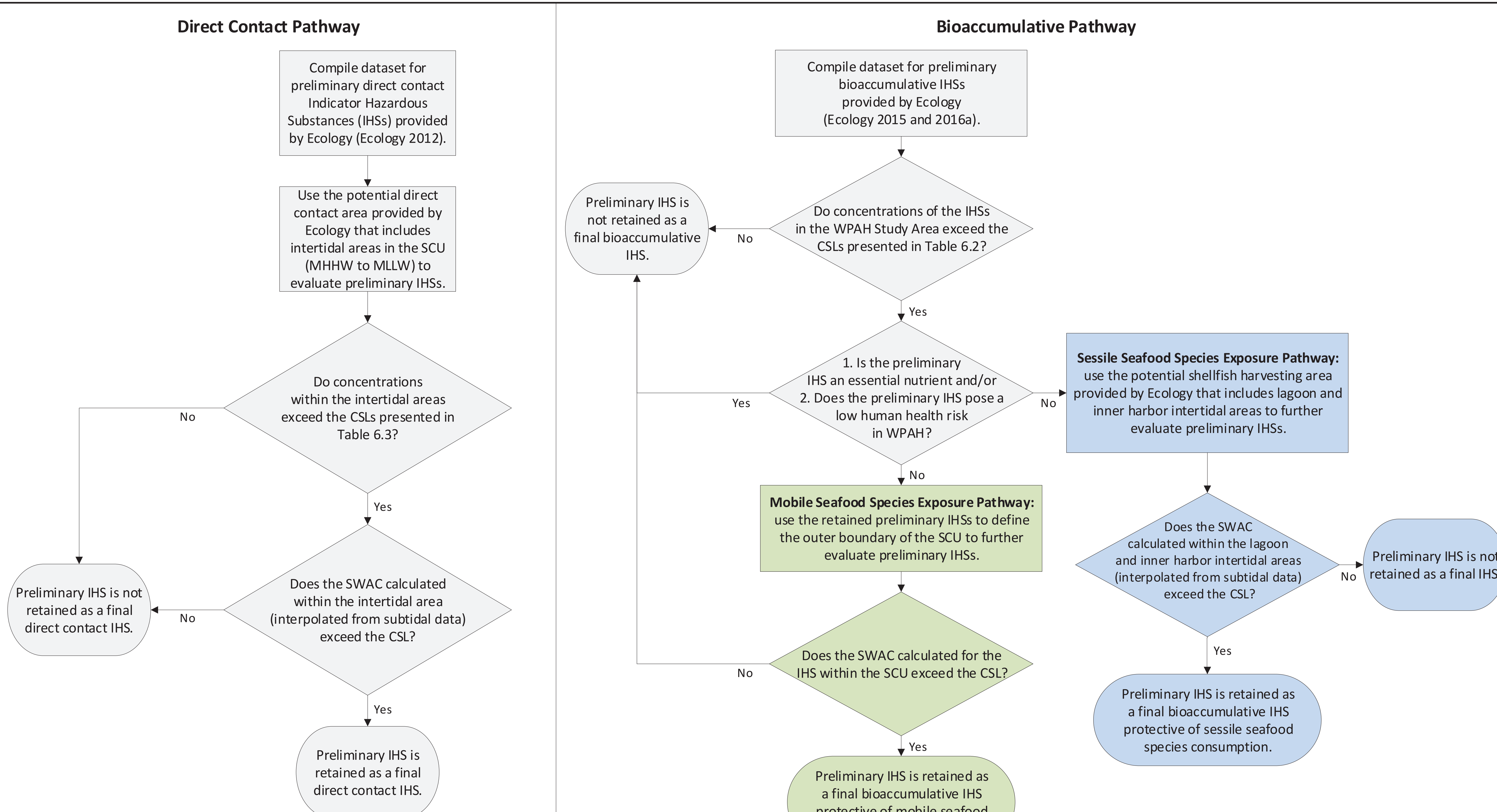
Western Port Angeles Harbor Group

Section 8.0:
Final Indicator Hazardous Substances and Development of Sediment Cleanup Standards

Figures

Western Port Angeles Harbor
Sediment Cleanup Unit

Remedial Investigation/Feasibility Study



Abbreviations: CSL = Cleanup screening level, Ecology = Washington State Department of Ecology, MHHW = Mean higher high water, MLLW = Mean lower low water, SCU = Sediment Cleanup Unit, SWAC = Surface-weighted average concentration, WPAH = Western Port Angeles Harbor

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Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 8.1
Final Bioaccumulative and Direct Contact Human Health Indicator Hazardous Substances Screening Flowchart

WPAHG

Western Port Angeles Harbor Group

Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 8.2
Exposure Areas Map

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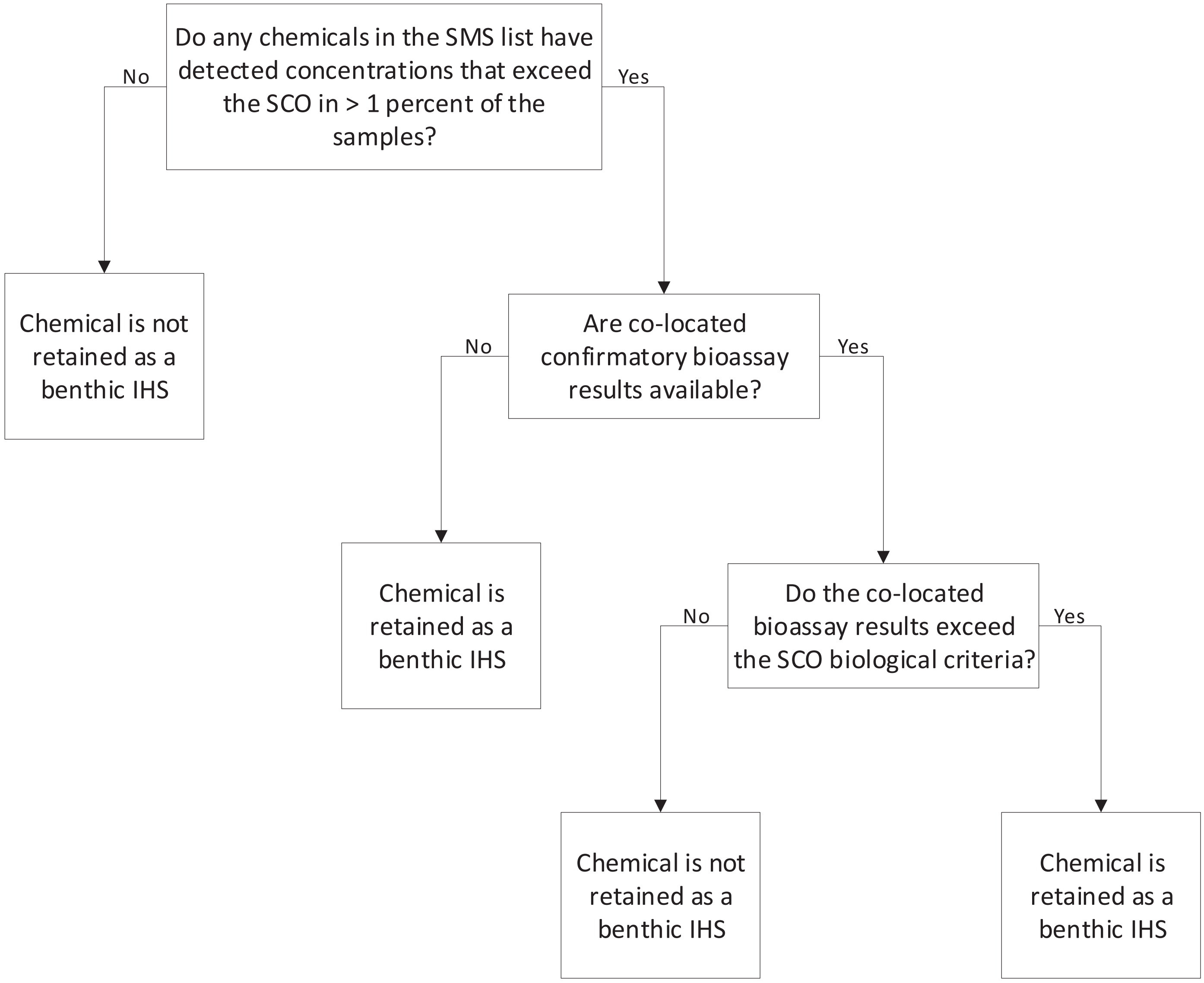
10/29/2020



Abbreviations: IHS = Indicator Hazardous Substance, SCO = Sediment cleanup objective, SMS = Sediment Management Standards

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Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 8.3
Final Benthic Indicator
Hazardous Substances
Screening Flowchart

F:\projects\WPAHG-RIFS\RIFS Report\01 RIFS Report\03 Figures\native and source files\Section 8 native files\Figure 8.3 Benthic IHS flowchart 2017-1127.vsdx
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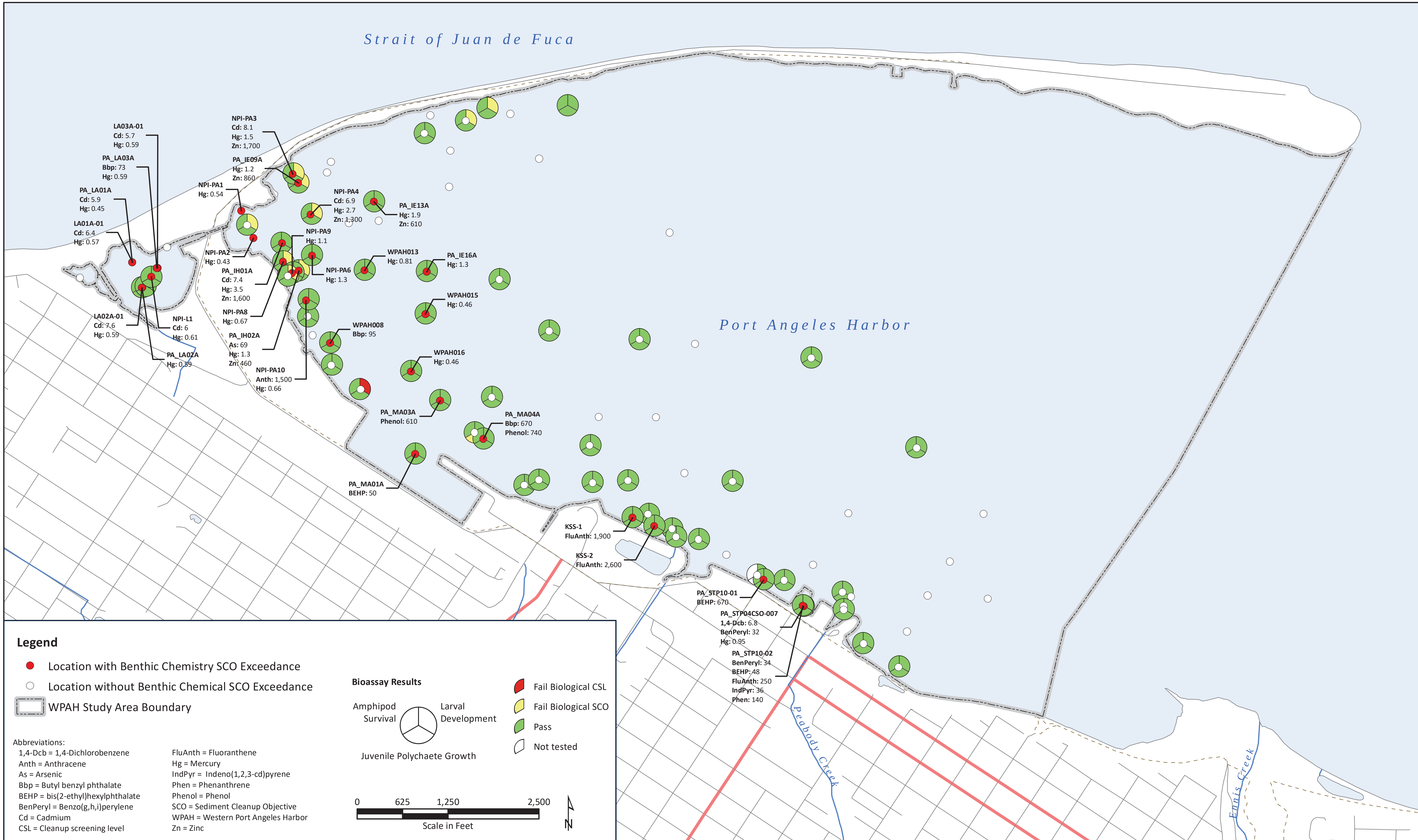

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Western Port Angeles Harbor Sediment Cleanup Unit
Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 8.4
Benthic Chemical Exceedances and Bioassay Failures

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Section 9.0: Remedial Investigation Conclusions and Conceptual Site Model

- The primary information from the RI sections that inform development of the Conceptual Site Model include:
  - Historical and ongoing sources of hazardous substances including wood processing facilities, stormwater discharges, atmospheric deposition, industrial wastewater discharges, marine facility operations, and chemically treated marine lumber and pilings.
  - Ongoing potential contaminant transport pathways include sediment transport and mixing, shoreline soil erosion to sediment and surface water, and migration from upland activities.
  - Exposure pathways including human health consumption of fish, mobile shellfish, and sessile shellfish; human health direct contact with contaminated sediment; and protection of benthic species.
  - The extent of indicator hazardous substances contamination within the Sediment Cleanup Unit (SCU).
  - Evaluation of the presence of wood debris.

9.0 Remedial Investigation Conclusions and Conceptual Site Model

The Harbor is a natural harbor that has been in active industrial use since the late 1800s. It is located adjacent to the City of Port Angeles, a small, primarily residential city with a population of approximately 19,000 people. Industrial properties located within the City are primarily located on or near the Harbor shoreline. The Harbor was historically and is currently an important transportation port and working waterfront with maritime-dependent uses critical to the livelihood of the Port Angeles community. Sections 2.0 through 8.0 describe the setting of the Harbor, including its geology and natural resources, the current and historical activities in the Harbor, the environmental investigations performed in the WPAH Study Area, the types and concentrations of contaminants detected in the WPAH Study Area, the potential and actual exposure pathways and receptors, and the final IHSs and their associated SCLs. As a transition to the FS, Section 9.0 provides a summary of the key information from these previous RI sections.

9.1 HISTORICAL AND ONGOING SOURCES OF HAZARDOUS SUBSTANCES

As described in Section 3.0, there have been multiple facilities in the Harbor that have been associated with historical releases of hazardous substances and/or wood debris to sediments, including upland, in-water, and overwater operations; spills; leaks; direct discharge of stormwater, sewage, and wastewater; nearshore hog fuel burning; and log rafting. The peak industrial use of the Harbor occurred in the 1950s and 1960s. In general, the scale and nature of the historical operations are considerably different than current operations. Major categories of historical and ongoing sources to the WPAH Study Area include:

- **Wood Processing Facilities.** Several major wood processing facilities have historically operated in the western portion of the Harbor including the Merrill & Ring lumber mill, the Fibreboard paperboard mill, the former K Ply plywood mill, and the NPIUSA paper mill (formerly operated by Georgia Pacific, Crown Zellerbach, and the James River Corporation, currently owned by McKinley Paper Company). The K Ply mill was identified as a MTCA cleanup site, with soil remediation completed in 2016. Additional entities have been involved historically and currently in nearshore and in-water wood handling operations within the Harbor, including log rafting operations and the use of hog fuel boilers.
- **Direct Wastewater and Stormwater Discharge.** Discharges are associated with both industrial facilities and municipally owned systems that currently discharge wastewater and/or stormwater through NPDES-permitted conveyance systems, via stormwater and CSO outfalls. Historically, greater concentrations of chemicals were discharged to the Harbor due to less effective wastewater and stormwater management systems in effect at the time. Generally, chemical discharges have decreased over time with improved treatment technologies, regulations, and source control.
- **Port and Other Marine Facility Operations.** There are a number of marine facilities located along the southern waterfront of the WPAH Study Area. The Port has

operated a full-service port in various capacities for over 80 years. The Port currently operates four deep-water marine terminals (Terminals 1, 3, 4, and 7), as well as terminals for ferry service, boat repair, and other industrial activities, and a marina. The Port is also engaged in ongoing log rafting and wood handling within the WPAH Study Area, managed with specific BMPs. Several bulk petroleum storage and distribution facilities have historically been present in the Harbor; Marathon (formerly Tesoro) operates the remaining active petroleum facility on Ediz Hook. In addition, the Harbor is a common stop-over for vessels travelling to Puget Sound.

- **Chemically Treated Marine Lumber and Pilings.** Chemically treated wood pilings and other wood marine structures have been used in marine waters of the United States for over 100 years. This treated wood generally has been used for bridge or dock supports, vessel mooring stations, or as shoreline bulkhead support. Over the past 100 years, the most common chemical used to preserve wood for use in the marine environment and prevent deterioration from marine organisms has been creosote, which contains PAHs. Both the Port and City have been systematically removing chemically treated piles and will continue this removal in the years to come.

These historical and ongoing sources of contaminants include marine-dependent uses that have occurred and will continue to occur within the WPAH Study Area. These uses can be the source of incidental petroleum or other spills, and general low-level impacts from marine transport, such as PAHs and leaching anti-fouling paints used on vessel hulls.

Sources of contamination to the WPAH Study Area are primarily historical, as waterfront industrial activities have declined, untreated wastewater and CSO discharges have been reduced, and stormwater controls have increased over time. However, ongoing diffuse, non-point sources of contaminants in stormwater and the atmosphere continuously enter the environment, and in many cases cannot be controlled or eliminated in any practicable or timely manner (e.g., creeks and atmospheric deposition). Additionally, as noted above, the Harbor has ongoing shipping and water-dependent marine transport businesses that may provide ongoing low-level sources. Ecology has identified surface runoff, broadly defined to include stormwater and non-point source overland flow to surface waters, as the most significant ongoing contributor of contaminants to Puget Sound, relative to WWTPs, groundwater, spills, CSOs, and atmospheric deposition (Herrera 2011b). This ongoing source loading to the WPAH Study Area, as well as source control recommendations, are discussed further in Appendix E.

9.2 ONGOING CONTAMINANT TRANSPORT PATHWAYS

9.2.1 Sediment Transport and Mixing

Based on the weight-of-evidence of the information described in Section 2.1, including radioisotope analyses, SPI observations, and hydrodynamic calculations, the vast majority of sediments in the Harbor are highly stable and are not subject to resuspension even under worst-case hydrodynamic conditions. However, there are localized areas of the Harbor that are subject to periodic scour and resuspension. These areas are either proximal to actively used docks and associated vessel propeller wash or areas of higher energy hydrodynamic environments (such as the lagoon channel connected to the inner harbor) that can generate higher velocity currents during peak ebb and flood tidal flows and nearshore wave-dominated areas. The inner harbor area with the potential for mixing of surface and subsurface sediments from propeller wash and other higher energy forces is depicted on Figure 2.3.

9.2.2 Shoreline Soil to Sediment

Surface soil has the potential to reach surface water and intertidal sediments via direct stormwater runoff or soil erosion along the shoreline. Due to the natural forces that are required for this pathway to be active, this pathway is limited to the upper horizon of soil in areas that are not paved and not covered by buildings or structures, and have the topographical features necessary for these physical actions to occur. Pavement, buildings, or continuous riprap all form physical barriers. The extent of this covered area is described further in Appendix E. In the unpaved areas and/or areas without riprap, stormwater as sheet flow has the potential to entrain soil and travel down slope toward the intertidal area. Limited eroded contamination may reach the subtidal sediment area. This pathway is discussed more fully in Appendix E.

9.2.3 Groundwater to Sediment

Sediment quality must be protected at the point where groundwater is discharged to the marine sediment. However, this pathway is not expected to be a significant source of contamination to the WPAH Study Area based on the nature of the final IHSs (mostly hydrophobic chemicals) and significant historical release mechanisms for these chemicals (direct discharge to sediments, overwater operations, hog fuel burning, etc.). As described in Section 3.4.5.5, the shoreline MTCA cleanup sites currently being addressed are primarily contaminated with hydrocarbons in soil and groundwater, including LNAPL. There is no indication that LNAPL or groundwater contamination from these cleanup sites has resulted in contamination of the WPAH Study Area sediments. At the MTCA sites described in Section 3.4.5.5, remedies for these MTCA sites will be protective of future sediment quality.

9.3 EXPOSURE PATHWAYS

As described in detail in Sections 6.0 and 8.0, multiple exposure pathways were evaluated within the WPAH Study Area. The identified pathways have been used for the development of SCOs and CSLs, and in evaluation of WPAH Study Area data, to determine final IHSs and cleanup standards and to establish the nature and extent of contamination in the SCU. These exposure pathways include:

- Protection of human health via the consumption of fish and mobile shellfish (crab, shrimp)
- Protection of human health via the consumption of sessile shellfish (bivalves)
- Protection of human health via direct contact (ingestion and dermal contact)
- Protection of aquatic life (benthic species)

9.4 CONCEPTUAL SITE MODEL

Using the information summarized in this section and presented in previous sections, a graphical CSM was developed for the SCU. Per MTCA, a CSM is "a conceptual understanding of a site that identifies potential or suspected sources of hazardous substances, types and concentrations of hazardous substances, potentially contaminated media, and actual and potential exposure pathways and receptors." Once developed, a CSM informs the selection of appropriate remedial actions. Figure 9.1 presents a graphical representation of the overall CSM for the SCU.

Key elements of the SCU CSM include the following:

- Historical sources of IHSs include a range of industrial and non-industrial operations including historical hog fuel burning and industrial process water discharge. These have been reduced over time as waterfront industrial activities have declined and as controls have improved.
- Historical and ongoing inputs to the Harbor include public and private (including industrial) stormwater discharges, log rafting, overwater operations, marine transportation and traffic, and chemically treated wood pilings, along with general sediment deposition. Localized nearshore sediment transport and mixing, including erosion along parts of the Harbor shoreline also occurs.
- Ongoing IHS exposure pathways include bioaccumulation in fish and shellfish, along with consumption of these organisms by humans, and direct contact of sediments by beach users and benthic organisms residing in the sediments.
- Atmospheric deposition, nearshore soil erosion, and creek inputs are also ongoing, low level inputs of IHSs.

9.5 EXTENT OF CONTAMINATION

The IHS contamination and wood debris extents throughout the WPAH Study Area are summarized in this section, with bioaccumulative and benthic IHSs described separately.

9.5.1 Bioaccumulative IHS Contamination Extent

- Mercury exceeds the 0.13 mg/kg SCL throughout most of the western half of the SCU, in the central portion of the lagoon, and in a limited area off the southern shoreline, for a total of 563 acres in the WPAH Study Area (refer to Table 8.5 and Figure 9.2). The greatest mercury concentrations occur in the inner harbor.
- cPAHs exceeded the 64 µg/kg SCL in approximately one-third of the WPAH Study Area, for a total of 620 acres (refer to Table 8.5 and Figure 9.2). The greatest cPAH TEQ values were generally found closest to the far western and southern shorelines.
- The greatest Total TEQ concentrations are present in the westernmost areas of the WPAH Study Area, and generally decrease to the east. Concentrations exceeded the

5.2 ng/kg SCL throughout approximately half of the WPAH Study Area with the exceptions of south of the tip of Ediz Hook, and isolated areas along the southeastern shoreline, for a total of 1,110 acres (refer to Table 8.5 and Figure 9.2). The Total TEQ SCL exceedances defined the outer boundary of the SCU.

9.5.2 Benthic IHS Contamination Extent

- Occurrences of cadmium and zinc greater than their respective 5.1 mg/kg and 410 mg/kg benthic SCLs are located primarily in the inner harbor along Ediz Hook and in limited areas along the southern shoreline. Cadmium SCL exceedances are also located within the central portion of the lagoon.
- Mercury concentrations greater than the 0.41 mg/kg SCL are more widespread than cadmium and zinc, with approximately the western third of the SCU and the central portion of the lagoon exceeding the mercury SCL.
- Despite a number of benthic SCL exceedances, bioassay exceedances are localized to the inner harbor, indicating that toxicity posed to benthic invertebrates is limited overall and benthic SCL exceedances do not necessarily predict sediment toxicity.
- Figure 9.2 presents an overall summary of benthic conditions across the SCU, including all locations with bioassay exceedances and locations with benthic criteria chemical exceedances where confirmatory bioassays were not performed.

9.5.3 Wood Debris Distribution and Benthic Habitat Quality

The wood debris levels mapped in Figures 7.3a through 7.3d represent the greater wood content measured in either the SPI or PV images from each location. Estimated wood content of surface sediments exceeding 50 percent either at the surface or buried, or both, were observed in five areas within the WPAH Study Area:

- The industrial waterfront from approximately the lagoon channel to the Port Angeles Boat Haven (southwest shoreline of the WPAH Study Area)
- An area of active and historical log rafting northeast of the Port Angeles Boat Haven
- Two former log rafting areas near the shoreline of Ediz Hook
- The current log storage area offshore and east of the McKinley Paper Company facility

Several stations in the WPAH Study Area also had buried pockets or layers of what appear to be wood pulp or high concentrations of semi-consolidated wood fibers.

Overall, the SPI benthic interpretative framework (Rhoads and Germano 1982, 1986) indicates that habitat quality over most of the SCU exhibits a high-order infaunal successional stage community. This shows the presence of high-quality benthic habitat or recovering benthic habitat. This benthic habitat condition is evident in areas that range from no wood debris to high wood debris cover. Exceptions are noted in Section 7.2.4.

Prior to the RI field investigation, there was concern that wood debris may be a potential stressor to ecological receptors in the Harbor. However, bioassay testing, including bioassay retesting, combined with the SPI investigation, indicates that areas exhibiting bioassay toxicity are relatively constrained within the WPAH Study Area, are generally co-located with or in close proximity to exceedances of the benthic SCO criteria, and are correlated with chemical concentrations. Therefore, wood debris does not appear to be a widespread toxicity concern within the WPAH Study Area, and the extent of sediment remediation as required under SMS is driven by addressing areas of benthic toxicity, and areas exceeding the human health SCLs, based on regional background concentrations, within the SCU.

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Section 9.0: Remedial Investigation Conclusions and Conceptual Site Model

Figures

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Sediment Cleanup Unit

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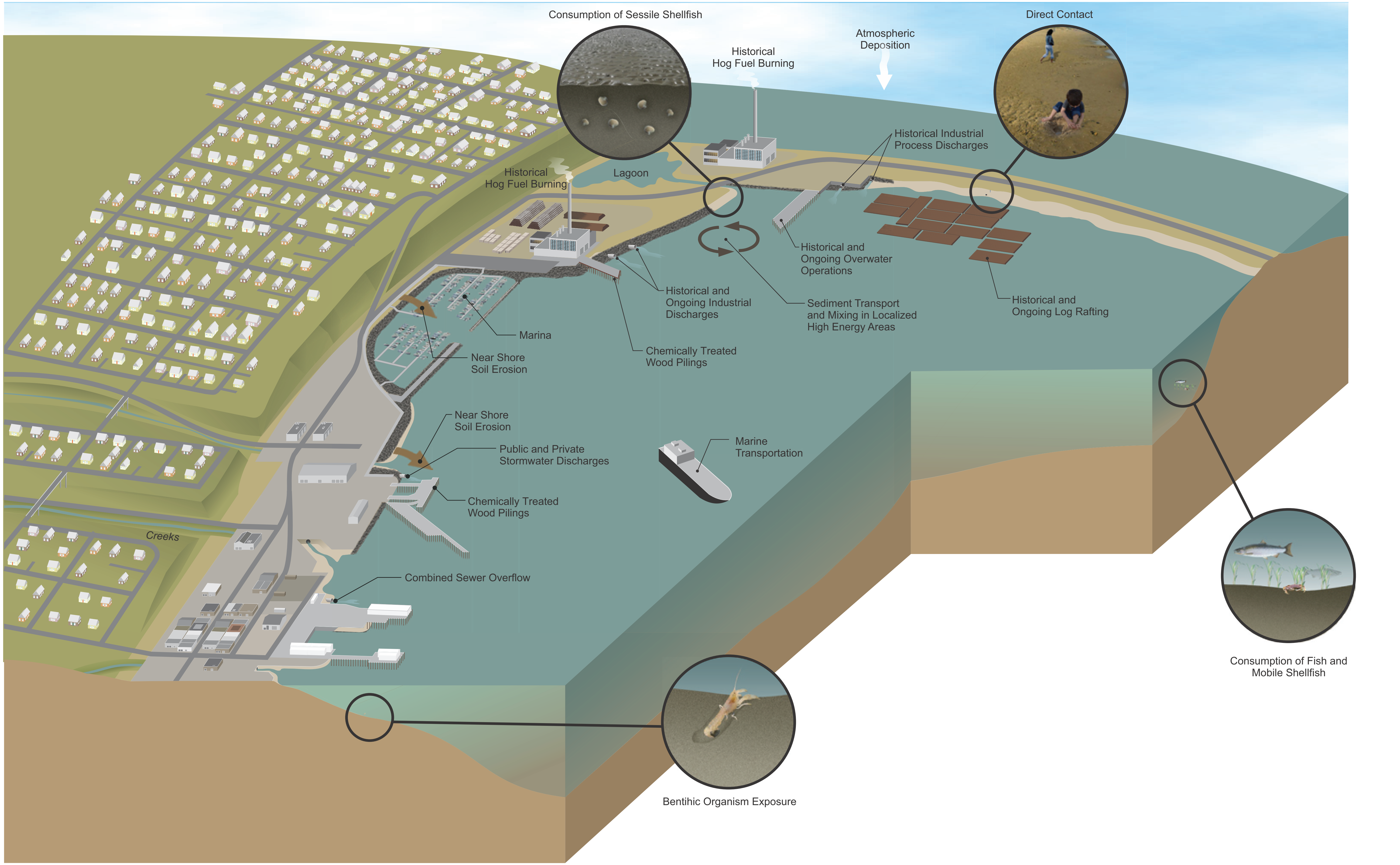

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Remedial Investigation/Feasibility Study
Port Angeles, Washington

Figure 9.1
Conceptual Site Model

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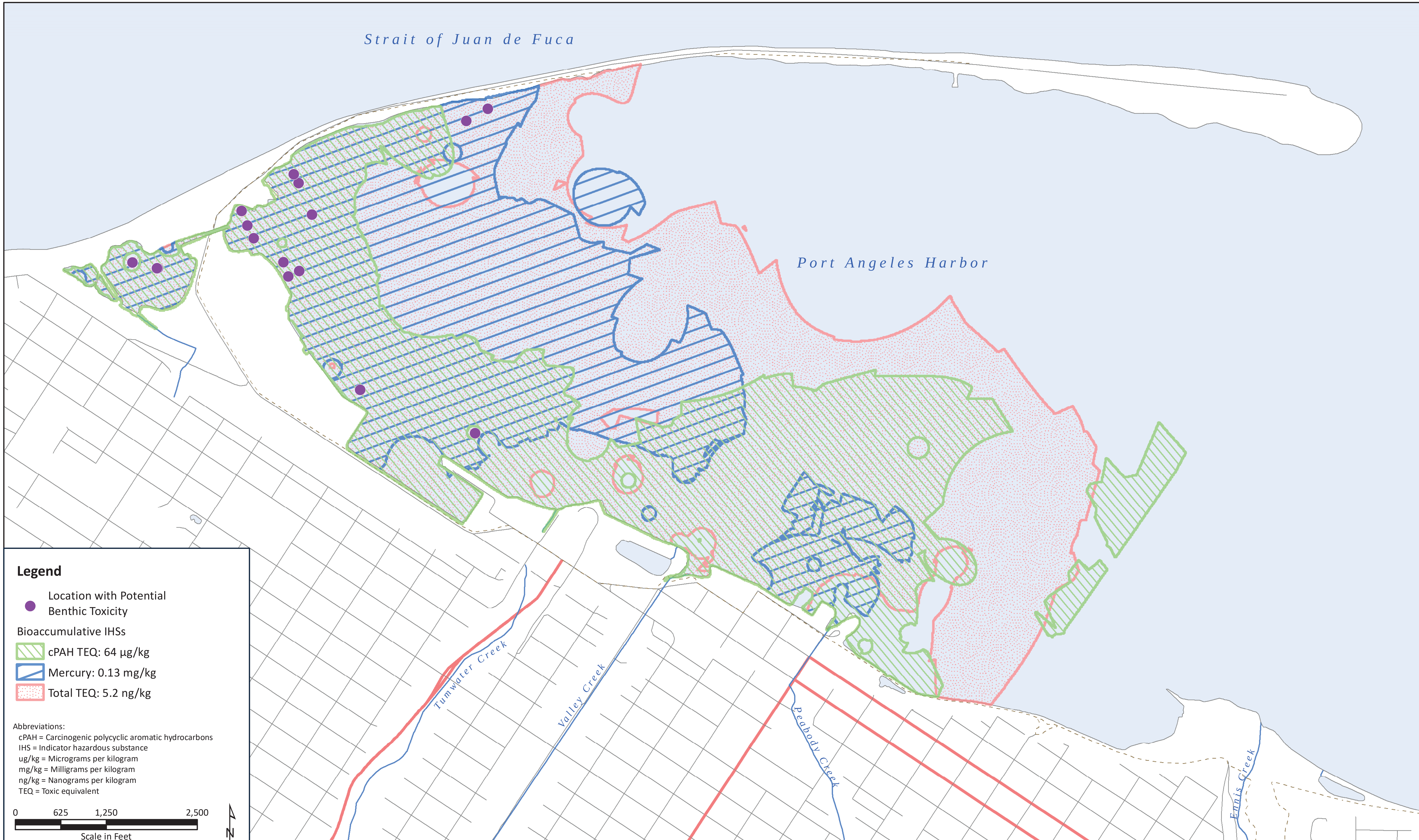

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Figure 9.2
Bioaccumulative IHS Contamination Extents and Potential Benthic Toxicity Locations

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