FORMER RAYONIER MILL IN PORT ANGELES
INTERIM ACTION REPORT VOLUME II:
MARINE DATA SUMMARY REPORT

FINAL

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Table of Contents

Tables

Figures

Maps

Acronyms

Acronym	Definition
AET	apparent effects threshold
BHC	benzene hexachloride
BBP	butyl benzyl phthalate
BEHP	bis(2-ethylhexyl) phthalate
BHC	benzene hexachloride
BTV	background threshold value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
CSM	conceptual site model
CSO	combined sewer overflow
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DF	detection frequency
DQO	data quality objective
dw	dry weight
Ecology	Washington State Department of Ecology
EF	exceedance factor
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
ESI	expanded site inspection
FS	feasibility study
HHRA	human health risk assessment
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HpCDD	heptachlorodibenzo-*p*-dioxin
HpCDF	heptachlorodibenzofuran
HxCDD	hexachlorodibenzo-*p*-dioxin

HxCDF	hexachlorodibenzofuran
HQ	hazard quotient
ICP	inductively coupled plasma
ID	identification
J	estimated concentration
LAET	lowest apparent effects threshold
2LAET	second lowest apparent effects threshold
LDW	Lower Duwamish Waterway
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MS	mass spectrometry
MTCA	Model Toxics Control Act
N	tentative identification
NCMA	normalized combined mortality and abnormality
NPDES	National Pollutant Discharge Elimination System
OC	organic carbon
OCDD	octachlorodibenzo-*p*-dioxin
OCDF	octachlorodibenzofuran
OSV	ocean survey vessel
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PeCDD	pentachlorodibenzo-*p*-dioxin
PeCDF	pentachlorodibenzofuran
PEF	potency equivalency factor
PSAMP	Puget Sound Ambient Monitoring Program
QA	quality assurance
QC	quality control
RI	remedial investigation
RL	reporting limit
RME	reasonable maximum exposure
SIR	sediment investigation report
SMS	Washington State Sediment Management Standards
SCO	sediment cleanup objective

STA	sediment trend analysis
SVOC	semivolatile organic compound
SWAC	spatially weighted average concentration
TBT	tributyltin
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
TEF	toxic equivalency factor
TEQ	toxic equivalent
TOC	total organic carbon
TVS	total volatile solids
U	not detected at given concentration
USGS	US Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
ww	wet weight

Executive Summary

The former Rayonier mill site is located in the City of Port Angeles in Clallam County, Washington, on the shore of Port Angeles Harbor. Rayonier operated the facility as a dissolving pulp mill from 1930 to 1997 and decommissioned the mill in 1999. Multiple investigations of contamination in the Rayonier study area have been conducted since the late 1990s, including studies by Rayonier, the US Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology).

In accordance with Agreed Order No.DE 6815 (Ecology 2010), the primary objectives of this report were as follows:

- Summarize all existing marine data as of the effective date of the Agreed Order (Ecology 2010), including the 2008 data collected by Ecology from the marine portion of the study area, as documented in the Port Angeles Harbor sediment characterization study (Ecology 2012b)
- Describe the nature and extent of contamination in the marine portion of the study area for the purpose of developing and evaluating interim action alternatives for the study area

Sediment samples, including surface and subsurface samples, and tissue samples for multiple aquatic species have been collected from areas within the study area. Sediment toxicity tests, using testing protocols standardized for Puget Sound were performed on a subset of the collected sediment samples.

Based on comparison of sediment concentrations with Washington State Sediment Management Standards (SMS), elevated concentrations of contaminants were located in the log pond and near the mill dock and appear to be associated with former nearshore outfall locations. SMS exceedances were detected for mercury, polycyclic aromatic hydrocarbons (PAHs), phthalates, other semivolatile organic compounds (SVOCs), and polychlorinated biphenyls (PCBs). The distribution of dioxins/furans, which do not have SMS criteria, followed a similar pattern, with the highest concentrations located in nearshore environments.

Ecology and Rayonier have each developed a conceptual site model (CSM) to describe sediment transport in the study area. These CSMs have many similarities but also have some key differences. They agree that fine material may temporarily settle in the nearshore and that wind waves can resuspend this material for transport to the offshore. In the offshore, the CSMs agree that tidal velocities are generally low in this area and allow fine material to settle. The CSMs disagree on the depth separating the nearshore and offshore, transport in deeper regions in the harbor, and on the importance of waves and storms from the north and the net impact of these factors. Any CSM differences that may affect in-water remedial alternatives will be addressed in Volume III.

In accordance with the Agreed Order (Ecology 2010), study area data were also compared with background data. Tissue data from the study area were compared with non-urban tissue data, and surface sediment data from the study area were compared with natural background data. These comparisons are preliminary because, under the new SMS rule released in February 2013, Ecology is conducting a study to better define background concentrations in sediment. The *North Olympic Peninsula Regional Background Sediment Characterization, Port Angeles-Port Townsend, WA: Sampling and Analysis Plan – Final* (Ecology 2013) will be used, in addition to other considerations, in the determination of cleanup screening levels to address potential human health risk for bioaccumulative contaminants as defined by Washington Administrative Code (WAC) 173-204-505.

1 Introduction

This document presents the marine summary data report for the former Rayonier mill site in Port Angeles, Washington. The former Rayonier mill site is located on the eastern side of Port Angeles Harbor (Figure 1-1). The in-water study area boundary was proposed in Agreed Order No. 6815 (Ecology 2010). The site operated as a pulp mill from 1930 to 1997. Decommissioning of the mill was completed in 1999. The investigation of legacy contamination in Port Angeles Harbor began in the late 1990s as part of the US Environmental Protection Agency's (EPA's) site investigation program and has continued under Washington State Department of Ecology's (Ecology's) Model Toxics Control Act (MTCA). Both Ecology and EPA have conducted routine regulatory compliance inspections at the former Rayonier mill, including a multi-media compliance investigation in 1993 and an expanded site inspection (ESI) in 1997 (Ecology and Environment 1998). Upon completion of the ESI, EPA opted to defer the listing of the former Rayonier mill and allow a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) protective cleanup to proceed under Ecology's direction.

Figure 1-1. Location of former Rayonier mill and in-water study area in Port Angeles

In 2002, Rayonier, Inc., and Ecology entered into an Agreed Order (Ecology 2002), which resulted in the submittal of three investigative reports for the marine environment near the former Rayonier mill site. These reports included a remedial investigation (RI) for the marine environment (Malcolm Pirnie 2007b), an addendum to the RI (Malcolm Pirnie 2007a), and an ecological risk assessment (ERA) (Malcolm Pirnie 2006). Following the submittal of these reports, Ecology collected additional data from Port Angeles Harbor in 2008 as part of the *Port Angeles Harbor Sediment Characterization Study, Port Angeles, Washington, Sediment Investigation Report* (Ecology 2012b). In 2010, Rayonier Properties LLC and Ecology entered into another Agreed Order (Ecology 2010), which required Rayonier to complete the first four volumes of an interim action report: Volume I, the data summary report for the upland portion of the study area; Volume II, the data summary report for the marine portion of the study area; Volume III, the interim action alternatives evaluation; and Volume IV, the draft interim action plan. This data report is Volume II of the interim action report.

The primary objective of this report is to summarize all existing marine data associated with the former Rayonier mill site as of the effective date of the Agreed Order (Ecology 2010), including the 2008 data collected by Ecology within the marine portion of the study area as part of the Port Angeles Harbor sediment characterization study (Ecology 2012b). Based on these data, this report describes the nature and extent of contamination in the marine environment in the vicinity of the former Rayonier mill and compares the sediment and tissue chemistry results with natural background values from Ecology (Ecology 2012b). Appendices to this document present the project setting (Appendix A), summaries of the screening-level risk assessments (Appendix B), the detailed conceptual site model (CSM) (Appendix C), and data management rules (Appendix D).

2 Nature and Extent of Contamination

This section discusses the nature and extent of contamination in the study area based on available data for surface sediment, subsurface sediment, and tissue. Section 2.1 describes how data were selected for use in this evaluation. Section 2.2 compares the Washington State Sediment Management Standards (SMS) marine sediment criteria with chemical concentrations in surface sediment samples and with toxicity test results. Section 2.3 presents an analysis of chemical distributions in sediment and tissue. Section 2.4 discusses the Ecology and Rayonier CSMs for sediment transport within the study area, which are discussed in more detail in Appendix C.

2.1 DATA SELECTION AND REDUCTION

This section presents the data quality objectives (DQOs) for available sediment and tissue data and describes how data were selected for use in this data summary report. It also describes how raw data from the laboratories were managed for use in the evaluation of the nature and extent of contamination.

2.1.1 Data quality objectives

DQOs were established to determine whether chemistry data were acceptable for all uses in the RI/feasibility study (FS). All uses include characterization of nature and extent of contamination, determination of CSMs, and decisions on whether remedial action is warranted at specific locations. Table 2-1 lists the DQOs that must be satisfied for chemistry data to be considered acceptable for all uses in the RI/FS, categorizing them according to the level at which each DQO would be applied: event, station, sample, or result. A DQO applied at the result level could cause a result record to be qualified for a particular chemical but not for other chemicals analyzed during the same study.

Table 2-1. Data quality objectives for chemistry data to be considered acceptable for all uses in the RI/FS

Level	Data Quality Objective
Event	Sampling coordinates must be available
	Data must have been collected in 1997 or later
	Data must have been collected using appropriate sampling methods
Station	Stations were located within areas that were not subsequently dredged
Sample	Sediment sample depth (relative to mudline) must be identified
Result	Data validation qualifiers must be present, or derivable from laboratory qualifiers or QA information, and must be applied in a manner consistent with EPA functional guidelines (EPA 2010, 2008)
	For non-detects, RLs and appropriate qualifiers must be given
	Calculated values must be recalculated
	Analytical methods must be identified

EPA – US Environmental Protection Agency
FS – feasibility study
QA – quality assurance
RI – remedial investigation
RL – reporting limit

Ecology has not established definitive guidelines for specifying the level of data validation required for investigations conducted under MTCA. Ecology guidance identifies two levels of data validation for chemistry data (PTI 1989): a summary data validation, referred to as QA1, which represents a lower level of effort compared with a full validation, and a full validation, referred to as QA2. The elements of these two validation levels are presented in Table 2-2.

Table 2-2. Elements of summary and full data validations for environmental chemistry data

Element	Applicable Analyses	Summary Data Validation (QA1)	Full Data Validation (QA2)
Quality control analysis frequencies	all	X	X
Analysis holding times	all	X	X
Instrument performance check	organic compounds, ICP-MS metals		X
Initial instrument calibration	all		X
Continuing instrument calibration	all		X
Laboratory blanks	all	X	X
ICP interference check sample	metals		X
System monitoring compounds (surrogates)	organic compounds	X	X
Matrix spikes/matrix spike duplicates	all	X	X
Laboratory control samples	all	X	X
ICP serial dilution	metals		X
Field QA/QC (field blanks, field duplicates)	all	X	X

Element	Applicable Analyses	Summary Data Validation (QA1)	Full Data Validation (QA2)
Internal standards	VOCs, SVOCs, ICP-MS metals		X
Pesticide cleanup checks	pesticides/PCBs		X
Target compound identification and quantitation (requires verification of reported results with raw data)	organic compounds		X
RLs	all	X	X

ICP – inductively coupled plasma
MS – mass spectrometry
PCB – polychlorinated biphenyl
QA – quality assurance
QA1 – summary data validation
QA2 – full data validation
QC – quality control
RL – reporting limit
SVOC – semivolatile organic compound
VOC – volatile organic compound

2.1.2 Data selection

Environmental investigations conducted within the study area have included the collection of surface sediment, subsurface sediment, and fish or shellfish tissue for chemical analysis. In addition, a subset of surface sediment samples has been tested for toxicity using sediment bioassays. This section describes the data selected for inclusion in the marine dataset for the Rayonier study area.

2.1.2.1 Surface sediment

Four surface sediment investigations have been conducted that met the DQOs presented in Section 2.1.1. As part of these investigations, surface sediment samples were collected at depths from 0 to 10 cm at 168 locations from the study area (Table 2-3). The Port Angeles Harbor sediment investigation and the ESI (Ecology 2012b; Ecology and Environment 1998) (Map 2-1) involved the collection of samples from 72 locations throughout the study area. The Rayonier RI involved the collection of samples from 67 locations in the Rayonier area in 2002 (Malcolm Pirnie 2007b) followed by the collection of additional samples from 29 locations in 2006 (Malcolm Pirnie 2007a) (Map 2-1).

Table 2-3. Summary of sampling events included in the surface sediment dataset

Sampling Event	Year of Sampling	Chemicals	No. of Samples	Data Validation Level[a]	Source
Port Angeles Harbor Sediment Investigation	2008	PCBs (Aroclors)	26	QA1	Ecology (2012b)
		dioxins and furans	35	QA2	
		PAHs	35	QA2	
		phthalates and other SVOCs	35	QA1	
		metals	35	QA1	
		pesticides	14	QA1	
		grain size and conventionals	36	QA1	
		fatty acids and resin acids	24 – 28	QA1	
		petroleum	26	QA1	
Rayonier Phase 2 RI Addendum	2006	PCBs (congeners), dioxins and furans, grain size, conventionals	28 – 29	QA1	Malcolm Pirnie (2007a)
Rayonier Marine RI	2002	PCBs (Aroclors), metals, PAHs, other SVOCs, and pesticides	45 – 48	QA1	Malcolm Pirnie (2007b)
		dioxins and furans	33		
		phthalates	25		
		grain size	54		
		conventionals	66		
		fatty acids and resin acids	41		
Expanded Site Inspection	1997	metals, PAHs, phthalates, other SVOCs, PCBs (Aroclors), pesticides, VOCs, and conventionals	33 – 36	QA1	Ecology and Environment (1998)
		dioxins and furans	12		

[a] Data validation levels QA1 or QA2 are summarized in Table 2-2.

PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
QA1 – summary data validation
QA2 – full data validation
RI – remedial investigation
SVOC – semivolatile organic compound
VOC – volatile organic compound

An additional two investigations that collected surface sediment from 15 locations in the study area have been conducted, but only the top 2 or 3 cm of sediment was analyzed (Table 2-4). Data from these two events were not included in the surface sediment dataset, consistent with the Ecology screening-level ERA (Ecology 2012b), because the full biologically active zone was not analyzed.

Surface sediment samples were also collected from five locations in the Rayonier log pond area (Foster Wheeler 2001), but these data were not included in the sediment dataset because they were composite samples consisting of sediment collected from

two locations for each sample. Although not included in the dataset, the results of this sampling event were considered in the discussion of results in the log pond area in Section 2.3.1.1.

Table 2-4. Summary of sampling events not included in the surface sediment dataset

Sampling Event	Year of Sampling	Chemicals	No. of Samples
Log Pond Survey	2000	dioxins and furans, metals, PAHs, other SVOCs	5[a]
Port Angeles NPDES Sediment Analysis	2004	metals, PAHs phthalates, other SVOCs, PCBs, grain size, conventionals	8
PSAMP Spatial/Temporal Monitoring 2002-2003	2003	metals, organometals, PAHs, phthalates, other SVOCs, PCBs, pesticides, grain size, conventionals	7

[a] Each sample consisted of sediment composited from two locations.

NPDES – National Pollutant Discharge Elimination System
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PSAMP – Puget Sound Ambient Monitoring Program
SVOC – semivolatile organic compound

2.1.2.2 Subsurface sediment

Two investigations involved the collection of subsurface sediment cores in the study area and met DQOs discussed in Section 2.1.1 (Table 2-5). The most extensive subsurface sampling was conducted by Ecology at 23 locations in the study area (Map 2-2); at each location, selected core intervals were analyzed for a variety of chemicals based on visual and olfactory screening of the sediment (Table 2-5) (Ecology 2012b). As part of the Rayonier RI, nine subsurface sediment samples were collected from five locations in the Rayonier log pond area and were analyzed for a full suite of chemicals (Map 2-2); additional samples were collected but were only analyzed for grain size and total organic carbon (TOC). All available subsurface sediment data from the study area were included in the Volume II dataset.

Table 2-5. Summary of sampling events included in the subsurface sediment dataset

Sampling Event	Year of Sampling	Chemicals	No. of Samples	Data Validation Level	Source
Port Angeles Harbor Sediment Investigation	2008	PAHs	37	QA2	Ecology (2012b)
		dioxins and furans	36		
		phthalates, other SVOCs, grain size, and conventionals	37	QA1	
		PCBs (Aroclors)	31		
		metals	31		
		pesticides	15		
		fatty acids and resin acids	20-36		
		petroleum	31		
Rayonier Marine RI	2002	metals, PCBs (Aroclors), dioxins and furans, fatty acids, resin acids	9	QA1	Malcolm Pirnie (2007b)
		grain size and conventionals	26 – 27		

PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
QA1 – summary data validation
QA2 – full data validation
RI – remedial investigation
SVOC – semivolatile organic compound

2.1.2.3 Tissue

Tissue samples were collected from the study area during four sampling events: the ESI in 1998, the Rayonier Marine RI in 2002, the Rayonier Phase 2 RI addendum in 2006, and the Port Angeles Harbor Sediment Investigation in 2008 (Table 2-6) (Ecology and Environment 1999; Malcolm Pirnie 2007b, a; Ecology 2012b). During the ESI, geoduck and red rock crab tissue samples were collected from the central portion of the study area and analyzed for a full suite of chemicals (Map 2-3). As part of the Rayonier Marine RI, rock sole, coonstripe shrimp, Dungeness crab, geoduck, and horse clam tissue samples were collected from throughout the study area (Map 2-3); these samples were also analyzed for a full suite of chemicals (Table 2-6). During the Rayonier Phase 2 RI, additional sampling of Dungeness crab and horse clams was conducted near the mill dock and log pond; these samples were analyzed only for PCB congeners and dioxin and furan congeners (Map 2-3; Table 2-6). In 2008, Ecology collected bull kelp, eelgrass and ling cod samples near Ediz Hook and in the inner portion of Port Angeles Harbor in 2008 (Ecology 2012b); these data were not included in this report. These species, with the possible exception of ling cod, are either stationary or have small home ranges, and thus are not expected to represent exposure from the study area.

Table 2-6. Summary of sampling events included in the tissue dataset

Species	Sampling Event	Sampling Date	No. of Samples	No. of Locations	Sample Type	Individual or Composite	Chemicals	Data Validation Level	Source
Coonstripe shrimp	Rayonier marine RI	2002	3	1	whole body	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007b)
Dungeness Crab	Rayonier Phase 2 RI addendum	2006	8	3	hepatopancreas	individual	PCBs (congeners), dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007a)
			8	3	muscle	individual	PCBs (congeners), dioxins and furans, conventionals	QA1	
	Rayonier marine RI	2002	3	various crab pot locations	hepatopancreas	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007b)
			3	various crab pot locations	muscle	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	
Red rock crab	Expanded Site Inspection	1998	2	2	muscle	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, phthalates, dioxins and furans	QA1	Ecology and Environment (1999)
Geoduck	Port Angeles Harbor sediment investigation	2008	1	1	whole body	composite	metals, phthalates, other SVOCs, PCBs (subset of congeners), pesticides, conventionals	QA1	Ecology (2012b)
							PAHs, dioxins and furans	QA2	
	Rayonier marine RI	2002	3	1	whole body	individual	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007b)
	Expanded Site Inspection	1998	2	2	whole body[a]	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, phthalates, dioxins and furans	QA1	Ecology and Environment (1999)

Species	Sampling Event	Sampling Date	No. of Samples	No. of Locations	Sample Type	Individual or Composite	Chemicals	Data Validation Level	Source
Horse clam	Port Angeles Harbor sediment investigation	2008	6	6	whole body	composite and individual	metals, phthalates, other SVOCs, PCBs (subset of congeners), pesticides (subset of 4 samples), conventionals	QA1	Ecology (2012b)
							PAHs, dioxins and furans	QA2	
	Rayonier Phase 2 RI addendum	2006	10	2	visceral cavity	individual	PCBs (congeners), dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007a)
			17	4	tissue without visceral cavity	individual	PCBs, dioxins and furans, conventionals	QA1	
	Rayonier marine RI	2002	9	3	whole body	individual	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007b)
Rock sole	Rayonier marine RI	2002	3	various trawls	fillet	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	Malcolm Pirnie (2007b)
			3	various trawls	whole body	composite	metals, PAHs, other SVOCs, PCBs (Aroclors), pesticides, dioxins and furans, conventionals	QA1	

[a] The siphon, mantle, and adductor muscle were resected and considered whole body samples because these three tissue types make up the bulk of the geoduck mass.

Ecology – Washington State Department of Ecology
na – not available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
QA1 – summary data validation
QA2 – full data validation
RI – remedial investigation
SVOC – semivolatile organic compound

2.1.2.4 Toxicity Tests

Twenty-nine of the surface sediment samples that were chemically analyzed were also tested for toxicity using sample splits collected at the same time and location. Two sampling events in the study area included the collection of synoptic toxicity and sediment chemistry data: the Rayonier Marine RI (Malcolm Pirnie 2007b) and the Port Angeles Harbor sediment investigation (Ecology 2012b) (Table 2-7). Twelve of the fifteen samples tested for toxicity for the Rayonier RI were collected from the log pond area and the remaining three samples were collected from the vicinity of the mill dock (Map 2-4). The 14 samples collected as part of the Port Angeles Harbor sediment investigation (Ecology 2012b) were collected from throughout the study area (Map 2-4).

Table 2-7. Summary of sampling events included in the sediment toxicity test dataset

Sampling Event	Year of Sampling	Toxicity Tests Conducted	Number of Sampling Locations	Source
Rayonier Marine RI	2002	10-day amphipod (*Rhepoxynius abronius*), larval development (*Mytilus edulis*), and juvenile polychaete growth (*Neanthes arenaceodentata*)	15	Malcolm Pirnie (2007b)
Port Angeles Harbor Sediment Investigation	2008	10-day amphipod (*Eohaustorius estuarius*), larval development (*Dendraster excentricus*), and juvenile polychaete growth (*Neanthes arenaceodentata*)	14	Ecology (2012b)

Ecology – Washington State Department of Ecology
RI – remedial investigation

2.1.3 Data reduction

Data reduction refers to methods used to aggregate raw data for use in the Volume II dataset. A detailed discussion of data reduction methods is presented in Appendix D and briefly summarized as follows:

- No averaging of chemical concentrations obtained from the analysis of laboratory or field duplicates was conducted; duplicate results were only used to evaluate data quality.
- Surface sediment was re-sampled for grain size analyses at 12 locations on a date approximately 2 weeks after the initial sampling date during the Rayonier Marine RI in 2002. In addition, surface sediment samples from two locations were collected and analyzed for PCBs, metals, PAHs, SVOCs, and DDTs during both the ESI in 1997 and the Rayonier Marine RI in 2002. Only results from the most recent analyses were retained in the dataset.

- In some instances, the laboratory generated more than one result for a chemical for a given sample if re-analysis was required or if two different analytical methods were used for that chemical. The procedures for selecting the best result are described in Appendix D.
- The precision of each result was stored in the project database by recording the number of significant figures assigned by the laboratory. These significant figures were treated according to methods described in Appendix D.

For several chemical groups (PCBs, dichlorodiphenyltrichloroethanes [DDTs], polycyclic aromatic hydrocarbons (PAHs), and chlordane isomers), total concentrations were calculated in individual samples by summing concentrations of individual components (i.e., seven Aroclor mixtures or individual congeners for total PCBs, six DDT isomers for total DDTs, specific individual PAH compounds for high molecular weight or low molecular weight PAHs, and specific individual chlordane isomers for total chlordane). The treatment of non-detects for these sums were as follows:

- If some of the individual components were detected in a sample and some were not, only the detected concentrations were included in the sum.
- If none of the individual components were detected in a sample, the total concentration was given a value equal to the highest reporting limit (RL) of an individual component and assigned a U-qualifier.

Toxic equivalents (TEQs) of dioxins and furans, PCBs, and carcinogenic PAHs were calculated by summing the products of concentrations and compound-specific toxic equivalency factors (TEFs) for individual compounds, as discussed in more detail in Appendix D. Compounds that were undetected for a given sample were assigned a value equal to one-half the sample-specific RL for use in the calculations.

2.2 SEDIMENT MANAGEMENT STANDARDS EVALUATION

This section provides an overview of SMS marine sediment criteria (Washington Administrative Code [WAC] 173-204) as well as a comparison of surface sediment chemistry data and toxicity test results with SMS criteria.

2.2.1 SMS criteria

The SMS provide both chemical and biological effects-based criteria. Numerical SMS chemical criteria are available for 47 chemicals or groups of chemicals. The sediment cleanup objective (SCO) criteria for the protection of the benthic community represent numerical chemical concentrations below which sediment quality is expected to result in no adverse effects. The cleanup screening level (CSL) criteria represent chemical concentrations above which there is a potential for a more pronounced adverse effect. At chemical concentrations above the SCO but below the CSL, sediment quality is

expected to result in minor effects to the benthic community. The SMS chemical criteria for the 47 chemicals (or groups of chemicals) are presented in Table 2-8.

Table 2-8. SMS chemical criteria for marine sediment

Chemical	Unit	SCO	CSL
Metals			
Arsenic	mg/kg dw	57	93
Cadmium	mg/kg dw	5.1	6.7
Chromium	mg/kg dw	260	270
Copper	mg/kg dw	390	390
Lead	mg/kg dw	450	530
Mercury	mg/kg dw	0.41	0.59
Silver	mg/kg dw	6.1	6.1
Zinc	mg/kg dw	410	960
PAHs			
2-Methylnaphthalene	mg/kg OC	38	64
Acenaphthene	mg/kg OC	16	57
Acenaphthylene	mg/kg OC	66	66
Anthracene	mg/kg OC	220	1,200
Benzo(a)anthracene	mg/kg OC	110	270
Benzo(a)pyrene	mg/kg OC	99	210
Benzo(g,h,i)perylene	mg/kg OC	31	78
Total benzofluoranthenes[a]	mg/kg OC	230	450
Chrysene	mg/kg OC	110	460
Dibenzo(a,h)anthracene	mg/kg OC	12	33
Dibenzofuran	mg/kg OC	15	58
Fluoranthene	mg/kg OC	160	1,200
Fluorene	mg/kg OC	23	79
Indeno(1,2,3-cd)pyrene	mg/kg OC	34	88
Naphthalene	mg/kg OC	99	170
Phenanthrene	mg/kg OC	100	480
Pyrene	mg/kg OC	1,000	1,400
Total HPAH[b]	mg/kg OC	960	5,300
Total LPAH[c]	mg/kg OC	370	780
Phthalates			
BEHP	mg/kg OC	47	78
BBP	mg/kg OC	4.9	64
Diethyl phthalate	mg/kg OC	61	110
Dimethyl phthalate	mg/kg OC	53	53
Di-n-butyl phthalate	mg/kg OC	220	1,700
Di-n-octyl phthalate	mg/kg OC	58	4,500

Chemical	Unit	SCO	CSL
Other SVOCs			
1,2,4-Trichlorobenzene	mg/kg OC	0.81	1.8
1,2-Dichlorobenzene	mg/kg OC	2.3	2.3
1,4-Dichlorobenzene	mg/kg OC	3.1	9.0
2,4-Dimethylphenol	µg/kg dw	29	29
2-Methylphenol	µg/kg dw	63	63
4-Methylphenol	µg/kg dw	670	670
Benzoic acid	µg/kg dw	650	650
Benzyl alcohol	µg/kg dw	57	73
Hexachlorobenzene	mg/kg OC	0.38	2.3
Hexachlorobutadiene	mg/kg OC	3.9	6.2
n-Nitrosodiphenylamine	mg/kg OC	11	11
Pentachlorophenol	µg/kg dw	360	690
Phenol	µg/kg dw	420	1,200
PCBs			
Total PCBs	mg/kg OC	12	65

[a] Total benzofluoranthenes were calculated as the sum of benzo(b)fluoranthene, benzo(j)fluroanthene, and benzo(k)fluoranthene.

[b] Total HPAHs were calculated as the sum of benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene.

[c] Total LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

BBP – butyl benzyl phthalate
BEHP – bis(2-ethylhexyl) phthalate
CSL – cleanup screening level
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
OC –organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards
SVOC – semivolatile organic compound

Many of the SCO and CSL criteria are in units normalized to the organic carbon (OC) content in the sediment sample (mg/kg OC). Concentrations originally in units of µg/kg dry weight (dw) were converted to mg/kg OC using Equation 2-1.

$$C_{OC} = \frac{C_{dw}}{TOC} \qquad \textbf{Equation 2-1}$$

Where:

C_{dw} = dry-weight chemical concentration (mg/kg dw)
C_{oc} = OC-normalized chemical concentration (mg/kg OC)
TOC = fraction of total organic carbon

OC-normalization was not conducted for samples with TOC concentrations ≤ 0.5 or ≥ 3.5%. The upper bound of 3.5% was requested for use in this document by Ecology

to be consistent with the approach used by Ecology in their sediment investigation report (Ecology 2012b). When the TOC of a sample was outside this range, dry-weight chemical concentrations were compared with the lowest apparent effects threshold (LAET), which is functionally equivalent to the SCO, or the second LAET (2LAET), which is functionally equivalent to the CSL. Table 2-9 presents the LAET and 2LAET values for chemicals with SMS criteria that are OC-normalized.

Table 2-9. LAETs for chemicals with OC-normalized SMS criteria

Chemical	Concentration (µg/kg dw)	
	LAET	2LAET
PAHs		
2-Methylnaphthalene	670	670
Acenaphthene	500	500
Acenaphthylene	1,300	1,300
Anthracene	960	960
Benzo(a)anthracene	1,300	1,600
Benzo(a)pyrene	1,600	1,600
Benzo(g,h,i)perylene	670	720
Total benzofluoranthenes[a]	3,200	3,600
Chrysene	1,400	2,800
Dibenzo(a,h)anthracene	230	230
Dibenzofuran	540	540
Fluoranthene	1,700	2,500
Fluorene	540	540
Indeno(1,2,3-cd)pyrene	600	690
Naphthalene	2,100	2,100
Phenanthrene	1,500	1,500
Pyrene	2,600	3,300
Total HPAH[b]	12,000	17,000
Total LPAH[c]	5,200	5,200
Phthalates		
BEHP	1,300	3,100
BBP	63	900
Diethyl phthalate	200	1,200
Dimethyl phthalate	71	160
Di-n-butyl phthalate	1,400	5,100
Di-n-octyl phthalate	6,200	6,200
Other SVOCs		
1,2,4-Trichlorobenzene	31	51
1,2-Dichlorobenzene	35	50
1,4-Dichlorobenzene	110	110
Hexachlorobenzene	22	70

Chemical	Concentration (µg/kg dw)	
	LAET	2LAET
Hexachlorobutadiene	11	120
n-Nitrosodiphenylamine	28	40
PCBs		
Total PCBs	130	1,000

[a] Total benzofluoranthenes were calculated as the sum of benzo(b)fluoranthene, benzo(j)fluoranthene, and benzo(k)fluoranthene.

[b] Total HPAHs were calculated as the sum of benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene.

[c] Total LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

BBP – butyl benzyl phthalate
BEHP – bis(2-ethylhexyl) phthalate
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LAET – lowest apparent effects threshold
2LAET – second lowest apparent effects threshold
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
nv – no value
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SMS – Washington State Sediment Management Standards
SVOC – semivolatile organic compound

The SMS also include biological criteria based on sediment toxicity tests or benthic infaunal abundance. Because apparent effects thresholds (AETs), which form the basis for the chemical criteria, are based on sediment samples with a mixture of chemicals from various locations in Puget Sound and the exceedance of the SMS chemical criteria is not always an accurate predictor of adverse effects, the regulations state that site-specific biological tests (sediment toxicity tests or the assessment of benthic infaunal abundances) may also be conducted. The SCO and CSL biological effects criteria for the toxicity tests conducted are presented in Table 2-10.

Table 2-10. SMS biological effects criteria for marine sediment toxicity tests

Toxicity Test	Biological Effects Criteria	
	SCO	CSL
Amphipod mortality	mean mortality is > 25% on an absolute basis and statistically different from the reference sediment ($p \leq 0.05$)	mean mortality is greater than the response in the reference sediment plus 30% and statistically different from the reference sediment ($p \leq 0.05$)
Larval development	mean normal survivorship[a] is < 85% of that of the reference sediment and statistically different ($p \leq 0.10$)	mean normal survivorship[a] is < 70% of that of the reference sediment and statistically different ($p \leq 0.10$)
Juvenile polychaete growth	mean individual growth rate is < 70% of that of the reference sediment and statistically different ($p \leq 0.05$)[b]	mean individual growth rate is < 50% of that of the reference sediment and statistically different ($p \leq 0.05$)[b]

[a] Mean normal survivorship is a combined measure of mortality and abnormality (i.e., the number of normal larvae relative to the initial number of organisms).

[b] The mortality endpoint for the polychaete toxicity test is not used for the determination of SMS compliance.

CSL – cleanup screening level
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards

According to the regulations (WAC 173-204-562), the SCO is exceeded if the SCO biological criteria are exceeded for any one of the three toxicity tests conducted for a sampling location. Likewise, the CSL is exceeded if the CSL biological criteria are exceeded for any one of the three toxicity tests. The CSL is also exceeded if the SCO biological effects criteria are exceeded in any two of the three toxicity tests conducted for a sampling location. The SCO and CSL designations based on biological criteria override the SCO and CSL designations based on chemistry results. For example, if a location has a chemical SCO exceedance but is tested and found not to be toxic, it is not categorized as an SCO exceedance.

2.2.2 Comparison of surface sediment data with SMS criteria

In total, surface sediment samples from 151 locations in the study area were analyzed for at least one SMS chemical (Map 2-5). Of these 151 locations, samples from 26 locations had an exceedance of the SCO criteria for at least one chemical. The SCO or CSL was exceeded for the following chemicals (Table 2-11):

- Metals – mercury
- PAHs – acenaphthene, benzo(g,h,i)perylene, chrysene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, total high-molecular-weight PAH (HPAH), and total low-molecular-weight PAH (LPAH)
- Phthalates – bis(2-ethylhexyl) phthalate (BEHP)
- Other SVOCs – 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, and phenol
- Total PCBs

Table 2-11. Comparison of surface sediment chemical data to SMS chemical criteria within the study area

Chemical	Detection Frequency[a]		Frequency of Detected Concentrations > SCO and ≤ CSL[b]			Maximum Detected SCO EF[c]	Frequency of Detected Concentrations > CSL[d]			Maximum Detected CSL EF[e]
	No. of Samples	%	No. of Samples	%	No. with RL > SCO and ≤ CSL		No. of Samples	%	No. with RL > CSL	
Metals										
Arsenic	105/115	91	0/115	0.0	0	0.35	0/115	0.0	0	0.22
Cadmium	103/115	90	0/115	0.0	0	0.82	0/115	0.0	0	0.63
Chromium	92/92	100	0/92	0.0	0	0.21	0/92	0.0	0	0.20
Copper	115/115	100	0/115	0.0	0	0.19	0/115	0.0	0	0.19
Lead	115/115	100	0/115	0.0	0	0.59	0/115	0.0	0	0.50
Mercury	100/116	86	1/116	0.86	0	1.0	0/116	0.0	0	0.73
Silver	56/92	61	0/92	0.0	0	0.044	0/92	0.0	0	0.044
Zinc	115/115	100	0/115	0.0	0	0.36	0/115	0.0	0	0.15
PAHs										
2-Methylnaphthalene	82/116	71	0/116	0.0	0	0.76	0/116	0.0	1	0.45
Acenaphthene	64/116	55	1/116	0.86	0	1.5	1/116	0.86	1	1.5
Acenaphthylene	60/116	52	0/116	0.0	0	0.18	0/116	0.0	0	0.18
Anthracene	82/116	71	0/116	0.0	0	0.67	0/116	0.0	0	0.67
Benzo(a)anthracene	87/116	75	0/116	0.0	0	0.87	0/116	0.0	0	0.52
Benzo(a)pyrene	84/116	72	0/116	0.0	0	0.79	0/116	0.0	0	0.37
Benzo(g,h,i)perylene	68/116	59	1/116	0.86	1	1.1	0/116	0.0	0	0.44
Total benzofluoranthenes[f]	88/116	76	0/116	0.0	0	0.78	0/116	0.0	0	0.40
Chrysene	91/116	78	2/116	1.7	0	1.5	0/116	0.0	0	0.73
Dibenzo(a,h)anthracene	31/116	27	0/116	0.0	0	0.81	0/116	0.0	2	0.29
Dibenzofuran	54/95	57	1/95	1.1	0	1.2	1/95	1.1	1	1.2
Fluoranthene	107/116	92	1/116	0.86	0	8.8	2/116	1.7	0	6.0

Chemical	Detection Frequency[a]		Frequency of Detected Concentrations > SCO and ≤ CSL[b]			Maximum Detected SCO EF[c]	Frequency of Detected Concentrations > CSL[d]			Maximum Detected CSL EF[e]
	No. of Samples	%	No. of Samples	%	No. with RL > SCO and ≤ CSL		No. of Samples	%	No. with RL > CSL	
Fluorene	76/116	66	0/116	0.0	0	2.2	1/116	0.86	1	2.2
Indeno(1,2,3-cd)pyrene	66/116	57	1/116	0.86	0	1.0	0/116	0.0	0	0.39
Naphthalene	93/116	80	0/116	0.0	0	0.75	0/116	0.0	0	0.52
Phenanthrene	102/116	88	0/116	0.0	0	7.9	1/116	0.86	0	7.9
Pyrene	104/116	90	0/116	0.0	0	3.2	1/116	0.86	0	2.5
Total HPAHs[g]	107/116	92	1/116	0.86	0	2.4	1/116	0.86	0	1.7
Total LPAHs[h]	102/116	88	0/116	0.0	0	2.8	1/116	0.86	0	2.8
Phthalates										
Bis(2-ethylhexyl)phthalate	41/60	68	1/60	1.7	0	2.1	0/60	0.0	0	0.87
Butyl benzyl phthalate	3/60	5.0	0/60	0.0	10	0.43	0/60	0.0	0	0.030
Diethyl phthalate	1/60	1.7	0/60	0.0	3	0.10	0/60	0.0	0	0.017
Dimethyl phthalate	3/60	5.0	0/60	0.0	3	0.30	0/60	0.0	7	0.13
Di-n-butyl phthalate	11/60	18	0/60	0.0	0	0.11	0/60	0.0	0	0.031
Di-n-octyl phthalate	2/60	3.3	0/60	0.0	0	0.014	0/60	0.0	0	0.014
Other SVOCs										
1,2,4-Trichlorobenzene	0/60	0.0	0/60	0.0	10	nd	0/60	0.0	11	nd
1,2-Dichlorobenzene	1/60	1.7	0/60	0.0	0	0.089	0/60	0.0	10	0.062
1,4-Dichlorobenzene	1/60	1.7	0/60	0.0	0	0.031	0/60	0.0	9	0.031
2,4-Dimethylphenol	2/83	2.4	0/83	0.0	0	1.9	1/83	1.2	46	1.9
2-Methylphenol	3/83	3.6	0/83	0.0	0	3.2	1/83	1.2	11	3.2
4-Methylphenol	88/116	76	0/116	0.0	0	61	10/116	8.6	0	61
Benzoic acid	9/95	9.5	0/95	0.0	0	0.54	0/95	0.0	10	0.54
Benzyl alcohol	0/34	0.0	0/34	0.0	0	nd	0/34	0.0	0	nd
Hexachlorobenzene	0/60	0.0	0/60	0.0	20	nd	0/60	0.0	10	nd

Chemical	Detection Frequency[a]		Frequency of Detected Concentrations > SCO and ≤ CSL[b]			Maximum Detected SCO EF[c]	Frequency of Detected Concentrations > CSL[d]			Maximum Detected CSL EF[e]
	No. of Samples	%	No. of Samples	%	No. with RL > SCO and ≤ CSL		No. of Samples	%	No. with RL > CSL	
Hexachlorobutadiene	0/60	0.0	0/60	0.0	10	nd	0/60	0.0	7	nd
n-Nitrosodiphenylamine	0/60	0.0	0/60	0.0	0	nd	0/60	0.0	10	nd
Pentachlorophenol	2/83	2.4	0/83	0.0	4	0.12	0/83	0.0	8	0.064
Phenol	73/116	63	2/116	1.7	0	1.8	0/116	0.0	0	0.63
PCBs										
Total PCB Aroclors	54/104	52	9/104	8.7	0	4.9	0/104	0.0	0	0.64
Total PCB congeners	28/28	100	6/28	21	0	2.7	0/28	0.0	0	0.35
Total PCB (Aroclors and congeners)	82/132	62	15/132	11	0	4.9	0/132	0.0	0	0.64

[a] Represents the number of detects per total number of samples.

[b] Represents the number of detects > SCO and ≤ CSL per total number of samples. If any individual sample had a TOC content > 3.5% or < 0.5% and the dry-weight concentration was > LAET and ≤ 2LAET, the concentration was considered to be > SCO and ≤ CSL.

[c] The maximum SCO EF is the maximum detected concentration divided by the SCO.

[d] Represents the number of detects > CSL per the total number of samples. If any individual location had a TOC content > 3.5% or < 0.5% and the dry-weight concentration was > 2LAET, the concentration was considered to be > CSL.

[e] The maximum CSL EF is the maximum detected concentration divided by the CSL.

[f] Total benzofluoranthenes were calculated as the sum of benzo(b)fluoranthene, benzo(j)fluoranthene, and benzo(k)fluoranthene.

[g] Total HPAHs were calculated as the sum of benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene.

[h] Total LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

CSL – cleanup screening level
DDT – dichlorodiphenyltrichloroethane
EF – exceedance factor
HPAH – low-molecular-weight polycyclic aromatic hydrocarbon
LPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LAET – lowest-apparent-effect threshold
2LAET – second-lowest-apparent-effect threshold
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
SCO – sediment cleanup objective
SVOC – semivolatile organic compound
TOC – total organic carbon

For most chemicals with detected SCO or CSL exceedances, there were just one or two samples with exceedances. However, for 4-methylphenol and total PCBs, there were more (Table 2-11). For 4-methylphenol, ten exceedances of the CSL (which is equal to the SCO in the case of 4-methylphenol) were detected; all but one of the exceedances were located near the Rayonier log pond or mill dock area (Map 2-5). For total PCBs, 15 samples had detected SCO exceedances; there were no CSL exceedances. The total PCB SCO exceedances were located near the Rayonier log pond or mill dock area (Map 2-5).

For some chemicals, analytical laboratory RLs were greater than the SCO or CSL (Table 2-11). These chemicals, primarily BBP, 1,2,4-trichlorobenzene, 2,4-dimethylphenol, hexachlorobenzene, and hexachlorobutadiene, rarely had detected concentrations that were greater than the SCO or CSL.

2.2.3 Comparison of toxicity test results with SMS criteria

Of the 29 samples tested for toxicity within the study area, 2 samples exceeded the overall SCO biological effects criteria (i.e., the SCO was exceeded for any one of the three endpoints), 9 samples exceeded the overall CSL biological effects criteria (i.e., the CSL was exceeded for one or more of the three endpoints or the SCO was exceeded for any two of the three endpoints), and the remaining 18 samples passed all toxicity tests (Table 2-12). In the log pond area, 7 of the 13 toxicity test samples had CSL designations and 1 sample had an SCO designation (Map 2-6). In the mill dock area, 2 of the 11 toxicity text samples had CSL designations and 1 sample had a SCO designation (Map 2-6).

Table 2-12. Toxicity test results

Location	SMS Designation Based on Chemistry	SMS Designation for Individual Toxicity Tests			SMS Designation based on Toxicity
		Amphipod Mortality Test	Juvenile Polychaete Growth Test	Larval Development Test	
Ecology 2008					
CO01A	ne	ne	ne	ne	ne
CO02A	ne	ne	ne	ne	ne
CO04A	ne	ne	ne	ne	ne
DO03A	ne	ne	ne	ne	ne
DO04A	ne	ne	ne	ne	ne
DO05A	ne	ne	ne	ne	ne
ED03A	ne	ne	ne	ne	ne
ED04A	CSL	CSL	ne	CSL	CSL
ED05A	ne	ne	ne	ne	ne
MD01A	ne	ne	ne	ne	ne
MD02A	ne	ne	ne	CSL	CSL

Location	SMS Designation Based on Chemistry	SMS Designation for Individual Toxicity Tests			SMS Designation based on Toxicity
		Amphipod Mortality Test	Juvenile Polychaete Growth Test	Larval Development Test	
MD03A	ne	ne	ne	SCO	SCO
OH02A	ne	ne	ne	ne	ne
WW01A	ne	ne	ne	ne	ne
Rayonier RI					
LP-03	SCO	ne	ne	ne	ne
LP-05	SCO	ne	ne	ne	ne
LP-06	CSL	ne	ne	ne	ne
LP-09	SCO	ne	ne	CSL	CSL
LP-10	SCO	CSL	SCO	CSL	CSL
LP-11	ne	ne	ne	ne	ne
LP-12	ne	CSL	SCO	CSL	CSL
LP-13	CSL	CSL	ne	CSL	CSL
LP-15	ne	ne	SCO	ne	SCO
LP-16	CSL	ne	ne	CSL	CSL
LP-18	CSL	ne	SCO	SCO	CSL
LP-20	CSL	CSL	ne	ne	CSL
MD-02	CSL	ne	ne	ne	ne
MD-04	SCO	ne	ne	ne	ne
MD-12	CSL	ne	ne	ne	ne

CSL – cleanup screening level
ID – identification
ne – no exceedance
NCMA – normalized combined mortality and abnormality
PSAMP – Puget Sound Ambient Monitoring Program
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards

Of the 29 samples tested for larval development using either *Mytilus edulis* or *Dendraster excentricus*; 2 samples failed the larval biological effects criteria at the SCO level, and 7 samples failed at the CSL level (Table 2-12). For the juvenile polychaete growth test, there were four failures of the biological effects criteria at the SCO level; and for the amphipod mortality test, there were five failures at the CSL level (Table 2-12). It should be noted that the study design for selecting bioassay locations was unusual because it involved the selection of bioassay locations prior to determining where exceedances of SMS occurred. As a result, toxicity data were obtained at some locations that did not have SMS exceedances, and some locations that had SMS exceedances were not evaluated for toxicity.

As described in Section 2.2.1, overall SCO and CSL designations based on toxicity overrule those based on chemistry because the toxicity test results provide a more direct assessment of sediment toxicity (Map 2-7). The SCO and CSL designations based on chemistry were the same as the SCO and CSL designations based on toxicity

for 17 of the 29 locations (Table 2-12). For another 6 of the 29 locations, the SCO or CSL designations based on chemistry were overruled by toxicity test results. For the remaining 6 locations, toxicity was observed where no chemical exceedances had been identified.

2.3 SEDIMENT AND TISSUE CHEMISTRY

This section presents the surface sediment (Section 2.3.1), subsurface sediment (Section 2.3.2), and tissue (Section 2.3.3) data for all chemicals analyzed in the study area. Data are presented for risk driver chemicals, chemicals of potential concern (COPCs), and all other chemicals analyzed. Risk driver chemicals are those with excess cancer risk estimates > 10^{-4} or non-cancer HQs >10, based on the results of the screening-level HHRA (Ecology 2012b) (see Appendix B). COPCs are defined as those chemicals with excess cancer risk estimates > 10^{-6} or non-cancer HQs > 1. Risk driver chemicals (dioxin and furan TEQ, total PCBs, PCB TEQ, carcinogenic PAH [cPAH] TEQs, arsenic, mercury, and alpha-benzene hexachloride [BHC]) and other COPCs are discussed in greater detail because of their greater importance from a human health perspective. Chemicals with SMS exceedances were discussed in Section 2.2.

2.3.1 Surface sediment

This section discusses surface sediment data for the study area. Summary statistics for all chemicals analyzed in surface sediment from the study area are presented in tabular format (Table 2-13). In addition, results from analyses of conventional parameters (Maps 2-19 through 2-21) and from Ecology's evaluation of wood waste in the study area (SAIC 1999) are discussed in this section. The following subsections present surface sediment results from the three areas where the majority of samples were collected (Map 2-1): the log pond area, the mill dock area, and the outfall area.

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Risk Drivers[c]							
Dioxins and furans							
2,3,7,8-TCDD	ng/kg dw	63/109	58	0.0650 J	5.02	0.49	0.0410 – 1.139
1,2,3,7,8-PeCDD	ng/kg dw	77/109	71	0.0410 J	25.16	1.5	0.0470 – 3.3
1,2,3,4,7,8-HxCDD	ng/kg dw	71/109	65	0.0340 J	27.53	1.6	0.0234 – 4.7
1,2,3,6,7,8-HxCDD	ng/kg dw	95/109	87	0.0810 J	60.97	4.5	0.263 – 4.0
1,2,3,7,8,9-HxCDD	ng/kg dw	84/109	77	0.0820 J	24.1	2.7	0.0660 – 3.3
1,2,3,4,6,7,8-HpCDD	ng/kg dw	106/109	97	0.418 J	793	76	1.236 – 2.0
OCDD	ng/kg dw	108/109	99	1.68	7680	770	54
2,3,7,8-TCDF	ng/kg dw	92/109	84	0.0320 J	26.4	2.6	0.0234 – 10.76
1,2,3,7,8-PeCDF	ng/kg dw	73/97	75	0.0290 J	19.33	1.4	0.0234 – 5.479
2,3,4,7,8-PeCDF	ng/kg dw	81/97	84	0.0280 J	22.45	2.2	0.0370 – 1.47
1,2,3,4,7,8-HxCDF	ng/kg dw	76/97	78	0.117 J	21.71	2.09	0.0249 – 1.433
1,2,3,6,7,8-HxCDF	ng/kg dw	73/97	75	0.0350 J	12.17	1.0	0.0234 – 0.889
1,2,3,7,8,9-HxCDF	ng/kg dw	30/97	31	0.0260 J	3.14	0.22	0.0234 – 1.320
2,3,4,6,7,8-HxCDF	ng/kg dw	68/97	70	0.0310 J	11.79	1.1	0.0234 – 2.949
1,2,3,4,6,7,8-HpCDF	ng/kg dw	100/109	92	0.176 J	112	13	0.110 – 3.2
1,2,3,4,7,8,9-HpCDF	ng/kg dw	57/97	59	0.0360 J	10.27	0.846	0.0234 – 6.222
OCDF	ng/kg dw	100/109	92	0.385 J	941.1	79	0.150 – 9.5
Dioxin/furan TEQ [d]	ng/kg dw	97/97	100	0.0827 J	59.4 J	5.61	na
PCBs							
Aroclor 1016	µg/kg dw	0/26	0	nd	nd	nc	5.8 – 18
Aroclor 1221	µg/kg dw	0/26	0	nd	nd	nc	5.8 – 18
Aroclor 1232	µg/kg dw	0/26	0	nd	nd	nc	5.8 – 18
Aroclor 1242	µg/kg dw	0/104	0	nd	nd	nc	5.8 – 71
Aroclor 1248	µg/kg dw	0/26	0	nd	nd	nc	5.8 – 18

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Aroclor 1254	µg/kg dw	12/104	12	3.5 J	640	24	1.5 – 44
Aroclor 1260	µg/kg dw	49/104	47	2.2 J	230	32	1.5 – 71
Total PCB Aroclors (dw)[e]	µg/kg dw	54/104	52	2.2 J	640	51	5.8 – 28
Total PCB congeners (dw)[e]	µg/kg dw	28/28	100	2.759 J	352.0 J	69.69	na
Total PCB Aroclors (OC-normalized)[f]	mg/kg OC	54/104	52	0.25	18	2.2	0.35 – 17
Total PCB congeners (OC-normalized)[f]	mg/kg OC	28/28	100	0.1760 J	19.70 J	3.822	na
PCB TEQ[d]	ng/kg dw	28/28	100	0.0464 J	7.86	1.59	na
Other Risk Drivers							
Arsenic (total)	mg/kg dw	105/115	91	1.1	20.2	5.0	0.73 – 6.3
Arsenic (inorganic)	mg/kg dw	20/20	100	2.139 J	6.377 J	3.549	na
cPAH TEQ[g]	µg/kg dw	92/116	79	3.60 J	1630	115	6.00 – 13.6
Mercury	mg/kg dw	100/116	86	0.010 J	0.43	0.073	0.0095 – 0.08
alpha-BHC	µg/kg dw	12/60	20	0.20 J	3.0 J	0.73	0.11 – 7.1
COPCs[h]							
4,4'-DDE	µg/kg dw	9/60	15	0.42 J	5.8 J	1.0	0.23 – 7.1
4,4'-DDT	µg/kg dw	37/60	62	0.31 J	110	7.4	0.21 – 6.0
beta-BHC	µg/kg dw	4/60	7	0.38 J	2.1	0.79	0.13 – 8.4
gamma-BHC	µg/kg dw	7/60	12	0.16 J	3.6 J	0.97	0.12 – 8.5
Pentachlorophenol	µg/kg dw	2/83	2	17 J	44 J	100	46 – 3500
Hexachlorobenzene	µg/kg dw	0/60	0	nd	nd	nc	7.8 – 700
Cadmium	mg/kg dw	103/115	90	0.0036 J	4.2	0.69	0.00034 – 1.6
Cobalt	mg/kg dw	36/36	100	3.6 J	13.8	7.3	na
Copper	mg/kg dw	115/115	100	5.6 J	75.2	22	na
Iron	mg/kg dw	36/36	100	9580	39500	23000	na
Selenium	mg/kg dw	39/80	49	0.2 J	3.8	0.60	0.2 – 2.4

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Silver	mg/kg dw	56/92	61	0.024 J	0.269	0.12	0.21 – 0.81
Vanadium	mg/kg dw	36/36	100	20.6	87.5	48.9	na
Zinc	mg/kg dw	115/115	100	17.8	148	45	na
All Other Chemicals							
Metals							
Aluminum	mg/kg dw	36/36	100	5,720	24,100	14,000	na
Antimony	mg/kg dw	4/71	6	0.17	1.2 J	0.30	0.0017 – 2.4
Barium	mg/kg dw	71/71	100	6.6	46.8 J	22	na
Beryllium	mg/kg dw	6/36	17	0.25 J	0.42 J	0.19	0.25 – 0.81
Calcium	mg/kg dw	36/36	100	2,530	24,200	7,030	na
Chromium	mg/kg dw	92/92	100	9.93	54.1	25	na
Lead	mg/kg dw	115/115	100	1.7	265	14	na
Magnesium	mg/kg dw	36/36	100	4,530	15,500	8,570	na
Manganese	mg/kg dw	36/36	100	106	420 J	237	na
Nickel	mg/kg dw	71/71	100	13.5	45.3	28	na
Potassium	mg/kg dw	36/36	100	714 J	3,850 J	1,680	na
Sodium	mg/kg dw	36/36	100	3,820	33,500	8,260	na
Thallium	mg/kg dw	18/36	50	0.77 J	1.7 J	0.88	0.77 – 2.4
PAHs							
1-Methylnaphthalene	µg/kg dw	20/70	29	10 J	254	19	7.0 – 99.7
2-Chloronaphthalene	µg/kg dw	0/35	0	nd	nd	nc	7.7 – 7.9
2-Methylnaphthalene	µg/kg dw	82/116	71	0.75 J	430	37	7.9 – 700
Acenaphthene	µg/kg dw	64/116	55	0.53 J	755	42	8.0 – 700
Acenaphthylene	µg/kg dw	60/116	52	0.65 J	169	25	8.4 – 700
Anthracene	µg/kg dw	82/116	71	1.7 J	728	79	7.5 – 18.0
Benzo(a)anthracene	µg/kg dw	87/116	75	2.5 J	1,390	110	5.7 – 18.0

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Benzo(a)pyrene	µg/kg dw	84/116	72	2.4 J	1,140	76	7.9 – 18.0
Benzo(b)fluoranthene	µg/kg dw	88/116	76	3.3 J	1,880	130	9.2 – 18.0
Benzo(g,h,i)perylene	µg/kg dw	68/116	59	2.5 J	506	38	6.5 – 700
Benzo(k)fluoranthene	µg/kg dw	78/116	67	1.9 J	754	75	9.0 – 280
Total benzofluoranthenes	µg/kg dw	88/116	76	3.3 J	2,630	200	9.2 – 18.0
Chrysene	µg/kg dw	91/116	78	2.8 J	2,210	190	6.4 – 85.9
Dibenzo(a,h)anthracene	µg/kg dw	31/116	27	0.62 J	142	22	8.3 – 700
Dibenzofuran	µg/kg dw	54/95	57	2.8 J	667	46	7.3 – 700
Fluoranthene	µg/kg dw	107/116	92	4.2 J	15,000	490	7.7 – 7.9
Fluorene	µg/kg dw	76/116	66	1.1 J	1,180	54	8.7 – 700
Indeno(1,2,3-cd)pyrene	µg/kg dw	66/116	57	2.2 J	499	36	8.3 – 107
Naphthalene	µg/kg dw	93/116	80	1.9 J	1,240	110	8.4 – 18.0
Phenanthrene	µg/kg dw	102/116	88	4.2 J	11,800	290	8.1 – 8.4
Pyrene	µg/kg dw	104/116	90	4.9 J	8,390	390	7.5 – 24.8
Total HPAHs	µg/kg dw	107/116	92	11 J	28,400 J	1,500	9.2 – 9.5
Total LPAHs	µg/kg dw	102/116	88	6.1 J	14,600 J	590	8.7 – 8.9
Total PAHs	µg/kg dw	107/116	92	11 J	43,000 J	2,100	9.2 – 9.5
Phthalates							
Bis(2-ethylhexyl) phthalate	µg/kg dw	41/60	68	13 J	2,700 J	94	11
Butyl benzyl phthalate	µg/kg dw	3/60	5	21	27 JN	25	11 – 700
Diethyl phthalate	µg/kg dw	1/60	2	20	20	26	11 – 700
Dimethyl phthalate	µg/kg dw	3/60	5	11 J	26	24	7.5 – 700
Di-n-butyl phthalate	µg/kg dw	11/60	18	3.5 J	160 J	27	11 – 700
Di-n-octyl phthalate	µg/kg dw	2/60	3	9.7 J	88 J	30	8.1 – 700

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Other SVOCs							
1,2,4-Trichlorobenzene	µg/kg dw	0/60	0	nd	nd	nc	8.8 – 700
1,2-Dichlorobenzene	µg/kg dw	1/60	2	3.1 J	3.1 J	23	7.6 – 700
1,3-Dichlorobenzene	µg/kg dw	0/35	0	nd	nd	nc	7.2 – 7.4
1,4-Dichlorobenzene	µg/kg dw	1/60	2	3.4 J	3.4 J	23	7.1 – 700
2,4,5-Trichlorophenol	µg/kg dw	0/35	0	nd	nd	nc	43 – 45
2,4,6-Trichlorophenol	µg/kg dw	1/70	1	69.3 J	69.3 J	54	45 – 214
2,4-Dichlorophenol	µg/kg dw	0/35	0	nd	nd	nc	39 – 41
2,4-Dimethylphenol	µg/kg dw	2/83	2	20 J	54 J	27	14 – 240
2,4-Dinitrophenol	µg/kg dw	0/35	0	nd	nd	nc	110
2,4-Dinitrotoluene	µg/kg dw	0/35	0	nd	nd	nc	37 – 38
2,6-Dinitrotoluene	µg/kg dw	0/35	0	nd	nd	nc	52 – 54
2-Chlorophenol	µg/kg dw	0/35	0	nd	nd	nc	7.2 – 7.5
2-Methylphenol	µg/kg dw	3/83	4	5.6 J	200 J	23	11 – 700
2-Nitroaniline	µg/kg dw	0/35	0	nd	nd	nc	40 – 42
2-Nitrophenol	µg/kg dw	0/35	0	nd	nd	nc	39 – 40
3,3'-Dichlorobenzidine	µg/kg dw	0/34	0	nd	nd	nc	47 – 49
3-Nitroaniline	µg/kg dw	0/35	0	nd	nd	nc	8.6 – 76
4,6-Dinitro-o-cresol	µg/kg dw	0/35	0	nd	nd	nc	81 – 84
4-Bromophenyl phenyl ether	µg/kg dw	0/35	0	nd	nd	nc	9.3 – 9.6
4-Chloro-3-methylphenol	µg/kg dw	0/35	0	nd	nd	nc	8.1 – 8.4
4-Chloroaniline	µg/kg dw	0/35	0	nd	nd	nc	34 – 35
4-Chlorophenyl phenyl ether	µg/kg dw	0/35	0	nd	nd	nc	8.1 – 8.4
4-Methylphenol	µg/kg dw	88/116	76	6.5 J	41,000	640	11 – 90.0
4-Nitroaniline	µg/kg dw	0/35	0	nd	nd	nc	50 – 51
4-Nitrophenol	µg/kg dw	0/35	0	nd	nd	nc	64 – 66

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Benzoic acid	µg/kg dw	9/95	9	110 J	354	320	110 – 14000
Benzyl alcohol	µg/kg dw	0/34	0	nd	nd	nc	14
bis(2-chloroethoxy)methane	µg/kg dw	0/35	0	nd	nd	nc	8.6 – 8.8
bis(2-chloroethyl)ether	µg/kg dw	0/35	0	nd	nd	nc	7.2 – 7.5
bis(2-chloroisopropyl)ether	µg/kg dw	0/35	0	nd	nd	nc	7.7 – 8.0
Carbazole	µg/kg dw	18/70	26	14 J	628	28	6.4 – 99.7
Hexachlorobutadiene	µg/kg dw	0/60	0	nd	nd	nc	7.9 – 700
Hexachlorocyclopentadiene	µg/kg dw	0/35	0	nd	nd	nc	43 – 44
Hexachloroethane	µg/kg dw	0/35	0	nd	nd	nc	7.0 – 7.2
Isophorone	µg/kg dw	0/35	0	nd	nd	nc	8.0 – 8.3
n-Nitroso-di-n-propylamine	µg/kg dw	0/35	0	nd	nd	nc	35 – 36
n-Nitrosodiphenylamine	µg/kg dw	0/60	0	nd	nd	nc	8.4 – 700
Nitrobenzene	µg/kg dw	0/35	0	nd	nd	nc	8.5 – 8.8
Phenol	µg/kg dw	73/116	63	6.3 J	760	84	13 – 101
Pyridine	µg/kg dw	2/48	4	4.2 J	160 J	150	54 – 3500
Retene	µg/kg dw	41/70	59	10	2,660	240	8.7 – 90.0
Pesticides							
4,4'-DDD	µg/kg dw	26/93	28	0.37 J	27	1.9	0.19 – 3.6
Aldrin	µg/kg dw	4/14	29	0.25 J	1.6	0.35	0.11 – 0.44
Dieldrin	µg/kg dw	1/14	7	9.3 J	9.3 J	0.79	0.23 – 0.31
Total aldrin/dieldrin	µg/kg dw	5/14	36	0.25 J	9.3 J	1.0	0.23 – 0.44
delta-BHC	µg/kg dw	0/60	0	nd	nd	nc	0.12 – 7.1
alpha-Chlordane	µg/kg dw	3/14	21	0.19 J	0.53 J	0.12	0.12 – 0.18
gamma-Chlordane	µg/kg dw	4/14	29	0.17 J	6.6 J	0.71	0.12 – 0.16
Total chlordane	µg/kg dw	5/14	36	0.17 J	6.6 J	0.77	0.12 – 0.16
alpha-Endosulfan	µg/kg dw	1/14	7	0.61 J	0.61 J	0.11	0.12 – 0.18

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
beta-Endosulfan	µg/kg dw	2/14	14	0.71 J	2.8 J	0.38	0.27 – 0.40
Endosulfan sulfate	µg/kg dw	1/14	7	4.7 J	4.7 J	0.52	0.35 – 0.52
Endrin	µg/kg dw	1/14	7	3.6 J	3.6 J	0.49	0.43 – 0.59
Endrin aldehyde	µg/kg dw	4/14	29	0.45 J	1.8 J	0.37	0.26 – 0.35
Endrin ketone	µg/kg dw	0/14	0	nd	nd	nc	0.26 – 0.39
Heptachlor	µg/kg dw	3/14	21	0.49 J	1.5 J	0.27	0.14 – 0.21
Heptachlor epoxide	µg/kg dw	7/14	50	0.24 J	7.0 J	1.0	0.13 – 0.15
Methoxychlor	µg/kg dw	1/14	7	3.3 J	3.3 J	0.95	1.4 – 1.9
Toxaphene	µg/kg dw	0/14	0	nd	nd	nc	10 – 15
VOCs							
Acetone	µg/kg dw	1/36	3	41.2 J	41.2 J	5.5	5.7 – 33.6
Carbon disulfide	µg/kg dw	1/36	3	38.4 J	38.4 J	5.3	5.7 – 33.6
Dichloromethane	µg/kg dw	0/36	0	nd	nd	nc	5.7 – 33.6
Methyl ethyl ketone	µg/kg dw	1/36	3	21.1 J	21.1 J	4.9	5.7 – 33.6
Toluene	µg/kg dw	1/36	3	18.0 J	18.0 J	4.8	5.7 – 33.6
Fatty Acids							
9,10-Dichlorostearic acid	µg/kg dw	0/24	0	nd	nd	190	98 – 500
Dichlorostearic acid	µg/kg dw	0/41	0	nd	nd	300	360 – 2,100
Linoleic acid	µg/kg dw	7/41	17	580	7600	620	360 – 2,100
Linolenic acid	µg/kg dw	0/24	0	nd	nd	nc	98 – 500
Oleic acid	µg/kg dw	7/24	29	140	2,300	380	98 – 490
Oleic-linolenic acid mixture	µg/kg dw	33/41	80	490	12,000	2300	390 – 1,100
Resin Acids							
12-Chlorodehydroabietic acid	µg/kg dw	1/65	2	72 J	72 J	260	99 – 2,100
14-Chlorodehydroabietic acid	µg/kg dw	0/65	0	nd	nd	nc	98 – 2,100
Abietic acid	µg/kg dw	28/65	43	320	15,000	1700	99 – 650

Table 2-13. Summary of chemical data in surface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
		Ratio	%	Minimum	Maximum		
Dehydroabietic acid	µg/kg dw	38/65	58	440 J	20,000	2300	99 – 520
Dichlorodehydroabietic acid	µg/kg dw	0/65	0	nd	nd	nc	98 – 4,300
Isopimaric acid	µg/kg dw	7/65	11	510	4,600	390	99 – 2,100
Neoabietic acid	µg/kg dw	0/24	0	nd	nd	nc	98 – 500
Palustric acid	µg/kg dw	0/24	0	nd	nd	nc	98 – 500
Pimaric acid	µg/kg dw	1/65	2	81 J	81 J	260	99 – 2,100
Sandaracopimaric acid	µg/kg dw	0/24	0	nd	nd	nc	98 – 500
3,4,5-Trichloroguaiacol	µg/kg dw	0/69	0	nd	nd	nc	19 – 2,100
Tetrachloroguaiacol	µg/kg dw	0/69	0	nd	nd	nc	19 – 2,100
3,4,6-Trichloroguaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
3,4-Dicloroguaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
4,5,6-Trichloroguaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
4,5-Dichloroguaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
4,6-Dichloroguaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
4-Chloroguaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
Guaiacol	µg/kg dw	0/28	0	nd	nd	nc	19 – 20
Petroleum							
TPH – diesel No. 2 range	mg/kg dw	15/26	58	6.6 J	200	31	6.2 – 27
TPH – motor oil range	mg/kg dw	20/26	77	7.8 J	290	78	6.1 – 8.0
Total petroleum hydrocarbons	mg/kg dw	22/26	85	6.6 J	490	110	6.2 – 8.9
Conventionals							
Acid volatile sulfides	mg/kg dw	49/54	91	1.2	2740 J	300	0.7 – 2.0
Ammonia	mg-N/kg dw	79/79	100	0.47	641	28	na
Total organic carbon	% dw	163/163	100	0.129	24.6	3.3	na
Total sulfides	mg/kg dw	84/87	97	0.4 J	3520	420	0.00884 – 23
Total volatile solids	% dw	80/80	100	1.3	50.24	10	na

[a] Calculated mean concentration is the average of detected concentrations and one-half the RL for non-detected results.

[b] The RL represents the method reporting limit, which is the smallest amount of a chemical that the laboratory determines can be practically quantitated in a sample. For dioxin and furan TEQ, PCB TEQ, total PCBs, and cPAH TEQ, calculated non-detected concentrations (as described in footnotes d, e, and g of this table) were reported rather than RLs.

[c] Risk drivers are chemicals or chemical groups that had excess cancer risk estimates > 10^{-4} or non-cancer HQs >10 based on the results of the screening-level HHRA (see Appendix B).

[d] TEQs for dioxins and furans and PCBs were calculated using TEFs for mammals presented in Van den Berg et al. (2006) (see Appendix D). If an individual congener was not detected, the TEF for that congener was multiplied by one-half the RL for that congener.

[e] Total PCBs (dw) represent the sum of the detected concentrations of the individual Aroclors or congeners. If no Aroclors or congeners were detected, the RL reported represents the highest RL for an individual Aroclor or congener.

[f] Summary statistics for OC-normalized PCB concentrations were calculated using only samples with TOC contents ≥ 0.5% and ≤ 3.5%.

[g] TEQs for cPAHs were calculated using PEFs for individual cPAH compounds (derived from WAC 173-340-708(e)), as discussed in detail in Appendix D. If an individual cPAH compound was not detected, the PEF for that compound was multiplied by one-half the RL for that compound.

[h] COPCs are chemicals or chemical groups that had excess cancer risk estimates > 10^{-6} or non-cancer HQs >1 based on the results of the screening-level HHRA (see Appendix B).

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
COPC – chemical of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
HHRA – human health risk assessment
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HpCDD – heptachlorodibenzo-*p*-dioxin
HpCDF – heptachlorodibenzofuran
HQ – hazard quotient
HxCDD – hexachlorodibenzo-*p*-dioxin
HxCDF – hexachlorodibenzofuran
J – estimated concentration
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
N – nitrogen
na – not applicable
nc – not calculated
nd – not detected
OCDD – octachlorodibenzo-*p*-dioxin
OCDF – octachlorodibenzofuran
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PeCDD – pentachlorodibenzo-*p*-dioxin
PeCDF – pentachlorodibenzofuran
RL – reporting limit
SVOC – semivolatile organic compound
TCDD – tetrachlorodibenzo-*p*-dioxin
TCDF – tetrachlorodibenzofuran
TEF – toxic equivalency factor
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
VOC – volatile organic carbon
WAC – Washington Administrative Code

2.3.1.1 Log pond area

Many of the maximum concentrations of risk drivers and COPCs were detected in the log pond area, with the highest concentrations in the eastern portion of the area and decreasing concentrations away from the shoreline and toward the west (Maps 2-8 through 2-18). This concentration gradient was observed for six of the risk drivers (dioxin and furan TEQ, total PCBs, PCB TEQ, arsenic, cPAHs, mercury) and seven of the COPCs (4,4'-dichlorodiphenyldichloroethylene [DDE], 4,4'-dichlorodiphenyl-trichloroethane [DDT], cadmium, copper, zinc, silver, and selenium). The gradient was less distinct or was not present because of the low detection frequency for alpha-BHC, beta-BHC, gamma-BHC, pentachlorophenol, and hexachlorobenzene, or because of the low numbers of samples for iron, cobalt, and vanadium.

For most of the risk drivers and COPCs with a concentration gradient (i.e., dioxin and furan TEQ, total PCBs, arsenic, mercury, 4,4'-DDE, 4,4'-DDT, cadmium, copper, zinc, selenium, and silver), the highest concentrations in the log pond area were greater than those in the 95th percentile of the dataset for the entire study area (hereafter referred to as the study area 95th percentile).[1] For PCB TEQ and cPAHs, the highest concentrations in the log pond area were greater than the study area 75th percentile but less than the study area 95th percentile.

Sediment samples with the highest fines content were located in the eastern portion of the log pond area; fines content in this area ranged from 30 to 60% (Map 2-19). In much of the western portion of the area, the sediment had ≤ 13% fines. TOC content in surface sediment was generally > 10% in the eastern half of the log pond area,[2] decreasing to ≤ 3.5% in much of the western half and ≤ 0.5% in the far western portion (Map 2-20). Ammonia, total sulfides, and total volatile solids (TVS) all had concentration gradients, with the highest concentrations in the eastern log pond area and lower concentrations to the west (Map 2-21). The highest concentrations of ammonia, total sulfides,[3] and TVS were greater than the 95th percentile calculated using data from the entire study area.

[1] Five samples collected from the eastern portion of the log pond area in 2000 were not part of the surface sediment dataset because they were composite samples. Four of these samples had dioxin and furan TEQs greater than the study area 95th percentile and one sample had a dioxin and furan TEQ greater than the 75th percentile but less than the 95th percentile. The dioxin and furan TEQs in the five composite samples ranged from 19.0 to 90.4 ng/kg dw.

[2] TOC content in the five composite samples collected from the eastern portion of the log pond area in 2000 was also >10%, ranging from 14.8 to 25.6%.

[3] Total sulfide concentrations in the composite samples collected from the eastern portion of the log pond area in 2000 were greater than the study area 95th percentile in four samples and greater than the 75th percentile but less than the 95th percentile in one sample. Total sulfide concentrations in these five composite samples ranged from 1,350 to 2,480 mg/kg dw.

NewFields (2013) indicated that surface sediment TOC concentrations < 10% (dry-weight basis) and TVS concentrations < 25% (dry-weight basis) are not likely to pose a risk to aquatic life. Thirteen of the thirty-nine surface sediment sampling locations in the eastern log pond area had TOC concentrations > 10%, and ten of the twenty-nine locations in this same area had TVS concentrations > 25% (Maps 2-20 and 2-21).

Ecology evaluated wood waste in sediment using an underwater video that was towed over two transects near the Rayonier site, as well as profile and plan-view sediment photography at four locations in the east log pond area in 1998 (SAIC 1999). In the portion of the log pond area where the towed underwater video was conducted (Figure 2-1), wood debris was observed, including logs and large bark or wood fragments. This wood debris was generally old, decomposing, or bio-fouled, and the size and abundance decreased with distance from the shoreline. Approximately 100 m from the shore, a discrete layer of accumulated wood waste with a depth of > 7.8 cm was observed (Figure 2-2). At another location approximately 300 m from the shore, trace to sparse amounts of wood pulp or chips were present in the sediment (Figure 2-2). At the remaining two locations in the western portion of the log pond area, no wood debris was observed.

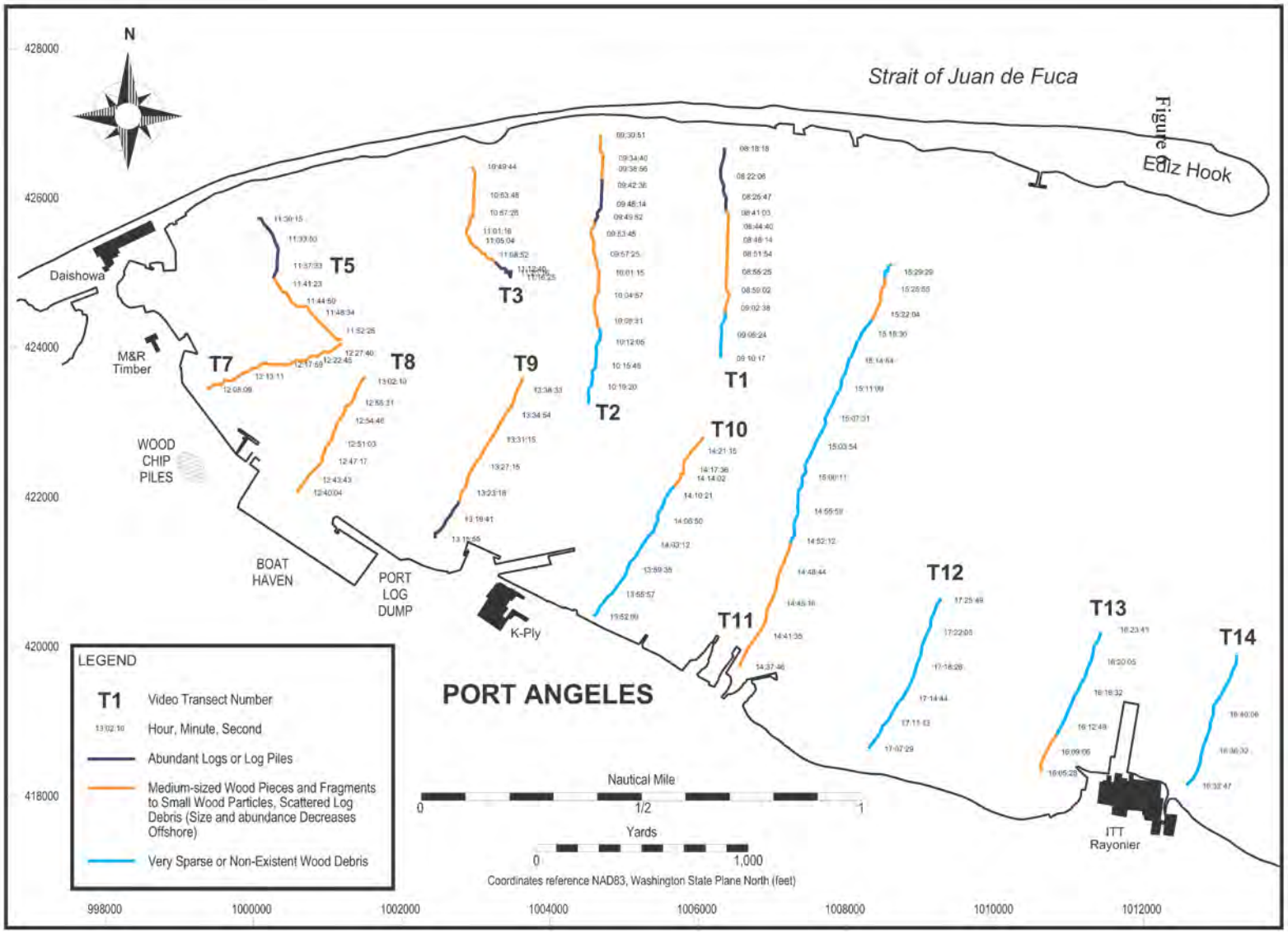


Figure 2-1.Wood waste distribution in Port Angeles Harbor using towed underwater video (from SAIC 1999)

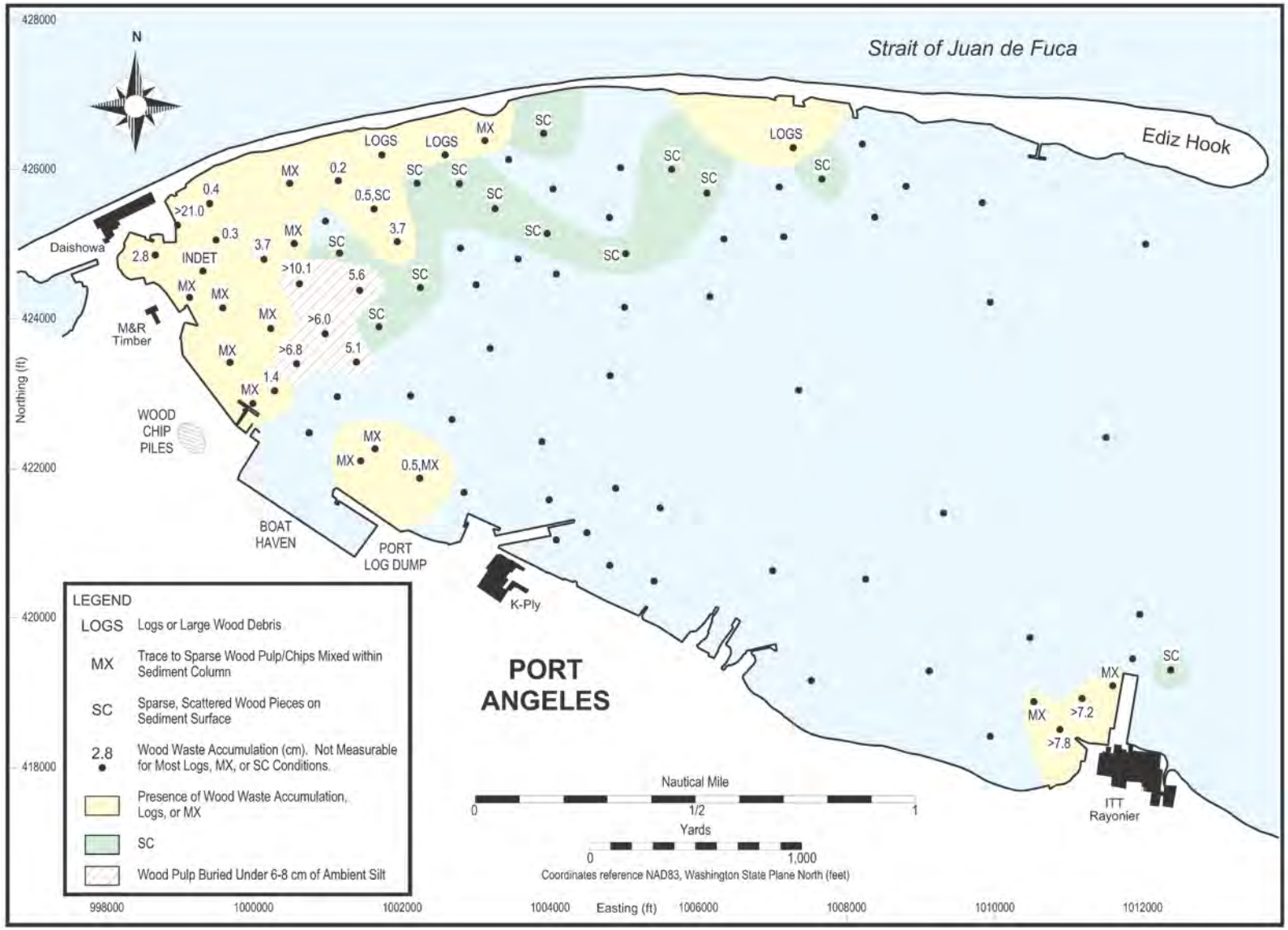


Figure 2-2.Wood waste distribution in Port Angeles Harbor using sediment photography (from SAIC 1999)

2.3.1.2 Mill Dock area

In the mill dock area, concentrations of risk drivers and COPCs in surface sediment were generally highest near the dock. For dioxin and furan TEQ, total PCBs, PCB TEQ, arsenic, cPAH TEQ, mercury, and 4,4'-DDT, a concentration gradient was observed in the mill dock area, with the highest concentrations being generally closer to the mill dock and decreasing with distance from the dock (Maps 2-8 through 2-13 and Map 2-15). Mercury concentrations were also elevated to the north and east of the mill dock (Map 2-13). Concentrations of other metals COPCs were also generally highest either near the mill dock or to the east of the mill dock (Maps 2-17 and 2-18). Pentachlorophenol, hexachlorobenzene, and pesticides other than 4,4'-DDT were rarely detected in this area (Maps 2-15 and 2-16).

All of the samples with cPAH TEQs greater than the study area 95th percentile were collected in this area (Map 2-12). Other chemicals with concentrations greater than the study area 95th percentile in this area were dioxin and furan TEQ, total PCBs, PCB TEQ, mercury, copper, zinc, cobalt, and vanadium.

Sediment samples with the highest fines content were located in a small area to the northeast of the mill dock; fines contents in this area ranged from 60 to 80% (Map 2-19). Samples collected closest to the shoreline had ≤13% fines. Most of the mill dock area had fines contents ranging from 13 to 60%.

TOC content in surface sediment was generally between 0.5 and 3.5%, with the exception of a few samples near the mill dock with TOC content >8% and some samples along the shoreline with TOC content < 0.5% (Map 2-20). Concentrations of ammonia, total sulfides and TVS were generally highest in the vicinity of the mill dock and lowest close to the shoreline. Some of the samples from the mill dock area had concentrations greater than the study area 95th percentile for each of these three parameters. Two surface sediment locations west of the mill dock had TOC concentrations greater than 10% and TVS concentrations greater than 25% (Maps 2-20 and 2-21).

Wood debris, including logs and large bark or wood fragments, was observed in the southern portion of the mill dock area in the underwater video tow (Table 2-13; Figure 2-1). The size and abundance of the debris decreased with distance from the shoreline; no debris was observed along most of the T14 transect within the mill dock area (Figure 2-1). No wood debris was observed along a second transect (T13) conducted west of the mill dock (Figure 2-1). Four sediment photography locations were within approximately 200 m of the mill dock (Figure 2-2). The area approximately 200 m west of the mill dock had a discrete layer of accumulated wood waste with a depth of > 7.2 cm on the sediment surface, and the area closest to the mill dock had trace to sparse amounts of wood pulp or chips present in the sediment. The location north of the mill dock had no wood debris and the location east of the mill dock had sparse, scattered wood pieces on the sediment surface. The other two

locations that were more than 200 m from the mill dock had no wood debris (Figure 2-2); these locations were at water depths of approximately 8 to 11 m (25 to 35 ft).

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
Risk Drivers[c]								
Dioxins and Furans								
2,3,7,8-TCDD	ng/kg dw	24/45	53	0.0630 J	1.68	0.37	0.0244 – 0.74	MD03C (89-119 cm)
1,2,3,7,8-PeCDD	ng/kg dw	33/45	73	0.0330 J	5.29	1.0	0.0520 – 2.01	MD02B (30-61 cm)
1,2,3,4,7,8-HxCDD	ng/kg dw	33/45	73	0.0290 J	5.91	1.1	0.0320 – 1.77	MD02B (30-61 cm)
1,2,3,6,7,8-HxCDD	ng/kg dw	37/45	82	0.139 J	22.4	4.1	0.0440 – 0.74	LP-20A-CS-0.3-1.85 (9-56 cm)
1,2,3,7,8,9-HxCDD	ng/kg dw	37/45	82	0.117 J	13.1	2.6	0.0660 – 1.80	ED04B (91-122 cm)
1,2,3,4,6,7,8-HpCDD	ng/kg dw	43/45	96	0.342 J	465	69.2	0.311 – 1.03	EC03B (15-30 cm)
OCDD	ng/kg dw	45/45	100	1.31	7,320	755	na	EC03B (15-30 cm)
2,3,7,8-TCDF	ng/kg dw	39/45	87	0.0270 J	17.0	2.8	0.0230 – 0.74	EC03B (15-30 cm)
1,2,3,7,8-PeCDF	ng/kg dw	29/45	64	0.109 J	11.54	1.1	0.0230 – 1.22	LP-20A-CS-0.3-1.85 (9-56 cm)
2,3,4,7,8-PeCDF	ng/kg dw	35/45	78	0.0290 J	22.38	2.0	0.0350 – 5.68	LP-20A-CS-0.3-1.85 (9-56 cm)
1,2,3,4,7,8-HxCDF	ng/kg dw	29/45	64	0.0620 J	22.37	3.0	0.0310 – 1.46	LP-20A-CS-0.3-1.85 (9-56 cm)
1,2,3,6,7,8-HxCDF	ng/kg dw	31/45	69	0.0420 J	5.07 J	0.99	0.0244 – 1.45	LP-20A-CS-0.3-1.85 (9-56 cm)
1,2,3,7,8,9-HxCDF	ng/kg dw	15/45	33	0.0330 J	0.310 J	0.15	0.0220 – 2.53	ED04B (91-122 cm)
2,3,4,6,7,8-HxCDF	ng/kg dw	30/45	67	0.0370 J	8.27	1.0	0.0228 – 1.42	LP-20A-CS-0.3-1.85 (9-56 cm)
1,2,3,4,6,7,8-HpCDF	ng/kg dw	36/45	80	0.0930 J	132	19	0.114 – 1.52	EC03B (15-30 cm)
1,2,3,4,7,8,9-HpCDF	ng/kg dw	24/45	53	0.0270 J	8.15	1.1	0.0244 – 2.93	EC03B (15-30 cm)
OCDF	ng/kg dw	38/45	84	0.431 J	1260	114	0.140 – 1.06	EC03B (15-30 cm)
Dioxin/furan TEQ [d]	ng/kg dw	45/45	100	0.0730 J	26.7 J	4.76	na	LP-20A-CS-0.3-1.85 (9-56 cm)
PCBs								
Aroclor 1016	µg/kg dw	0/31	0	nd	nd	nc	5.9 – 12	na
Aroclor 1221	µg/kg dw	0/31	0	nd	nd	nc	5.9 – 12	na
Aroclor 1232	µg/kg dw	0/31	0	nd	nd	nc	5.9 – 12	na
Aroclor 1242	µg/kg dw	0/40	0	nd	nd	nc	2.0 – 12	na
Aroclor 1248	µg/kg dw	0/31	0	nd	nd	nc	5.9 – 12	na
Aroclor 1254	µg/kg dw	0/40	0	nd	nd	nc	1.5 – 9.1	na

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
Aroclor 1260	µg/kg dw	18/40	45	16	410	66	1.5 – 2.4	EC03C (30-61 cm)
Aroclor 1268	µg/kg dw	1/8	13	250	250	32	1.6 – 3.0	ED05B (30-61 cm)
Total PCB Aroclors (dw)[e]	µg/kg dw	19/40	48	16	410	73	2.0 – 7.9	EC03C (30-61 cm)
Total PCB Aroclors (OC-normalized)[f]	mg/kg OC	19/40	48	0.24	15	2.5	0.25 – 5.4	EC03C (30-61 cm)
Other risk drivers								
Arsenic	mg/kg dw	40/40	100	1.1	14	4.5	na	ED01B (61-91 cm)
cPAH TEQ[g]	µg/kg dw	19/37	51	6.10 J	330	50.8	6.00 – 6.20	ED05B (30-61 cm)
Mercury	mg/kg dw	30/31	97	0.015 J	0.32	0.054	0.0090	EC03B (15-30 cm)
alpha-BHC	µg/kg dw	4/15	27	0.38 J	0.84 J	0.22	0.11 – 0.19	CO04B (30-61 cm)
Other COPCs[h]								
4,4'-DDE	µg/kg dw	6/15	40	0.40 J	5.4	0.79	0.24 – 0.40	EC03C (30-61 cm)
4,4'-DDT	µg/kg dw	6/15	40	0.68 J	3.6 J	0.92	0.27 – 0.34	EC03B (15-30 cm)
beta-BHC	µg/kg dw	2/15	13	1.6 J	3.1	0.83	0.15 – 2.5	EC03C (30-61 cm)
gamma-BHC	µg/kg dw	7/15	47	0.27 J	2.2 J	0.42	0.12 – 0.20	EE04C (30-61 cm)
Pentachlorophenol	µg/kg dw	0/37	0	nd	nd	nc	46 – 48	na
Hexachlorobenzene	µg/kg dw	0/37	0	nd	nd	nc	7.7 – 8.0	na
Cadmium	mg/kg dw	37/40	93	0.0069 J	2.52	0.40	0.00041 – 0.00065	LP-13A-CS-0.3-1.5 (9-46 cm)
Copper	mg/kg dw	31/31	100	5.8	280	34	na	MD02C (122-152 cm)
Selenium	mg/kg dw	9/9	100	0.2 J	1.9	0.98	na	LP-13A-CS-0.3-1.5 (9-46 cm)
Silver	mg/kg dw	31/31	100	0.014 J	0.20 J	0.071	na	EC03B (15-30 cm) ED04B (91-122 cm)
Zinc	mg/kg dw	40/40	100	12	160	48	na	MD02C (122-152 cm)
All Other Chemicals								
Metals								
Antimony	mg/kg dw	22/31	71	0.090 J	0.75	0.23	0.0015 – 0.47	EC03B (15-30 cm)
Barium	mg/kg dw	31/31	100	4.4	35	16	na	ED01B (61-91 cm)

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
Chromium	mg/kg dw	31/31	100	6.7	51	26	na	ED04B (91-122 cm)
Lead	mg/kg dw	31/31	100	1.3	33	8.0	na	EC03B (15-30 cm)
Nickel	mg/kg dw	31/31	100	7.8	50	29	na	ED01B (61-91 cm)
PAHs								
1-Methylnaphthalene	µg/kg dw	6/37	16	10 J	1,900	70	6.9 – 7.2	EC03C (30-61 cm)
2-Chloronaphthalene	µg/kg dw	0/37	0	nd	nd	nc	7.7 – 7.9	na
2-Methylnaphthalene	µg/kg dw	8/37	22	10 J	3,000	100	7.9 – 8.2	EC03C (30-61 cm)
Acenaphthene	µg/kg dw	9/37	24	11 J	4,900	180	7.9 – 8.2	EC03C (30-61 cm)
Acenaphthylene	µg/kg dw	9/37	24	10 J	22	6.9	8.4 – 8.6	ED03B (15-46 cm)
Anthracene	µg/kg dw	16/37	43	11 J	690	48	7.5 – 7.7	EC03C (30-61 cm)
Benzo(a)anthracene	µg/kg dw	16/37	43	17 J	440	55	5.7 – 5.9	EC03C (30-61 cm)
Benzo(a)pyrene	µg/kg dw	16/37	43	12 J	240	35	7.9 – 8.1	ED05B (30-61 cm)
Benzo(b)fluoranthene	µg/kg dw	17/37	46	11 J	250	51	9.2 – 9.5	ED03B (15-46 cm)
Benzo(g,h,i)perylene	µg/kg dw	12/37	32	11 J	67	9.4	6.5 – 6.7	ED05B (30-61 cm)
Benzo(k)fluoranthene	µg/kg dw	16/37	43	14 J	280	43	8.9 – 9.2	ED05B (30-61 cm)
Total benzofluoranthenes	µg/kg dw	17/37	46	11 J	510	91	9.2 – 9.5	ED05B (30-61 cm)
Chrysene	µg/kg dw	19/37	51	12 J	510	79	6.4 – 6.6	LP05B (15-30 cm)
Dibenzo(a,h)anthracene	µg/kg dw	4/37	11	12 J	33	5.9	8.3 – 8.5	ED05B (30-61 cm)
Dibenzofuran	µg/kg dw	10/37	27	10 J	2,700	100	7.3 – 7.5	EC03C (30-61 cm)
Fluoranthene	µg/kg dw	27/37	73	10 J	4,100	250	7.6 – 7.8	EC03C (30-61 cm)
Fluorene	µg/kg dw	13/37	35	10 J	4,100	150	8.6 – 8.9	EC03C (30-61 cm)
Indeno(1,2,3-cd)pyrene	µg/kg dw	12/37	32	10 J	70	9.9	8.3 – 8.6	ED05B (30-61 cm)
Naphthalene	µg/kg dw	13/37	35	11 J	6,300	210	8.4 – 8.7	EC03C (30-61 cm)
Phenanthrene	µg/kg dw	21/37	57	9.9 J	9,700	390	8.1 – 8.4	EC03C (30-61 cm)
Pyrene	µg/kg dw	26/37	70	13 J	2,300	180	7.5 – 7.7	EC03C (30-61 cm)
Total HPAHs	µg/kg dw	28/37	76	11 J	7,800 J	700	9.2 – 9.4	EC03C (30-61 cm)
Total LPAHs	µg/kg dw	22/37	59	9.9 J	25,700	970	8.7 – 8.9	EC03C (30-61 cm)

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
Total PAHs	µg/kg dw	28/37	76	11 J	33,500 J	1700	9.2 – 9.4	EC03C (30-61 cm)
Phthalates								
Bis(2-ethylhexyl)phthalate	µg/kg dw	5/37	14	14 J	73	11	11 – 120	ED03B (15-46 cm)
Butyl benzyl phthalate	µg/kg dw	2/37	5	12 J	36	6.5	11	ED05B (30-61 cm)
Diethyl phthalate	µg/kg dw	1/37	3	25	25	8.5	16	EC03B (15-30 cm)
Dimethyl phthalate	µg/kg dw	2/37	5	12 J	24	4.6	7.5 – 7.7	ED03B (15-46 cm)
Di-n-butyl phthalate	µg/kg dw	2/37	5	25	37	7.4	12	ED05B (30-61 cm)
Di-n-octyl phthalate	µg/kg dw	0/37	0	nd	nd	nc	8.1 – 8.3	na
Other SVOCs								
1,2,4-Trichlorobenzene	µg/kg dw	0/37	0	nd	nd	nc	8.8 – 9.1	na
1,2-Dichlorobenzene	µg/kg dw	0/37	0	nd	nd	nc	7.6 – 7.9	na
1,3-Dichlorobenzene	µg/kg dw	0/37	0	nd	nd	nc	7.2 – 7.4	na
1,4-Dichlorobenzene	µg/kg dw	0/37	0	nd	nd	nc	7.1 – 7.3	na
2,4,5-Trichlorophenol	µg/kg dw	0/37	0	nd	nd	nc	43 – 45	na
2,4,6-Trichlorophenol	µg/kg dw	0/37	0	nd	nd	nc	45 – 46	na
2,4-Dichlorophenol	µg/kg dw	0/37	0	nd	nd	nc	39 – 41	na
2,4-Dimethylphenol	µg/kg dw	1/37	3	15 J	15 J	7.5	14 – 15	EC03C (30-61 cm)
2,4-Dinitrophenol	µg/kg dw	0/37	0	nd	nd	nc	110	na
2,4-Dinitrotoluene	µg/kg dw	0/37	0	nd	nd	nc	37 – 38	na
2,6-Dinitrotoluene	µg/kg dw	0/37	0	nd	nd	nc	52 – 54	na
2-Chlorophenol	µg/kg dw	0/37	0	nd	nd	nc	7.2 – 7.5	na
2-Methylphenol	µg/kg dw	0/37	0	nd	nd	nc	14	na
2-Nitroaniline	µg/kg dw	0/37	0	nd	nd	nc	40 – 42	na
2-Nitrophenol	µg/kg dw	0/37	0	nd	nd	nc	38 – 40	na
3,3'-Dichlorobenzidine	µg/kg dw	0/37	0	nd	nd	nc	47 – 49	na
3-Nitroaniline	µg/kg dw	0/37	0	nd	nd	nc	74 – 76	na
4,6-Dinitro-o-cresol	µg/kg dw	0/37	0	nd	nd	nc	81 – 84	na

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
4-Bromophenyl phenyl ether	µg/kg dw	0/37	0	nd	nd	nc	9.3 – 9.6	na
4-Chloro-3-methylphenol	µg/kg dw	0/37	0	nd	nd	nc	8.1 – 8.4	na
4-Chloroaniline	µg/kg dw	0/36	0	nd	nd	nc	34 – 35	na
4-Chlorophenyl phenyl ether	µg/kg dw	0/37	0	nd	nd	nc	8.1 – 8.4	na
4-Methylphenol	µg/kg dw	16/37	43	13 J	690	82	12 – 13	EC03B (15-30 cm)
4-Nitroaniline	µg/kg dw	0/37	0	nd	nd	nc	49 – 51	na
4-Nitrophenol	µg/kg dw	0/37	0	nd	nd	nc	64 – 66	na
Benzoic acid	µg/kg dw	0/37	0	nd	nd	nc	110	na
Benzyl alcohol	µg/kg dw	1/34	3	23 JN	23 JN	7.5	14	LP05B (15-30 cm)
bis(2-chloroethoxy)methane	µg/kg dw	0/37	0	nd	nd	nc	8.6 – 8.8	na
bis(2-chloroethyl)ether	µg/kg dw	0/37	0	nd	nd	nc	7.2 – 7.5	na
bis(2-chloroisopropyl)ether	µg/kg dw	0/37	0	nd	nd	nc	7.7 – 8.0	na
Carbazole	µg/kg dw	8/37	22	10 J	810	34	6.4 – 6.6	EC03C (30-61 cm)
Hexachlorobutadiene	µg/kg dw	0/37	0	nd	nd	nc	7.8 – 8.1	na
Hexachlorocyclopentadiene	µg/kg dw	0/35	0	nd	nd	nc	42 – 44	na
Hexachloroethane	µg/kg dw	0/37	0	nd	nd	nc	6.9 – 7.2	na
Isophorone	µg/kg dw	0/37	0	nd	nd	nc	8.0 – 8.3	na
n-Nitroso-di-n-propylamine	µg/kg dw	0/37	0	nd	nd	nc	35 – 36	na
n-Nitrosodiphenylamine	µg/kg dw	0/37	0	nd	nd	nc	8.4 – 8.7	na
Nitrobenzene	µg/kg dw	0/37	0	nd	nd	nc	8.5 – 8.8	na
Phenol	µg/kg dw	7/37	19	14 J	130	12	13 – 14	LP05B (15-30 cm)
Retene	µg/kg dw	19/36	53	14	75,000	4,700	8.6 – 8.9	LP05B (15-30 cm)
Pesticides								
4,4'-DDD	µg/kg dw	7/15	47	0.55 J	7.2 J	0.95	0.28 – 0.34	EC03B (15-30 cm)
Aldrin	µg/kg dw	3/15	20	0.29 J	0.53 J	0.14	0.11 – 0.22	CO02B (15-30 cm)
Dieldrin	µg/kg dw	2/15	13	0.59 J	0.70 J	0.22	0.23 – 0.45	EE02C (61-91 cm)
Total aldrin/dieldrin	µg/kg dw	4/15	27	0.37 J	0.88 J	0.28	0.23 – 0.45	EE04B (15-30 cm)

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
delta-BHC	µg/kg dw	7/15	47	0.18 J	0.57 J	0.24	0.12 – 0.24	CO04B (30-61 cm)
alpha-Chlordane	µg/kg dw	9/15	60	0.16 J	2.3 J	0.38	0.14 – 0.21	EC03C (30-61 cm)
gamma-Chlordane	µg/kg dw	9/15	60	0.20 J	8.5	1.5	0.12 – 0.15	CO05B (61-91 cm)
Total chlordane	µg/kg dw	12/15	80	0.20 J	8.9 J	1.8	0.14 – 0.15	CO05B (61-91 cm)
alpha-Endosulfan	µg/kg dw	2/15	13	0.58 J	0.76 J	0.16	0.12 – 0.24	CO05B (61-91 cm)
beta-Endosulfan	µg/kg dw	7/15	47	0.35 J	4.9 J	1.0	0.27 – 0.45	EC03B (15-30 cm)
Endosulfan sulfate	µg/kg dw	7/15	47	1.0 J	13 J	2.5	0.35 – 0.44	CO05B (61-91 cm)
Endrin	µg/kg dw	1/15	7	1.0 J	1.0 J	0.34	0.44 – 0.85	CO02B (15-30 cm)
Endrin aldehyde	µg/kg dw	1/15	7	0.38 J	0.38 J	0.19	0.26 – 0.51	EE04B (15-30 cm)
Endrin ketone	µg/kg dw	1/15	7	0.60 J	0.60 J	0.20	0.26 – 0.51	CO04B (30-61 cm)
Heptachlor	µg/kg dw	4/15	27	0.24 J	0.33 J	0.14	0.14 – 0.27	EE02B (30-61 cm)
Heptachlor epoxide	µg/kg dw	8/15	53	0.44 J	2.6 J	0.65	0.14 – 1.8	EC03C (30-61 cm)
Methoxychlor	µg/kg dw	0/15	0	nd	nd	nc	1.4 – 2.7	na
Toxaphene	µg/kg dw	0/15	0	nd	nd	nc	10 – 20	na
Fatty Acids								
9,10-Dichlorostearic acid	µg/kg dw	0/20	0	nd	nd	nc	95 – 500	na
Linolenic acid	µg/kg dw	0/20	0	nd	nd	nc	95 – 500	na
Oleic acid	µg/kg dw	7/29	24	100	4,900 J	500	95 – 500	LP-20A-CS-0.3-1.85 (9-56 cm)
Resin Acids								
12-Chlorodehydroabietic acid	µg/kg dw	2/20	10	110	110	75	95 – 500	CO05B (61-91 cm) EC03C (30-61 cm)
14-Chlorodehydroabietic acid	µg/kg dw	0/20	0	nd	nd	nc	95 – 500	na
Abietic acid	µg/kg dw	18/28	64	40	32,000 J	4400	40 – 99	LP05B (15-30 cm)
Dehydroabietic acid	µg/kg dw	19/29	66	40	22,000	3400	40 – 99	LP05B (15-30 cm)
Dichlorodehydroabietic acid	µg/kg dw	0/19	0	nd	nd	nc	95 – 500	na
Isopimaric acid	µg/kg dw	11/29	38	50	5,500 J	580	50 – 99	LP-13A-CS-0.3-1.5 (9-46 cm)
Neoabietic acid	µg/kg dw	2/12	17	1500	3,100 J	420	96 – 99	LP05B (15-30 cm)
Palustric acid	µg/kg dw	1/18	6	670 JN	670 JN	95	95 – 500	MD02B (30-61 cm)

Table 2-14. Summary of chemical data in subsurface sediment in study area

Chemical	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]	Sample Name and Depth of Maximum Detected Concentration
		Ratio	%	Minimum	Maximum			
Pimaric acid	µg/kg dw	0/20	0	nd	nd	nc	95 – 500	na
Sandaracopimaric acid	µg/kg dw	2/20	10	820	1100	140	95 – 99	LP05B (15-30 cm)
3,4,5-Trichloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
Tetrachloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
3,4,6-Trichloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
3,4-Dicloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
4,5,6-Trichloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
4,5-Dichloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
4,6-Dichloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
4-Chloroguaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
Guaiacol	µg/kg dw	0/36	0	nd	nd	nc	19 – 20	na
Petroleum								
TPH – diesel No. 2 range	mg/kg dw	22/31	71	6.7 J	360	68	6.5 – 33	ED05B (30-61 cm)
TPH – motor oil range	mg/kg dw	23/31	74	7.8 J	940	170	6.1 – 7.2	EC03B (15-30 cm)
Total petroleum hydrocarbons	mg/kg dw	26/31	84	7.8 J	1,240	240	6.5 – 7.2	EC03B (15-30 cm)
Conventionals								
Ammonia	mg-N/kg dw	16/16	100	0.49	309	42	na	MD02B (30-61 cm)
Total organic carbon	% dw	63/63	100	0.128	34.4	4.0	na	LP-09B-CS-0.2-2.5 (6-76 cm)
Total sulfides	mg/kg dw	15/15	100	1.09	3,030 J	359	na	EC03C (30-61 cm)
Total volatile solids	% dw	26/26	100	0.8	70.3	14	na	LP-09B-CS-0.2-2.5 (6-76 cm)

[a] Calculated mean concentration is the average of detected concentrations and one-half the RL for non-detected results.

[b] The RL represents the method reporting limit, which is the smallest amount of a chemical that the laboratory determines can be practically quantitated in a sample. For dioxin and furan TEQ, total PCBs, and cPAH TEQ, calculated non-detected concentrations (as described in footnotes d, e, and g of this table) were reported rather than RLs.

[c] Risk drivers are chemicals or chemical groups that had excess cancer risk estimates > 10^{-4} or non-cancer HQs >10 based on the results of the screening-level HHRA.

[d] TEQs for dioxins and furans were calculated using TEFs for mammals presented in Van den Berg et al. (2006) (see Appendix D). If an individual congener was not detected, the TEF for that congener was multiplied by one-half the RL for that congener.

[e] Total PCBs (dw) represent the sum of the detected concentrations of the individual Aroclors or congeners. If no Aroclors or congeners were detected, the RL reported represents the highest RL for an individual Aroclor or congener.

[f] Summary statistics for OC-normalized PCB concentrations were calculated using only samples with TOC contents ≥ 0.5% and ≤ 3.5%.

[g] TEQs for cPAHs were calculated using PEFs for individual cPAH compounds (derived from WAC 173-340-708(e)), as discussed in detail in Appendix D. If an individual cPAH compound was not detected, the PEF for that compound was multiplied by one-half the RL for that compound.

[h] COPCs are chemicals or chemical groups that had excess cancer risk estimates > 10^{-6} or non-cancer HQs >1 based on the results of the screening-level HHRA.

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
HpCDD – heptachlorodibenzo-*p*-dioxin
HpCDF – heptachlorodibenzofuran
HxCDD – hexachlorodibenzo-*p*-dioxin
HxCDF – hexachlorodibenzofuran
J – estimated concentration
N – tentative identification
na – not applicable
nc – not calculated
nd – not detected
OCDD – octachlorodibenzo-*p*-dioxin
OCDF – octachlorodibenzofuran
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PeCDD – polychlorinated dibenzo-*p*-dioxin
PeCDF – polychlorinated dibenzofuran
RL – reporting limit
TCDD – tetrachlorodibenzo-*p*-dioxin
TCDF – tetrachlorodibenzofuran
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons

2.3.1.3 Outfall area

Dioxin and furan TEQ, PCB TEQ, arsenic and mercury concentrations were generally low (i.e., less than the study area 50th percentile) or not detected in the Rayonier deepwater outfall area (Maps 2-8, 2-10, 2-11, 2-12, and 2-13; the outfall area is defined on Map 2-1). A few samples had chemical concentrations greater than the study area 50th or 75th percentile (i.e., for arsenic, cPAH TEQ, or mercury). Pesticides were not detected in the three samples analyzed (Maps 2-14 and 2-15). There were no detected concentrations of pentachlorophenol or hexachlorobenzene (Map 2-16). Five of the eight metals COPCs (i.e., cadmium, cobalt, iron, vanadium, and zinc) had concentrations greater than the study area 75th percentile in the outfall area, but concentrations were less than the SCO. The remaining metals COPCs (i.e., copper, selenium, and silver) had mostly low (i.e., less than the study area 50th percentile) or non-detected concentrations. Only one sediment sample from the outfall area had a concentration greater than the SCO (i.e., a CSL exceedance of 4-methylphenol) (Map 2-5).

The fines content in the outfall area was primarily between 13 and 30%, with some areas having 30 to 60% fines (Map 2-19). TOC content was primarily between 0.5 and 3.5% with some areas < 0.5% (Map 2-20). Concentrations of ammonia, total sulfides, and TVS were generally low (i.e., less than the study area 50th percentile) (Map 2-21). None of the surface sediment locations in the outfall area had TVS concentrations greater than 25% (Map 2-21). Data for wood debris were not collected in the outfall area.

2.3.2 Subsurface sediment

This section discusses the subsurface sediment results within the study area. Results for all risk drivers and COPCs are presented on Maps 2-22 through 2-38. Summary statistics for all chemicals analyzed in subsurface sediment from the study area are presented in Table 2-14.

2.3.2.1 Log pond area

In general, subsurface samples from the log pond area had higher concentrations of total PCBs, arsenic, cadmium, and zinc than did the subsurface samples from other portions of the study area (Maps 2-23, 2-24, 2-34, and 2-38). For these chemicals, the samples from the deeper intervals (i.e., 56 to 91 cm [22 to 36 in.] and 27 to 61 cm [10.5 to 24 in.]) generally had lower concentrations than those from the shallower intervals.

Two of the five cores from the log pond area had dioxin and furan TEQs that were higher than the study area 75th percentile (6.34 ng/kg dw) (Map 2-22). The deepest sample interval from the log pond area (56 to 91 cm [22 to 36 in.]) had a dioxin and furan TEQ that was less than the study area 50th percentile (1.35 ng/kg dw).

Only one sample from the log pond area was analyzed for cPAH TEQ; the concentration in this sample (collected from 15 to 30 cm [6 to 12 in.]) was greater than the 75th percentile (84 µg/kg dw) (Map 2-25). Only one sample from the log pond area was analyzed for hexachlorobenzene and pentachlorophenol, which were not detected.

Cores from the log pond area but not from other parts of the study area were analyzed for selenium. Concentrations of selenium were generally highest in the shallower depth intervals (Map 2-36). Subsurface samples from the log pond area were not analyzed for any of the remaining risk drivers and COPCs.

2.3.2.2 Mill dock area

In general, subsurface samples from the mill dock area had lower concentrations of total PCBs, arsenic, cadmium, and zinc than those in samples from the log pond area but higher concentrations than those in the rest of the study area (Map 2-23, 2-24, 2-32, and 2-38). When more than one core interval was analyzed, the deepest sample intervals generally had lower concentrations of these chemicals than did the shallower sample intervals. Below a depth of approximately 90 cm (35 in.), concentrations of these chemicals were less than the 75th percentile, with a few exceptions (i.e., location ED04 for arsenic, cadmium, and zinc and location MD02 for zinc).

Dioxin and furan TEQ, cPAH TEQ, and mercury, copper, and silver concentrations were generally higher in the mill dock area than those in samples collected in the outfall area or east of the mill dock area (Maps 2-22, 2-25, 2-26, 2-35, and 2-37). In general, when more than one core interval was analyzed, the deeper intervals had lower concentrations than did the shallower intervals. Below a depth of approximately 90 cm (35 in.), concentrations of these chemicals were less than the 75th percentile at all core locations in the mill dock area, except ED04 and MD02.

Concentrations of pesticide risk drivers and COPCs were generally higher in samples from the eight cores collected in the mill dock area than the concentrations detected in cores collected east of the mill dock area (Maps 2-27 through 2-31). In general, the deepest sample intervals (61 to 91 cm [24 to 36 in.]) had either non-detected concentrations or lower concentrations than did the shallowest sample intervals (15 to 30 cm [6 to 12 in.]).

Pentachlorophenol and hexachlorobenzene were not detected in mill dock area subsurface samples. None of the subsurface samples in this area were analyzed for the remaining risk drivers and COPCs.

2.3.2.3 Outfall and other areas

Concentrations of risk drivers and COPCs were generally lowest in the outfall area and other areas outside of the log pond and mill dock areas (Maps 2-22 to 2-38). The deepest sample intervals generally had lower concentrations than did the shallower sample intervals within a core when more than one core interval was analyzed.

2.3.3 Tissue

This section discusses the tissue chemistry results for samples collected within the study area (Map 2-3).

Dioxins and furans and PCBs were frequently detected in all tissue samples. Dioxin and furan TEQ, total PCBs (both Aroclor and congener sums), and PCB TEQ were generally over an order of magnitude higher in Dungeness crab hepatopancreas tissue than in any of the other tissue types (Table 2-15).

Total arsenic was detected in all tissue samples. Total arsenic concentrations were highest in Dungeness crab hepatopancreas and slightly lower in Dungeness crab muscle tissue (Table 2-15). Inorganic arsenic was frequently detected in tissue samples, with the highest concentrations in geoduck clams. The mean inorganic arsenic concentrations were 21 and 33% of the mean total arsenic concentrations for geoduck clam and horse clam, and less than 2% of the mean total arsenic concentrations for all other tissue types.

cPAHs were detected most frequently and at the highest concentrations in geoduck and horse clam tissue samples. cPAHs were detected infrequently or were undetected in crab and rock sole tissue samples.

Mercury was frequently detected in all tissue samples, with the highest concentrations in Dungeness crab hepatopancreas tissue samples. Alpha-BHC was frequently detected in all tissue types except Dungeness crab muscle, horse clam, and rock sole fillet. The highest alpha-BHC concentrations were in geoduck tissue samples.

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Risk Drivers[c]								
Dioxin/Furan TEQ[d,e]								
Coonstripe shrimp, whole organism	composite	ng/kg	2/3	67	0.174 J	0.197 J	0.164	0.242
Dungeness crab, hepatopancreas	individual and composite	ng/kg	11/11	100	0.636	41.2 J	19.5	na
Dungeness crab, muscle	individual and composite	ng/kg	11/11	100	0.0264 J	0.734 J	0.251	na
Geoduck, whole organism	individual and composite	ng/kg	6/6	100	0.0153 J	1.19	0.432	na
Horse clam, tissue	individual	ng/kg	15/17	88	0.0133 J	0.0710 J	0.0347	0.0307 – 0.0486
Horse clam, visceral cavity	individual	ng/kg	10/10	100	0.112 J	0.180 J	0.134	na
Horse clam, whole organism	individual and composite	ng/kg	15/15	100	0.0222 J	0.217 J	0.0745	na
Red rock crab, muscle tissue	composite	ng/kg	2/2	100	1.19	1.20	1.20	na
Rock sole, fillet	composite	ng/kg	1/3	33	0.376 J	0.376 J	0.350	0.340 – 1.01
Rock sole, whole organism	composite	ng/kg	2/3	67	0.183 J	0.275 J	0.185	0.193
Total PCB Aroclors[f]								
Coonstripe shrimp, whole organism	composite	µg/kg ww	3/3	100	6.5	6.9	6.7	na
Dungeness crab, hepatopancreas	composite	µg/kg ww	3/3	100	92	960	390	na
Dungeness crab, muscle	composite	µg/kg ww	3/3	100	13.4	50	26	na
Geoduck, whole organism	individual and composite	µg/kg ww	3/5	60	2.8 J	10.3	3.6	1.9
Horse clam, whole organism	individual	µg/kg ww	9/9	100	17	36	26	na
Red rock crab, muscle tissue	composite	µg/kg ww	2/2	100	13 J	220 J	120	na
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	1.9
Rock sole, whole organism	composite	µg/kg ww	3/3	100	9.4	13.1	11	na

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Total PCB Aroclors (lipid)								
Coonstripe shrimp, whole organism	composite	mg/kg lipid	3/3	100	0.79	0.89	0.83	na
Dungeness crab, hepatopancreas	composite	mg/kg lipid	3/3	100	1.6	25	9.7	na
Dungeness crab, muscle	composite	mg/kg lipid	3/3	100	1.70	6.6	3.4	na
Geoduck, whole organism	individual	mg/kg lipid	1/3	33	1.10	1.10	0.48	0.34 – 0.35
Horse clam, whole organism	individual	mg/kg lipid	9/9	100	1.3	2.4	1.9	na
Rock sole, fillet	composite	mg/kg lipid	0/2	0	nd	nd	nc	0.35 – 0.39
Rock sole, whole organism	composite	mg/kg lipid	3/3	100	0.35	0.660	0.52	na
Total PCB Congeners[f]								
Dungeness crab, hepatopancreas	individual	µg/kg	8/8	100	2222 J	5800 J	3958	na
Dungeness crab, muscle	individual	µg/kg	8/8	100	11.07 J	178.9 J	52.90	na
Horse clam, tissue	individual	µg/kg	17/17	100	0.2730 J	3.726	2.066	na
Horse clam, visceral cavity	individual	µg/kg	10/10	100	36.43 J	67.00 J	52.23	na
Total PCB Congeners (lipid)								
Dungeness crab, hepatopancreas	individual	mg/kg lipid	8/8	100	7.947 J	55.20 J	22.71	na
Dungeness crab, muscle	individual	mg/kg lipid	8/8	100	5.540 J	108.0 J	43.83	na
Horse clam, tissue	individual	mg/kg lipid	17/17	100	0.07000 J	2.600 J	0.6756	na
Horse clam, visceral cavity	individual	mg/kg lipid	10/10	100	1.210 J	2.900 J	1.925	na
PCB TEQ[d]								
Dungeness crab, hepatopancreas	individual	ng/kg ww	8/8	100	17.1 J	90.9 J	40.5	na
Dungeness crab, muscle	individual	ng/kg ww	8/8	100	0.0932	0.768 J	0.275	na
Geoduck, whole organism	composite	ng/kg ww	1/1	100	0.0610 J	0.0610 J	0.0610	na
Horse clam, tissue	individual	ng/kg ww	17/17	100	0.00569 J	0.0323	0.0191	na
Horse clam, visceral cavity	individual	ng/kg ww	10/10	100	0.115	0.950 J	0.499	na
Horse clam, whole organism	individual and composite	ng/kg ww	6/6	100	0.0222 J	0.174 J	0.0696	na

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Arsenic								
Coonstripe shrimp, whole organism	composite	mg/kg ww	3/3	100	6.98	8.48	7.86	na
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	13.7	14.5	14.2	na
Dungeness crab, muscle	composite	mg/kg ww	3/3	100	11.7	12.8	12.3	na
Geoduck, whole organism	individual and composite	mg/kg ww	6/6	100	2.3	5.25	3.8	na
Horse clam, whole organism	individual and composite	mg/kg ww	15/15	100	0.82	5.8	2.5	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	5.85	5.85	5.85	na
Rock sole, fillet	composite	mg/kg ww	3/3	100	2.43	2.77	2.56	na
Rock sole, whole organism	composite	mg/kg ww	3/3	100	1.42	2.69	2.00	na
Arsenic (inorganic)								
Coonstripe shrimp, whole organism	composite	mg/kg ww	3/3	100	0.006 J	0.009 J	0.008	na
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	0.161	0.228	0.196	na
Dungeness crab, muscle	composite	mg/kg ww	2/3	67	0.005 J	0.011 J	0.0073	0.012
Geoduck, whole organism	individual	mg/kg ww	3/3	100	1.06	1.41	1.24	na
Horse clam, whole organism	individual	mg/kg ww	9/9	100	0.130	1.35	0.534	na
Rock sole, fillet	composite	mg/kg ww	3/3	100	0.009 J	0.013	0.011	na
Rock sole, whole organism	composite	mg/kg ww	1/3	33	0.005 J	0.005 J	0.0057	0.012
cPAH TEQ[g]								
Coonstripe shrimp, whole organism	composite	µg/kg ww	3/3	100	0.380 J	0.400 J	0.387	na
Dungeness crab, hepatopancreas	composite	µg/kg ww	1/3	33	0.470 J	0.470 J	0.283	0.380
Dungeness crab, muscle	composite	µg/kg ww	0/3	0	nd	nd	nc	0.380
Geoduck, whole organism	individual and composite	µg/kg ww	3/6	50	0.300 J	0.790 J	8.3	0.380 – 48

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Horse clam, whole organism	individual and composite	µg/kg ww	15/15	100	0.450 J	28.2	3.33	na
Red rock crab, muscle tissue	composite	µg/kg ww	0/2	0	nd	nd	nc	47
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	0.380
Rock sole, whole organism	composite	µg/kg ww	0/3	0	nd	nd	nc	0.380
Mercury								
Coonstripe shrimp, whole organism	composite	mg/kg ww	3/3	100	0.023 J	0.027 J	0.026	na
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	0.109	0.223	0.169	na
Dungeness crab, muscle	composite	mg/kg ww	3/3	100	0.091	0.107	0.10	na
Geoduck, whole organism	individual and composite	mg/kg ww	6/6	100	0.018	0.082	0.045	na
Horse clam, whole organism	individual and composite	mg/kg ww	14/15	93	0.006	0.027	0.011	0.0082
Red rock crab, muscle tissue	composite	mg/kg ww	1/2	50	0.044	0.044	0.035	0.050
Rock sole, fillet	composite	mg/kg ww	3/3	100	0.023 J	0.045 J	0.037	na
Rock sole, whole organism	composite	mg/kg ww	3/3	100	0.019 J	0.022 J	0.020	na
alpha-BHC								
Coonstripe shrimp, whole organism	composite	µg/kg ww	3/3	100	0.64 J	0.64 J	0.64	na
Dungeness crab, hepatopancreas	composite	µg/kg ww	3/3	100	1.5	2.0 J	1.7	na
Dungeness crab, muscle	composite	µg/kg ww	0/3	0	nd	nd	nc	1.0
Geoduck, whole organism	individual and composite	µg/kg ww	6/6	100	0.73 J	38	18	na
Horse clam, whole organism	individual and composite	µg/kg ww	3/13	23	0.29 J	0.63 J	0.40	0.10 – 1.0
Red rock crab, muscle tissue	composite	µg/kg ww	2/2	100	1.3 J	1.3 J	1.3	na
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	1.0
Rock sole, whole organism	composite	µg/kg ww	3/3	100	0.51 J	1.1 J	0.77	na

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Other COPCs[h]								
4,4'-DDE								
Coonstripe shrimp, whole organism	composite	µg/kg ww	0/3	0	nd	nd	nc	1.0
Dungeness crab, hepatopancreas	composite	µg/kg ww	3/3	100	8.5	13	11	na
Dungeness crab, muscle	composite	µg/kg ww	2/3	67	0.56 J	0.80 J	0.62	1.0
Geoduck, whole organism	individual and composite	µg/kg ww	3/6	50	0.42 J	1.6 J	0.60	0.22 – 1.0
Horse clam, whole organism	individual and composite	µg/kg ww	2/13	15	0.69 J	0.87 J	0.42	0.21 – 1.0
Red rock crab, muscle tissue	composite	µg/kg ww	2/2	100	0.52 J	0.83 J	0.68	na
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	1.0
Rock sole, whole organism	composite	µg/kg ww	3/3	100	0.97 J	1.0	0.99	na
4,4'-DDT								
Coonstripe shrimp, whole organism	composite	µg/kg ww	3/3	100	1.1	1.3	1.2	na
Dungeness crab, hepatopancreas	composite	µg/kg ww	3/3	100	14	110	47	na
Dungeness crab, muscle	composite	µg/kg ww	1/3	33	4.7	4.7	1.9	1.0
Geoduck, whole organism	individual and composite	µg/kg ww	3/6	50	0.58 J	1.7	0.92	0.25 – 2.0
Horse clam, whole organism	individual and composite	µg/kg ww	9/13	69	1.7	5.1	2.0	0.25
Red rock crab, muscle tissue	composite	µg/kg ww	0/2	0	nd	nd	nc	1.9 – 2.0
Rock sole, fillet	composite	µg/kg ww	2/2	100	0.31 J	0.39 J	0.35	na
Rock sole, whole organism	composite	µg/kg ww	3/3	100	1.0	1.6	1.3	na
beta-BHC								
Coonstripe shrimp, whole organism	composite	µg/kg ww	1/3	33	6.0 J	6.0 J	2.6	1.8 – 2.0
Dungeness crab, hepatopancreas	composite	µg/kg ww	3/3	100	1.7	2.1	2.0	na

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Dungeness crab, muscle	composite	µg/kg ww	0/3	0	nd	nd	nc	1.0
Geoduck, whole organism	individual and composite	µg/kg ww	6/6	100	0.63 J	15	9.4	na
Horse clam, whole organism	individual and composite	µg/kg ww	2/13	15	0.41 J	0.45 J	0.42	0.12 – 1.0
Red rock crab, muscle tissue	composite	µg/kg ww	0/2	0	nd	nd	nc	1.9 – 2.0
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	1.0
Rock sole, whole organism	composite	µg/kg ww	0/3	0	nd	nd	nc	0.99 – 1.0
gamma-BHC (Lindane)								
Coonstripe shrimp, whole organism	composite	µg/kg ww	0/3	0	nd	nd	nc	1.0
Dungeness crab, hepatopancreas	composite	µg/kg ww	0/3	0	nd	nd	nc	1.0
Dungeness crab, muscle	composite	µg/kg ww	0/3	0	nd	nd	nc	1.0
Geoduck, whole organism	individual and composite	µg/kg ww	5/6	83	1.2	4.0	1.9	0.11
Horse clam, whole organism	individual and composite	µg/kg ww	3/13	23	1.1	2.0 J	0.59	0.11 – 1.0
Red rock crab, muscle tissue	composite	µg/kg ww	0/2	0	nd	nd	nc	1.9 – 2.0
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	1.0
Rock sole, whole organism	composite	µg/kg ww	1/3	33	0.70 J	0.70 J	0.57	1.0
Pentachlorophenol								
Coonstripe shrimp, whole organism	composite	µg/kg ww	0/3	0	nd	nd	nc	200
Dungeness crab, hepatopancreas	composite	µg/kg ww	0/3	0	nd	nd	nc	200
Dungeness crab, muscle	composite	µg/kg ww	0/3	0	nd	nd	nc	200
Geoduck, whole organism	individual and composite	µg/kg ww	0/6	0	nd	nd	nc	196 – 2,400
Horse clam, whole organism	individual and composite	µg/kg ww	0/15	0	nd	nd	nc	200 – 10,000

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Red rock crab, muscle tissue	composite	µg/kg ww	1/2	50	461 JN	461 JN	279	194
Rock sole, fillet	composite	µg/kg ww	0/2	0	nd	nd	nc	200
Rock sole, whole organism	composite	µg/kg ww	0/3	0	nd	nd	nc	200
Hexachlorobenzene								
Geoduck, whole organism	composite	µg/kg ww	2/5	40	0.58 J	0.62 J	58	39.1 – 490
Horse clam, whole organism	individual and composite	µg/kg ww	0/6	0	nd	nd	nc	460 – 2,000
Red rock crab, muscle tissue	composite	µg/kg ww	0/4	0	nd	nd	nc	1.9 – 38.8
Cadmium								
Coonstripe shrimp, whole organism	composite	mg/kg ww	3/3	100	0.042	0.044	0.043	na
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	2.37	3.66	3.01	na
Dungeness crab, muscle	composite	mg/kg ww	3/3	100	0.014	0.015	0.014	na
Geoduck, whole organism	individual and composite	mg/kg ww	6/6	100	0.249	0.480	0.33	na
Horse clam, whole organism	individual and composite	mg/kg ww	15/15	100	0.121	0.35	0.23	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	0.212	0.212	0.212	na
Rock sole, fillet	composite	mg/kg ww	2/3	67	0.004 J	0.005	0.004	0.005
Rock sole, whole organism	composite	mg/kg ww	3/3	100	0.011	0.013	0.012	na
Cobalt								
Geoduck, whole organism	composite	mg/kg ww	2/2	100	0.533	0.553	0.543	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	0.077	0.077	0.077	na
Copper								
Coonstripe shrimp, whole organism	composite	mg/kg ww	3/3	100	4.82	5.14	4.99	na
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	55.1	99.8	74.1	na
Dungeness crab, muscle	composite	mg/kg ww	3/3	100	4.75	5.64	5.24	na

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Geoduck, whole organism	individual and composite	mg/kg ww	6/6	100	1.87	6.0	3.7	na
Horse clam, whole organism	individual and composite	mg/kg ww	15/15	100	0.84	2.5	1.6	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	7.38	7.38	7.38	na
Rock sole, fillet	composite	mg/kg ww	3/3	100	0.23	0.24	0.23	na
Rock sole, whole organism	composite	mg/kg ww	3/3	100	0.47	0.61	0.55	na
Iron								
Geoduck, whole organism	composite	mg/kg ww	2/2	100	286	911	599	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	10.7	10.7	10.7	na
Selenium								
Coonstripe shrimp, whole organism	composite	mg/kg ww	0/3	0	nd	nd	nc	0.2
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	2.5	2.8	2.7	na
Dungeness crab, muscle	composite	mg/kg ww	3/3	100	0.7	0.9	0.8	na
Geoduck, whole organism	individual and composite	mg/kg ww	5/5	100	0.6	0.824	0.76	na
Horse clam, whole organism	individual	mg/kg ww	9/9	100	0.2	1.9	0.60	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	0.743	0.743	0.743	na
Rock sole, fillet	composite	mg/kg ww	3/3	100	0.2	0.4	0.3	na
Rock sole, whole organism	composite	mg/kg ww	2/3	67	0.3	0.4	0.3	0.3
Silver								
Geoduck, whole organism	composite	mg/kg ww	3/3	100	0.328	0.94	0.58	na
Horse clam, whole organism	individual and composite	mg/kg ww	6/6	100	0.20	1.2	0.69	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	0.157	0.157	0.157	na

Table 2-15. Summary of chemical data in tissue in study area for risk drivers and other COPCs

Tissue Type	Individual or Composite	Unit	Detection Frequency		Detected Results		Calculated Mean[a]	RL or Range of RLs[b]
			Ratio	%	Minimum Detect	Maximum Detect		
Zinc								
Coonstripe shrimp, whole organism	composite	mg/kg ww	3/3	100	12.2	12.6	12.4	na
Dungeness crab, hepatopancreas	composite	mg/kg ww	3/3	100	21.3	25.3	23.4	na
Dungeness crab, muscle	composite	mg/kg ww	3/3	100	44.1	50.2	47.1	na
Geoduck, whole organism	individual and composite	mg/kg ww	6/6	100	8.02	24.2	15	na
Horse clam, whole organism	individual and composite	mg/kg ww	15/15	100	6.53	12	9.1	na
Red rock crab, muscle tissue	composite	mg/kg ww	1/1	100	61.9	61.9	61.9	na
Rock sole, fillet	composite	mg/kg ww	3/3	100	3.90	4.66	4.26	na
Rock sole, whole organism	composite	mg/kg ww	3/3	100	12.1	12.8	12.6	na
Lipid								
Coonstripe shrimp, whole organism	composite	% ww	3/3	100	0.74	0.85	0.80	na
Dungeness crab, hepatopancreas	individual and composite	% ww	11/11	100	3.9	33.45	16	na
Dungeness crab, muscle	individual and composite	% ww	11/11	100	0.0500	0.81	0.33	na
Geoduck, whole organism	individual and composite	% ww	4/4	100	0.55	0.94	0.74	na
Horse clam, tissue	individual	% ww	17/17	100	0.0500	0.790	0.455	na
Horse clam, visceral cavity	individual	% ww	10/10	100	1.62	4.02	2.87	na
Horse clam, whole organism	individual and composite	% ww	15/15	100	0.950	1.6	1.2	na
Rock sole, fillet	composite	% ww	3/3	100	0.47	0.54	0.50	na
Rock sole, whole organism	composite	% ww	3/3	100	2.0	2.7	2.3	na

[a] Calculated mean concentration is the average of detected concentrations and one-half the RL for non-detected results.

[b] The RL represents the method reporting limit, which is the smallest amount of a chemical that the laboratory determines can be practically quantitated in a sample. For dioxin and furan TEQ, PCB TEQ, total PCBs, and cPAH TEQ, calculated non-detected concentrations (as described in footnotes d, e, and f of this table) were reported rather than RLs.

[c] Risk drivers are chemicals or chemical groups that had excess cancer risk estimates > 10^{-4} or non-cancer HQs >10 based on the results of the screening-level HHRA.

[d] TEQs for dioxins and furans and PCBs were calculated using TEFs for mammals presented in Van den Berg et al. (2006) (see Appendix D). If an individual congener was not detected, the TEF for that congener was multiplied by one-half the RL for that congener.

[e] Dioxin and furan TEQ values for samples taken during the 2002 Marine RI were calculated from analyses performed by Analytical Perspectives when available because these analyses had the lowest reported detection limits.

[f] Total PCBs represent the sum of the detected concentrations of the individual Aroclors or congeners. If no Aroclors or congeners were detected, the RL reported represents the highest RL for an individual Aroclor or congener.

[g] TEQs for cPAHs were calculated using PEFs for individual cPAH compounds (derived from WAC 173-340-708(e)), as discussed in detail in Appendix D. If an individual cPAH compound was not detected, the PEF for that compound was multiplied by one-half the RL for that compound.

[h] COPCs are chemicals or chemical groups that had excess cancer risk estimates > 10^{-6} or non-cancer HQs >1 based on the results of the screening-level HHRA.

BHC – benzene hexachloride
COPC – chemical of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
J – estimated concentration
na – not applicable
nc – not calculated
nd – not detected
PCB – polychlorinated biphenyl
U – not detected at given concentration
ww – wet weight

2.4 CONCEPTUAL SITE MODEL

The distribution of contaminants, which are often strongly sorbed to fine organic sediment, is dependent on the hydrodynamics and sediment transport processes occurring in the region.

Two CSMs for the study area near the former Rayonier Mill have been prepared. These CSMs are summarized in Appendix C. Section 2.1 presents the NewFields (2012) near-field CSM for the study area, and Section 2.2 presents the near-field CSM prepared by SeaEngineering, Inc. (SEI). Although these two CSMs agree in many ways, they also have some fundamental differences. This section summarizes the similarities and differences between the two CSMs. Any differences that may affect in-water remedial alternatives will be addressed in Volume III.

2.4.1 Key similarities

The key similarities between the NewFields and SEI CSMs are summarized below:

- Contaminant transport is strongly associated with particle transport.
- Tidal velocities are generally low in the offshore and net surface currents to the east.
- The weak tidal currents allow fine material to settle in the offshore regions. Although fine material may temporarily settle in the nearshore, wind waves can resuspend this material for transport offshore.
- Deposition rates are typically highest near a sediment source.
- Waves play a key role in nearshore sediment transport, as evidenced by the generally sandy sediment found in the nearshore.
- The study area is moving to a new equilibrium condition. The fines offshore, which were dominated by sources from the historical outfalls, are now undergoing diagenesis and potentially being covered with sand from local sources (e.g., Ennis Creek).

2.4.2 Key differences

Although the similarities outlined above are of fundamental importance in the development of a CSM, there are a number of differences that affect some contaminant transport patterns. The key differences are summarized below.

- **Northeasterly Waves –** The NewFields (2012) CSM suggests that extreme weather events, particularly storms originating from the northerly direction, are a dominant event with regard to sediment transport. The SEI CSM does not agree. Instead, the analysis (presented in Appendix C, Section 2.3.2) concludes that no significant sediment transport resulting from wave activity occurs

outside the 15-ft (4.5-m) depth during infrequent storms from the north and northeast.

- **Westward Tidal Forcing –** The NewFields (2012) CSM asserts that there is westward tidal forcing. While it is agreed that tidal currents disperse material in all directions due to the bi-directional nature, the SEI CSM asserts that the weak nature of the tidal currents is not strong enough to resuspend or transport resuspended sediment from the offshore regions of the study area. The documented circulation patterns are contrary to the concept of the net westward transport and deposition of sediment from the former Rayonier mill (Appendix C, Section 2.3.4).
- **Enhanced Westward Bottom Currents –** Resuspended sediment is hypothesized to be transported to a deeper area of the harbor termed the parting zone in the NewFields (2012) CSM. From there, the sediment is hypothesized to be mobilized and distributed throughout the harbor, with the transport favoring westward movement due to enhanced westward bottom currents. The mechanism for these enhanced currents is not supported by available information. Measured currents at three locations in the harbor, from the bottom to the top of the water column, show no evidence of these currents. While it is recognized that there is tidal dispersion in the east and west direction, site observations from multiple studies show net easterly hydrodynamic transport along the southern shore and currents that are too low to resuspend sediment offshore of the former Rayonier mill (Appendix C, Section 2.3). There is no evidence to support a net westward bottom current near the former Rayonier mill.
- **Lack of Sediment Supply to the Study Area -** The NewFields (2012) CSM asserts that there is a lack of sediment supply to the study area. The limited radioisotope data show sediment accumulation over the past 50 years in the inner harbor, and a comparison of bathymetry data from approximately 2000, 2010, and 2014 in the log pond show recent sedimentation near the former Rayonier Mill (Appendix C, Section 2.3.5).
- **Potential Impact of Elwha River Dam Removal –** The US Geological Survey (USGS) study (Gelfenbaum et al. 2006) reported that the removal of dams on the Elwha River will further enhance sediment accumulation rates in Port Angeles Harbor through the introduction of additional sediment. They reported that an additional 0.1-to-0.5 cm/yr would be transported and deposited in Port Angeles Harbor. This material would be distributed inside the harbor according to net transport. Gelfenbaum's model does not provide sufficient small-scale resolution to determine additional deposition in specific locations within the harbor, but these rates are comparable to rates measured in central and eastern Port Angeles Harbor (0.14 to 0.21 cm/hr at Stations RL03 and MA06) and thus may represent a significant contribution. All of these lines of evidence suggest

that there has historically been sediment supply to the study area from local tributaries and the estuary and that the removal of dams on the Elwha River will enhance the sediment accumulation.

- **High Energy at the Harbor Mouth –** The deeper waters at the north end of the harbor (i.e., mouth of the harbor), have some of the highest measured tidal currents in Port Angeles Harbor. This region is not relevant to material discharged from the former Rayonier mill approximately 2.5 km to the south.

2.4.3 Overall CSM conclusions

In summary, two CSMs have been developed to describe sediment transport in the former Rayonier mill study area (see Appendix C). These CSMs agree on many of the key principles but disagree on some key components of the models. These differences are significant enough to potentially affect cleanup considerations. Any differences that may affect in-water remedial alternatives within the study area will be addressed in Volume III.

3 Chemical Concentrations in Background Areas

In accordance with the Agreed Order (Ecology 2010), this section presents a comparison of contaminant concentrations in surface sediment and tissue data collected from the study area with the sediment background threshold values provided in the 2012 supplemental sediment data evaluation (NewFields 2012). Tissue data are also compared with non-urban tissue data for informational purposes. In addition, surface sediment data are presented relative to natural background levels in NewFields (2013) and GeoEngineers and Windward (2013) for comparison purposes.

This comparison is provided only as a point of reference relative to existing natural background data. This comparison does not reflect the final background values that may be used to establish sediment cleanup standards for two main reasons. First, as noted by NewFields (2012), the existing natural background datasets are not ideal in that the background areas sampled do not match the characteristics (e.g., TOC, grain size) of sediment in Port Angeles Harbor. Additional background data were collected in 2013. Second, the SMS rule was revised on February 22, 2013. In this new rule, which went into effect September 1, 2013, Ecology defined a new background concept referred to as "regional background."

Regional background is defined as "the concentration of a contaminant within a 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" (WAC 173-204). This concept is important because sediment remediation levels should not be established at concentrations below background, and sediment quality in urban areas is less pristine than in non-urban areas because of the diffuse urban sources of contaminants that result from daily living, including driving cars,

maintaining lawns, and the ubiquitous use of plastic and other manufactured products. Thus, the intention of the regional background concept is to define background conditions in urban areas so that sediment areas remediated are not recontaminated from diffuse urban sources. Over time, these regional background concentrations may decline through long-term source control efforts.

In 2013, Ecology collected additional background sediment data in order to calculate regional background values for key contaminants. These new data will be used in the determination of regional background for the former Rayonier mill site, which may ultimately be important in defining sediment cleanup standards. These standards are determined based on a comparison of background levels, practical quantitation limits, and risk-based concentrations.

In the interim, for this document, data are compared with natural background levels defined in NewFields (2012, 2013) and GeoEngineers and Windward (2013) for comparison; these comparisons are highly preliminary.

3.1 SEDIMENT

NewFields (2012) compiled existing natural background sediment data and derived three natural background datasets representing three overlapping areas. The three background datasets evaluated by NewFields (2012) are summarized as follows:

- Puget Sound-wide — Consisting of all sampling locations from the 2008 *Ocean Survey Vessel (OSV) Bold* sediment survey (DMMP 2009)
- Puget Sound reference areas — Consisting of reference area sampling locations from the 2008 *OSV Bold* sediment survey (DMMP 2009) (i.e., Dabob Bay, Carr Inlet, Holmes Harbor, and Samish Bay)
- Port Angeles proximal area — Consisting of Strait of Juan de Fuca and San Juan Islands sampling locations from the 2008 *OSV Bold* sediment survey (DMMP 2009) and sampling locations in Freshwater Bay and Dungeness Bay

Table 3-1 presents a point-by-point comparison of the study area surface sediment data with the preliminary natural background values presented in various sources. Note that the background values presented in NewFields (2012) and NewFields (2013) were calculated for each chemical according to methods provided in WAC 173-340-709. These methods defined the BTV as the true upper 90th percentile or four times the true 50th percentile, whichever was lower. In GeoEngineers and Windward (2013), natural background was calculated for the *OSV Bold* dataset based on the upper 90th percent confidence limit on the 90th percentile (90/90 upper tolerance limit [UTL]) using methods provided in the *Draft Sediment Cleanup Users Manual II* (Ecology 2012a). The statistical method to be used in the determination of natural background is still under review at Ecology. Less than 20% of the detected metals concentrations in the study area were greater than the preliminary BTVs, except for cadmium, lead, and mercury, which had to up to 44% of the concentrations greater than the BTVs. Less

than 10% of detected concentrations of all metals were greater than the *OSV Bold* 90/90 UTLs (Table 3-1).

For dioxin/furan TEQs, 42 to 76% of the study area concentrations were greater than the preliminary natural background values, depending on the background dataset (Table 3-1). For total LPAHs, total HPAHs, and cPAHs, 62 to 87% of the study area concentrations were greater than the preliminary natural background values (Table 3-1). Preliminary natural background values were not determined for PCB Aroclors because of the high incidence of non-detects, but 86 to 96% of the study area samples had a PCB TEQ greater than the preliminary calculated natural background values.

Table 3-1. Comparison of study area surface sediment chemistry data with preliminary natural background values

Analyte	Study Area Surface Sediment Data					Preliminary BTVs/SCOs and Percentage of Study Area Surface Sediment Samples with Detected Concentrations Greater than Preliminary BTVs/SCOs									
						Puget Sound-Wide[a]		Puget Sound Reference Areas[a]		Port Angeles Proximal Area[a]		Natural Background for the Port Angeles Proximal Area[b]		*OSV BOLD* Study 90/90 UTL[c]	
	Detected Frequency	Min	Max	Mean (detects only)	Mean (half-RL for non-detects)	BTV	% > BTV	BTV	% > BTV	BTV	% > BTV	BKGD	% > BKGD	UTL	% > UTL
Metals (mg/kg dw)															
Antimony	4/71	0.17	1.2 J	0.63	0.30	na	nc	na	nc	0.31	3%	na	nc	na	nc
Arsenic	105/115	1.1	20.2	5.3	5.0	11	8%	9.7	10%	7	17%	7	17%	12.5	4%
Cadmium	103/115	0.0036 J	4.2	0.74	0.69	0.7	37%	0.79	36%	0.49	44%	0.49	44%	10	0%
Chromium	92/92	9.93	54.1	25.3	25.3	55	0%	50	1%	39	10%	na	nc	na	nc
Copper	115/115	5.6 J	75.2	22	22	40	4%	41	4%	30	17%	30	17%	47.7	3%
Lead	115/115	1.7	265	14	14	18	16%	17	16%	10	27%	na	nc	na	nc
Mercury	100/116	0.01 J	0.43	0.08	0.07	0.2	4%	0.23	3%	0.079	32%	0.079	32%	0.18	7%
Nickel	71/71	13.5	45.3	28.1	28.1	50	0%	44	4%	37	20%	na	nc	na	nc
Selenium	39/80	0.2 J	3.8	0.7	0.6	na	nc	na	nc	na	nc	na	nc	1	9%
Silver	56/92	0.024 J	0.269	0.088	0.12	0.2	5%	0.25	1%	0.13	10%	na	nc	na	nc
Zinc	115/115	17.8	148	45.5	45.5	92	0.9%	85	0.9%	70	6%	70	6%	93.5	0.9%
PCB Aroclors (µg/kg dw)															
Total PCB Aroclors	54/104	2.2 J	640	91	51	na	nc	na	nc	na	nc	na	nc	na	nc
PCB TEQ (ng/kg dw)															
PCB TEQ – mammal (half DL)	28/28	0.0464 J	7.86	1.59	1.59	na	nc	na	nc	0.077	96%	0.077	96%	0.131	86%
Dioxin/furan TEQ (ng/kg dw)															
Dioxin/furan TEQ – mammal (half DL)	97/97	0.0827 J	59.4 J	5.61	5.61	2.2	51%	1.9	57%	0.95	76%	0.95	76%	3.39	42%
cPAH TEQ (µg/kg dw)															
cPAHs 2005 – mammal (half DL)	92/116	3.60 J	1,630	144	115	na	nc	na	nc	na	nc	9.2	69%	19.7	62%
LPAHs (µg/kg dw)															
Naphthalene	93/116	1.9 J	1,240	140	110	4.6	77%	4.6	77%	22	59%	na	nc	na	nc
Acenaphthene	64/116	0.53 J	755	66	42	4.6	50%	4.6	50%	21	35%	na	nc	na	nc
Phenanthrene	102/116	4.2 J	11,800	330	290	7.9	86%	5.1	87%	21	75%	na	nc	na	nc
Anthracene	82/116	1.7 J	728	110	79	4.5	67%	na	nc	19	59%	na	nc	na	nc
2-Methylnaphthalene	82/116	0.75 J	430	46	37	4.6	64%	4.6	64%	21	41%	na	nc	na	nc
Total LPAHs	102/116	6.1 J	14,600 J	670	590	11	87%	7.9	87%	18	85%	na	nc	na	nc
HPAHs (µg/kg dw)															
Fluoranthene	107/116	4.2 J	15,000	530	490	12	86%	11	87%	11	87%	na	nc	na	nc
Pyrene	104/116	4.9 J	8,390	430	390	12	84%	11	84%	8.6	86%	na	nc	na	nc
Benzo(a)anthracene	87/116	2.5 J	1,390	150	110	6.2	70%	4.9	71%	15	61%	na	nc	na	nc
Chrysene	91/116	2.8 J	2,210	240	190	6.9	73%	5.8	73%	17	66%	na	nc	na	nc
Benzo(b)fluoranthene	88/116	3.3 J	1,880	170	130	16	66%	13	68%	10	69%	na	nc	na	nc
Benzo(k)fluoranthene	78/116	1.9 J	754	110	75	8.8	61%	5.1	64%	23	49%	na	nc	na	nc
Benzo(a)pyrene	84/116	2.4 J	1,140	100	76	10	65%	6.5	67%	8.1	66%	na	nc	na	nc

Analyte	Study Area Surface Sediment Data					Preliminary BTVs/SCOs and Percentage of Study Area Surface Sediment Samples with Detected Concentrations Greater than Preliminary BTVs/SCOs									
						Puget Sound-Wide[a]		Puget Sound Reference Areas[a]		Port Angeles Proximal Area[a]		Natural Background for the Port Angeles Proximal Area[b]		*OSV BOLD* Study 90/90 UTL[c]	
	Detected Frequency	Min	Max	Mean (detects only)	Mean (half-RL for non-detects)	BTV	% > BTV	BTV	% > BTV	BTV	% > BTV	BKGD	% > BKGD	UTL	% > UTL
Indeno(1,2,3-cd)pyrene	66/116	2.2 J	499	58	36	4.8	54%	5.5	54%	8.6	51%	na	nc	na	nc
Dibenzo(a,h)anthracene	31/116	0.62 J	142	23	22	4.6	22%	na	nc	21	6%	na	nc	na	nc
Benzo(g,h,i)perylene	68/116	2.5 J	506	52	38	5	57%	5.7	57%	17	46%	na	nc	na	nc
Total HPAHs	107/116	11 J	28,400 J	1,600	1,500	75	74%	60	76%	49	78%	na	nc	na	nc
Phthalates (µg/kg dw)															
Bis(2-ethylhexyl) phthalate	41/60	13 J	2,700 J	140	94	46	37%	46	37%	na	nc	na	nc	na	nc
Phenols (µg/kg dw)															
Pentachlorophenol	2/83	17 J	44 J	31	100	9.3	2%	9.3	2%	na	nc	na	nc	na	nc
Phenol	73/116	6.3 J	760	120	84	480	0.9%	800	0%	260	4%	na	nc	na	nc
Pesticides															
alpha-BHC	12/60	0.20 J	3.0 J	0.84	0.73	na	nc	na	nc	0.6	8%	0.6	8%	na	nc
OC-normalized (mg/kg OC)															
cPAHs 2005 – mammal (half DL)	92/116	0.459	237 J	8.60	7.09	na	nc	na	nc	na	nc	na	nc	1.66	59%
OC-normalized (µg/kg OC)															
PCB TEQ – mammal (half DL)	28/28	0.00518 J	0.436	0.0863	0.0863	na	nc	na	nc	na	nc	na	nc	0.0123	93%
Dioxin/furan TEQ – mammal (half DL)	96/96	0.00972 J	0.816 J	0.212	0.212	na	nc	na	nc	na	nc	na	nc	0.246	32%

[a] Source: NewFields (2012).
[b] Source: NewFields (2013).
[c] GeoEngineers and Windward (2013).

BHC – benzene hexachloride
BTV – background threshold value
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DL – detection limit
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
J – estimated concentration
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
na – not applicable
nc – not calculated
OC – organic carbon
OSV –ocean survey vessel
PCB – polychlorinated biphenyl
RL – reporting limit
TEQ – toxic equivalent
UTL – upper tolerance limit

3.2 TISSUE

This section presents a comparison of chemical concentrations in tissue samples collected from the study area with those collected from non-urban areas. The concentrations of six risk drivers (i.e., arsenic, mercury, cPAHs, PCBs, dioxins/furans, and alpha-BHC) in study area tissue samples were compared with data from two reference bays (Dungeness Bay and Freshwater Bay) and a Puget Sound-wide, non-urban dataset to provide context. These chemicals were selected for a comparison to background because their excess cancer risk estimates were greater than 10^{-4}, or the non-cancer HQ was >10 based on the results of the screening-level HHRA (see Appendix B) and background data are available. Tissue data for all chemicals analyzed in samples collected from the study area are presented in Section 2.3.3.

Because these risk drivers were identified based on their contribution to human health risks, ingestion-weighted average concentrations were calculated in order to compare tissue data in the context of human health risk associated with seafood consumption. Ingestion-weighted average concentrations give a more complete picture of the diets assumed in the screening-level HHRA exposure calculations and take into account the differences in concentrations across species and the different amounts of each seafood type consumed. Ingestion-weighted average concentrations were calculated using the same assumptions as those presented in the screening-level HHRA (Ecology 2012b).

3.2.1 Method for the calculation of ingestion-weighted averages

Ingestion-weighted averages were calculated assuming the consumption of a combination of species (i.e., a market basket approach). The market basket included whole-body tissue of the following species based on Ecology's screening-level HHRA (Ecology 2012b):

- Shellfish (30% Dungeness crab, 30% geoduck, 30% horse clam, and 10% shrimp)
- Bottom fish (rock sole)
- Pelagic fish (lingcod)

Ingestion-weighted averages were calculated by weighting the chemical concentration for a given species by the percent of the total diet represented by that species. These weighted concentrations were then summed to calculate the ingestion-weighted average, as shown in Equation 3-1:

$$C_{I-W} = (C_{dc} \times P_{dc}) + (C_g \times P_g) + (C_{hc} \times P_{hc}) + (C_{sh} \times P_{sh}) + (C_{bf} \times P_{bf}) + (C_{pf} \times P_{pf}) \quad \textbf{Equation 3-1}$$

Where:

$C_{I\text{-}W}$ = Ingestion-weighted tissue concentration
C_{sh} = Chemical concentration in shrimp
P_{sh} = Percent of the diet attributable to shrimp
C_{dc} = Chemical concentration in whole-body Dungeness crab
P_{dc} = Percent of the diet attributable to Dungeness crab
C_{g} = Chemical concentration in whole-body geoduck
P_{g} = Percent of the diet attributable to geoduck
C_{hc} = Chemical concentration in whole-body horse clam
P_{hc} = Percent of the diet attributable to horse clam
C_{bf} = Chemical concentration in whole-body bottom fish
P_{bf} = Percent of the diet attributable to bottom fish
C_{pf} = Chemical concentration in whole-body pelagic fish
P_{pf} = Percent of the diet attributable to whole-body pelagic fish

The percentage of the diet for each species used in Equation 3-1 is presented in Table 3 2. These percentages were calculated based on the species-specific ingestion rates and total ingestion rate of 583 grams per day, per the screening-level HHRA (Ecology 2012b). For some chemical-location combinations, data were not available for all species in the market basket. In these cases, the consumption of the species for which data were unavailable was apportioned to other species if data for an acceptable surrogate species were not available.

Table 3-2. Species-specific ingestion rates and dietary percentages

Consumption Category	Species[a]	Species-Specific Ingestion Rate (g/day)	Percentage of Total Diet	Species-Specific Ingestion Rate, Excluding Lingcod (g/day)[b]
Shellfish	Dungeness crab	149.4	25.6%	165.3
	Geoduck	149.4	25.6%	165.3
	Horse clam	149.4	25.6%	165.3
	Shrimp	49.8	8.5%	54.9
Bottom fish	Rock sole and/or English sole	29.0	5.0%	32.2
Pelagic fish	lingcod	56.0	9.6%	-
Total		**583**	**100%**	**583**

Source: Ecology (2012b); species-specific ingestion rates are based on the adult subsistence fisher RME scenario, as presented in Table 3-8 of Ecology's 2012 Port Angeles Harbor screening-level HHRA and ERA (Ecology 2012b).

[a] Whole-body data were used for all species.

[b] Ingestion-weighted averages were calculated excluding pelagic fish (lingcod) because this data type was available for only the Port Angeles Harbor area. The portion of the diet assigned to lingcod was distributed proportionally among the other consumption categories.

3.2.2 Comparison of ingestion-weighted averages for key chemicals

Tables 3-3 through 3-8 present summary statistics and ingestion-weighted averages for inorganic arsenic, cPAHs, dioxins/furans, mercury, total PCBs, and alpha-BHC using minimum, mean, and maximum concentrations in each consumption category. The following provide a brief summary of the comparison of ingestion-weighted concentrations. Note that sample sizes are relatively small, particularly in non-urban reference locations, and did not always contain the same species; these conclusions should be viewed in that context. Larger and more complete datasets might change some of these conclusions.

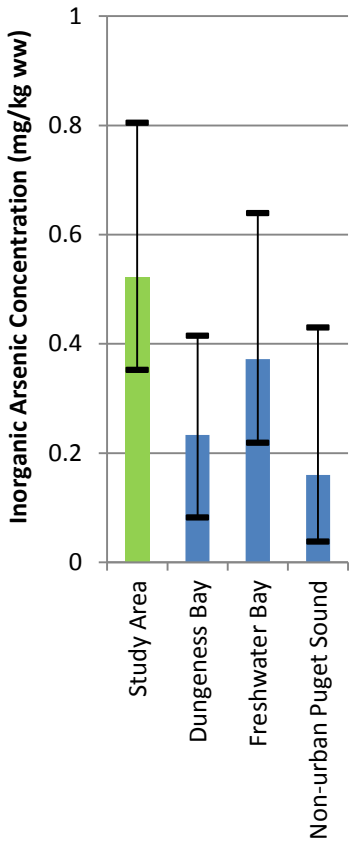
- The mean ingestion-weighted arsenic concentration was higher in the study area dataset than those in the Dungeness Bay, Freshwater Bay, or non-urban Puget Sound datasets. However, it should be noted that the ranges for these datasets (defined by minimum and maximum concentrations) overlapped. The consumption of geoducks or horse clams had the highest contribution to the ingestion-weighted average in all locations (Table 3-3).
- The mean ingestion-weighted cPAH TEQ was higher in the study area dataset than those in the Dungeness Bay, Freshwater Bay, or non-urban Puget Sound datasets. The low end of the range (defined by the minimum TEQ) for the study area was just within the ranges for the background areas. The consumption of geoducks and horse clams was again an important contributor to the ingestion-weighted average in all locations, driven largely by non-detected samples for other tissue types (Table 3-4). The consumption of crab contributed 45% of the ingestion-weighted average for the non-urban Puget Sound dataset (in part because no fish data were available); all of the crab data were non-detects.
- The mean ingestion-weighted dioxin/furan TEQ was higher in the study area dataset than those in the Dungeness Bay, Freshwater Bay, or non-urban Puget Sound datasets. However, it should be noted that the high end of the range (defined by the maximum TEQ) for the non-urban Puget Sound dataset was similar to the mean study area TEQ. The consumption of crab had the highest contribution to the ingestion-weighted average in most of the datasets; this was particularly true for the study area dataset (Table 3-5). This is attributable largely to the hepatopancreas portion of the whole-body crab concentrations (edible meat concentrations are considerably lower than those in the hepatopancreas).
- The mean ingestion-weighted mercury concentration was higher in the study area dataset than those in the Dungeness Bay or Freshwater Bay datasets. However, it should be noted that the ranges (defined by minimum and

maximum concentrations) for the study area and Dungeness Bay datasets overlapped slightly. The consumption of crab was again an important contributor to the ingestion-weighted averages (Table 3-6).

- The mean ingestion-weighted PCB concentration was higher in the study area than in Dungeness Bay, Freshwater Bay, and the non-urban Puget Sound dataset. Consumption of crab contributed the highest contribution to the ingestion-weighted averages (Table 3-7).
- The mean ingestion-weighted alpha-BHC concentration was lower in the study area dataset than those in the Dungeness Bay or Freshwater Bay datasets. However, the ranges for these three datasets (defined by minimum and maximum concentrations) overlapped. The consumption of geoduck had the highest contribution to the ingestion-weighted averages (Table 3-8).

Table 3-3. Comparison of inorganic arsenic concentrations in study area tissue with concentrations in tissue from background areas

Species by Location	DF	Inorganic Arsenic Concentration in Tissue (mg/kg ww)			Percent Contribution to Ingestion-Weighted Mean[b]	Ingestion-Weighted Concentrations
		Minimum	Maximum	Mean[a]		
Study Area[c]						
Dungeness crab	3/3	0.05 J	0.075	0.065	4%	
Geoduck	3/3	1.06	1.41	1.2	67%	
Horse clam	9/9	0.13	1.35	0.53	29%	
Rock sole	1/3	0.005 J	0.012 U	0.006	0.1%	
Shrimp	3/3	0.006 J	0.009 J	0.008	0.1%	
Ingestion-weighted		**0.35**	**0.80**	**0.52**		
Dungeness Bay[c]						
Dungeness crab	3/3	0.1 J	0.20 J	0.17	20%	
Geoduck	3/3	0.013 J	0.399 J	0.21	28%	
Horse clam	3/3	0.155 J	0.740 J	0.377	51%	
Rock sole	0/1	0.012 U	0.012 U	0.006	0.2%	
Shrimp	3/3	0.008 J	0.012	0.0093	0.4%	
Ingestion-weighted		**0.082**	**0.41**	**0.23**		
Freshwater Bay						
Dungeness crab	3/3	0.02 J	0.024	0.022	2%	
Geoduck	3/3	0.583	1.80	1.02	86%	
Horse clam	3/3	0.094	0.214	0.14	12%	
Rock sole	3/3	0.012	0.023	0.016	0.3%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**0.22**	**0.64**	**0.37**		
Non-Urban Puget Sound[d]						
Dungeness crab[e]	6/6	0.032	0.13	0.078	15%	
Geoduck[f]	12/12	0.044 J	0.616 J	0.21	42%	
Horse clam[f]	12/12	0.044 J	0.616 J	0.21	42%	
English sole	12/12	0.007	0.03	0.015	1%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**0.038**	**0.43**	**0.16**		



Bars indicate mean ingestion-weighted concentrations; error bars show the range of minimum to maximum ingestion-weighted concentrations.

[a] The mean value is calculated as the average of detected concentration and half-RLs for non-detects.

[b] The percent contribution to the ingestion-weighted mean takes into account the percentage of the diet represented by each species and the mean tissue concentration of each species.

[c] The 1998 ESI red rock crab and geoduck data from the study area and Dungeness Bay (Ecology and Environment 1999) were excluded because only total arsenic (rather than inorganic arsenic) data were available from this study.

[d] The non-urban Puget Sound dataset was developed as part of the feasibility study for the LDW (AECOM 2012), and is presented here for informational purposes only. Some of the data rules used for arsenic were different from those used in the Rayonier project dataset; these differences are described in Appendix D.

[e] Whole-body crab samples were calculated as part of the compilation of the non-urban Puget Sound dataset for the LDW; the ratio used for these calculations (69% edible meat and 31% hepatopancreas based on data from the LDW) is different than that used for the other areas (75% edible meat and 25% hepatopancreas). Using the

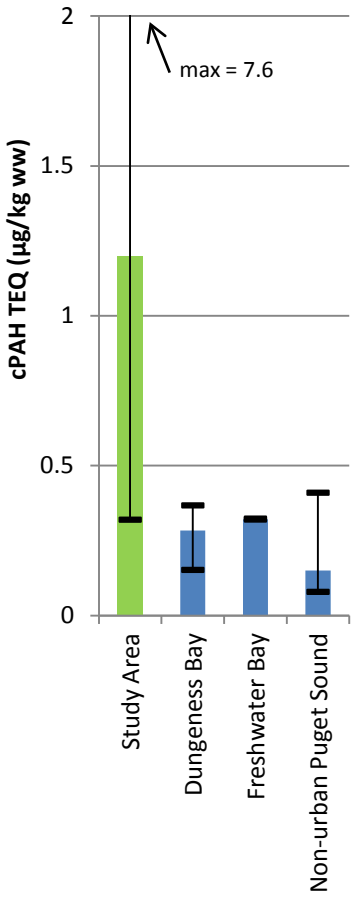
Rayonier database ratios would have resulted in somewhat lower concentrations for the non-urban Puget Sound dataset (see Appendix D for details).

[f] No geoduck or horse clam samples were available in the non-urban Puget Sound dataset. Samples of Eastern soft-shell clam and samples of mixed clam species were used as a surrogate.

DF – detection frequency
J – estimated concentration
LDW – Lower Duwamish Waterway
nc – not calculated
nd – no data
RL – reporting limit
U – not detected at given concentration
ww – wet weight

Table 3-4. Comparison of cPAH TEQs in study area tissue with TEQs in tissue from background areas

Species by Location	DF	cPAH TEQs in Tissue (µg/kg ww)			Percent Contribution to Ingestion-Weighted Mean[a]	Ingestion-Weighted TEQs
		Minimum	Maximum	Mean		
Study Area[b]						
Dungeness crab	1/3	0.190 U	0.277 J	0.22	5%	
Geoduck	3/4	0.300 J	0.790 J	0.52	12%	
Horse clam	15/15	0.38 U	28.2	3.3	78%	
Rock sole	0/3	0.38 U	0.38 U	0.38	2%	
Shrimp	3/3	0.380 J	0.400 J	0.39	3%	
Ingestion-weighted		**0.32**	**8.4**	**1.2**		
Dungeness Bay[b]						
Dungeness crab	0/3	0.190 U	0.190 U	0.19	19%	
Geoduck	2/4	0.0719 JN	0.400 J	0.31	31%	
Horse clam	2/5	0.0757 JN	0.380 U	0.26	26%	
Rock sole	0/1	0.380 U	0.380 U	0.38	7%	
Shrimp	1/3	0.380 U	0.760	0.51	17%	
Ingestion-weighted		**0.15**	**0.37**	**0.28**		
Freshwater Bay						
Dungeness crab	0/3	0.190 U	0.190 U	0.19	18%	
Geoduck	1/3	0.380 U	0.390 J	0.38	37%	
Horse clam	0/3	0.380 U	0.380 U	0.38	37%	
Rock sole	0/3	0.380 U	0.380 U	0.38	7%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**0.32**	**0.32**	**0.32**		
Non-Urban Puget Sound[c]						
Dungeness crab[d]	0/7	0.1 U	0.9 U	0.2	45%	
Geoduck	3/7	0.069	0.171	0.12	27%	
Horse clam[e]	3/7	0.069	0.171	0.12	27%	
Rock sole	nd	nd	nd	nd	nd	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**0.079**	**0.41**	**0.15**		



Bars indicate mean ingestion-weighted concentrations; error bars show the range of minimum to maximum ingestion-weighted concentrations.

[a] The percent contribution to the ingestion-weighted mean takes into account the percentage of the diet represented by each species and the mean tissue concentration of each species.

[b] The 1998 ESI red rock crab and geoduck data from the study area and Dungeness Bay (Ecology and Environment 1999) were excluded because the analytical method for PAHs for these samples (EPA 8270, rather than EPA 8270C-SIM as was used for all other samples in this database) resulted in significantly high reporting limits for non-detected results.

[c] The non-urban Puget Sound dataset was developed as part of the feasibility study for the LDW (AECOM 2012), and is presented here for informational purposes. Some of the data rules used to calculate the cPAH TEQs were different from those used in the Rayonier project dataset; these differences are described in Appendix D.

[d] Whole-body crab samples were calculated as part of the compilation of the non-urban Puget Sound dataset for the LDW; the ratio used for these calculations (69% edible meat and 31% hepatopancreas based on data from the LDW) is different than that used for the other areas (75% edible meat and 25% hepatopancreas). Using the

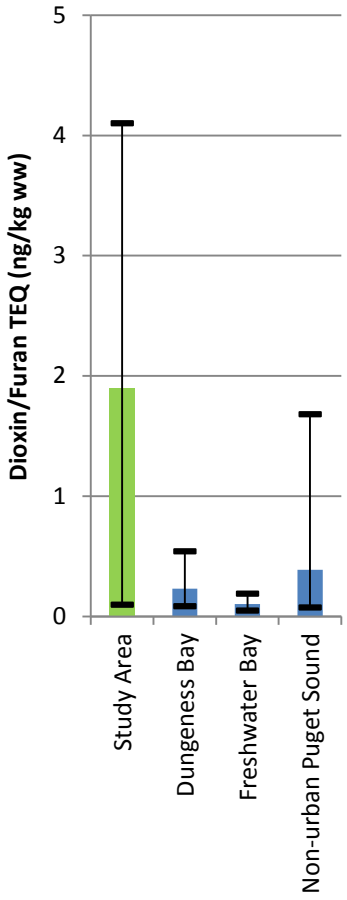
Rayonier database ratios would have resulted in somewhat lower concentrations for the non-urban Puget Sound dataset (see Appendix D for details).

[e] Geoduck data were used a surrogate for horse clam data.

cPAHs – carcinogenic polycyclic aromatic hydrocarbons
DF – detection frequency
EPA – US Environmental Protection Agency
J – estimated concentration
LDW – Lower Duwamish Waterway
N – tentative identification
nd – no data
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TEQ – toxic equivalent
U – not detected at given concentration
ww – wet weight

Table 3-5. Comparison of dioxin/furan TEQs in study area tissue with TEQs in tissue from background areas

Species by Location	DF	Dioxin/Furan TEQs in Tissue (ng/kg ww)			Percent Contribution to Ingestion-Weighted Mean[a]	Ingestion-Weighted TEQs
		Minimum	Maximum	Mean		
Study Area[b]						
Dungeness crab	11/11	0.215 J	12.9 J	6.2	91%	
Geoduck	6/6	0.0153 J	1.19	0.43	6%	
Horse clam	30/32	0.0133 J	0.217 J	0.055	1%	
Rock sole	2/3	0.183 J	0.275 J	0.22	1%	
Shrimp	2/3	0.174 J	0.242 U	0.20	1%	
Ingestion-weighted		**0.096**	**4.1**	**1.9**		
Dungeness Bay[b]						
Dungeness crab	10/10	0.122 J	0.490 J	0.28	34%	
Geoduck	1/5	0.0780 U	1.14 U	0.40	48%	
Horse clam	6/13	0.0133 J	0.145 J	0.043	5%	
Rock sole	0/1	0.152 U	0.152 U	0.15	4%	
Shrimp	1/3	0.161 U	0.342 U	0.22	9%	
Ingestion-weighted		**0.083**	**0.54**	**0.23**		
Freshwater Bay						
Dungeness crab	11/11	0.0678 J	0.400 J	0.20	60%	
Geoduck	11/11	0.0164 J	0.0541	0.029	9%	
Horse clam	10/11	0.0167 J	0.0647 J	0.038	12%	
Rock sole	3/3	0.257 J	0.417 J	0.32	19%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**0.047**	**0.19**	**0.10**		
Non-Urban Puget Sound[c]						
Dungeness crab[d]	25/25	0.089	5.12[e]	0.813	60%	
Geoduck	7/7	0.085	0.297	0.222	16%	
Horse clam	8/8	0.00029	0.318	0.202	15%	
Rock/English sole	7/7	0.152	0.417	0.281	4%	
Shrimp	3/3	0.161	0.342	0.224	5%	
Ingestion-weighted		**0.073**	**1.7**	**0.39**		



Bars indicate mean ingestion-weighted concentrations; error bars show the range of minimum to maximum ingestion-weighted concentrations.

[a] The percent contribution to the ingestion-weighted mean takes into account the percentage of the diet represented by each species and the mean tissue concentration of each species.

[b] The 1998 ESI red rock crab data from the study area and Dungeness Bay (Ecology and Environment 1999) was excluded because only edible meat data were available (rather than whole-body data as was available from the other studies). Samples from Dungeness Bay (1991) and Padilla Bay (1999) appear elevated compared with more recent samples only because detection limits were higher in those earlier studies.

[c] The non-urban Puget Sound dataset was developed as part of the feasibility study for the LDW (AECOM 2012) and is presented here for informational purposes. Some of the data rules used to calculate the dioxin/furan TEQs were different from those used in the Rayonier project dataset; these differences are described in Appendix D.

[d] Whole-body crab samples were calculated as part of the compilation of the non-urban Puget Sound dataset for the LDW; the ratio used for these calculations (69% edible meat and 31% hepatopancreas based on data from the LDW) is different than that used for the other areas (75% edible meat and 25% hepatopancreas). Using the

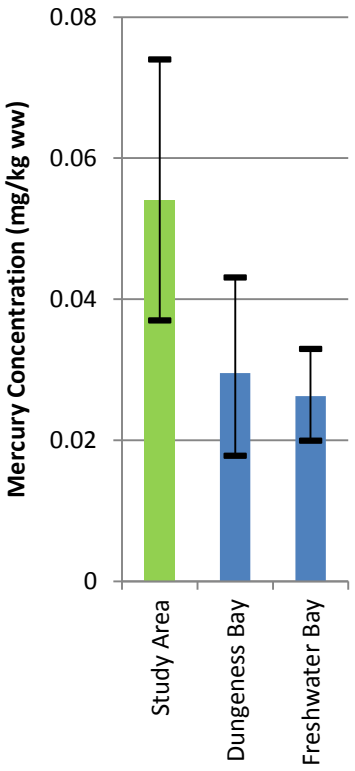
Rayonier database ratios would have resulted in somewhat lower concentrations for the non-urban Puget Sound dataset (see Appendix D for details).

[e] Three of the 25 whole-body crab samples (all collected in the vicinity of the Anderson-Ketron disposal site) in the non-urban dataset were detected at concentrations significantly higher than those in other crab samples in this database. The inclusion or exclusion of samples in this dataset, which was compiled as part of the LDW FS (AECOM 2012), was determined based on location (rather than concentration). In addition, it should be noted that concentrations in other species were not elevated at this location. Thus, as previously agreed, no changes were made to the non-urban Puget Sound dataset as part of this report.

DF – detection frequency
J – estimated concentration
LDW – Lower Duwamish Waterway
nd – no data
TEQ – toxic equivalent
U – not detected at given concentration
ww – wet weight

Table 3-6. Comparison of mercury concentrations in study area tissue with concentrations in tissue from background areas

Species by Location	DF	Mercury Concentration in Tissue (mg/kg ww)			Percent Contribution to Ingestion-Weighted Mean[b]	Ingestion-Weighted Concentrations
		Minimum	Maximum	Mean[a]		
Study Area[c]						
Dungeness crab	3/3	0.097	0.14	0.12	64%	
Geoduck	6/6	0.018	0.082	0.045	23%	
Horse clam	14/15	0.0041	0.027	0.011	6%	
Rock sole	3/3	0.019 J	0.022 J	0.02	2%	
Shrimp	3/3	0.023 J	0.027 J	0.026	5%	
Ingestion-weighted		**0.037**	**0.074**	**0.054**		
Dungeness Bay[c]						
Dungeness crab	3/3	0.037	0.089	0.062	59%	
Geoduck	3/5	0.0086 U	0.026	0.017	16%	
Horse clam	4/5	0.005	0.018 J	0.0086	8%	
Rock sole	1/1	0.012 J	0.012 J	0.012	2%	
Shrimp	3/3	0.045 J	0.050 J	0.047	15%	
Ingestion-weighted		**0.018**	**0.043**	**0.030**		
Freshwater Bay						
Dungeness crab	3/3	0.038	0.052	0.046	54%	
Geoduck	3/3	0.019	0.042	0.029	35%	
Horse clam	3/3	0.004	0.007	0.0057	7%	
Rock sole	3/3	0.014	0.022	0.018	4%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**0.020**	**0.033**	**0.026**		



Bars indicate mean ingestion-weighted concentrations; error bars show the range of minimum to maximum ingestion-weighted concentrations.

Note: The non-urban Puget Sound dataset developed as part of the feasibility study for the Lower Duwamish Waterway (AECOM 2012) did not include data for mercury.

[a] The mean value is calculated as the average of detected concentration and half-RLs for non-detects.

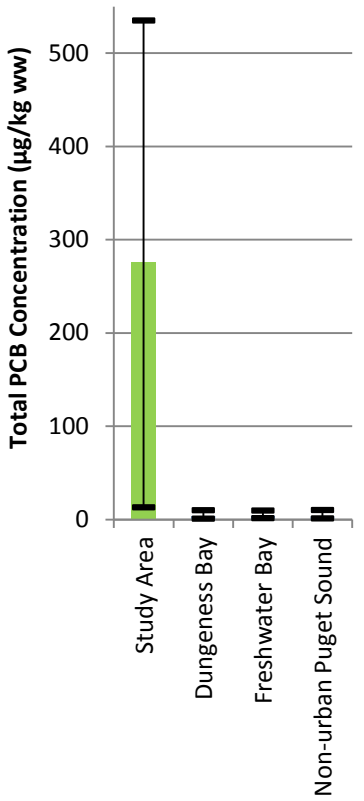
[b] The percent contribution to the ingestion-weighted mean takes into account the percentage of the diet represented by each species and the mean tissue concentration of each species.

[c] The 1998 ESI red rock crab data from the study area and Dungeness Bay (Ecology and Environment 1999) was excluded because only edible meat data were available (rather than whole-body data as was available from the other studies).

DF – detection frequency
J – estimated concentration
nd – no data
RL – reporting limit
U – not detected at given concentration
ww – wet weight

Table 3-7. Comparison of total PCBs concentrations in study area tissue with concentrations in tissue from background areas

Species by Location	DF	Total PCB Concentration in Tissue (µg/kg ww)			Percent Contribution to Ingestion-Weighted Mean[b]	Ingestion-Weighted Concentrations
		Minimum	Maximum	Mean[a]		
Study Area[c]						
Dungeness crab	11/11	39	1,835 J	957	98%	
Geoduck	3/5	1.9 U	10.3	3.6	0.4%	
Horse clam	26/26	0.273 J	36	10.4	1%	
Rock sole	3/3	9.4	13.1	11.3	0.2%	
Shrimp	3/3	6.5	6.9	6.7	0.2%	
Ingestion-weighted		**13**	**535**	**276**		
Dungeness Bay[c]						
Dungeness crab	9/10	0.95 U	29	9.7	72%	
Geoduck	1/4	1.9 U	3.5	2.0	14%	
Horse clam	8/11	0.088 J	1.9 U	0.34	3%	
Rock sole	1/1	5.9	5.9	5.9	9%	
Shrimp	0/3	1.9 U	1.9 U	0.95	2%	
Ingestion-weighted		**0.84**	**9.9**	**3.8**		
Freshwater Bay						
Dungeness crab	11/11	3.01 J	25	9.9	77%	
Geoduck	8/11	0.242 J	1.9 U	0.73	6%	
Horse clam	8/11	0.10 J	1.9 U	0.36	3%	
Rock sole	3/3	5.7	16	9.3	14%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**1.4**	**9.5**	**4.0**		
Non-Urban Puget Sound[d]						
Dungeness crab[e]	15/15	3	16	7.1	70%	
Geoduck	8/8	0.24	1.43	0.64	6%	
Horse clam	16/16	0.09	0.23	0.13	1%	
Rock/English sole	158/242	1.3	75.4	11.8	23%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**1.1**	**10**	**3.2**		



Bars indicate mean ingestion-weighted concentrations; error bars show the range of minimum to maximum ingestion-weighted concentrations.

Note: Total PCB data includes both total PCBs based on congeners and total PCBs based on Aroclors.

[a] The mean value is calculated as the average of detected concentration and half-RLs for non-detects.

[b] The percent contribution to the ingestion-weighted mean takes into account the percentage of the diet represented by each species and the mean tissue concentration of each species.

[c] The 1998 ESI red rock crab data from the study area and Dungeness Bay (Ecology and Environment 1999) was excluded because only edible meat data were available (rather than whole-body data as was available from the other studies).

[d] The non-urban Puget Sound dataset was developed as part of the feasibility study for the LDW (AECOM 2012) and is presented here for informational purposes. Some of the data rules used to calculate the total PCBs were different from those used in the Rayonier project dataset; these differences are described in Appendix D.

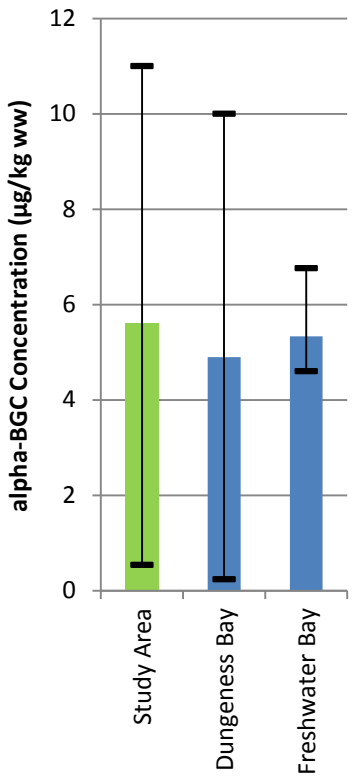
[e] Whole-body crab samples were calculated as part of the compilation of the non-urban Puget Sound dataset for the LDW; the ratio used for these calculations (69% edible meat and 31% hepatopancreas based on data from the LDW) is different than that used for the other areas (75% edible meat and 25% hepatopancreas). Using the

Rayonier database ratios would have resulted in somewhat lower concentrations for the non-urban Puget Sound dataset (see Appendix D for details).

DF – detection frequency
J – estimated concentration
LDW – Lower Duwamish Waterway
nd – no data
PCB – polychlorinated biphenyl
RL – reporting limit
U – not detected at given concentration
ww – wet weight

Table 3-8. Comparison of alpha-BHC concentrations in study area tissue with concentrations in tissue from background areas

Species by Location	DF	alpha-BHC Concentration in Tissue (mg/kg ww)			Percent Contribution to Ingestion-Weighted Mean[b]	Ingestion-Weighted Concentrations
		Minimum	Maximum	Mean[a]		
Study Area[c]						
Dungeness crab	3/3	0.81	0.97 J	0.88	4%	
Geoduck	6/6	0.73 J	38	18.0	92%	
Horse clam	3/13	0.10 U	0.63 J	0.40	2%	
Rock sole	3/3	0.51 J	1.1 J	0.77	1%	
Shrimp	3/3	0.64 J	0.64 J	0.64	1%	
Ingestion-weighted		**0.54**	**11**	**5.6**		
Dungeness Bay[c]						
Dungeness crab	2/3	0.50 U	1.7 J	0.83	6%	
Geoduck	5/5	0.23 J	33	16	89%	
Horse clam	0/5	0.10 U	1.0 U	0.32	2%	
Rock sole	0/1	1.0 U	1.0 U	0.5	1%	
Shrimp	3/3	0.64 J	0.71 J	0.67	2%	
Ingestion-weighted		**0.24**	**10**	**4.9**		
Freshwater Bay						
Dungeness crab	3/3	1.1 J	1.5 J	1.27	7%	
Geoduck	3/3	13	19	15	88%	
Horse clam	1/3	1.0	1.0	0.67	4%	
Rock sole	0/3	1.0 U	1.0 U	0.5	1%	
Shrimp	nd	nd	nd	nd	nd	
Ingestion-weighted		**4.6**	**6.8**	**5.3**		



Bars indicate mean ingestion-weighted concentrations; error bars show the range of minimum to maximum ingestion-weighted concentrations.

Note: The non-urban Puget Sound dataset developed as part of the feasibility study for the Lower Duwamish Waterway (AECOM 2012) did not include data for alpha-BHC.

[a] The mean value is calculated as the average of detected concentration and half-RLs for non-detects.

[b] The percent contribution to the ingestion-weighted mean takes into account the percentage of the diet represented by each species and the mean tissue concentration of each species.

[c] The 1998 ESI red rock crab data from the study area and Dungeness Bay (Ecology and Environment 1999) was excluded because only edible meat data were available (rather than whole-body data as was available from the other studies).

BHC – benzene hexachloride
DF – detection frequency
J – estimated concentration
nd – no data
RL – reporting limit
U – not detected at given concentration
ww – wet weight

Thus, based on the available tissue data, mean concentrations of the key COPCs in study area tissue were generally higher than those in tissue collected from the background areas (i.e., Dungeness Bay, Freshwater Bay, and the non-urban Puget Sound). However, for many of the risk drivers, the ranges (defined by minimum and maximum concentrations) for the study area dataset overlapped with the ranges for the background areas. Thus, incremental risk assessment (i.e., comparison of risks in the study area with those of reference areas) would be an important approach to consider. This approach would allow consideration of regional tissue concentrations and thus help set expectations for risk reduction.

4 Conclusions

This document fulfills the requirements of the Agreed Order (Ecology 2010) for Volume II of the Interim Action Report by summarizing all existing marine data for the study area, describing the nature and extent of contamination, and comparing surface sediment and tissue data with natural background data.

The data summarized in this document are sufficient to delineate the nature and extent of contamination in the study area and will be used in Volume III to finalize preliminary cleanup standards, to delineate areas of sediment remediation, and to evaluate remedial alternatives.

5 References

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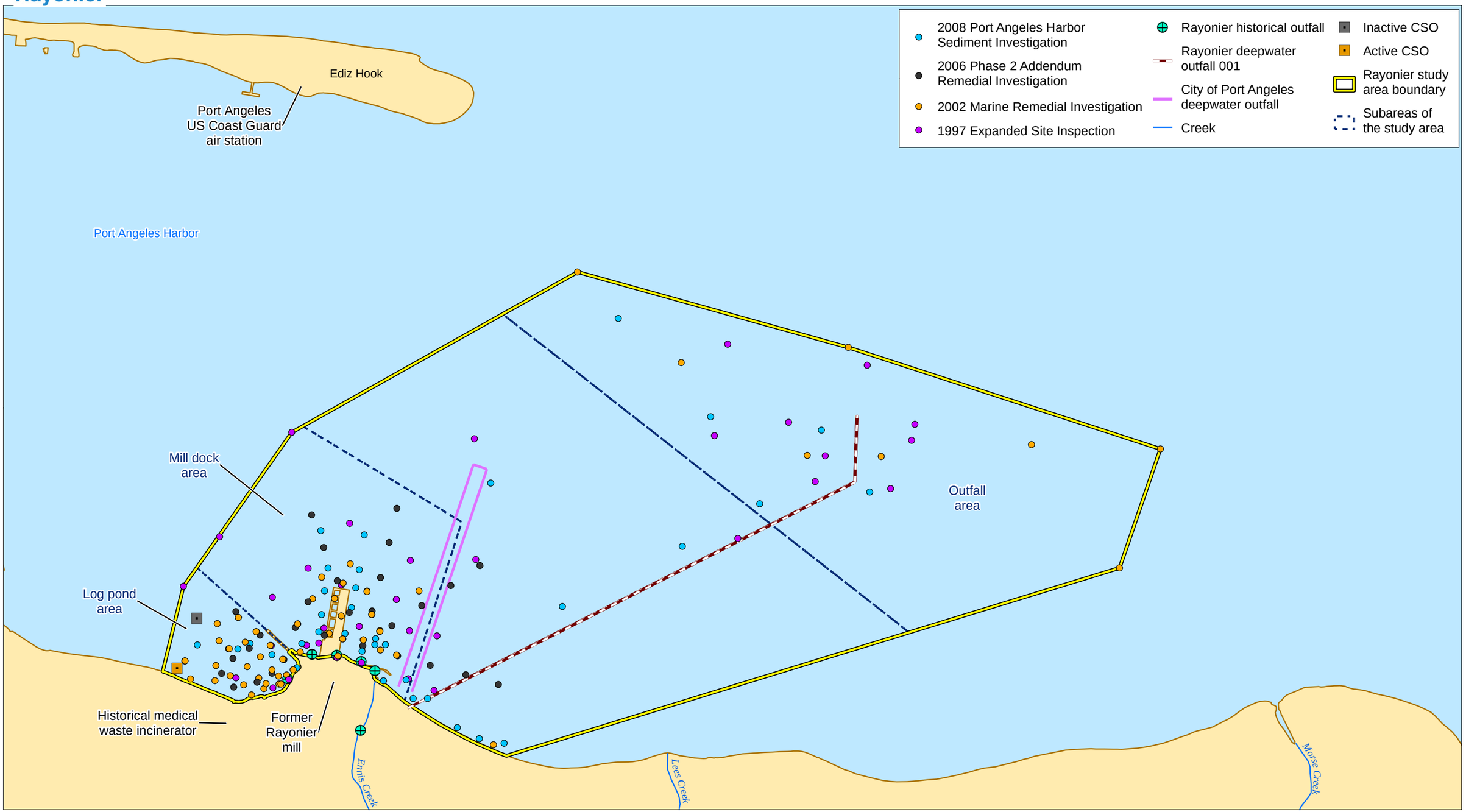
Rayonier



Wind Ward environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

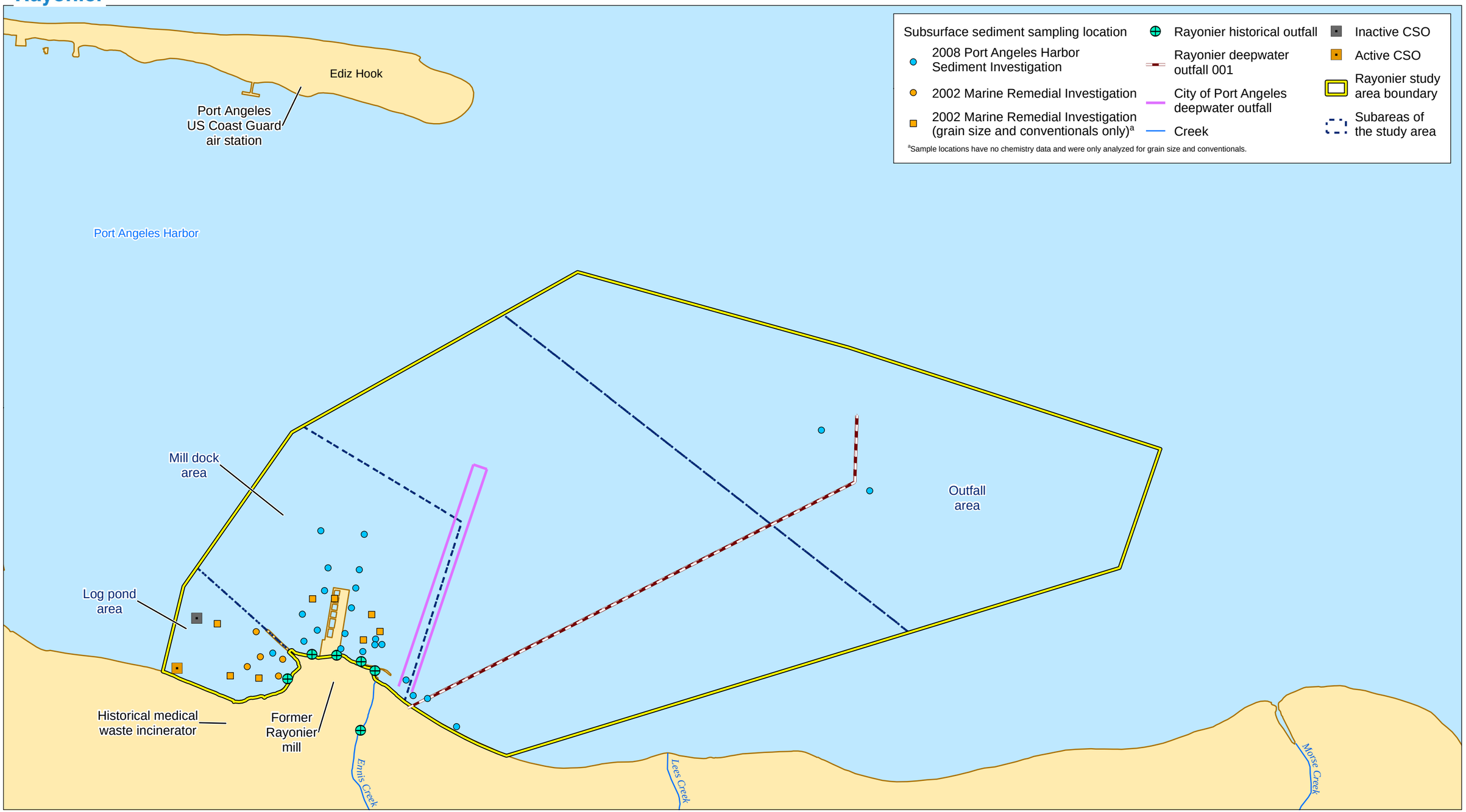
N

0 0.125 0.25 0.5 Miles

Map 2-1. Surface sediment sampling locations in the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5007_Surface sediment sampling locations in Port Angeles Harbor_MTY_08152013.mxd

Rayonier



Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles
storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

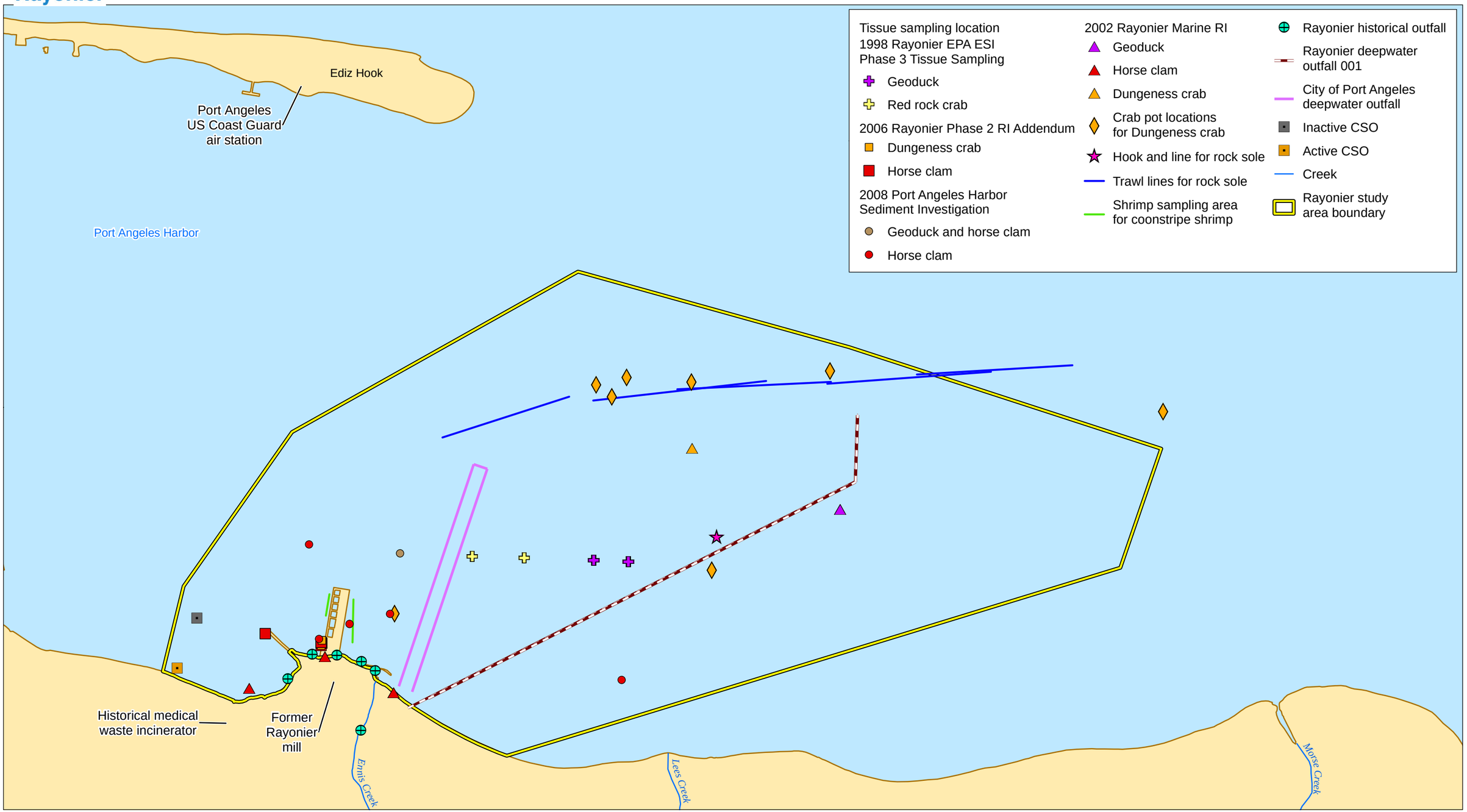
N

0 0.125 0.25 0.5 Miles

Map 2-2. Subsurface sediment sampling locations in the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5014_Subsurface sediment sampling locations in Port Angeles Harbor_MTY_08152013.mxd

Rayonier



Tissue sampling location

1998 Rayonier EPA ESI
Phase 3 Tissue Sampling
- Geoduck
- Red rock crab

2006 Rayonier Phase 2 RI Addendum
- Dungeness crab
- Horse clam

2008 Port Angeles Harbor
Sediment Investigation
- Geoduck and horse clam
- Horse clam

2002 Rayonier Marine RI
- Geoduck
- Horse clam
- Dungeness crab
- Crab pot locations for Dungeness crab
- Hook and line for rock sole
- Trawl lines for rock sole
- Shrimp sampling area for coonstripe shrimp

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

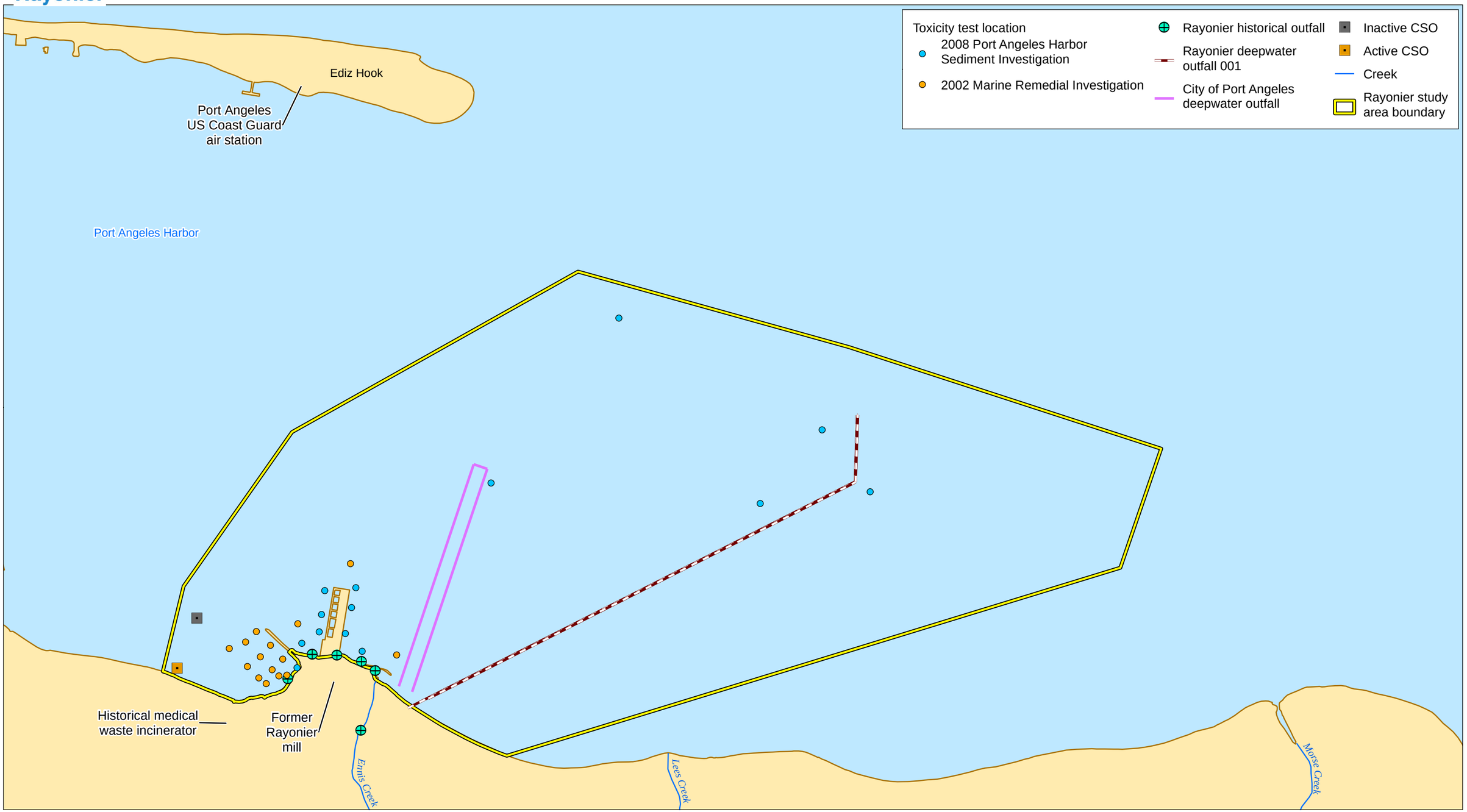
N

0 0.125 0.25 0.5 Miles

Map 2-3. Tissue sampling locations in the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5015_Tissue sampling locations in PA Harbor_MTY_08292013.mxd

Rayonier



Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

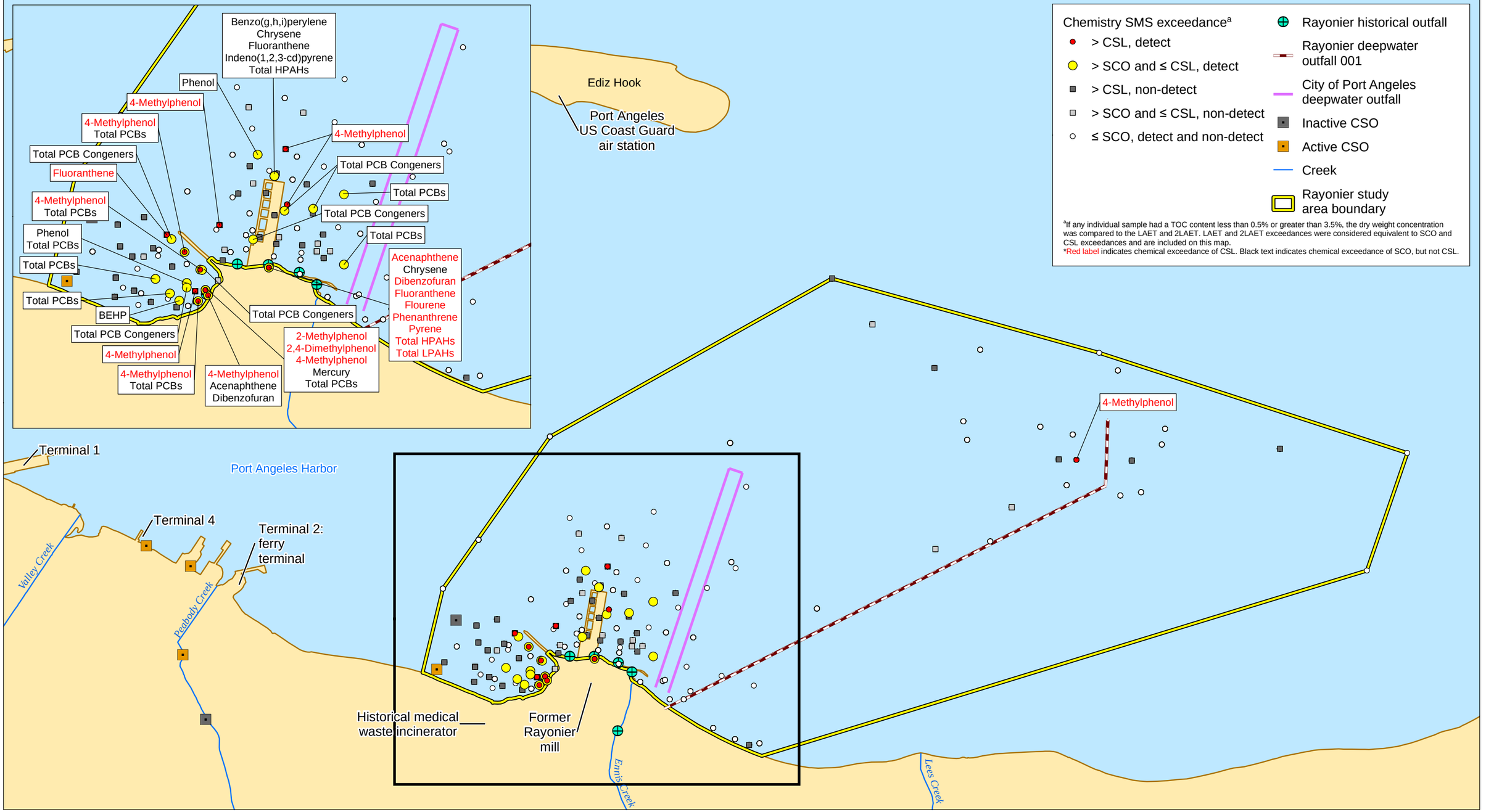
N

0 0.125 0.25 0.5 Miles

Map 2-4. Toxicity test sampling locations in the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5016_Toxicity test sampling locations in PA Harbor_MTY_08162013.mxd

Rayonier



Wind Ward environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

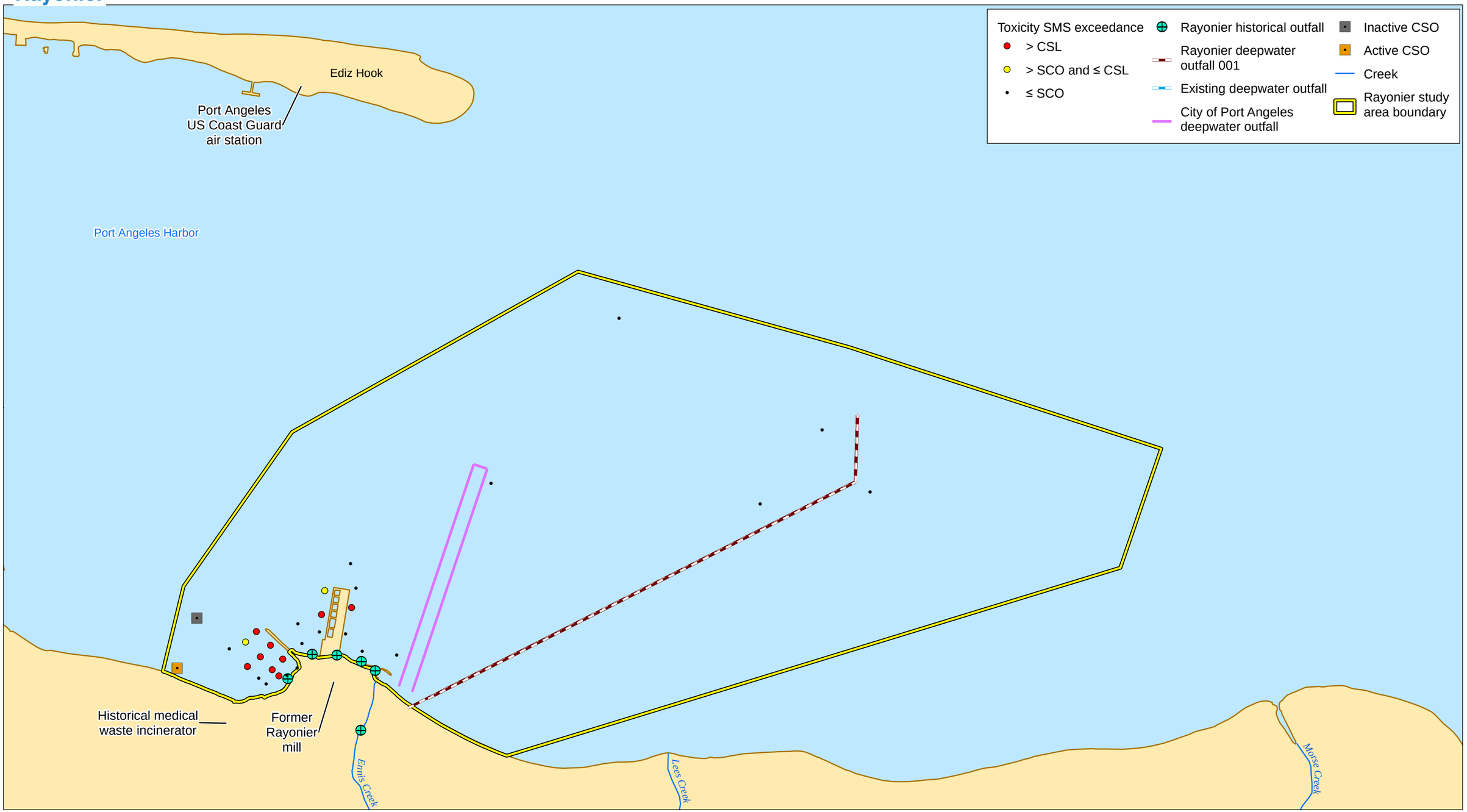
N

0 0.125 0.25 0.5 Miles

Map 2-5. Surface sediment sampling locations with SMS exceedances based on chemistry

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5017_Surface sediment sampling locations with SMS exceedances based on chemistry with labels_MTY_08272013.mxd

Rayonier



Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles
storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.125 0.25 0.5 Miles

Map 2-6. Surface sediment sampling locations with SMS exceedances based on toxicity

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5019_Surface sediment sampling locations with SMS exceedances based on toxicity_MTY_08292013.mxd

Rayonier

Ediz Hook

Port Angeles US Coast Guard air station

Port Angeles Harbor

Historical medical waste incinerator

Former Rayonier mill

Ennis Creek

Lees Creek

Morse Creek

Chemistry SMS exceedance

- > CSL, detect
- > SCO and ≤ CSL, detect
- > CSL, non-detect
- > SCO and ≤ CSL, non-detect
- ≤ SCO, detect and non-detect

Toxicity SMS exceedance

- > CSL
- > SCO and ≤ CSL
- ≤ SCO

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

[a]If any individual sample had a TOC content less than 0.5% or greater than 3.5%, the dry weight concentration was compared to the LAET and 2LAET. LAET and 2LAET exceedances were considered equivalent to SCO and CSL exceedances and are included on this map.

Wind Ward environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.125 0.25 0.5 Miles

Map 2-7. Surface sediment sampling locations with SMS exceedances based on chemistry and toxicity

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5020_Sediment sampling locations with SMS exceedances based on both chemistry and toxicity_MTY_08292013.mxd

Rayonier

Ediz Hook

Port Angeles
US Coast Guard
air station

Port Angeles Harbor

Historical medical
waste incinerator

Former
Rayonier
mill

Ennis Creek

Lees Creek

Morse Creek

Dioxin and furan TEQs (ng/kg dw)[a]	Dioxin and furan TEQs (ng/kg dw)[a]
> 20.4	> 20.4
> 7.06 and ≤ 20.4	> 7.06 and ≤ 20.4
> 2.44 and ≤ 7.06	> 2.44 and ≤ 7.06
> 0.984 and ≤ 2.44	> 0.984 and ≤ 2.44
≤ 0.984	≤ 0.984

95th percentile = 20.4
75th percentile = 7.06
50th percentile = 2.44
25th percentile = 0.984

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

[a] Dioxin and furan TEQs were calculated using mammalian TEFs for individual dioxin and furan congeners (Van den Berg et al. 2006), using one-half the reporting limit for undetected congeners (see Appendix D for details). At least one dioxin and furan congener was detected in all 97 surface sediment samples analyzed for dioxins and furans.

Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

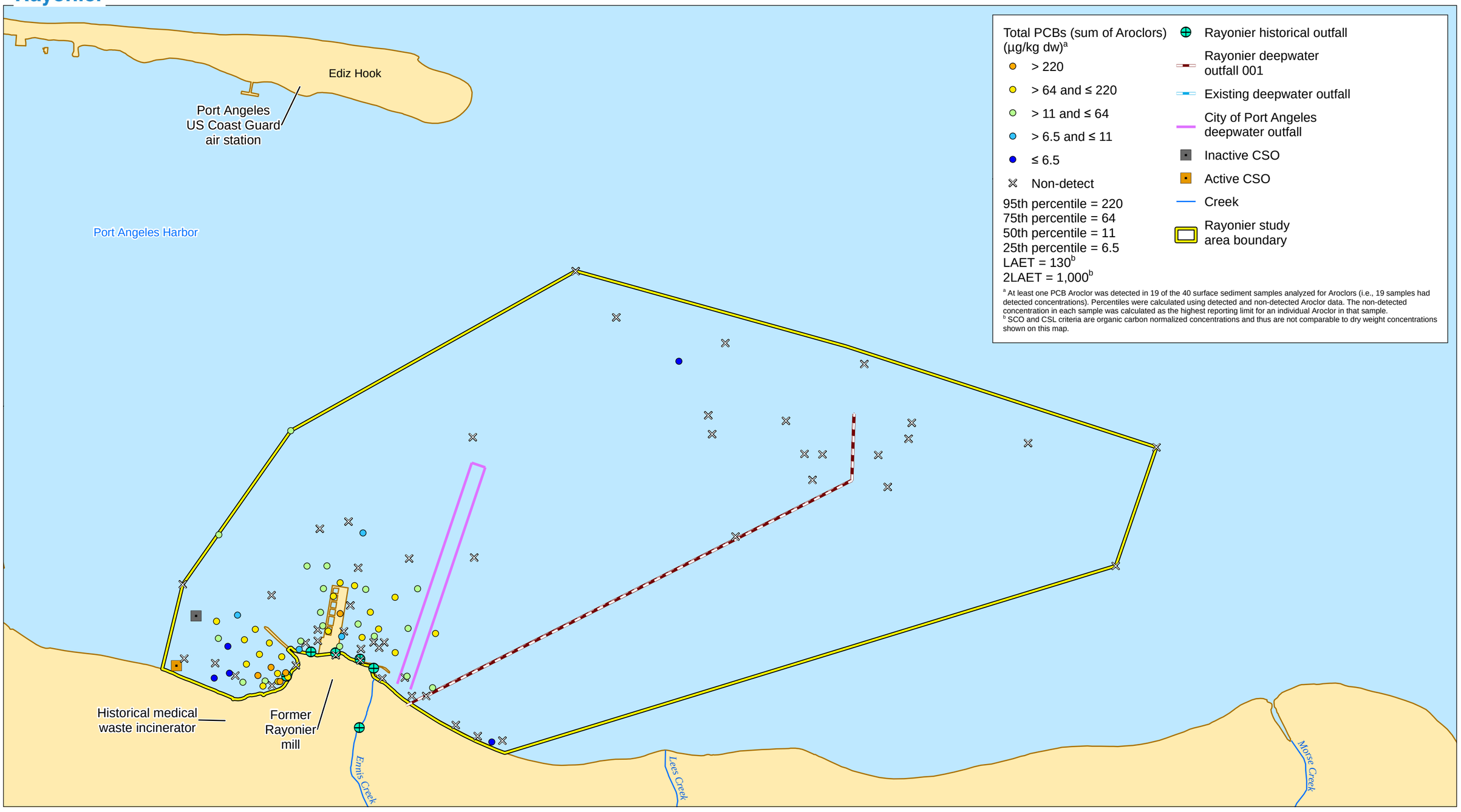
N

0 0.125 0.25 0.5 Miles

Map 2-8. Dioxin and furan TEQs in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5021_Dioxin furan TEQ in surface sediment samples from PA Harbor_MTY_08202013.mxd

Rayonier



Total PCBs (sum of Aroclors) (µg/kg dw)[a]

- > 220
- > 64 and ≤ 220
- > 11 and ≤ 64
- > 6.5 and ≤ 11
- ≤ 6.5
- Non-detect

95th percentile = 220
75th percentile = 64
50th percentile = 11
25th percentile = 6.5
LAET = 130[b]
2LAET = 1,000[b]

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- Existing deepwater outfall
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

[a] At least one PCB Aroclor was detected in 19 of the 40 surface sediment samples analyzed for Aroclors (i.e., 19 samples had detected concentrations). Percentiles were calculated using detected and non-detected Aroclor data. The non-detected concentration in each sample was calculated as the highest reporting limit for an individual Aroclor in that sample.
[b] SCO and CSL criteria are organic carbon normalized concentrations and thus are not comparable to dry weight concentrations shown on this map.

Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.125 0.25 0.5 Miles

Map 2-9. Total PCB (Aroclor sum) concentrations in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5023_Total PCBs in surface sediment from PA Harbor_MTY_08202013.mxd

Rayonier

Ediz Hook

Port Angeles
US Coast Guard
air station

Port Angeles Harbor

Historical medical
waste incinerator

Former
Rayonier
mill

Ennis Creek

Lees Creek

Morse Creek

PCB TEQs (ng/kg dw)[a]

- > 6.48
- > 2.14 and ≤ 6.48
- > 0.777 and ≤ 2.14
- > 0.293 and ≤ 0.777
- ≤ 0.293

95th percentile = 6.48
75th percentile = 2.14
50th percentile = 0.777
25th percentile = 0.293

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

[a] PCB TEQs were calculated using mammalian TEFs for individual PCB congeners (Van den Berg et al. 2006), using one-half the reporting limit for undetected congeners (see Appendix D for details). At least one PCB congener was detected in all 28 surface sediment samples analyzed for PCB congeners (i.e., 28 samples had detected PCB TEQs). Data for all 28 samples were used in calculating percentiles.

Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

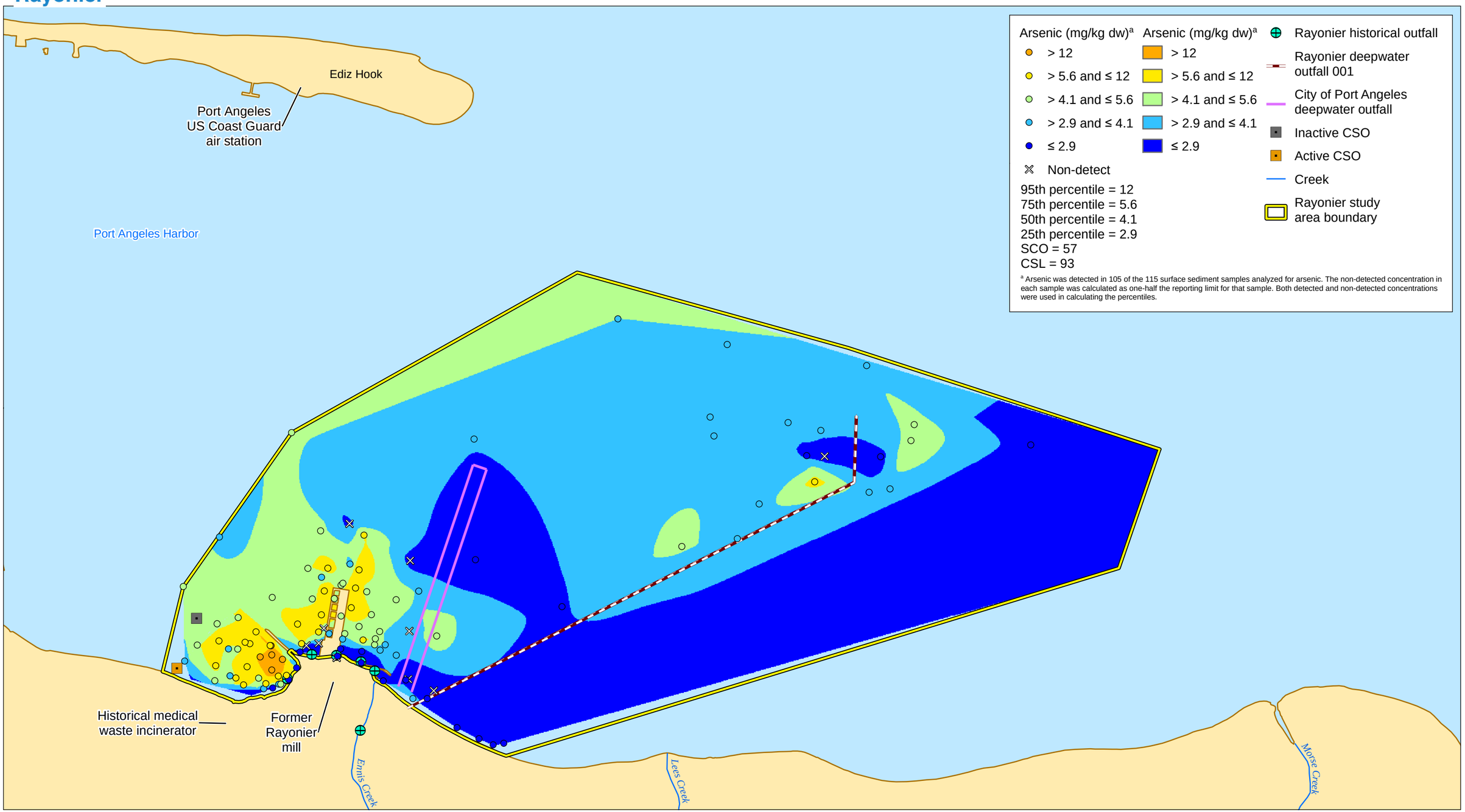
N

0 0.125 0.25 0.5 Miles

Map 2-10. PCB TEQs in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5025_PCB TEQs in surface sediment from PA Harbor_MTY_08202013.mxd

Rayonier



Arsenic (mg/kg dw)[a]

- > 12
- > 5.6 and ≤ 12
- > 4.1 and ≤ 5.6
- > 2.9 and ≤ 4.1
- ≤ 2.9
- Non-detect

Arsenic (mg/kg dw)[a]

- > 12
- > 5.6 and ≤ 12
- > 4.1 and ≤ 5.6
- > 2.9 and ≤ 4.1
- ≤ 2.9

95th percentile = 12
75th percentile = 5.6
50th percentile = 4.1
25th percentile = 2.9
SCO = 57
CSL = 93

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

[a] Arsenic was detected in 105 of the 115 surface sediment samples analyzed for arsenic. The non-detected concentration in each sample was calculated as one-half the reporting limit for that sample. Both detected and non-detected concentrations were used in calculating the percentiles.

Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.125 0.25 0.5 Miles

Map 2-11. Arsenic concentrations in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5027_Arsenic in surface sediment samples from Port Angeles Harbor_MTY_08202013.mxd

Rayonier

Ediz Hook

Port Angeles
US Coast Guard
air station

Port Angeles Harbor

Historical medical
waste incinerator

Former
Rayonier
mill

Ennis Creek

Lees Creek

Morse Creek

cPAH TEQ (µg/kg dw)[a]
- > 470
- > 140 and ≤ 470
- > 46 and ≤ 140
- > 6.6 and ≤ 46
- ≤ 6.6
- Non-detect

95th percentile = 470
75th percentile = 140
50th percentile = 46
25th percentile = 6.6

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

[a] cPAH TEQs were calculated using compound-specific mammalian PEFs for seven individual cPAH compounds (Washington Administrative Code 173-340-708[e]), using one-half the reporting limit for undetected compounds (see Appendix D for details). At least one cPAH compound was detected in 92 of the 116 surface sediment samples analyzed for cPAHs. The non-detected concentration in each sample with no detected cPAH compounds was calculated as the sum of one-half the reporting limit multiplied by the PEF for each compound. Both detected and non-detected concentrations were used in calculating percentiles.

WindWard environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles
storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

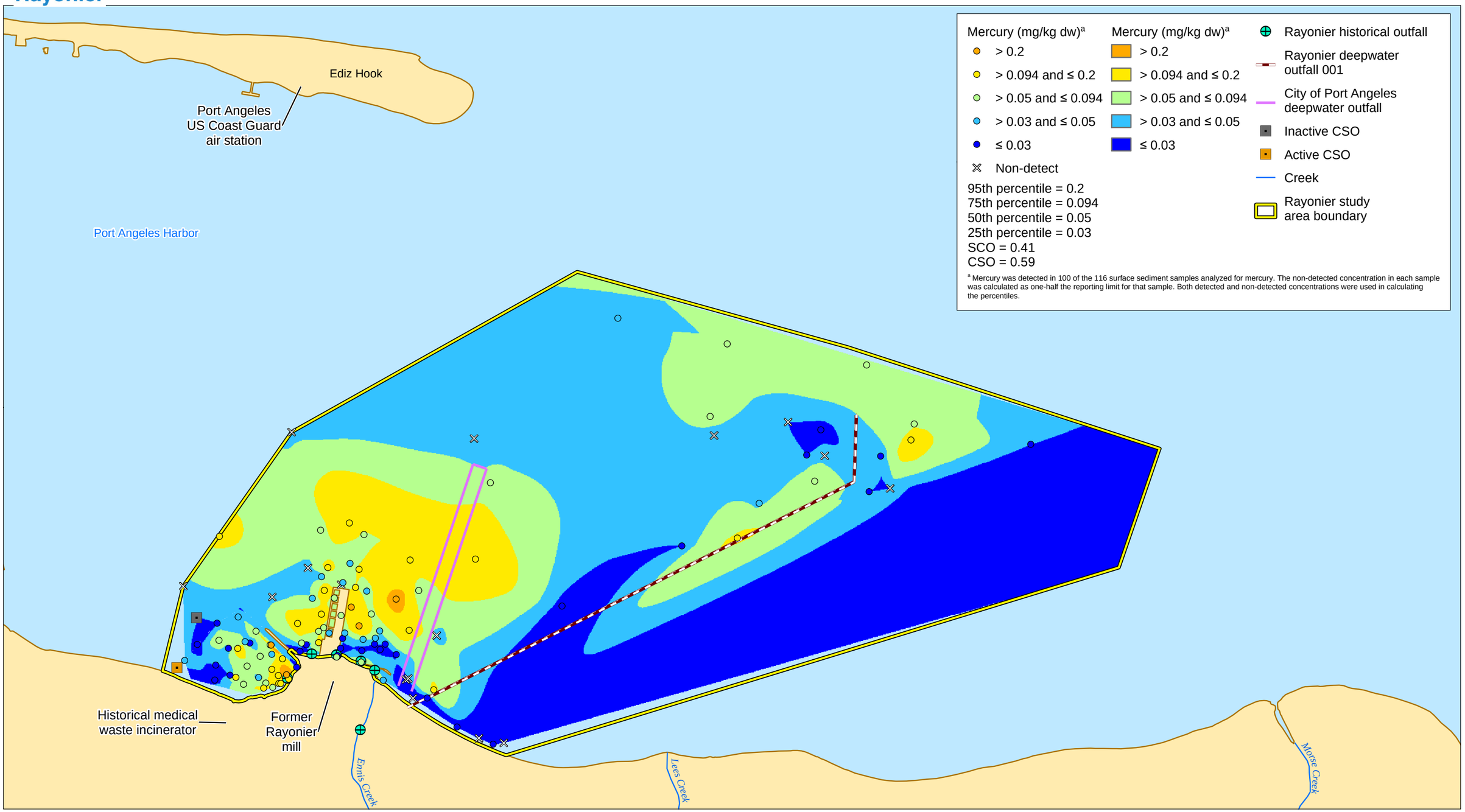
N

0 0.125 0.25 0.5 Miles

Map 2-12. cPAH TEQs in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5030_cPAHs in surface sediment samples from Port Angeles Harbor_MTY_08202013.mxd

Rayonier



Mercury (mg/kg dw)[a]
- > 0.2
- > 0.094 and ≤ 0.2
- > 0.05 and ≤ 0.094
- > 0.03 and ≤ 0.05
- ≤ 0.03
- Non-detect

Mercury (mg/kg dw)[a]
- > 0.2
- > 0.094 and ≤ 0.2
- > 0.05 and ≤ 0.094
- > 0.03 and ≤ 0.05
- ≤ 0.03

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

95th percentile = 0.2
75th percentile = 0.094
50th percentile = 0.05
25th percentile = 0.03
SCO = 0.41
CSO = 0.59

[a] Mercury was detected in 100 of the 116 surface sediment samples analyzed for mercury. The non-detected concentration in each sample was calculated as one-half the reporting limit for that sample. Both detected and non-detected concentrations were used in calculating the percentiles.

Wind Ward environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

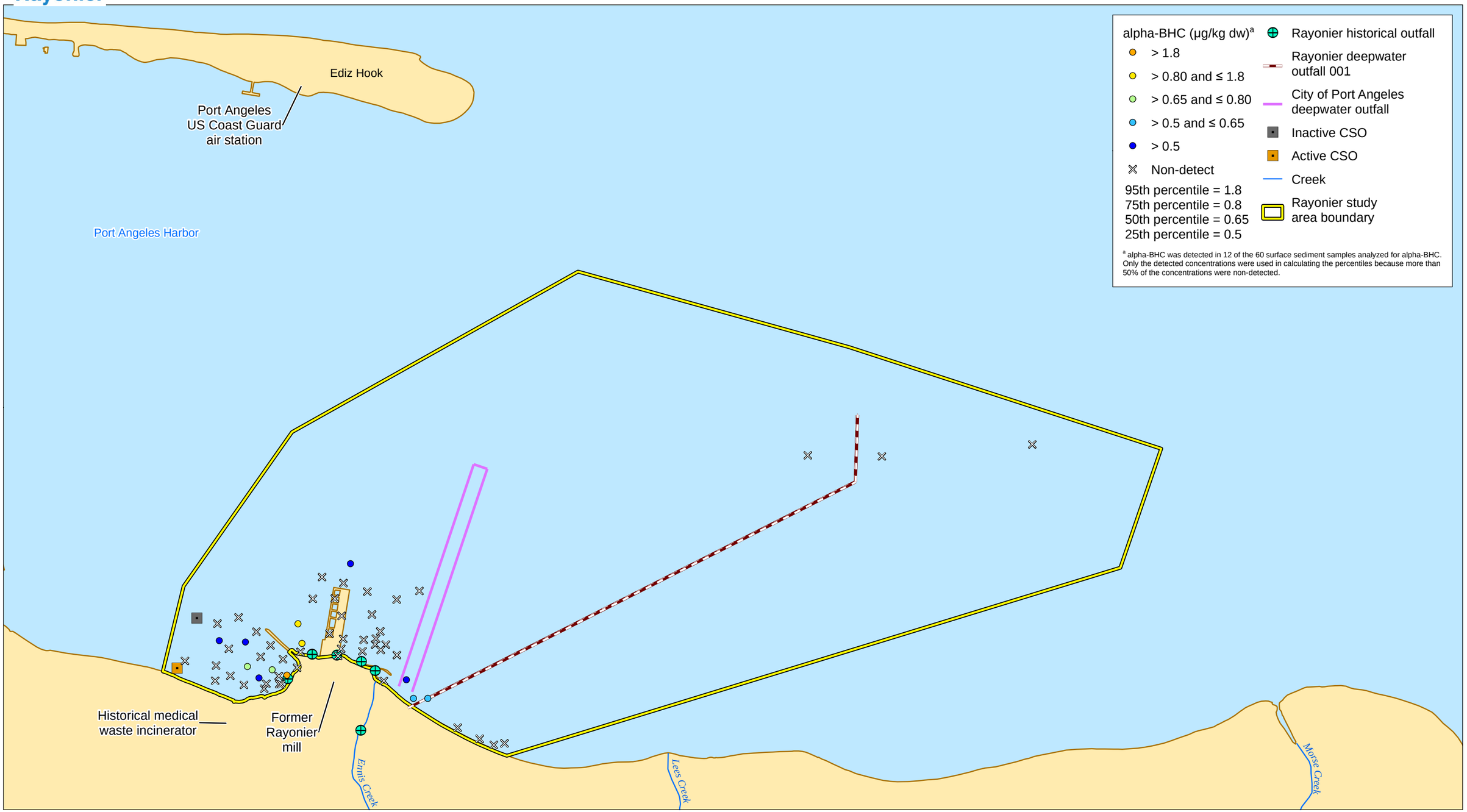
N

0 0.125 0.25 0.5 Miles

Map 2-13. Mercury concentrations in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5032_Mercury in surface sediment samples from Port Angeles Harbor_MTY_08202013.mxd

Rayonier



Wind Ward environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

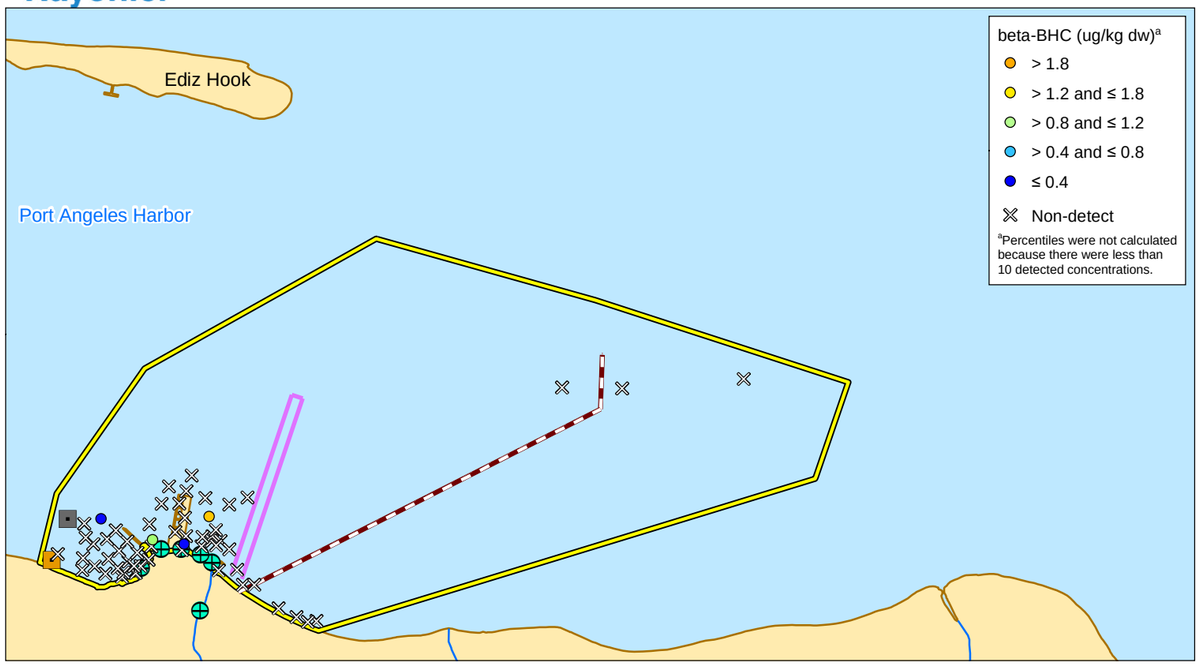
N

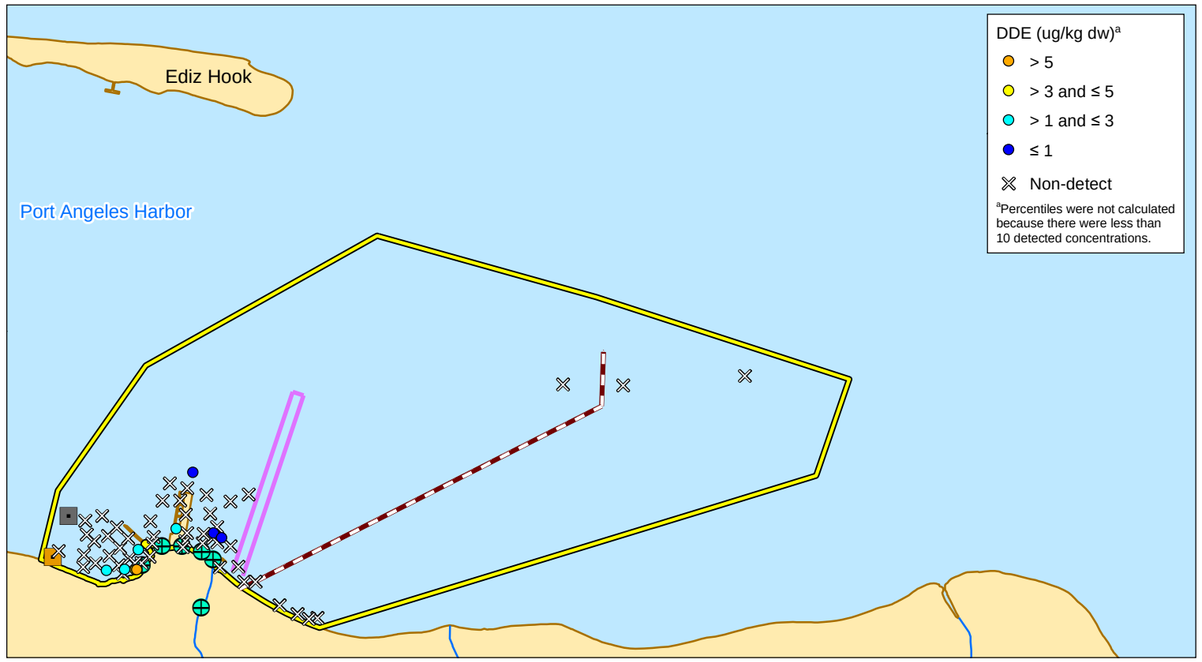
0 0.125 0.25 0.5 Miles

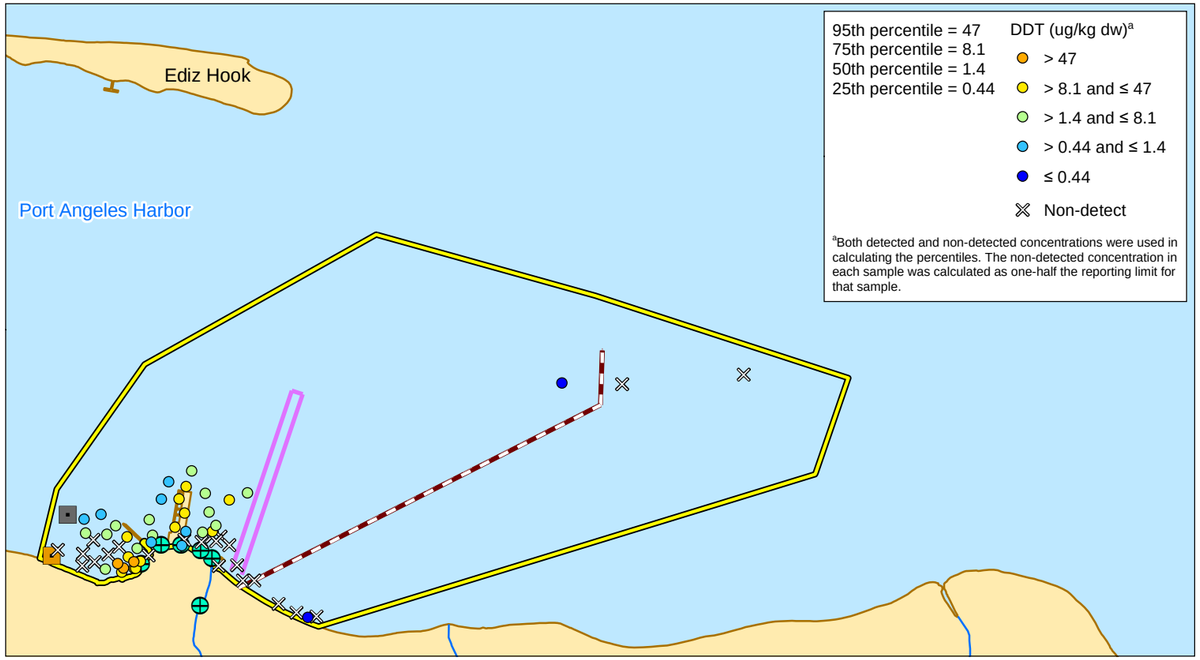
Map 2-14. alpha-BHC concentrations in surface sediment samples from the study area

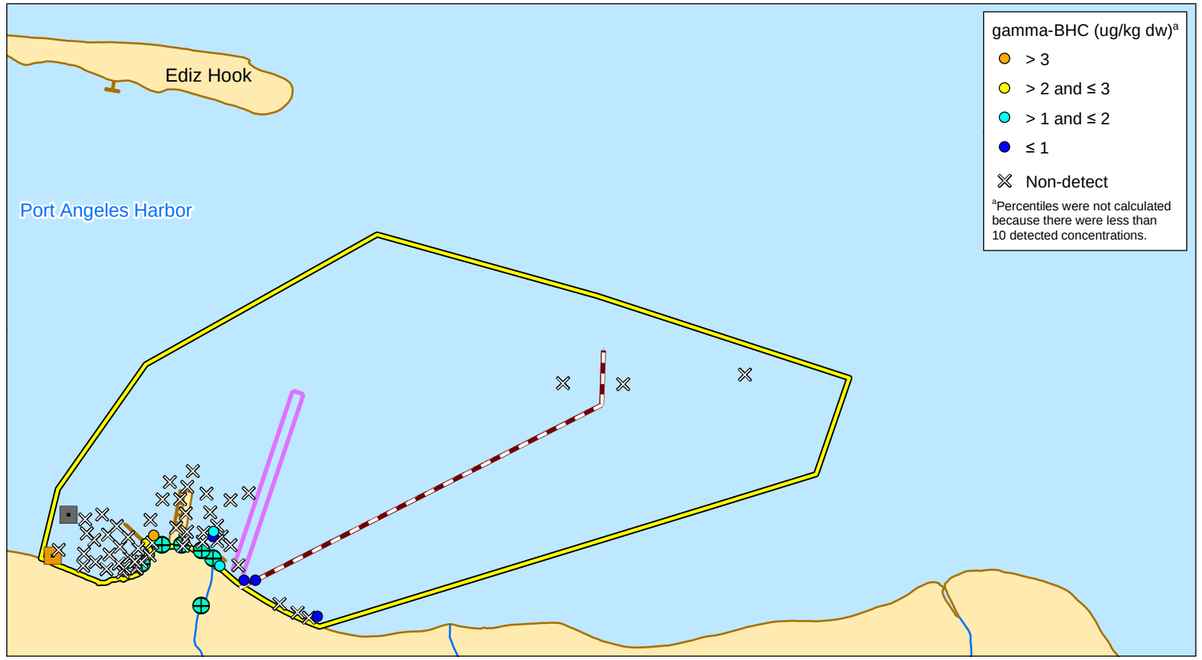
Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5035_Alpha-BHC in surface sediment samples from Port Angeles Harbor_MTY_08202013.mxd

Rayonier









Wind Ward LLC environmental

N

0 0.225 0.45 0.9 Miles

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

Map 2-15. beta-BHC, DDE, DDT, and gamma-BHC concentrations in surface sediment sampling locations from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5620_DDE_DDT_Beta-BHC_and Gamma-BHC concentrations in surface sediment sample locations from PA Harbor_MTY_08202013.mxd

Rayonier

Hexachlorobenzene[a]
Non-detect

Ediz Hook

Port Angeles Harbor

Pentachlorophenol (ug/kg dw)[b]
> 40
> 30 and ≤ 40
> 20 and ≤ 30
> 10 and ≤ 20
≤ 10
Non-detect
SCO = 360
CSL = 690

Rayonier historical outfall
Rayonier deepwater outfall 001
City of Port Angeles deepwater outfall
Inactive CSO
Active CSO
Creek
Rayonier study area boundary

N
0 0.25 0.5 1 Miles

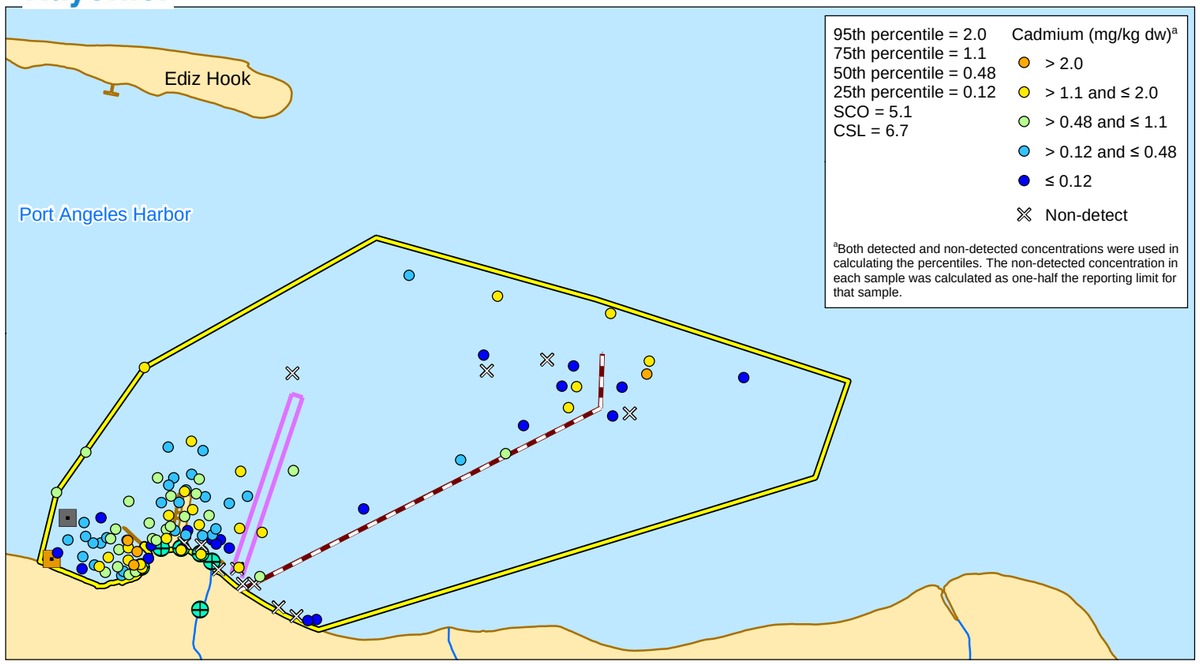
[a]Hexachlorobenzene was not detected in any of the 60 surface sediment samples analyzed for hexachlorobenzene.
[b]Pentachlorophenol was detected in 2 of 83 surface sediment samples analyzed for pentachlorophenol. Percentiles were not calculated because there were less than 10 detected concentrations.

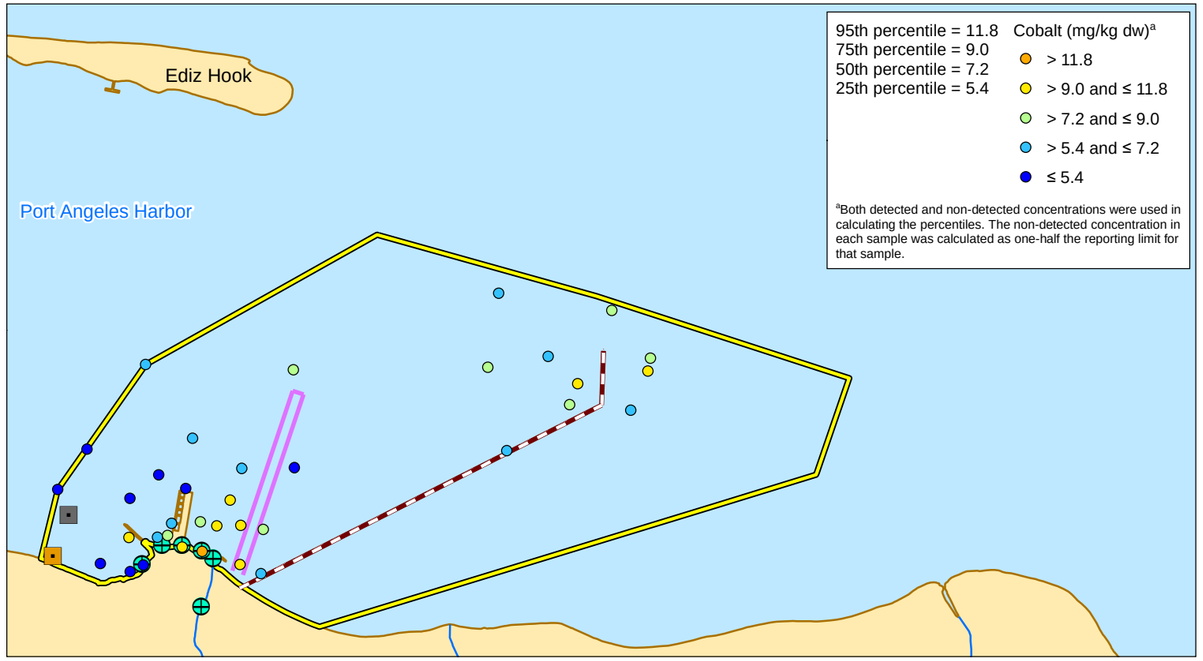
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

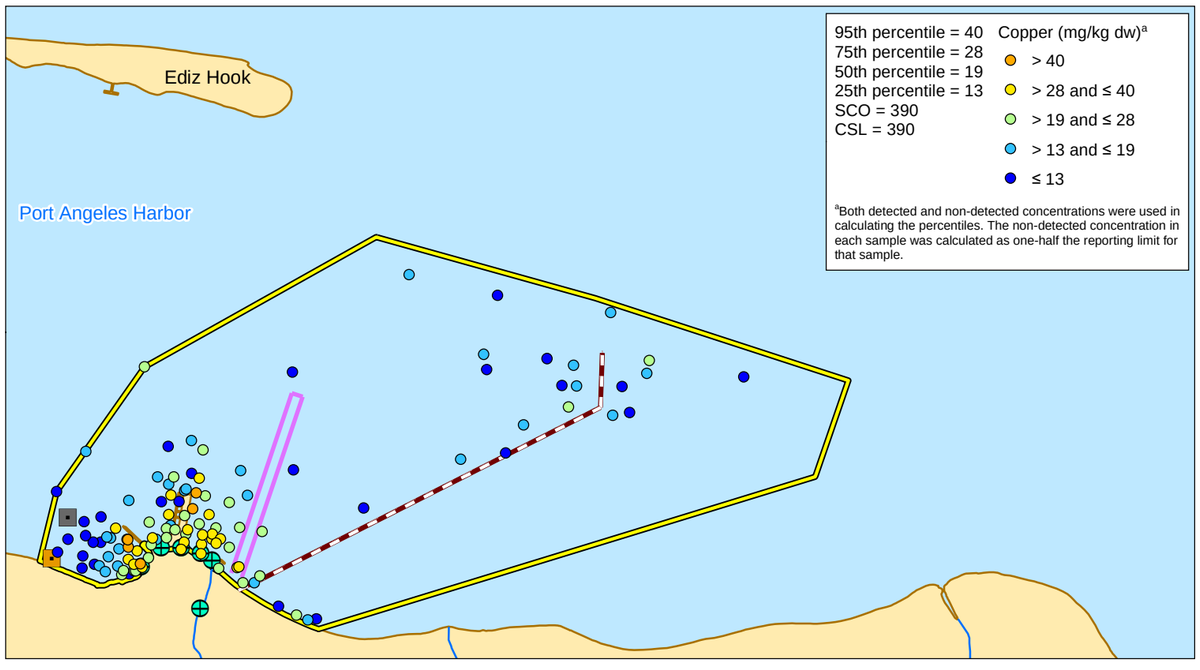
Map 2-16. Hexachlorobenzene and pentachorophenol concentrations in surface sediment sampling locations from the study area

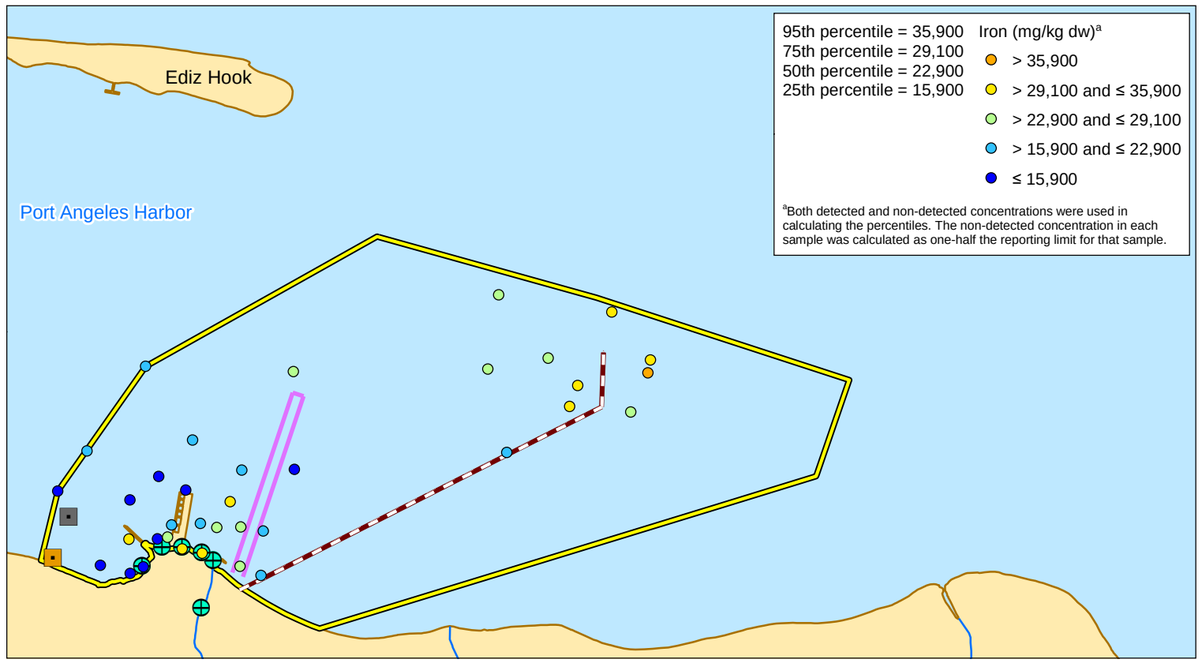
Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5622_Pentachlorophenol and hexachlorobenzene concentrations in surface sediment sample locations from PA Harbor_MTY_08232013.mxd

Rayonier









Wind Ward LLC environmental

N

0 0.225 0.45 0.9 Miles

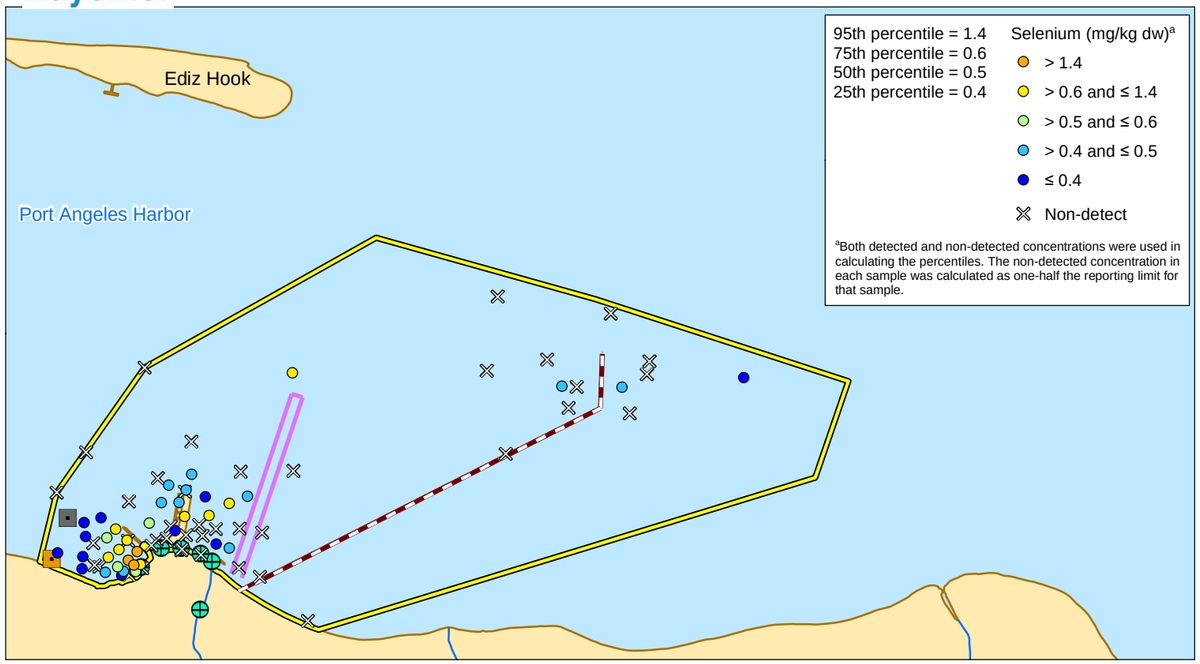
Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

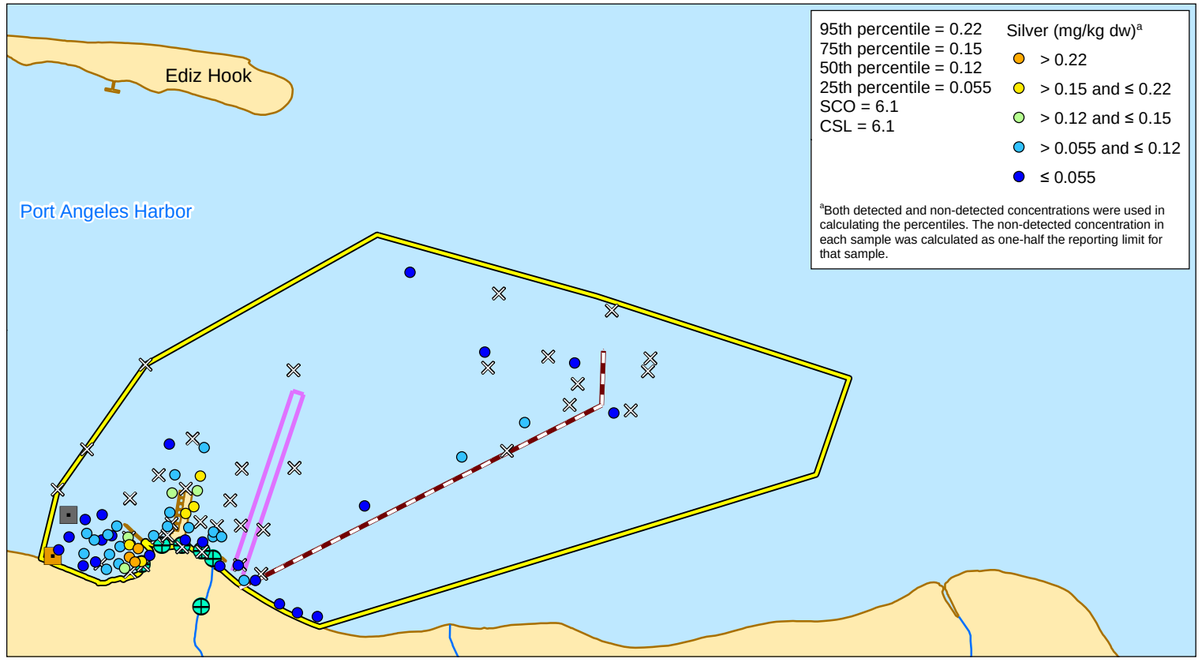
- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

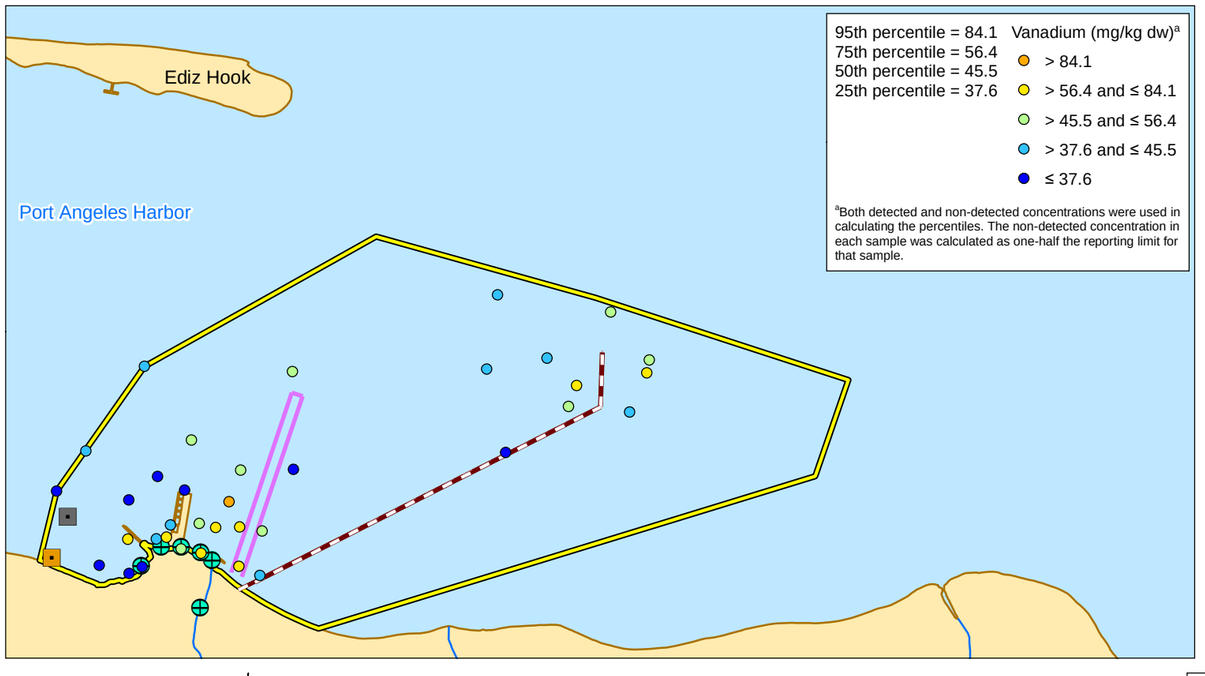
Map 2-17. Cadmium, cobalt, copper, and iron concentrations in surface sediment sampling locations from the study area

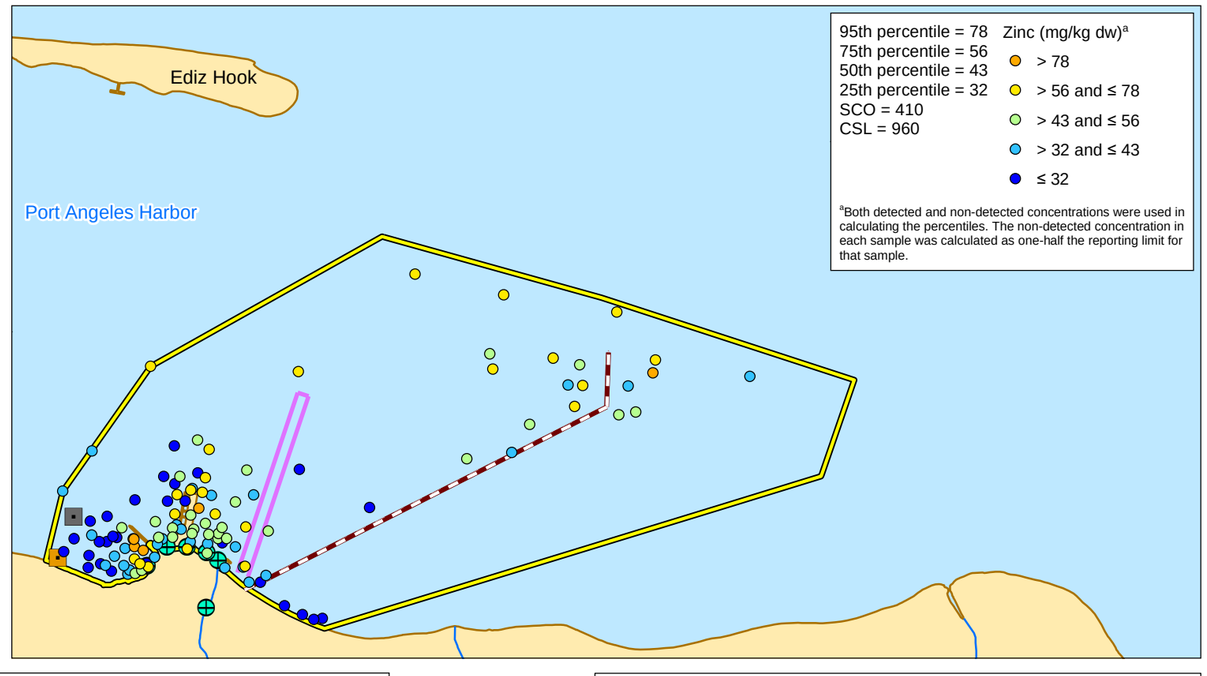
Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5625_Cadmium, cobalt, copper, and iron concentrations in surface sediment sample locations from PA Harbor_MTY_08262013.mxd

Rayonier









Wind Ward LLC environmental

N

0 0.225 0.45 0.9 Miles

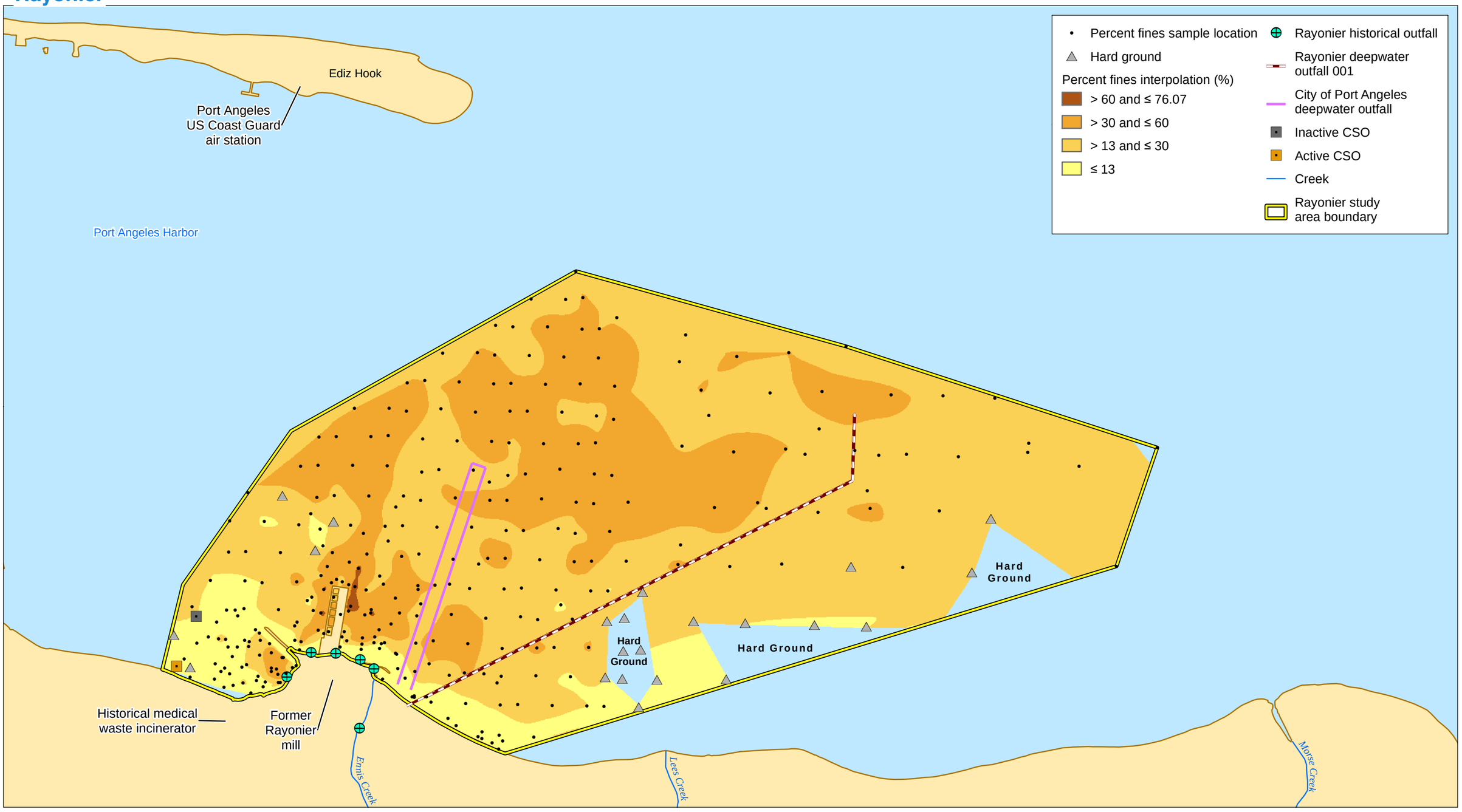
Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

- Rayonier historical outfall
- Rayonier deepwater outfall 001
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO
- Creek
- Rayonier study area boundary

Map 2-18. Selenium, silver, vanadium, and zinc concentrations in surface sediment sampling locations from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5626_Selenium, silver, vanadium, and zinc concentrations in surface sediment sample locations from PA Harbor_MTY_08262013.mxd

Rayonier



Wind Ward environmental LLC

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

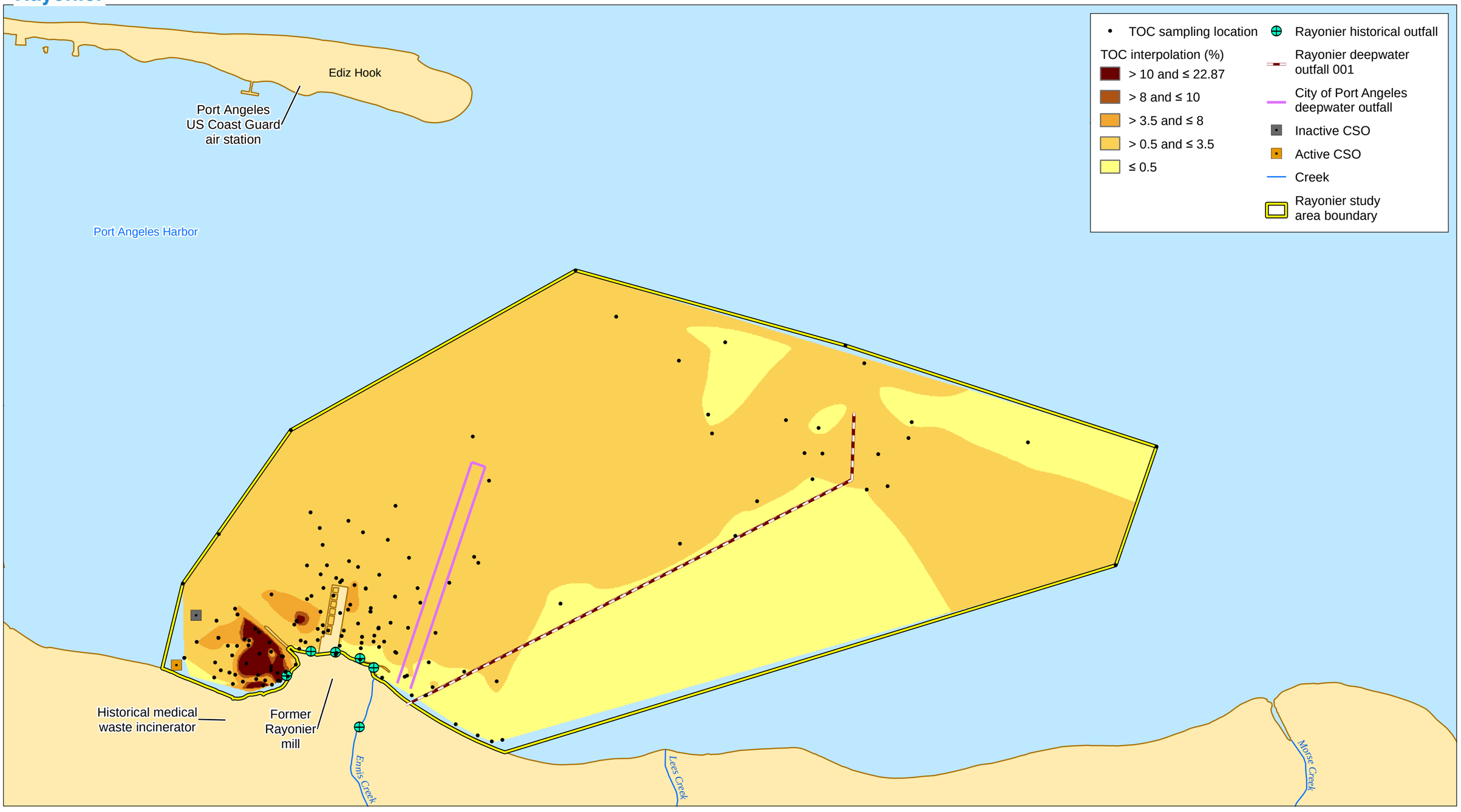
N

0 0.125 0.25 0.5 Miles

Map 2-19. Sediment grain size in surface sediment samples from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5131_Grain size w STA and WW combined dataset_MTY_081913.mxd

Rayonier



Wind Ward environmental LLC

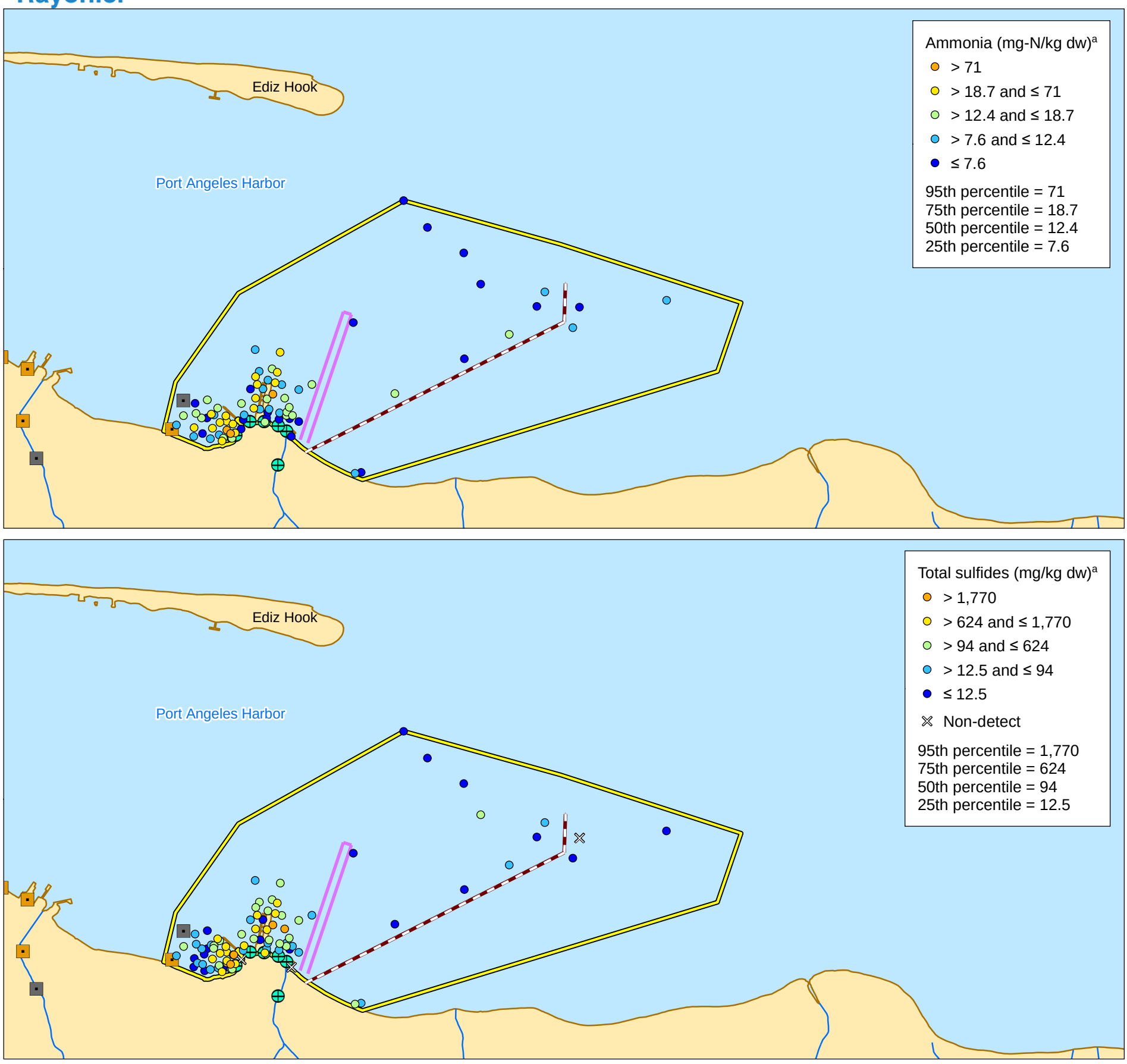
Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.125 0.25 0.5 Miles

Map 2-20. TOC content in surface sediment from the study area

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5054_TOC content in surface sediment for PA Harbor w NN interpolation_MTY_08202013.mxd

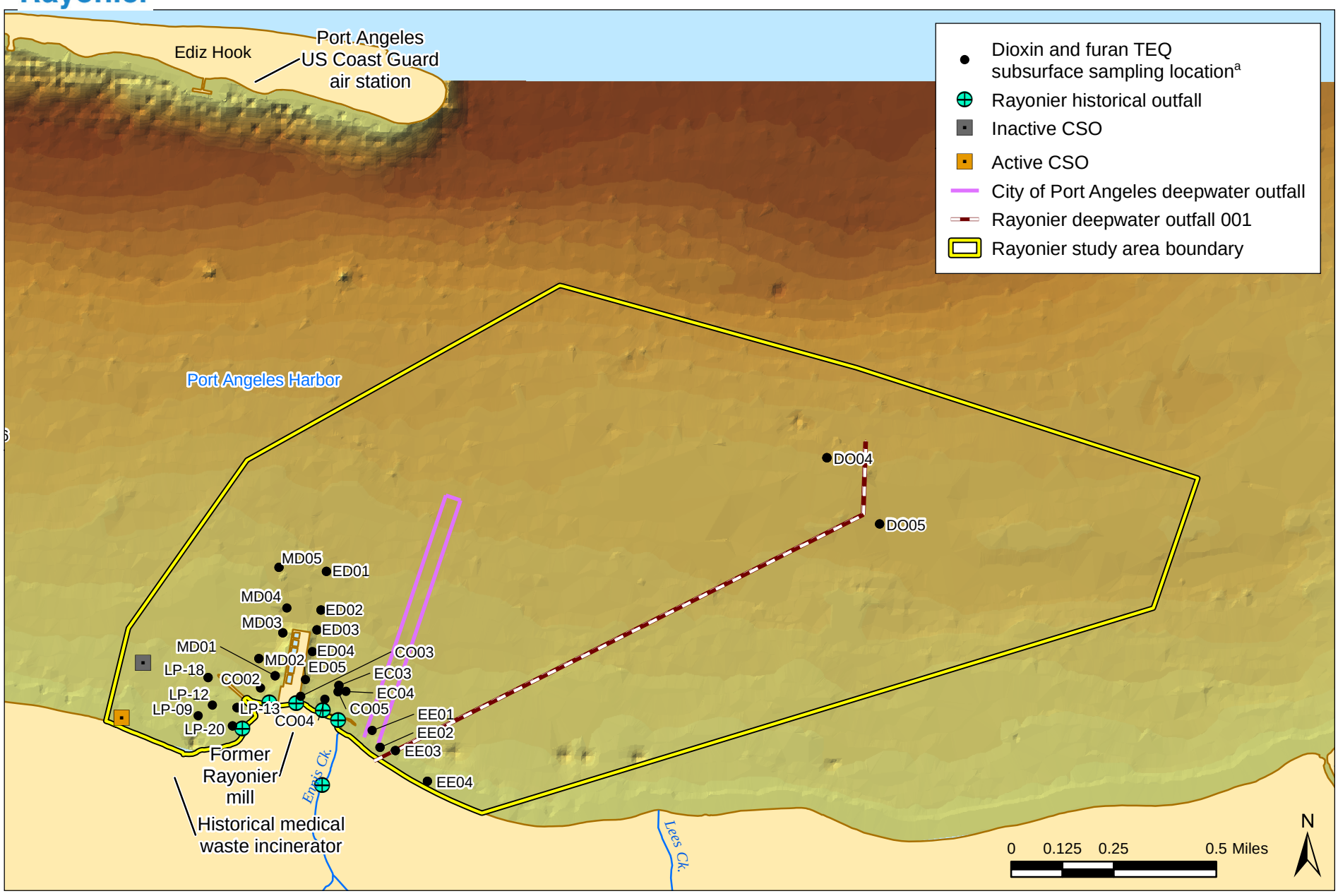


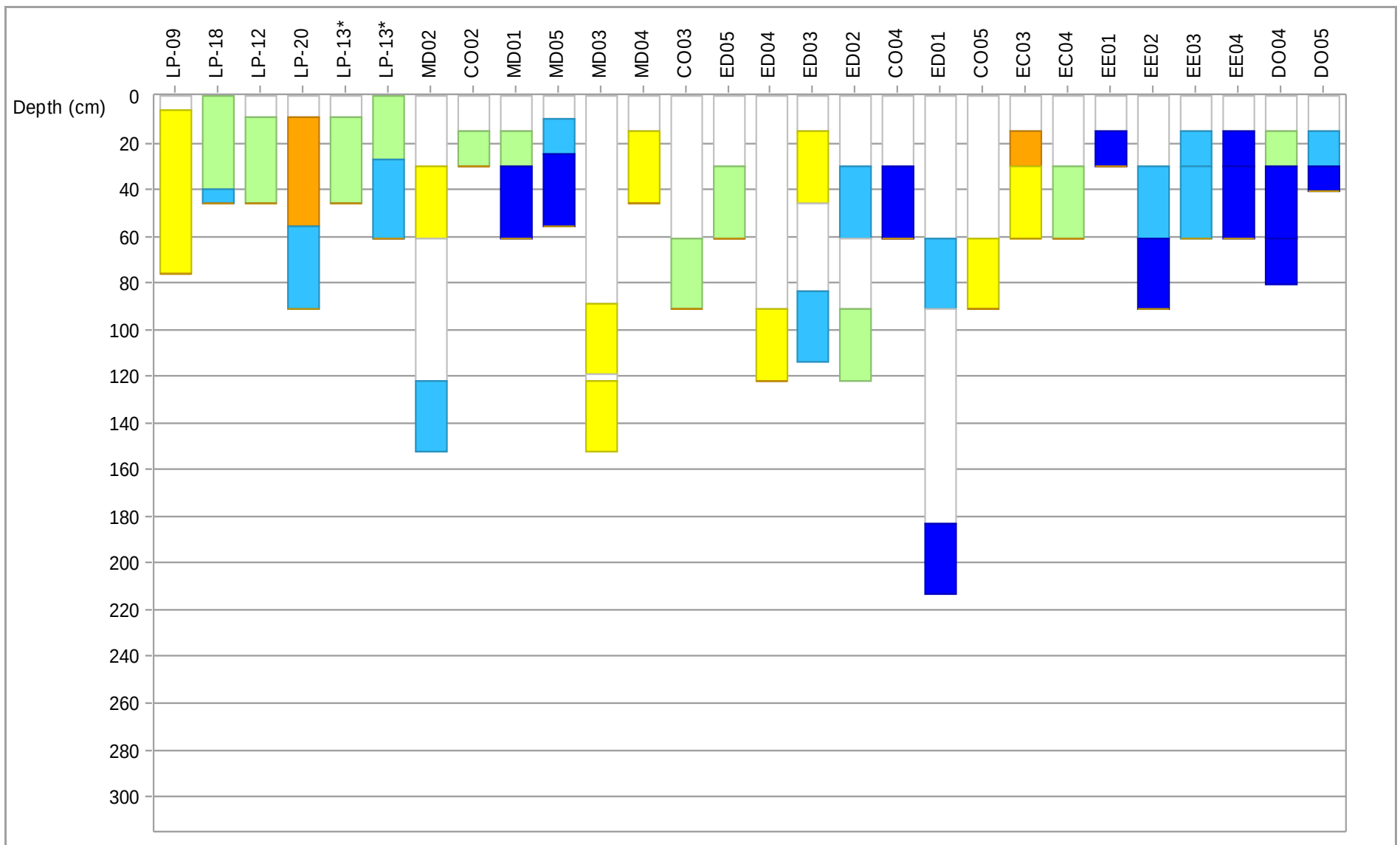
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

[a]Both detected and non-detected concentrations were used in calculating the percentiles. The non-detected concentration in each sample was calculated as one-half the reporting limit for that sample.

Map 2-21. Ammonia, total sulfides, and total volatile solids concentrations in surface sediment samples from the study area

Rayonier





*Samples collected from location LP-13 were analyzed at overlapping depth intervals.

Dioxin and furan TEQ (ng/kg dw) in subsurface cores[a]

95th percentile = 21.5
75th percentile = 6.34
50th percentile = 1.35
25th percentile = 0.604

- > 21.5
- > 6.34 and ≤ 21.5
- > 1.35 and ≤ 6.34
- > 0.604 and ≤ 1.35
- ≤ 0.604
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

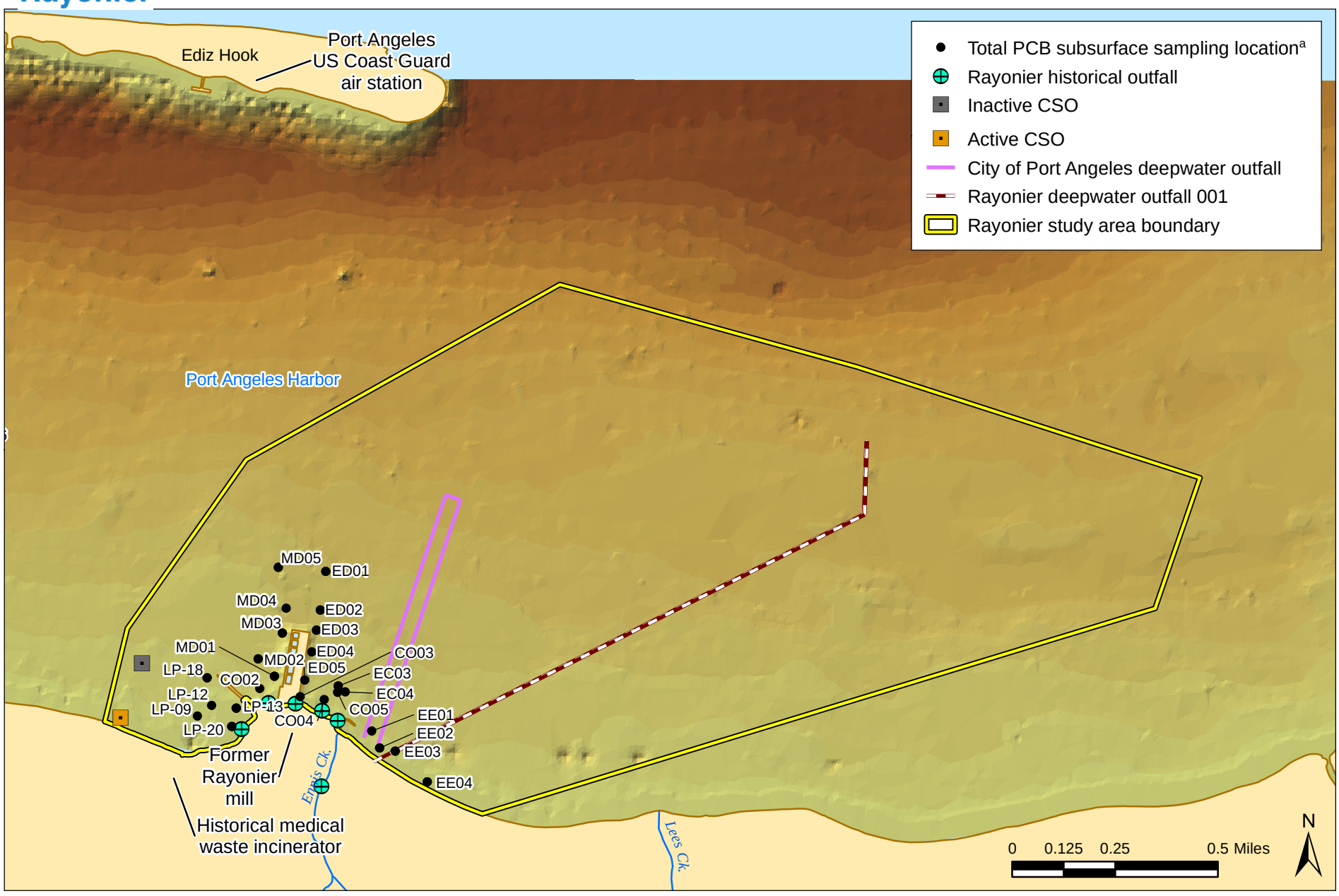
[a] Dioxin and furan TEQs were calculated using mammalian TEFs for individual dioxin and furan congeners (Van den Berg et al. 2006), using one-half the reporting limit for undetected congeners (see Appendix D for details). At least one dioxin and furan congener was detected in all 45 subsurface sediment samples. Data for all 45 samples were used in calculating percentiles.

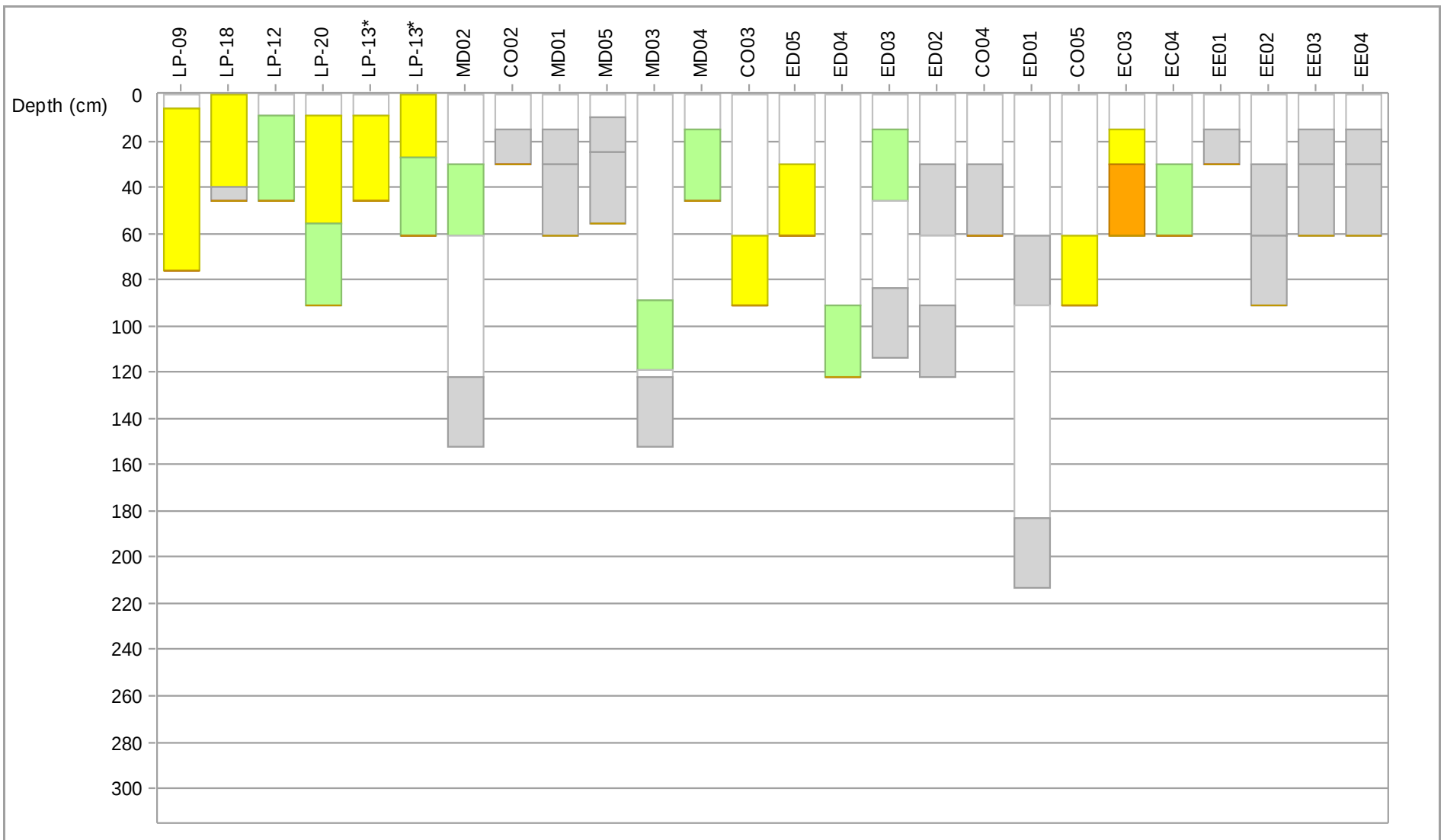
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-22. Dioxin and furan TEQs in subsurface sediment samples from the study area

Wind Ward environmental LLC

Rayonier





*Samples collected from location LP-13 were analyzed at overlapping depth intervals.

Total PCB concentration
(ug/kg dw) in subsurface cores[a]

95th percentile = 380
75th percentile = 76
50th percentile = 3.9
25th percentile = 3.4
LAET = 130[b]
2LAET = 1,000[b]

- > 380
- > 76 and ≤ 380
- > 3.9 and ≤ 76
- > 3.4 and ≤ 3.9
- ≤ 3.4
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-23. Total PCB concentrations in subsurface sediment samples from the study area

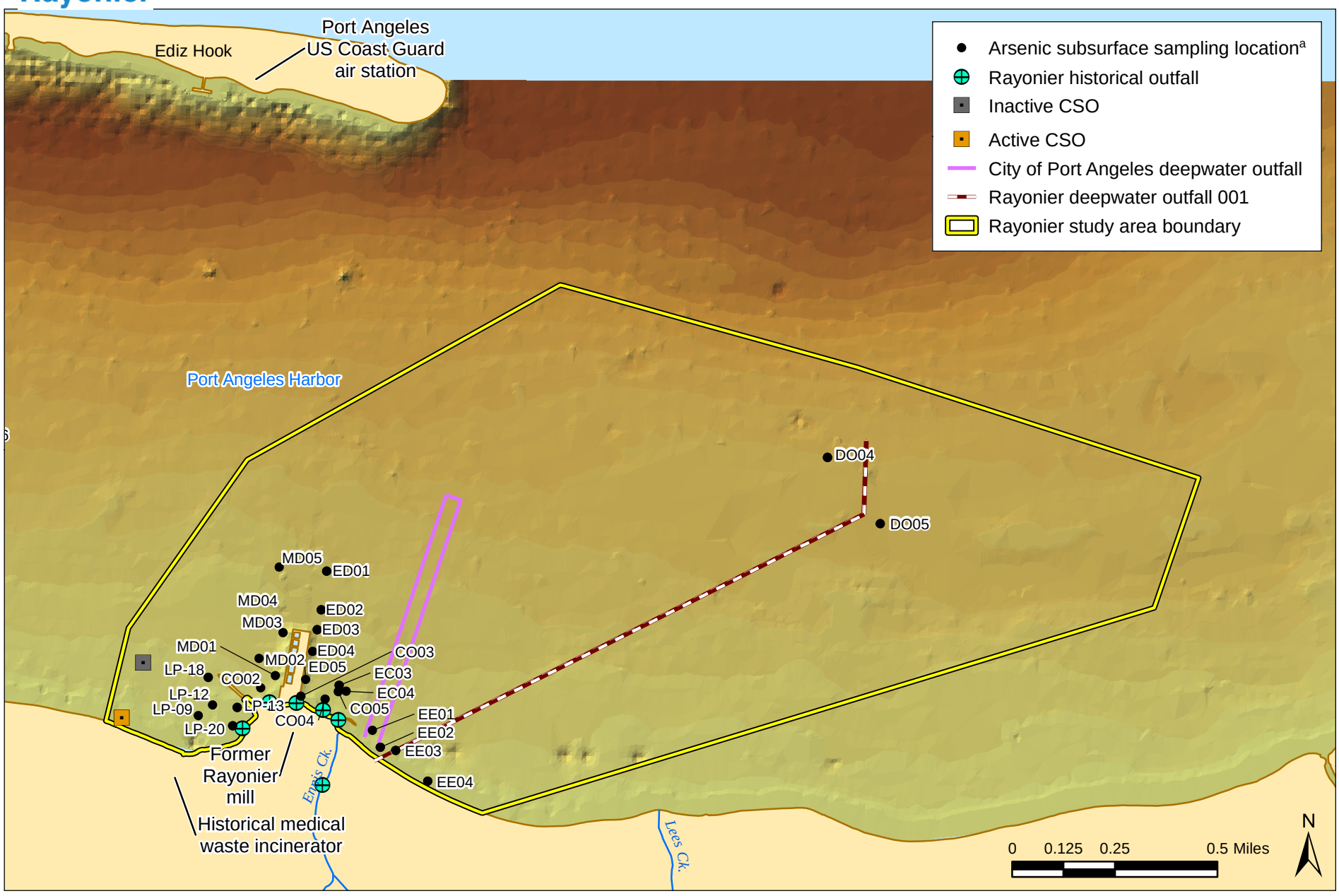
[a] Total PCBs were detected in 19 of the 40 subsurface sediment samples analyzed for PCBs (only Aroclor data are available). The non-detected concentration in each sample was calculated as one-half the highest reporting limit for an individual Aroclor in that sample. Both detected and non-detected concentrations were used in calculating percentiles.

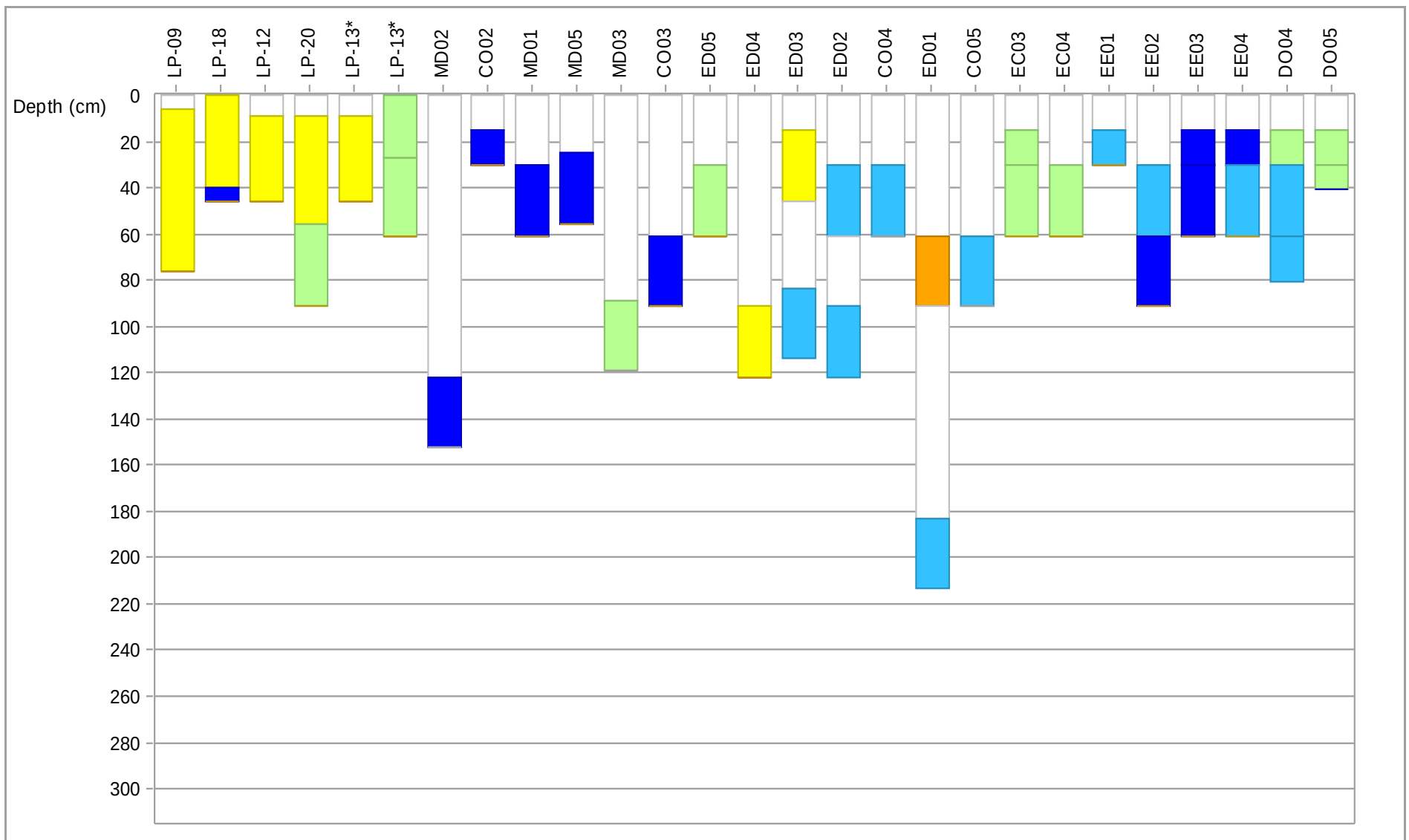
[b] SCO and CSL criteria are organic carbon normalized concentrations and thus are not comparable to dry weight concentrations shown on this map.

Wind Ward LLC environmental

Prepared by MTY, 01/18/12, map#5026; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis

Rayonier





*Samples collected from location LP-13 were analyzed at overlapping depth intervals.

Arsenic concentration (mg/kg dw) in subsurface cores[a]

95th percentile = 9.0
75th percentile = 5.4
50th percentile = 4.4
25th percentile = 2.3
SCO = 57
CSL = 93

- > 9.0
- > 5.4 and ≤ 9.0
- > 4.4 and ≤ 5.4
- > 2.3 and ≤ 4.4
- ≤ 2.3
- Not analyzed

[a] Arsenic was detected in all 40 of the subsurface sediment samples analyzed for arsenic. Both detected and non-detected concentrations were used in calculating percentiles.

Bathymetry (Feet)

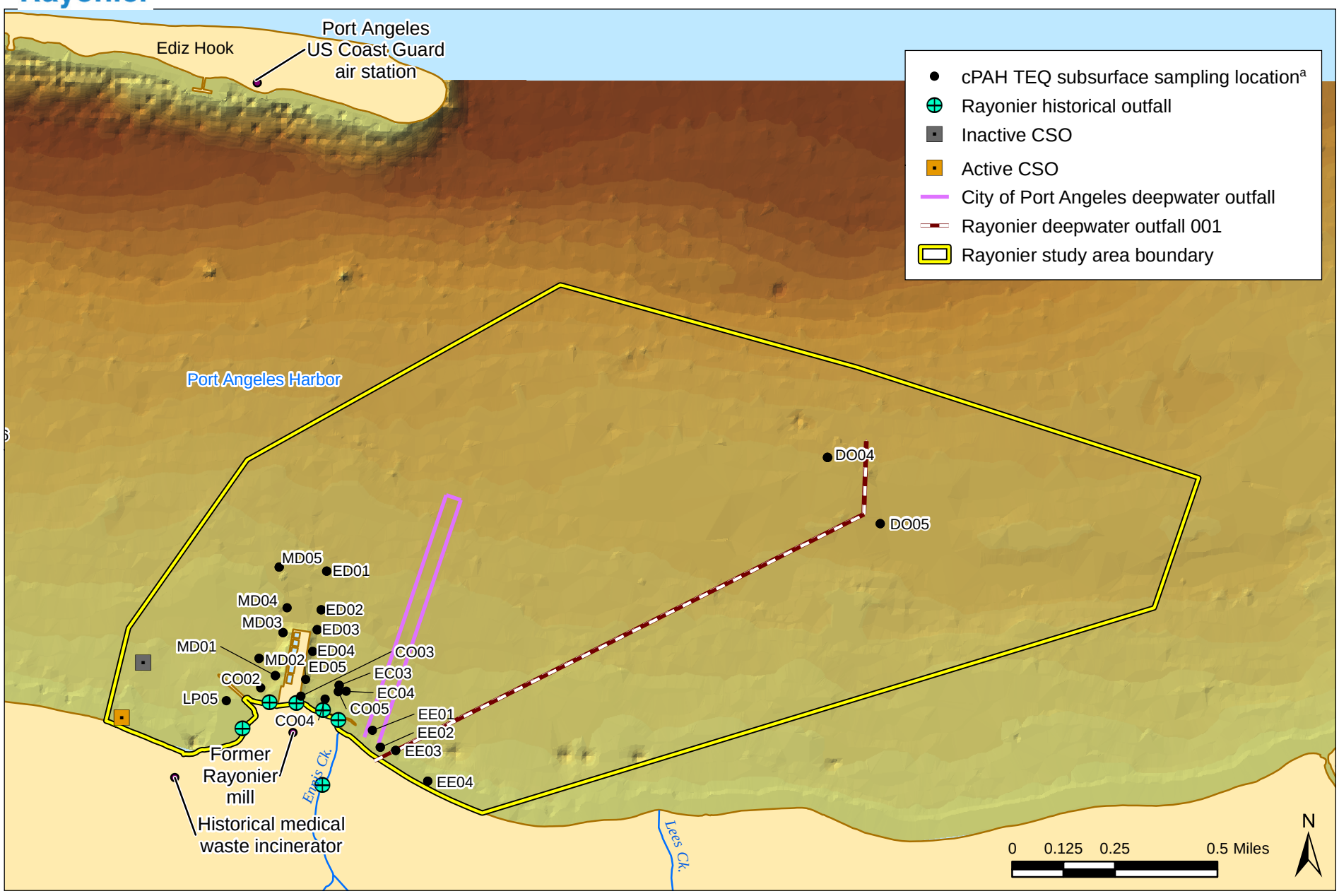
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

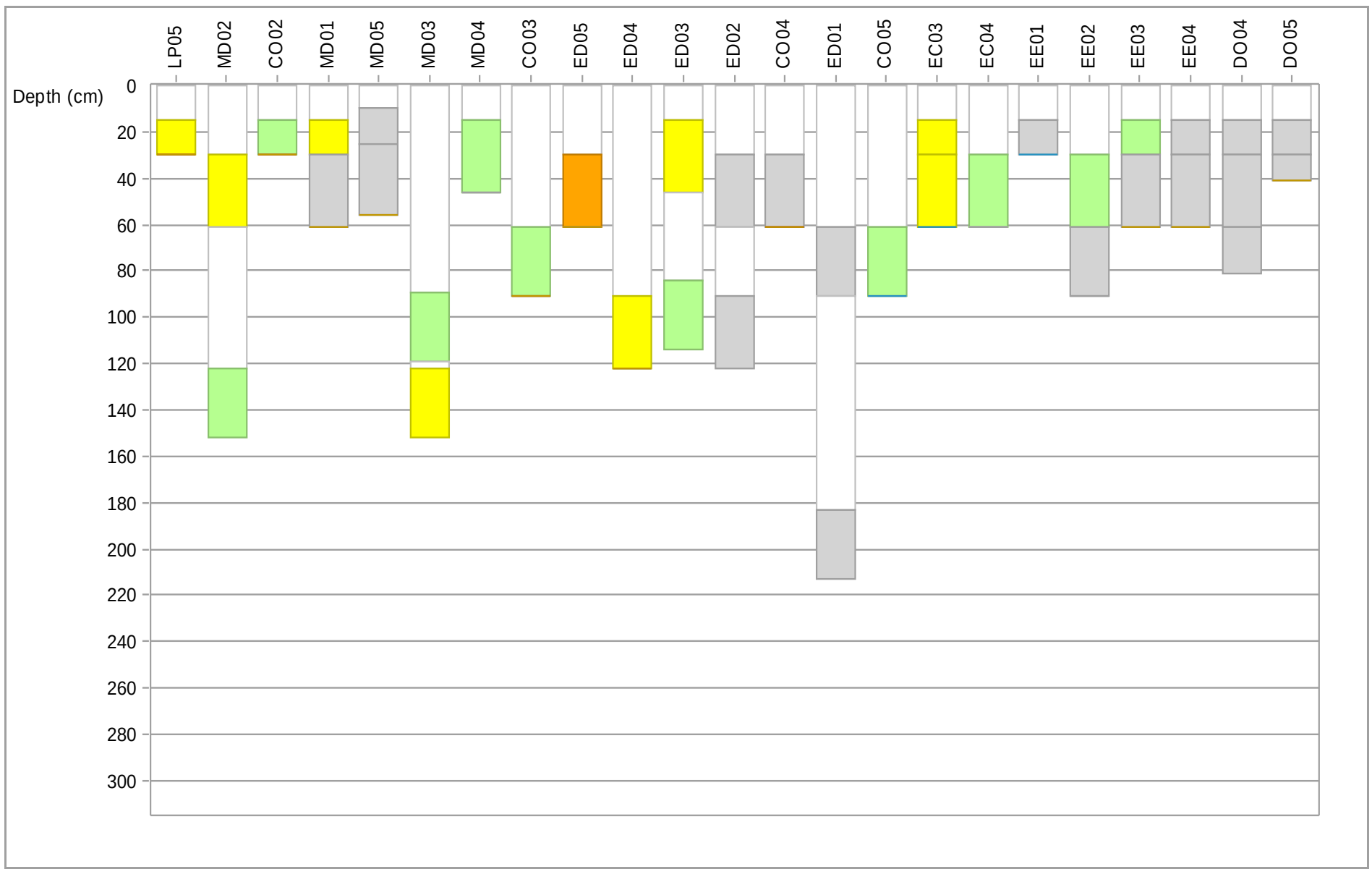
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-24. Arsenic concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Rayonier





cPAH TEQ (ug/kg dw) in subsurface cores[a]

95th percentile = 230
75th percentile = 84
50th percentile = 6.1
25th percentile = 3.1

- > 230
- > 84 and ≤ 230
- > 6.1 and ≤ 84
- > 3.1 and ≤ 6.1
- ≤ 3.1
- Not detected
- Not analyzed

Bathymetry (Feet)

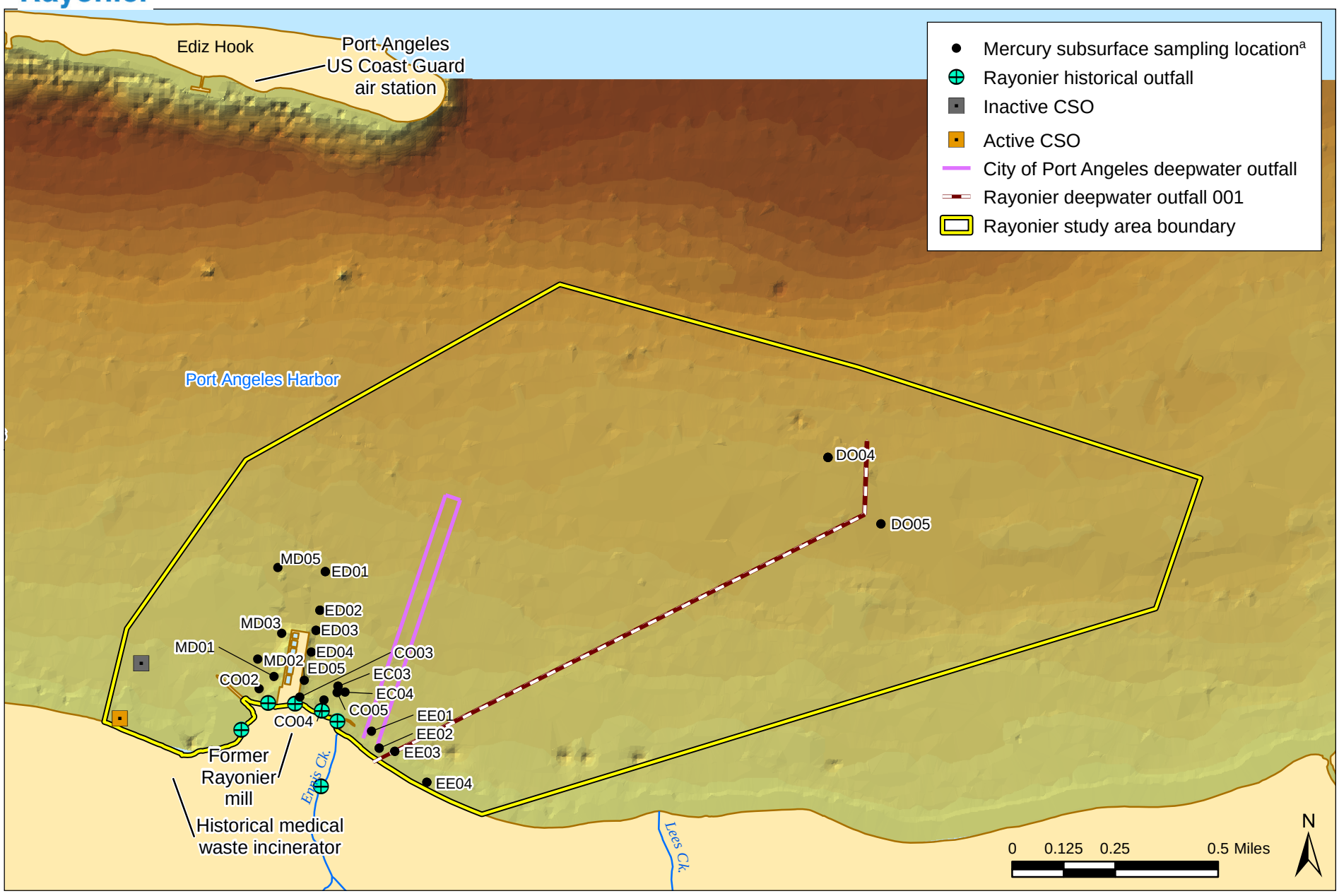
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

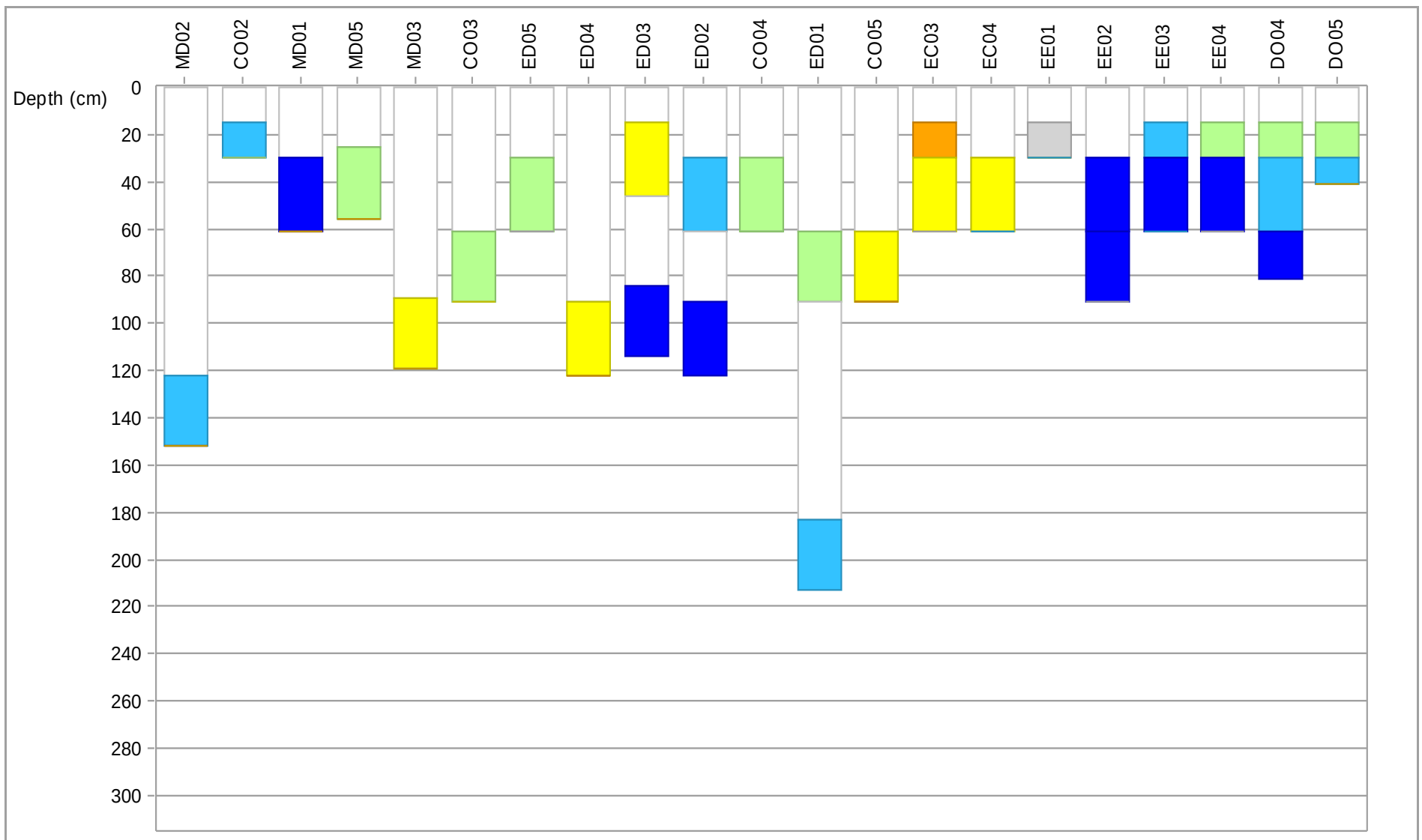
[a] cPAH TEQs were calculated using compound-specific mammalian PEFs for seven individual cPAH compounds (Washington Administrative Code 173-340-708[e]), using one-half the reporting limit for undetected compounds (see Appendix D for details). At least one cPAH compound was detected in 19 of the 37 subsurface sediment samples analyzed for cPAHs. Only the detected concentrations were used in calculating percentiles.

Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-25. cPAH TEQs in subsurface sediment samples from the study area

Wind Ward environmental LLC





Mercury concentration (mg/kg dw) in subsurface cores[a]

95th percentile = 0.22
75th percentile = 0.059
50th percentile = 0.031
25th percentile = 0.024
SCO = 0.41
CSL = 0.59

- > 0.22
- > 0.059 and ≤ 0.22
- > 0.031 and ≤ 0.059
- > 0.024 and ≤ 0.031
- ≤ 0.024
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

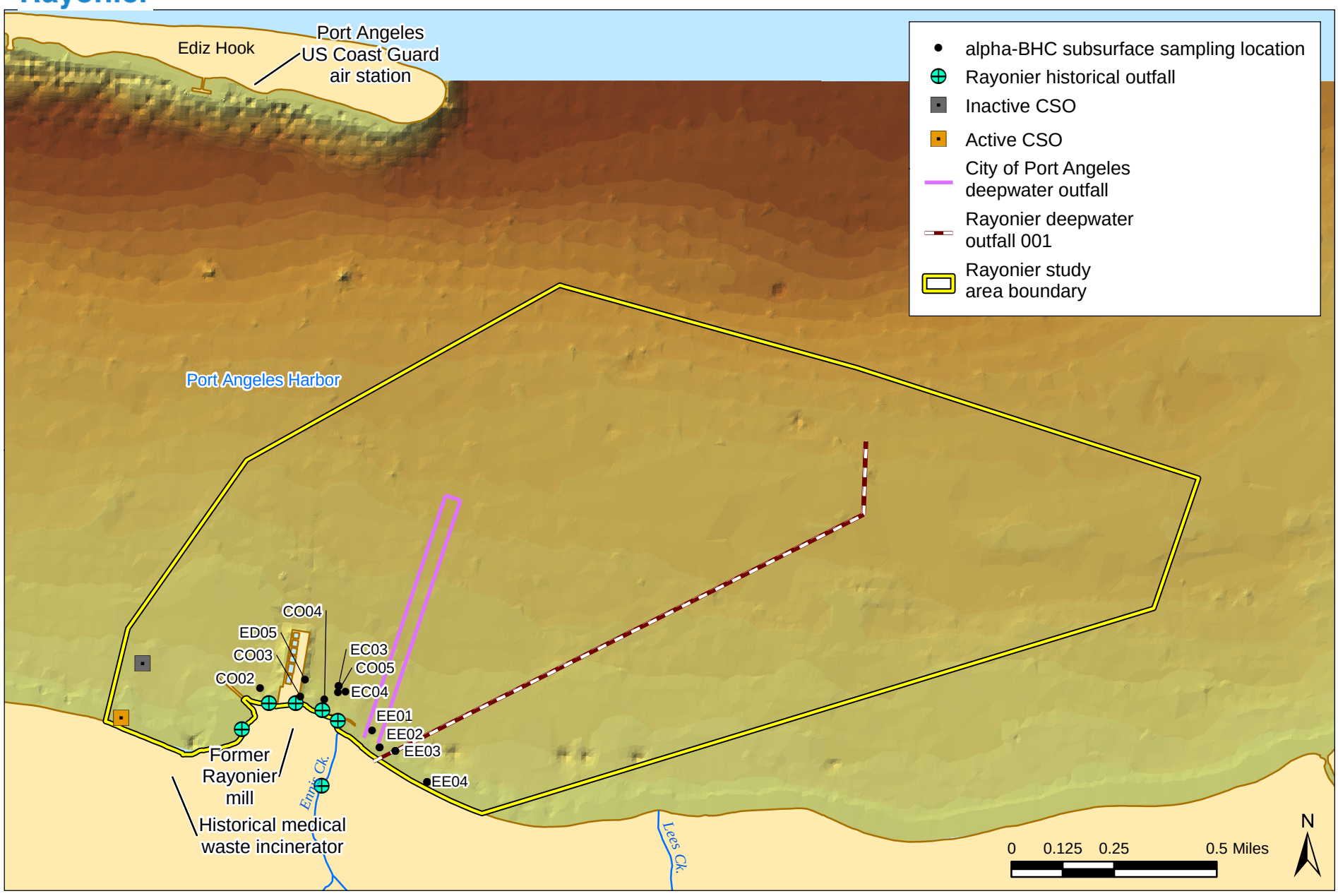
[a] Mercury was detected in 30 of the 31 subsurface sediment samples analyzed for mercury. The non-detected concentration was calculated as one-half the reporting limit. Both detected and non-detected concentrations were used in calculating the percentiles.

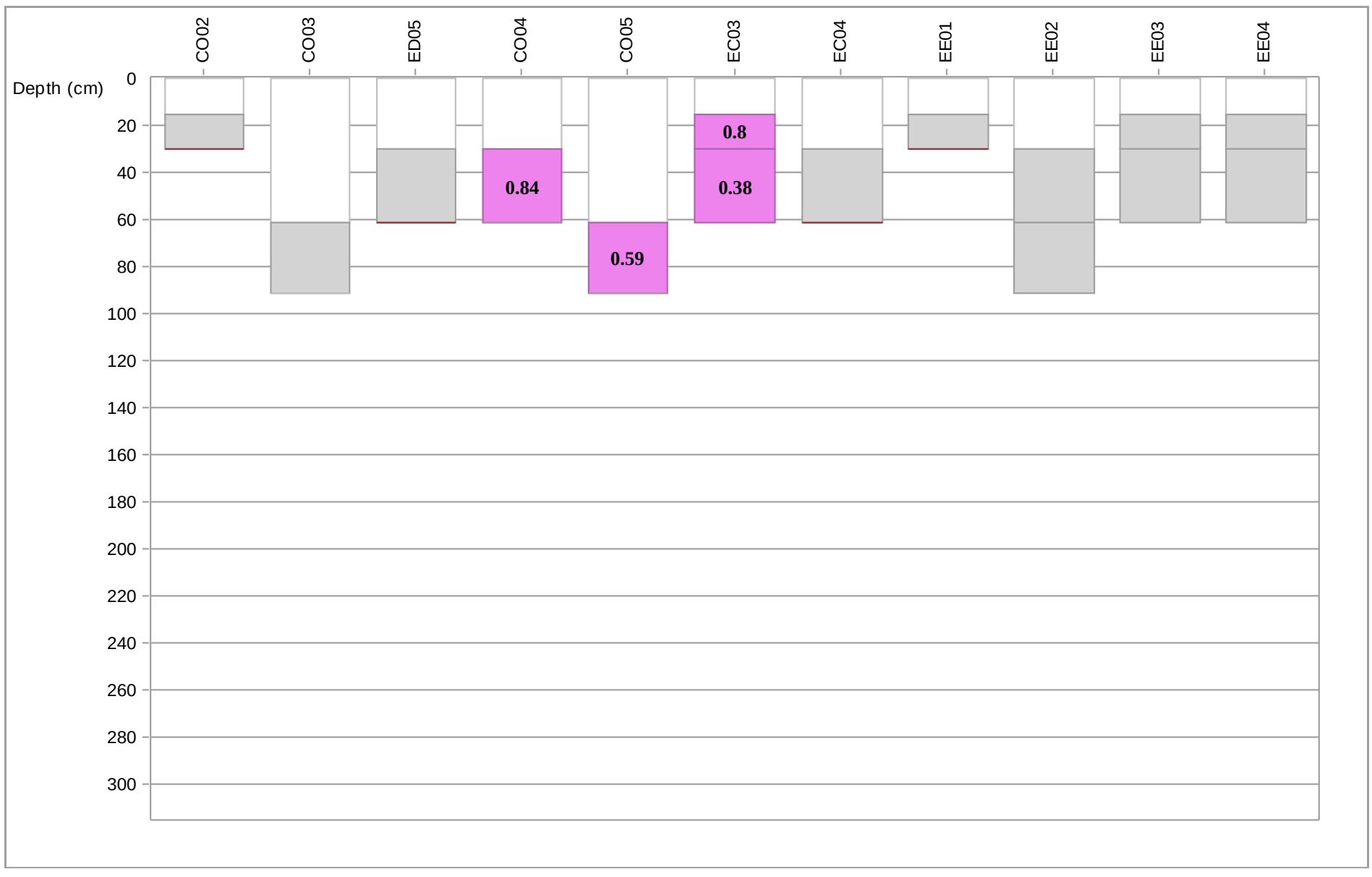
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-26. Mercury concentrations in subsurface sediment samples from the study area

Wind Ward environmental LLC

Rayonier





alpha-BHC concentration (ug/kg dw) in subsurface cores

- Detected concentration (shown on chart)
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

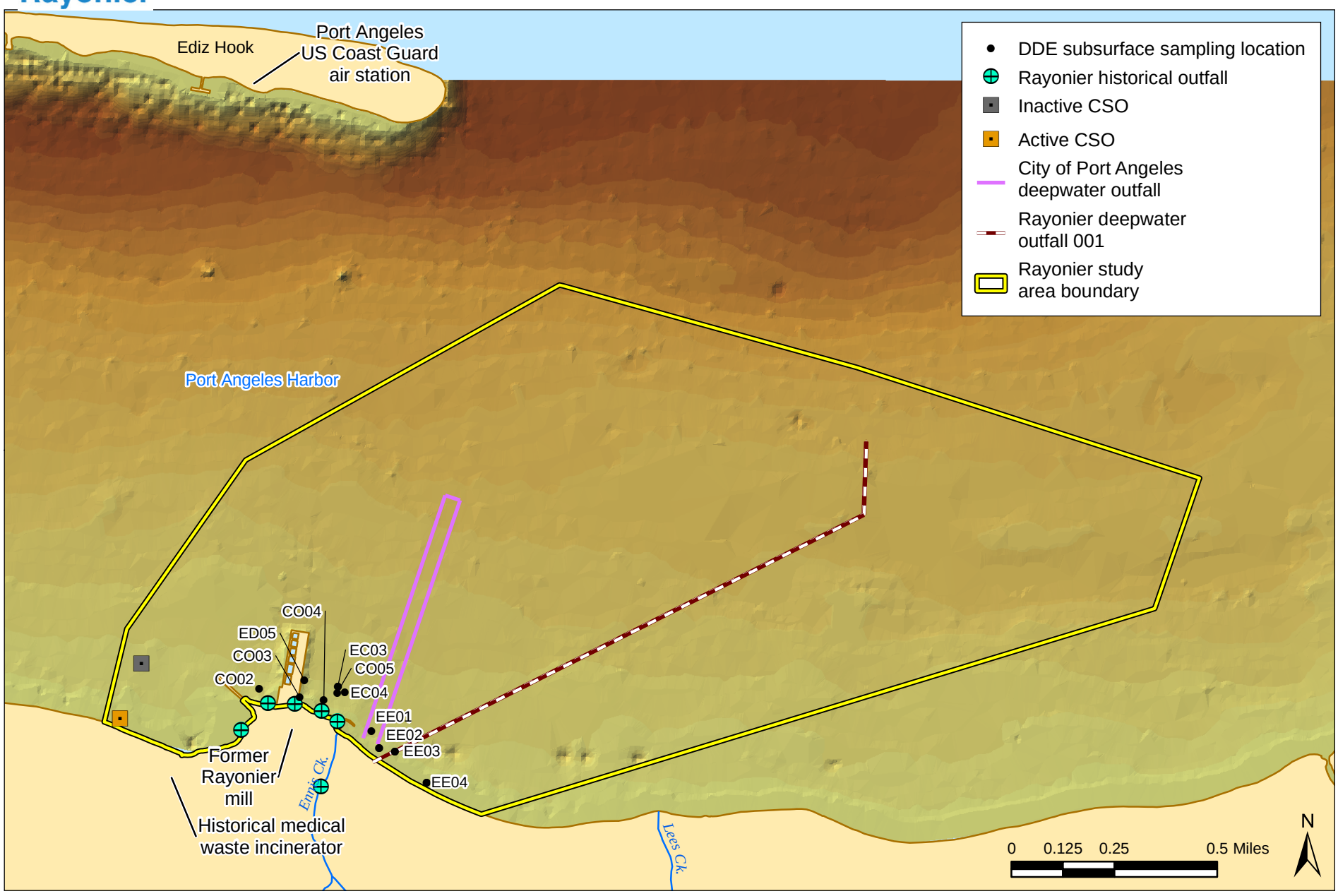
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

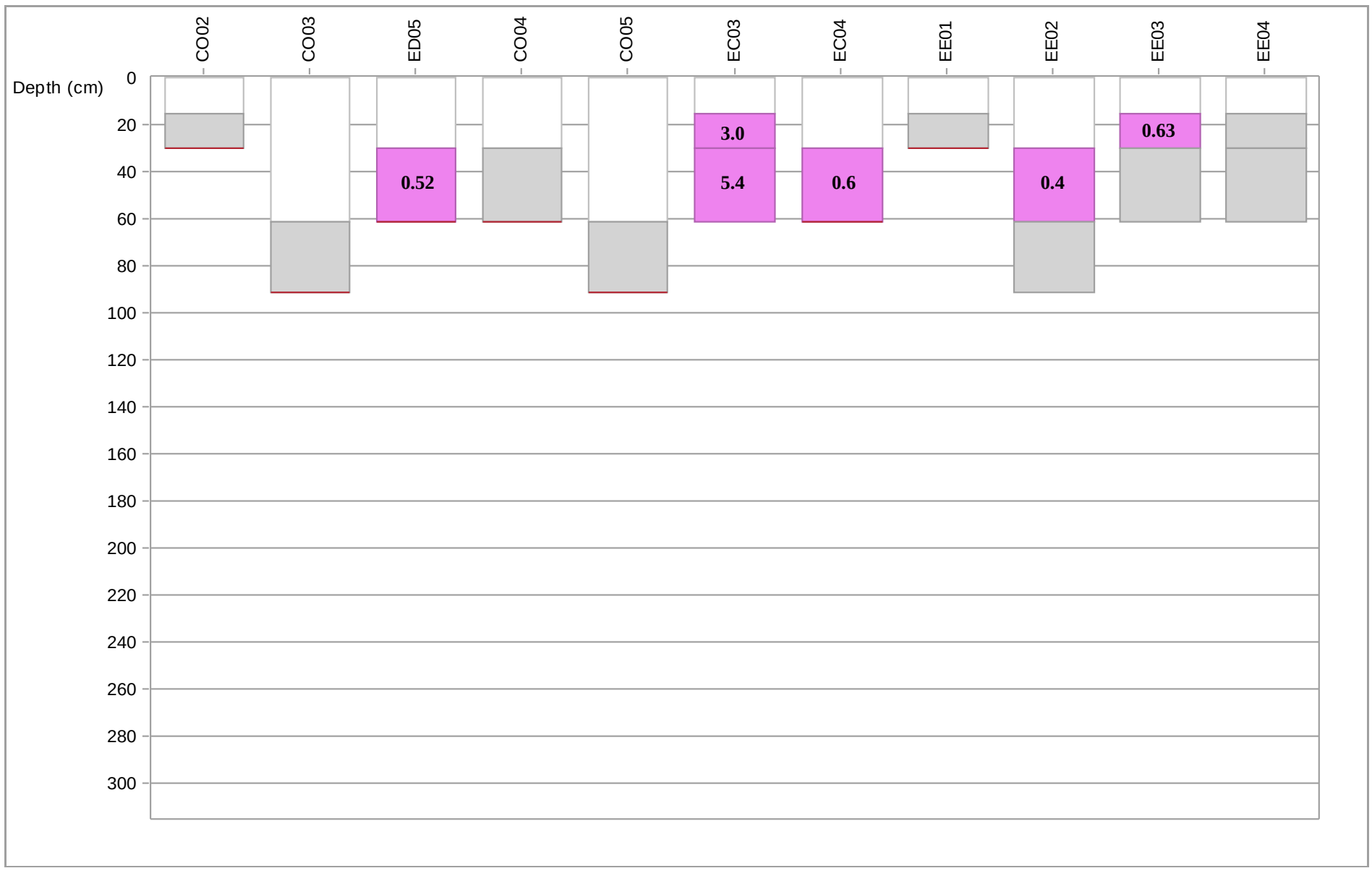
Map 2-27. alpha-BHC concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5036_alpha-BHC in subsurface sediment samples from PA Harbor_MTY_08272013.mxd

Rayonier





DDE concentration
(ug/kg dw) in subsurface cores

- Detected concentration (shown on chart)
- Not detected
- Not analyzed

Bathymetry (Feet)

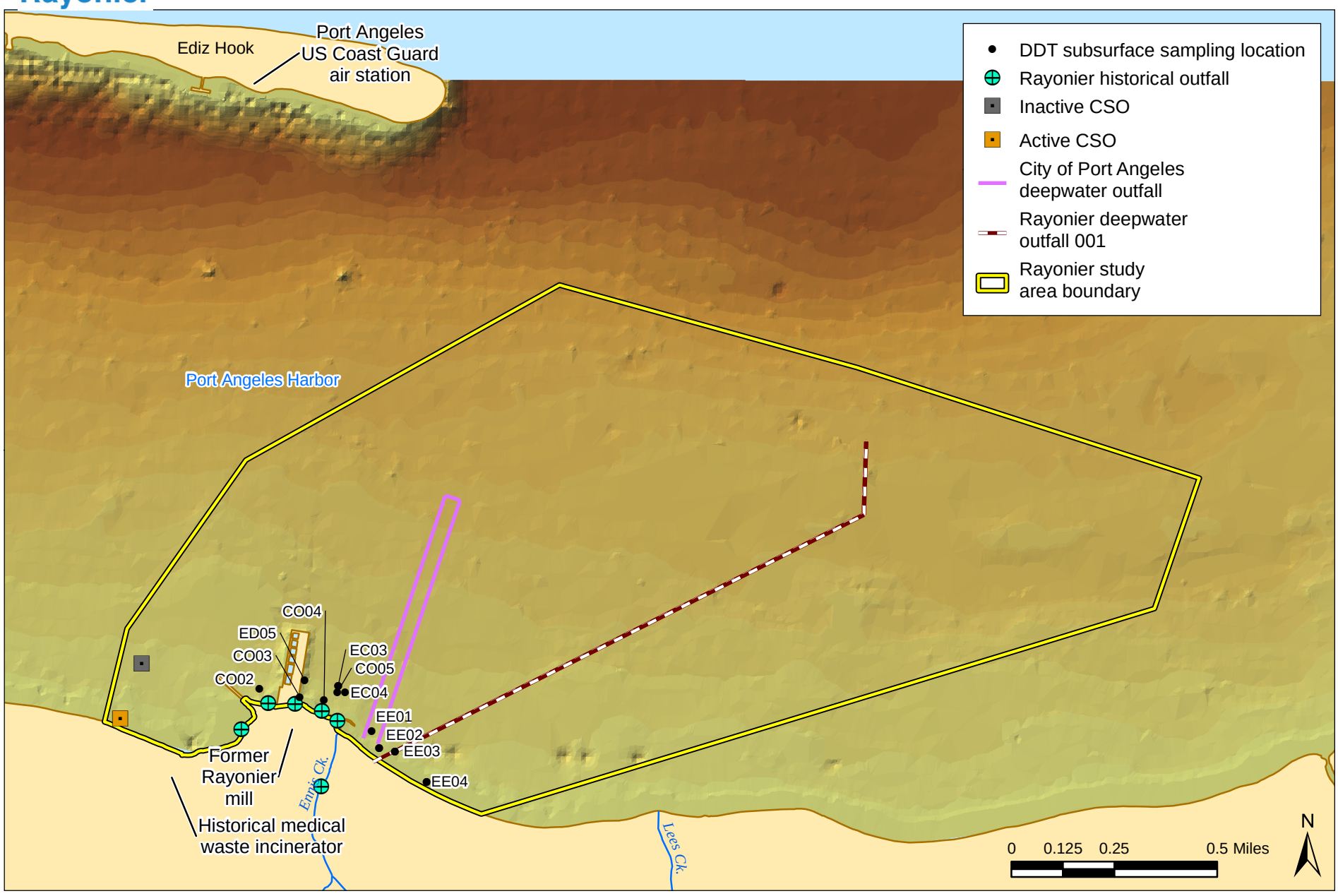
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

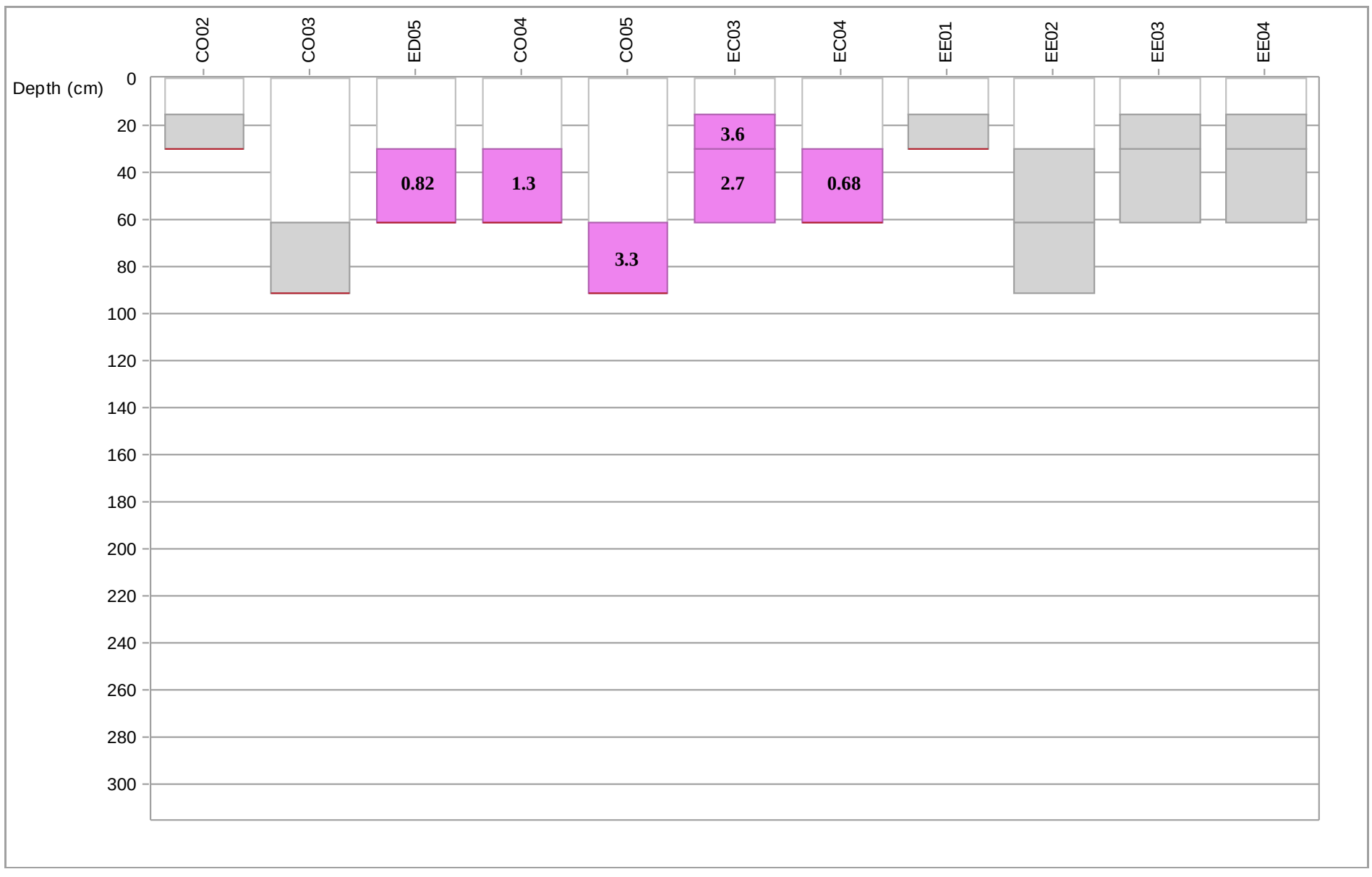
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-28. DDE concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Rayonier





DDT concentration
(ug/kg dw) in subsurface cores

- Detected concentration (shown on chart)
- Not detected
- Not analyzed

Bathymetry (Feet)

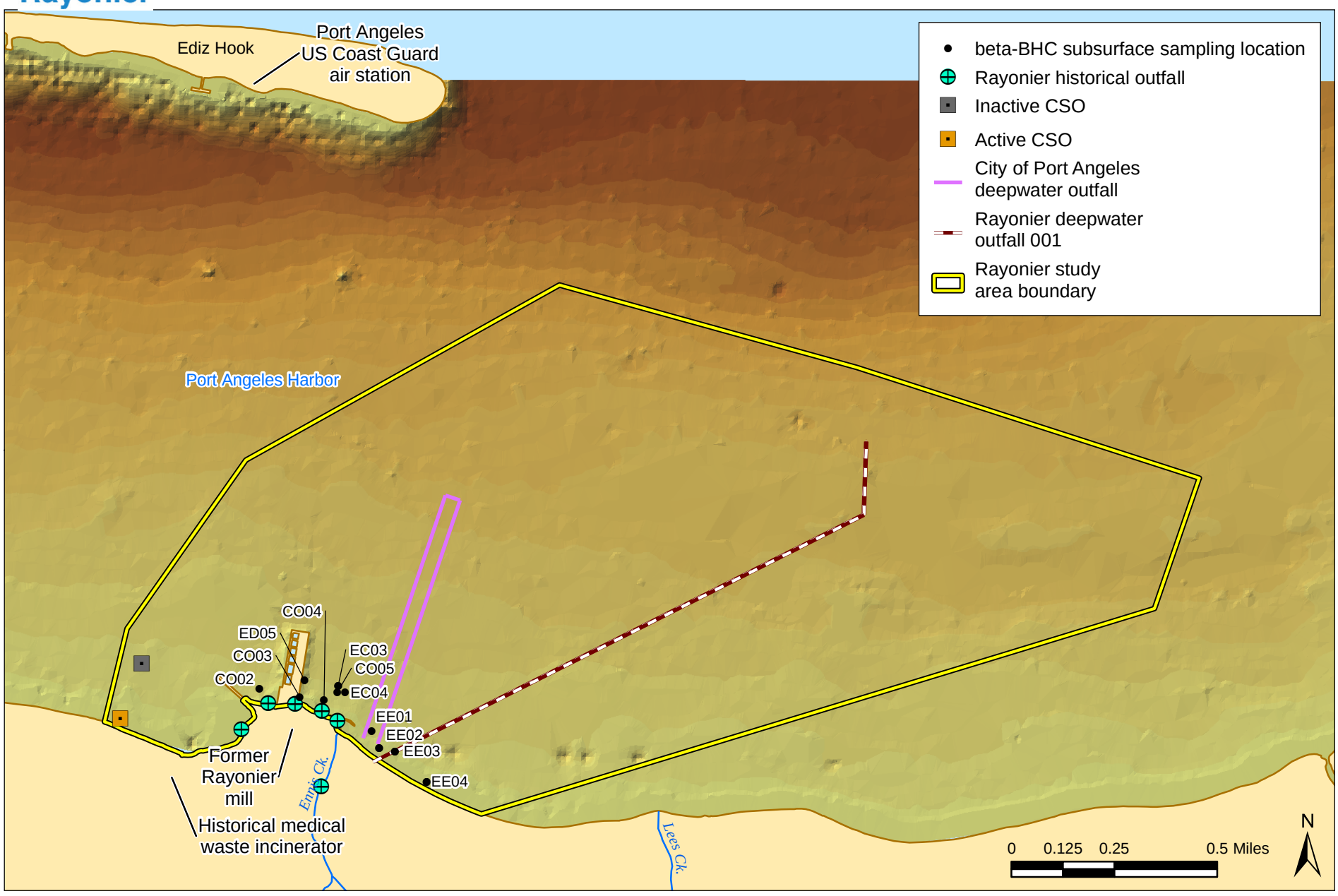
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

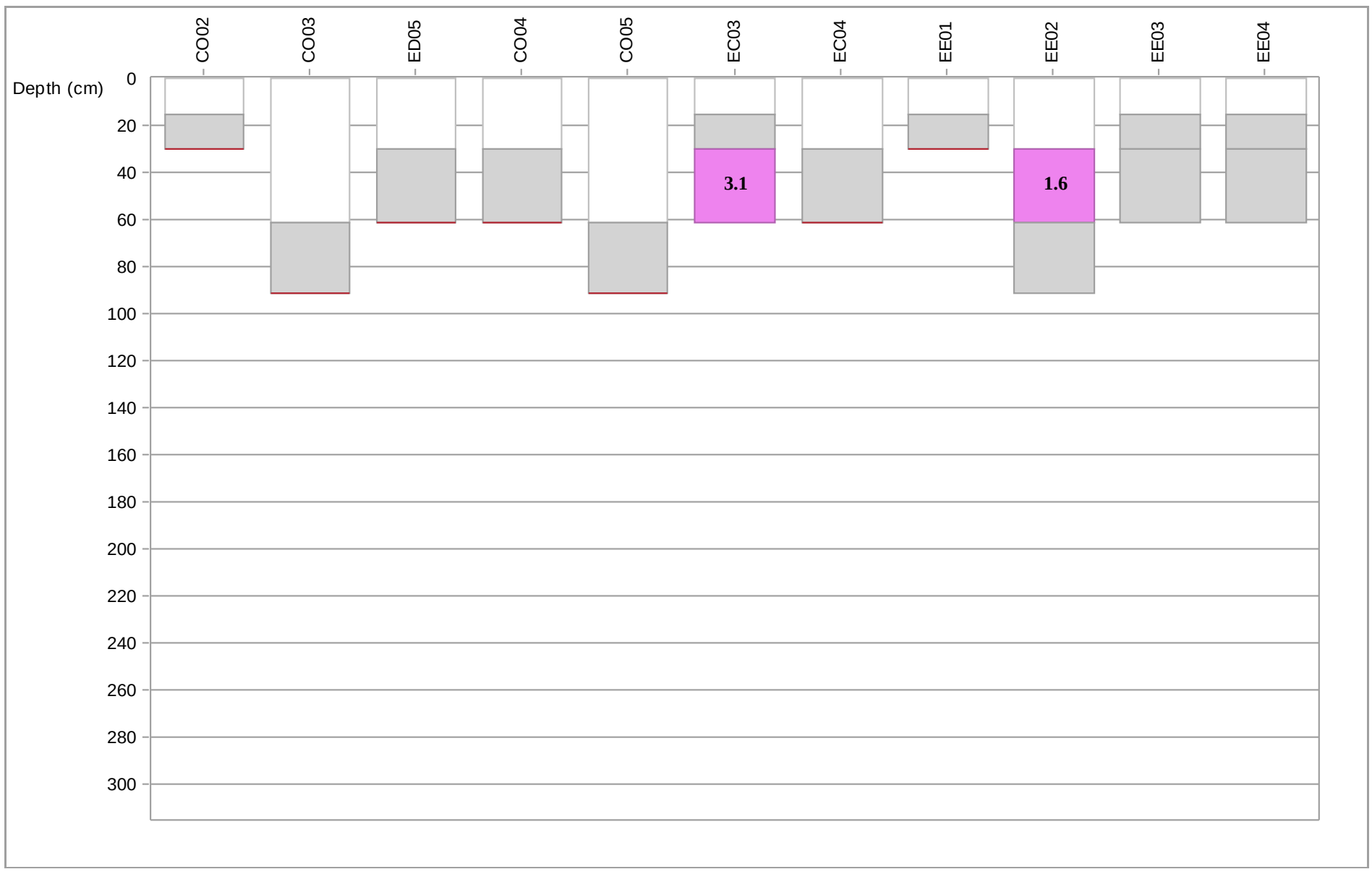
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-29. DDT concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Rayonier





beta-BHC concentration
(ug/kg dw) in subsurface cores

- Detected concentration (shown on chart)
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

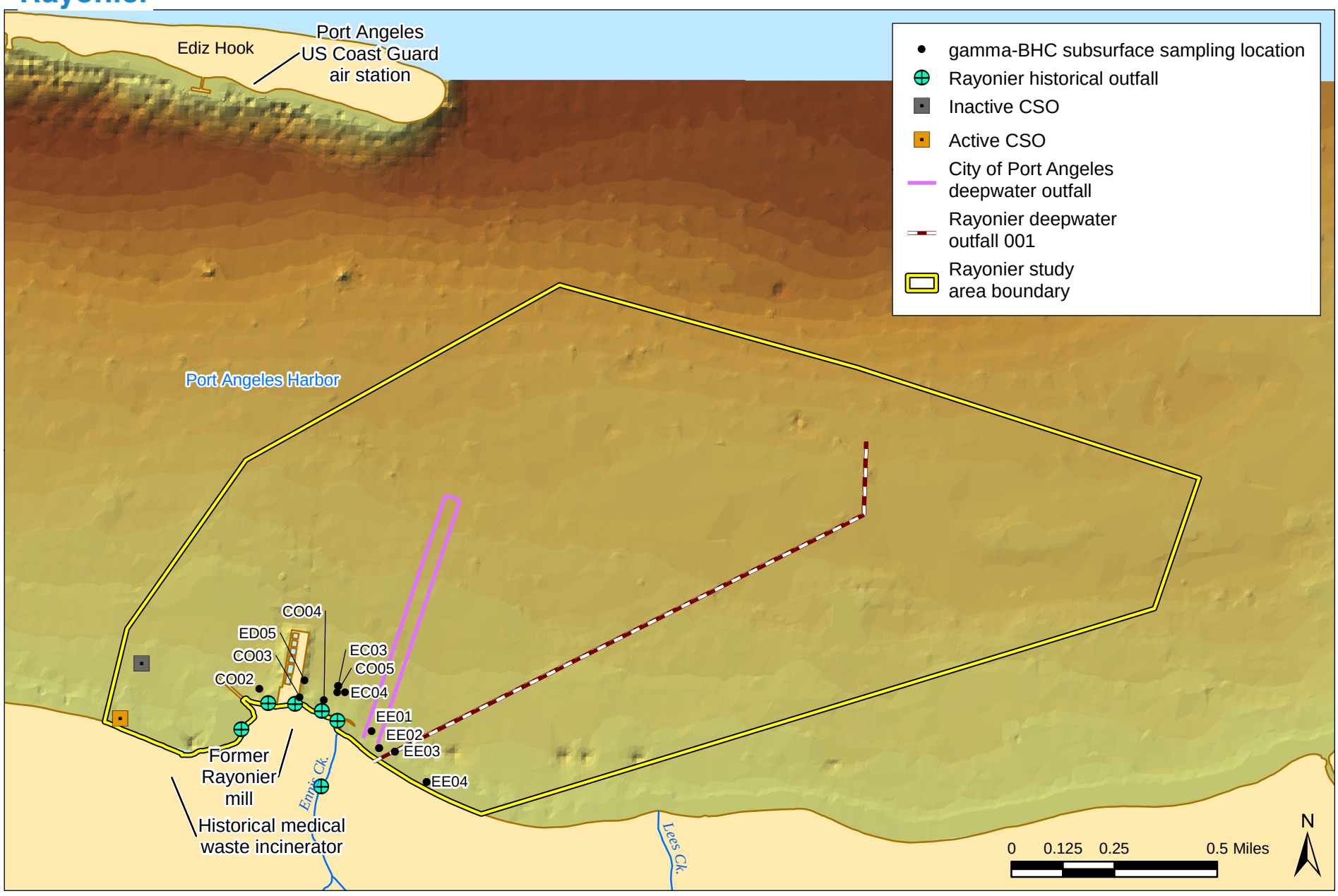
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

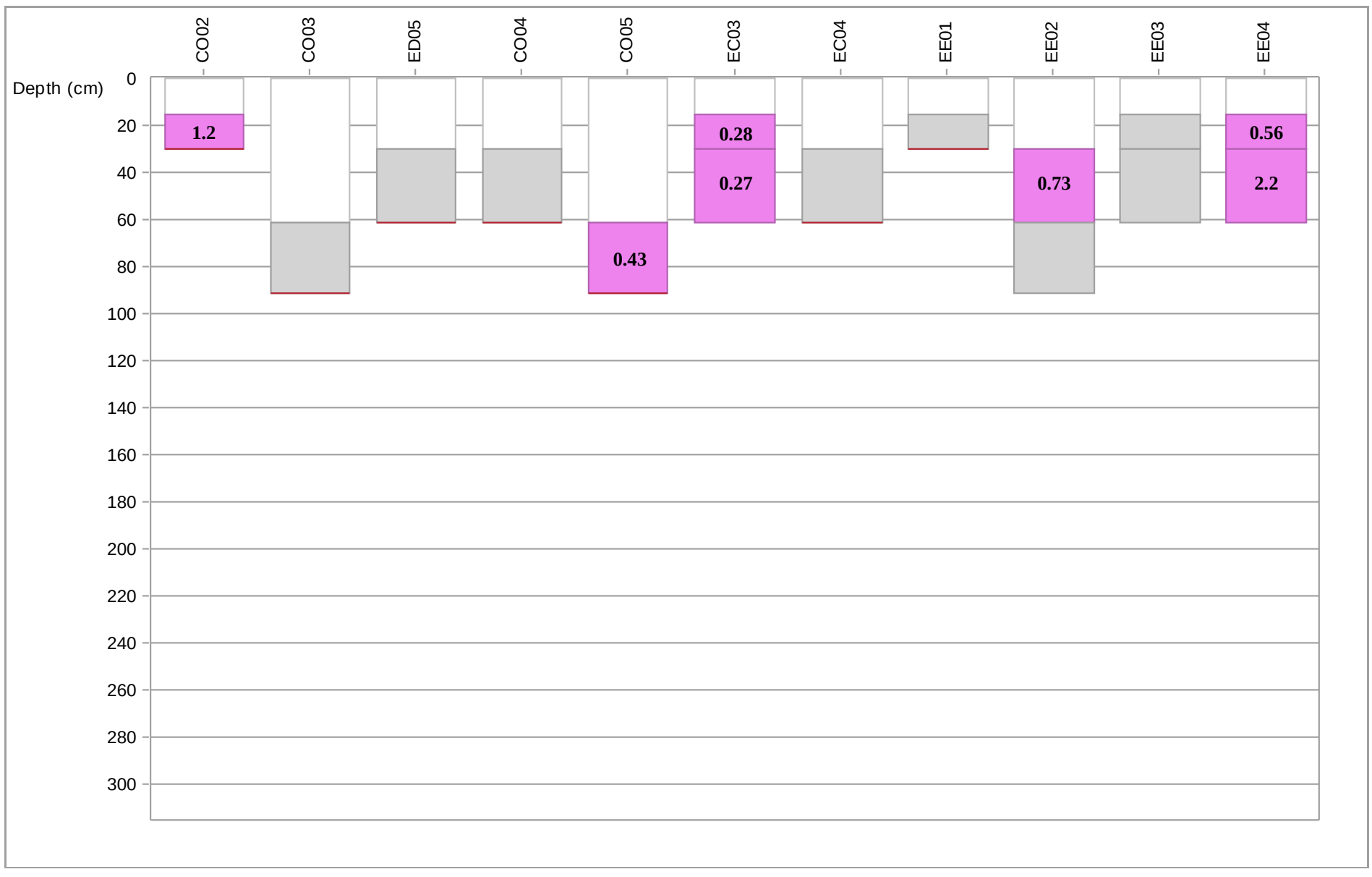
Map 2-30. beta-BHC concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5631_beta-BHC in subsurface sediment samples from the study area_MTY_08302013.mxd

Rayonier





gamma-BHC concentration (ug/kg dw) in subsurface cores

- Detected concentration (shown on chart)
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

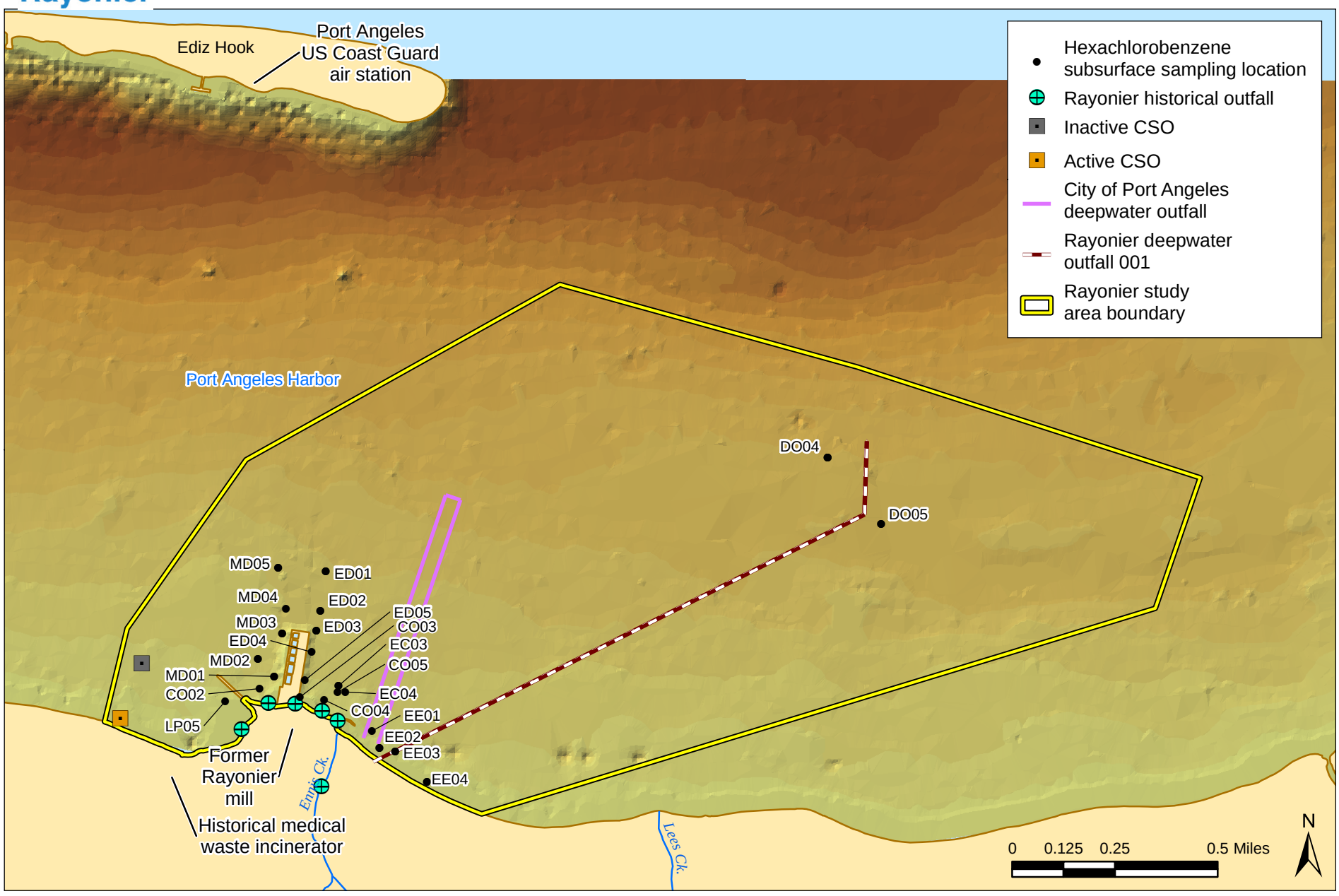
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

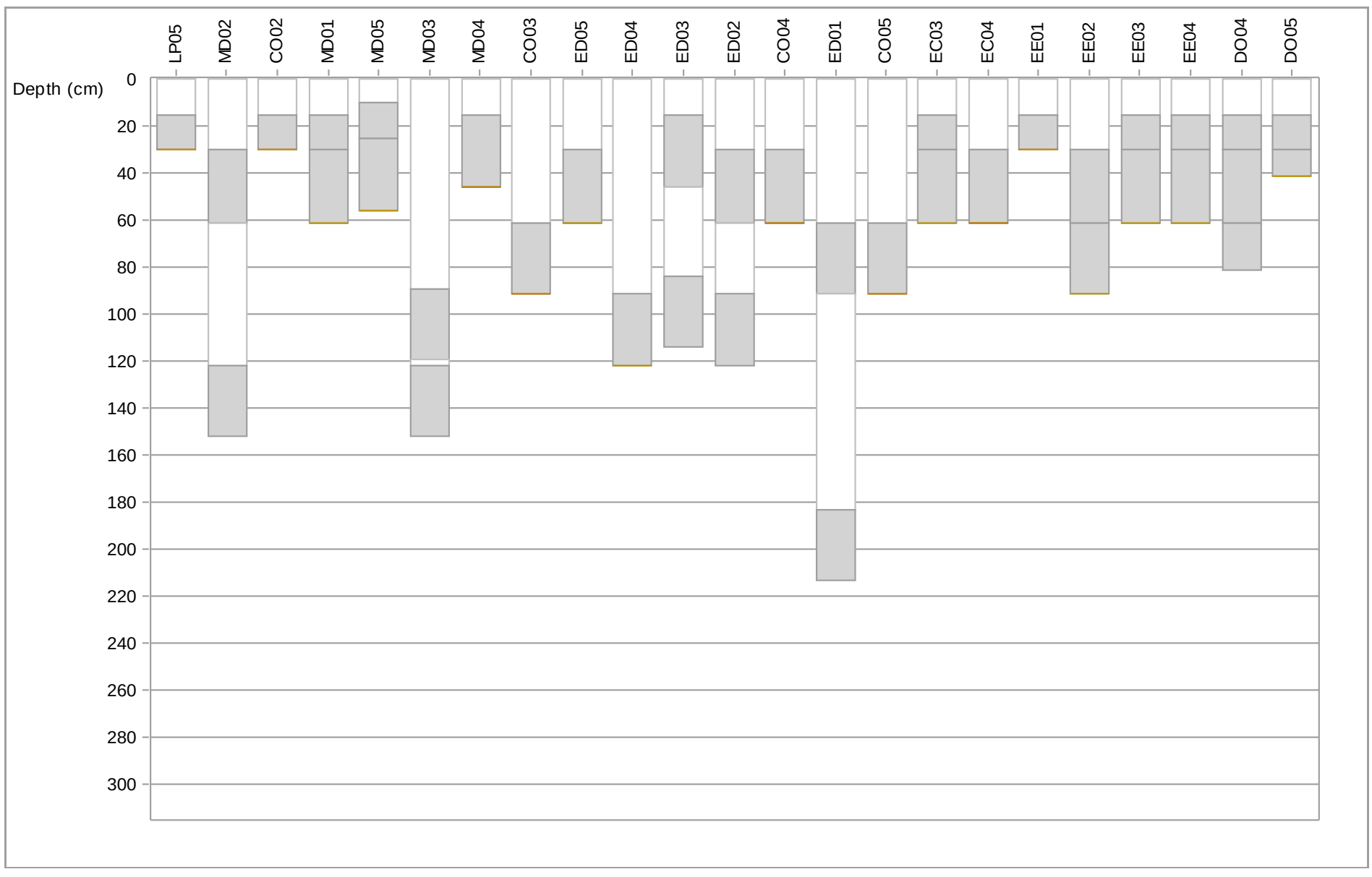
Map 2-31. gamma-BHC concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5632_gamma-BHC in subsurface sediment samples from the study area_MTY_08302013.mxd

Rayonier





Hexachlorobenzene concentration (ug/kg dw) in subsurface cores

- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

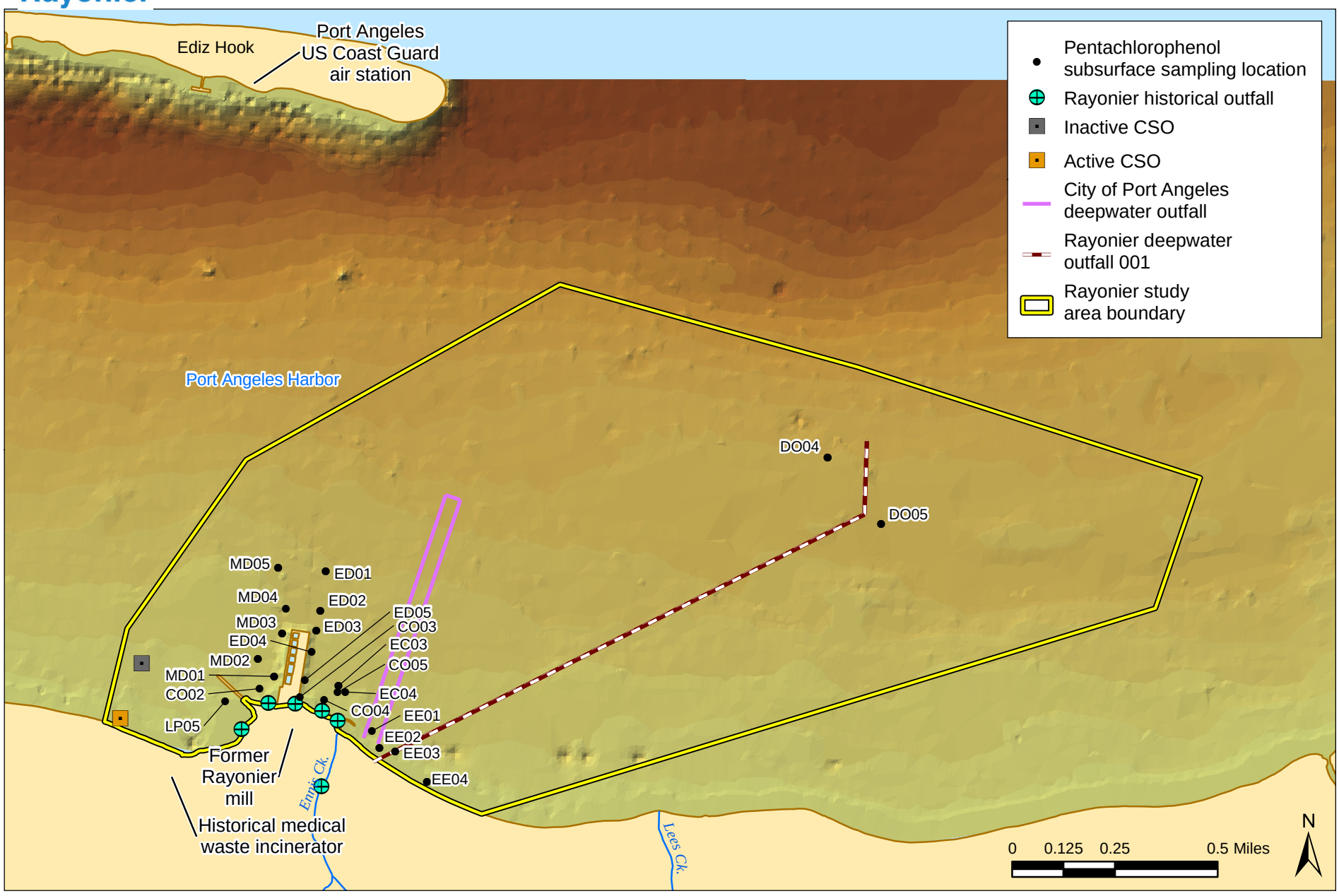
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

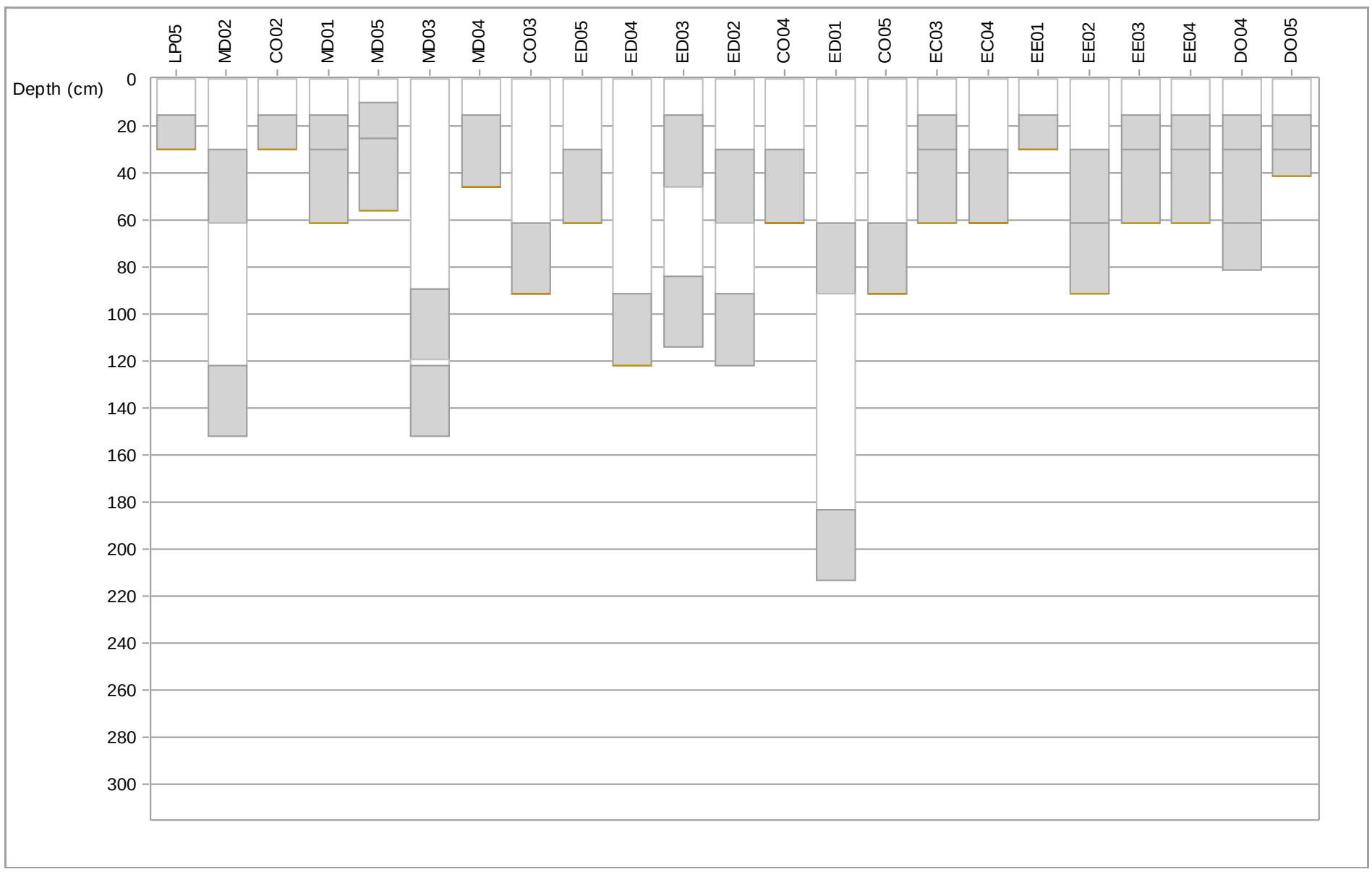
Map 2-32. Hexachlorobenzene concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5634_Hexachlorobenzene in subsurface sediment samples from the study area_MTY_08302013.mxd

Rayonier





Pentachlorophenol concentration (ug/kg dw) in subsurface cores

- Not detected
- Not analyzed

Bathymetry (Feet)

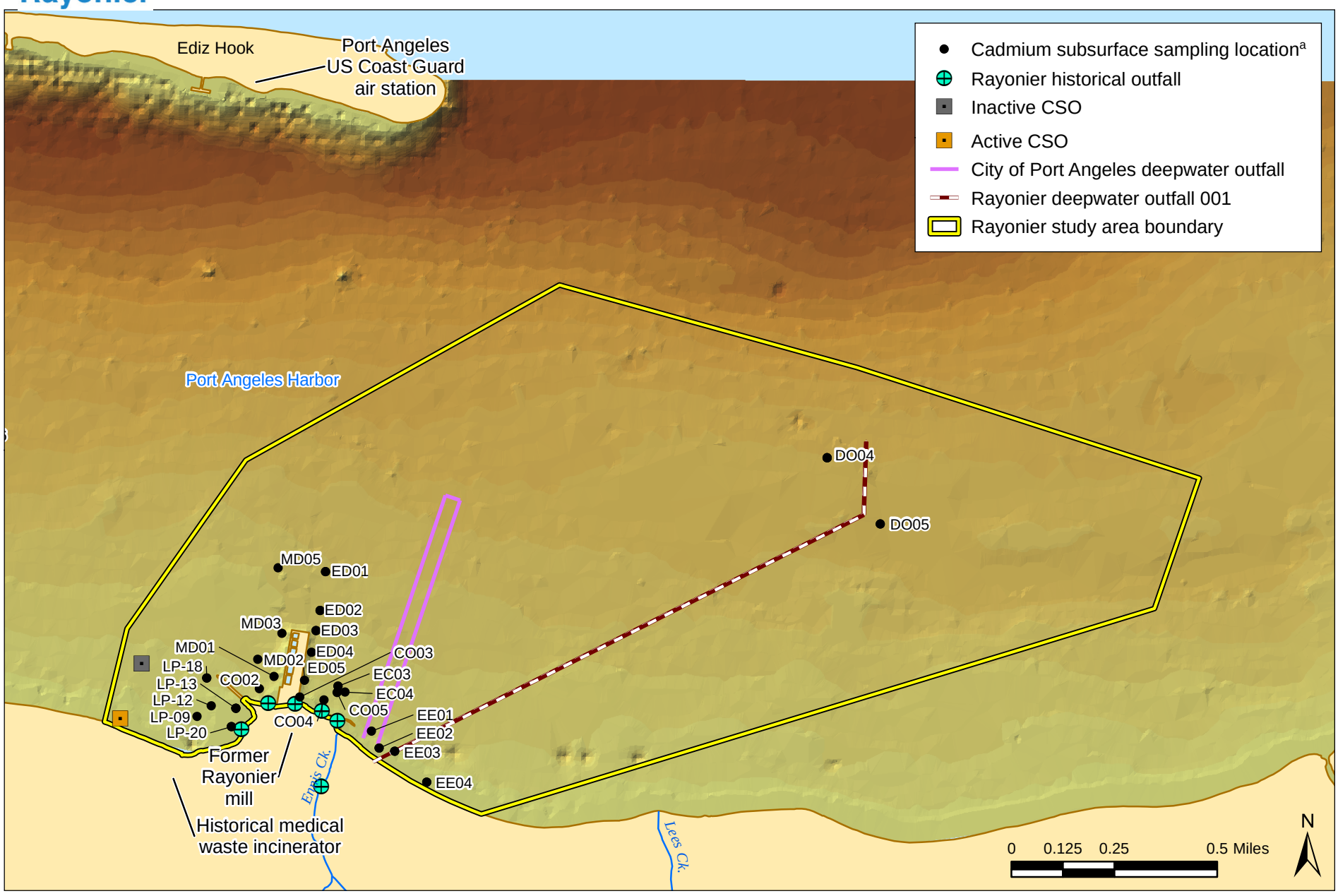
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

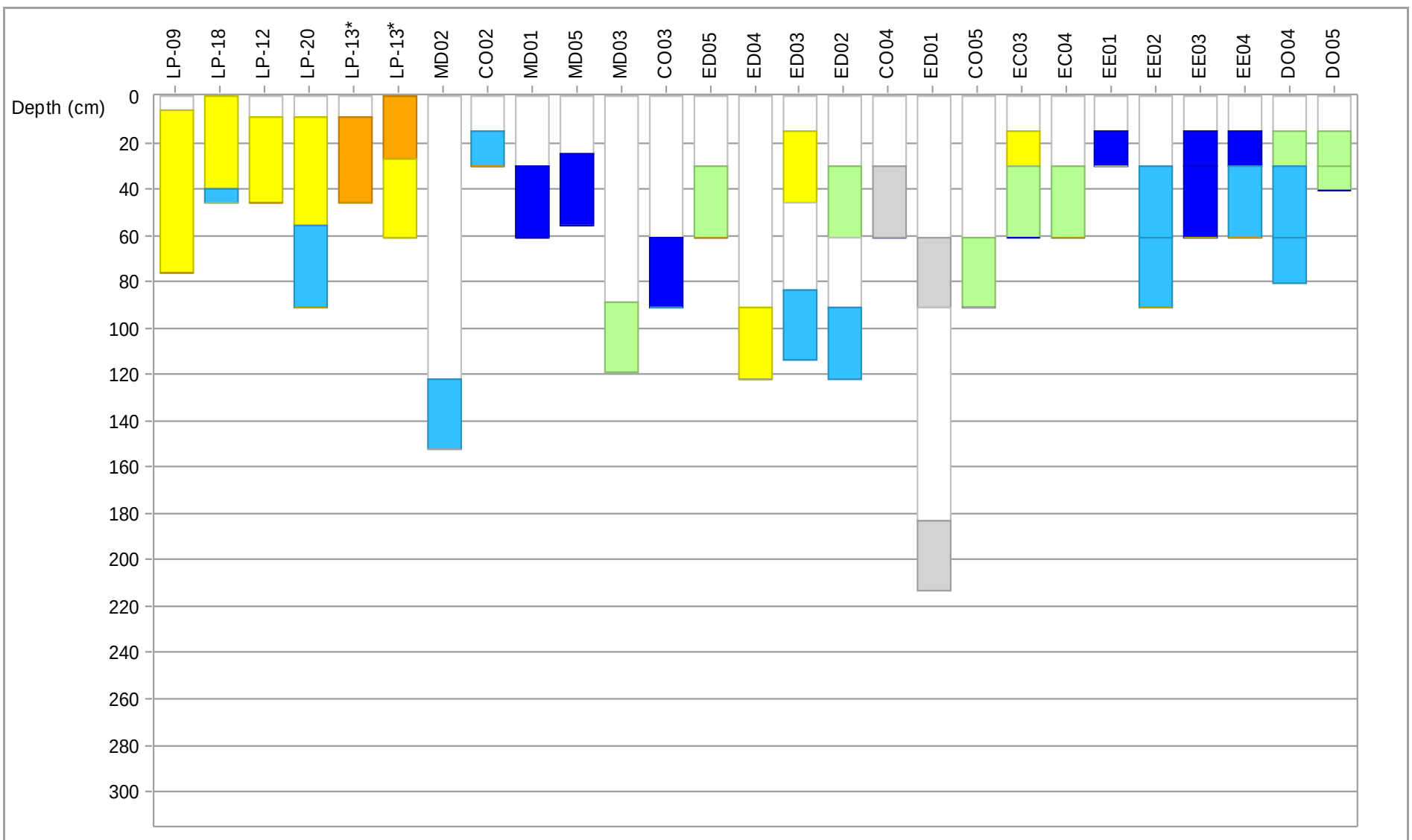
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-33. Pentachlorophenol concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Rayonier





*Samples collected from location LP-13 were analyzed at overlapping depth intervals.

Cadmium concentration (mg/kg dw) in subsurface cores[a]

95th percentile = 1.4
75th percentile = 0.67
50th percentile = 0.2
25th percentile = 0.054
SCO = 5.1
CSL = 6.7

- > 1.4
- > 0.67 and ≤ 1.4
- > 0.2 and ≤ 0.67
- > 0.054 and ≤ 0.2
- ≤ 0.054
- Not detected
- Not analyzed

Bathymetry (Feet)

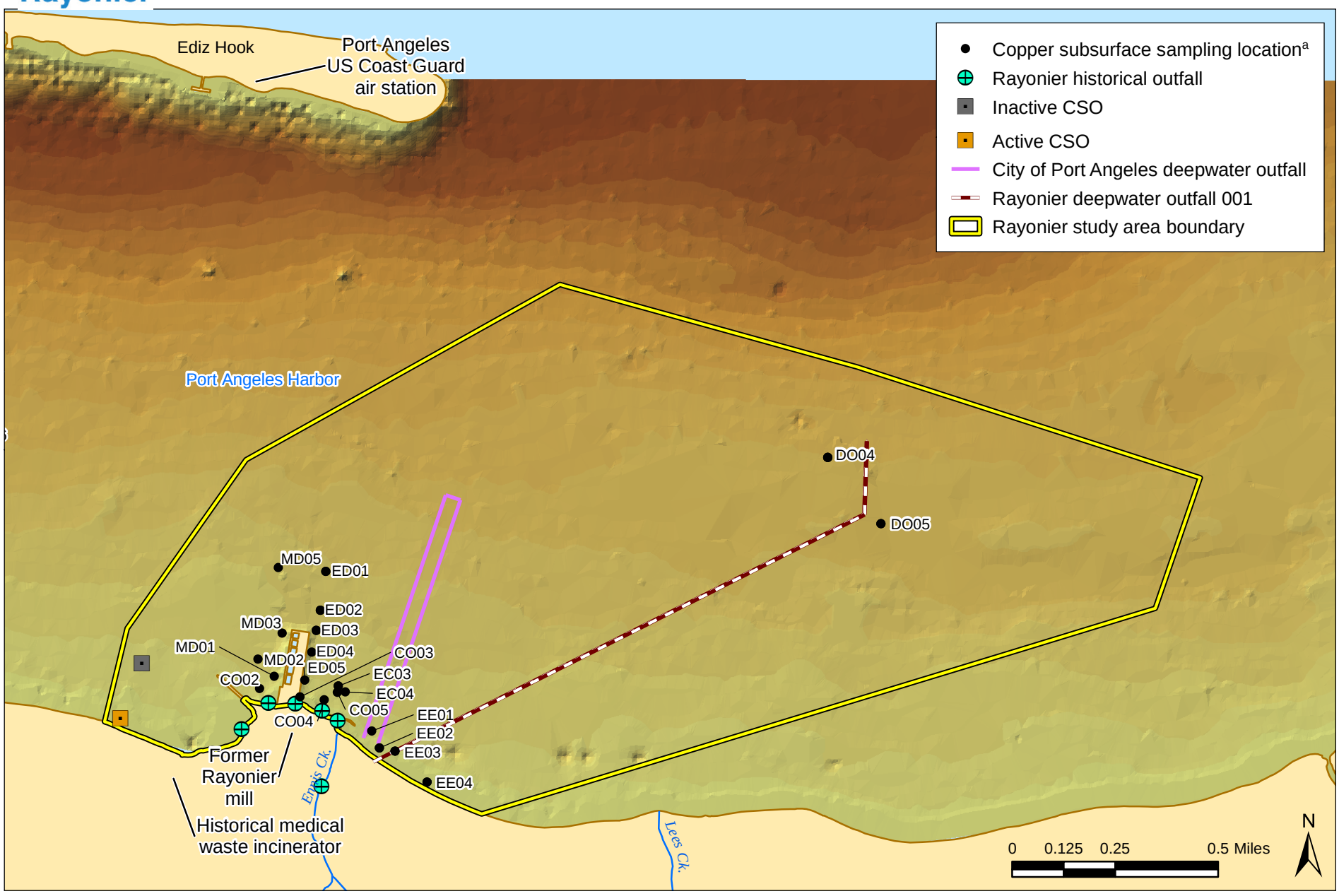
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

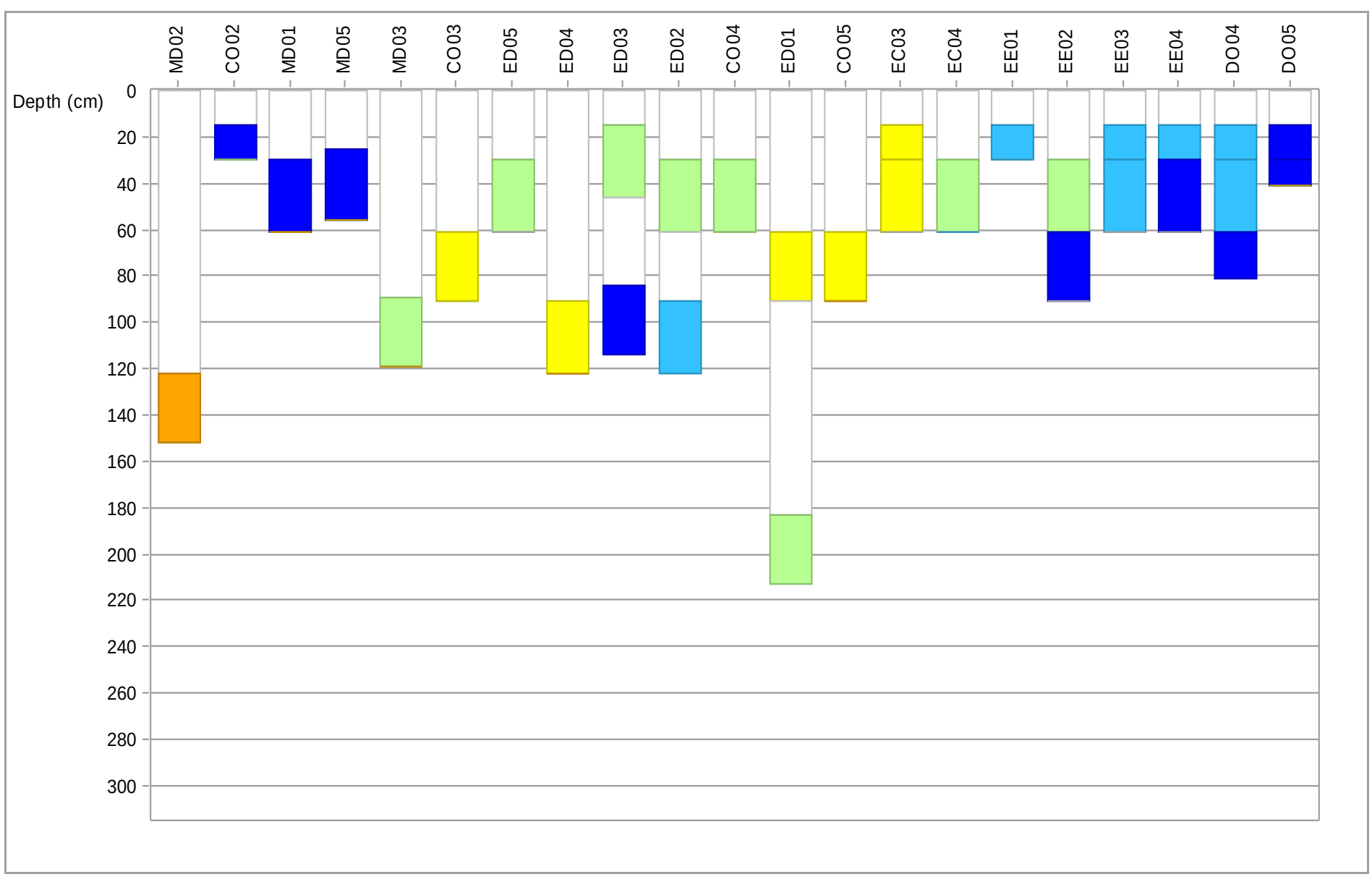
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

[a] Cadmium was detected in 37 of the 40 subsurface sediment samples analyzed for cadmium. The non-detected concentration was calculated as one-half the reporting limit. Both detected and non-detected concentrations were used in calculating the percentiles.

Map 2-34. Cadmium concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental





Copper concentration (mg/kg dw) in subsurface cores[a]

95th percentile = 147
75th percentile = 40
50th percentile = 22
25th percentile = 14
SCO = 390
CSL = 390

- > 147
- > 40 and ≤ 147
- > 22 and ≤ 40
- > 14 and ≤ 22
- ≤ 14
- Not detected
- Not analyzed

Bathymetry (Feet)

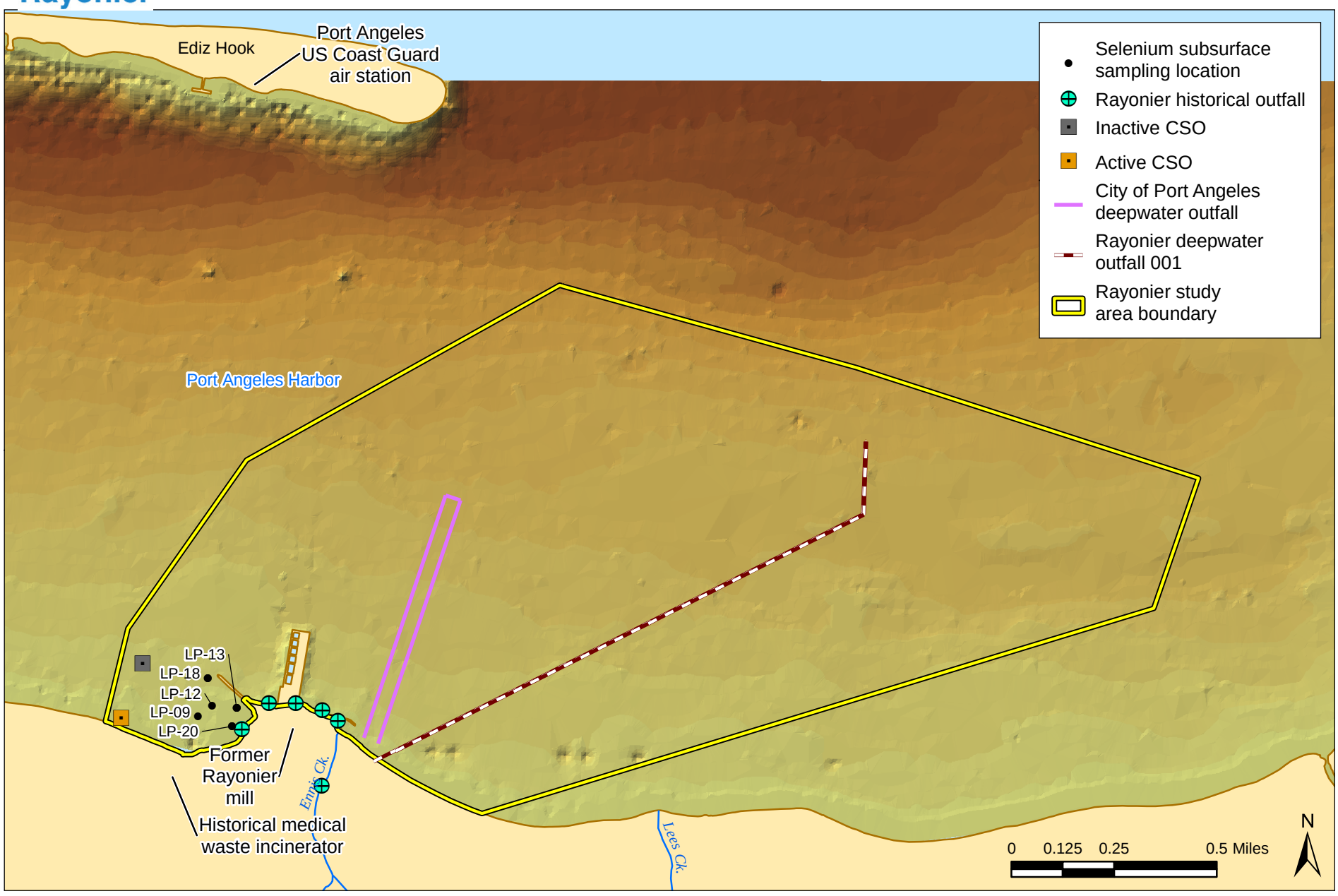
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

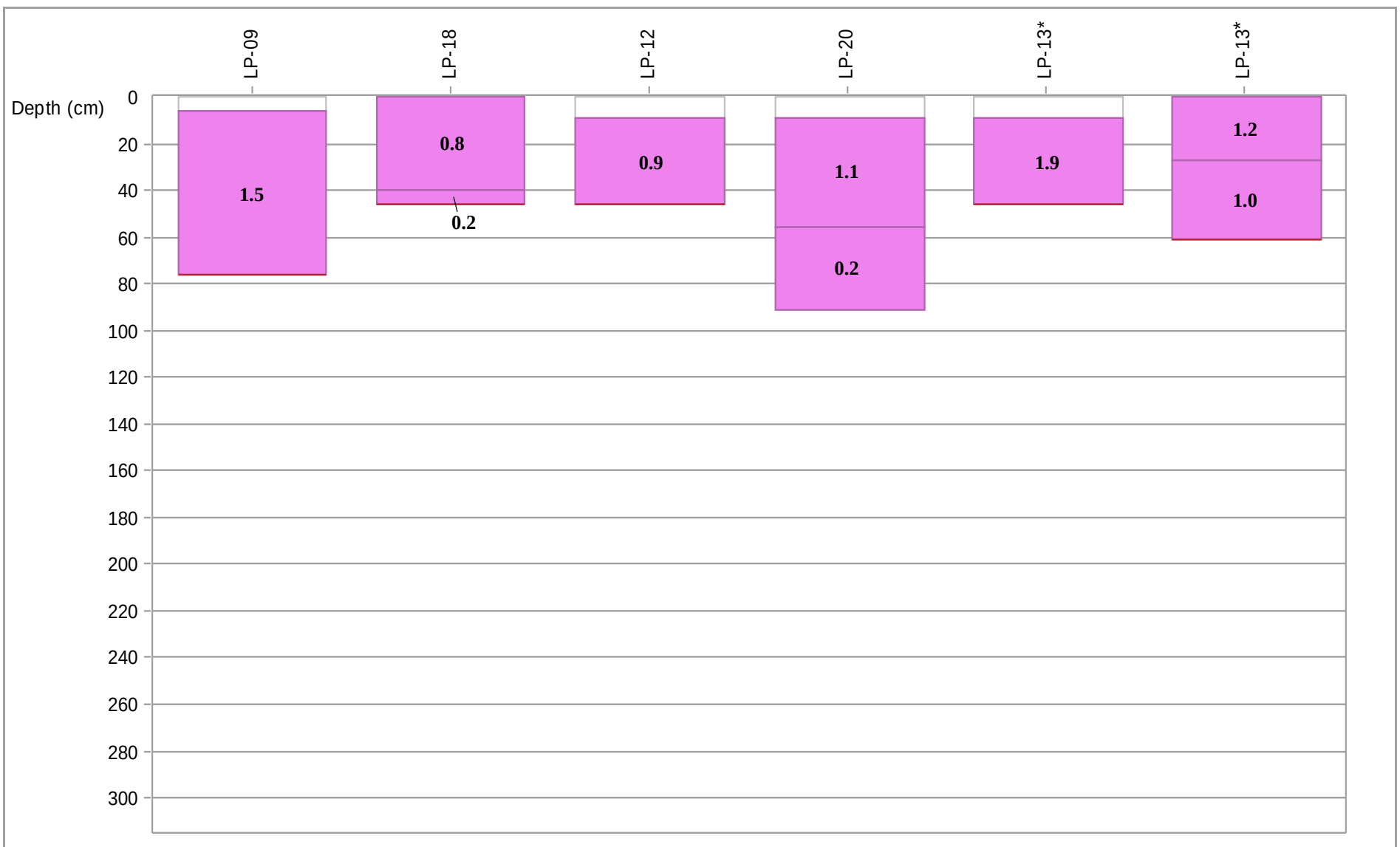
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-35. Copper concentrations in subsurface sediment samples from the study area

[a] Copper was detected in all 31 of the 31 subsurface sediment samples analyzed for copper. The non-detected concentration was calculated as one-half the reporting limit. Both detected and non-detected concentrations were used in calculating the percentiles.

Rayonier





*Samples collected from location LP-13 were analyzed at overlapping depth intervals.

Selenium concentration (mg/kg dw) in subsurface cores

- Detected concentration (shown on chart)
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

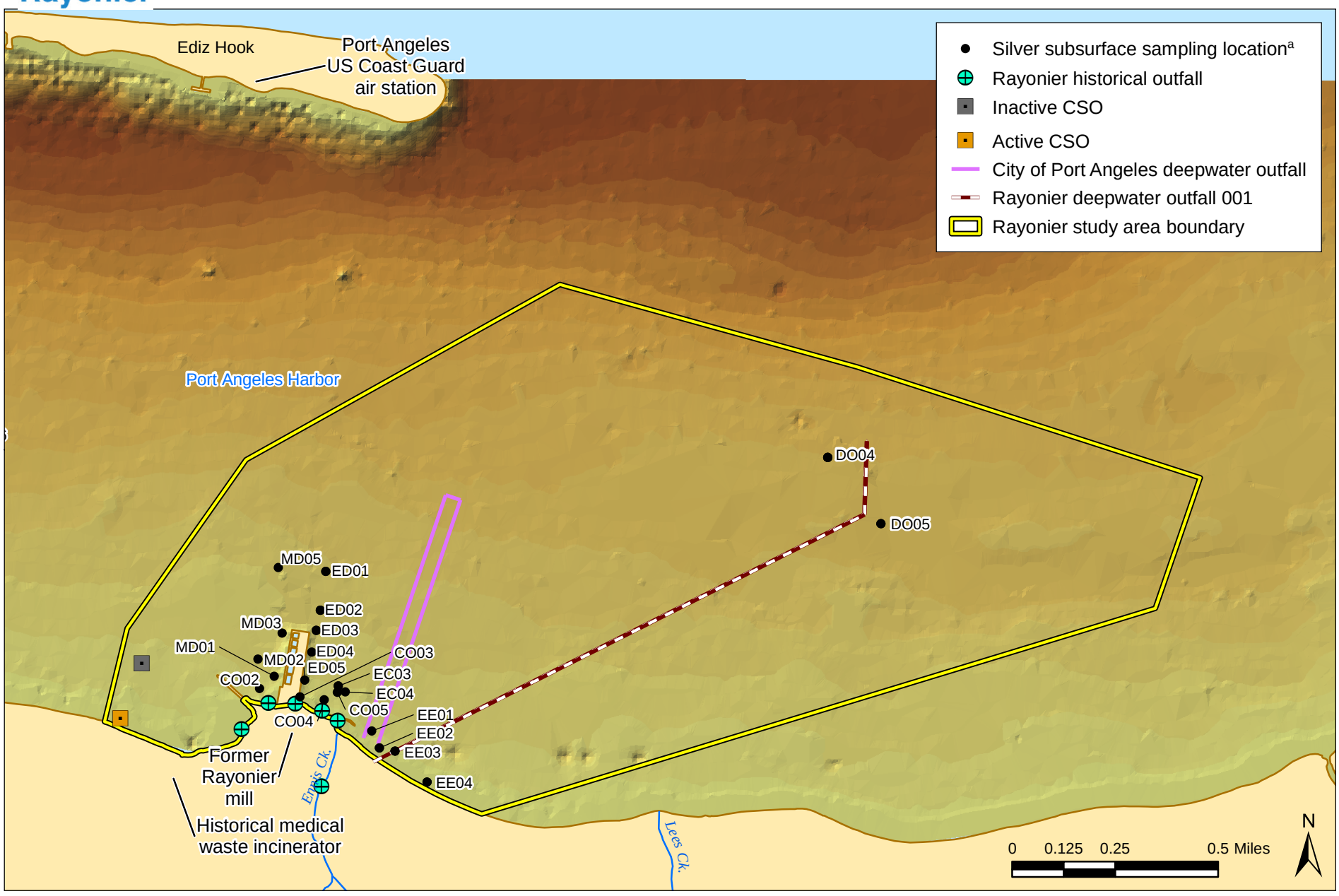
Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

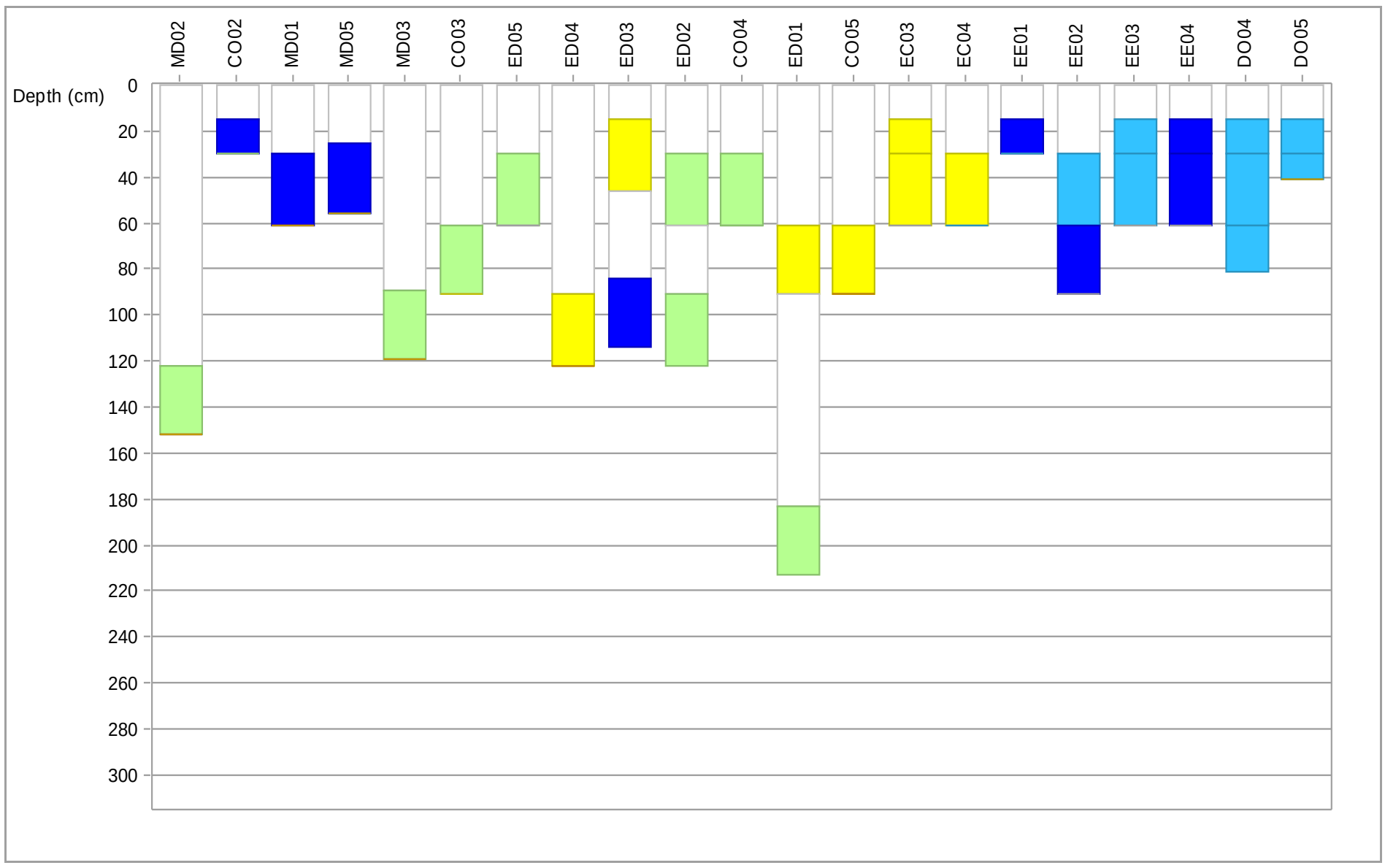
Map 2-36. Selenium concentrations in subsurface sediment samples from the study area

Wind Ward LLC environmental

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5637_Selenium in subsurface sediment samples from the study area_MTY_08302013.mxd

Rayonier





Silver concentration (mg/kg dw) in subsurface cores[a]

95th percentile = 0.2
75th percentile = 0.082
50th percentile = 0.063
25th percentile = 0.032
SCO = 6.1
CSL = 6.1

- > 0.2
- > 0.082 and ≤ 0.2
- > 0.063 and ≤ 0.082
- > 0.032 and ≤ 0.063
- ≤ 0.032
- Not detected
- Not analyzed

Bathymetry (Feet)

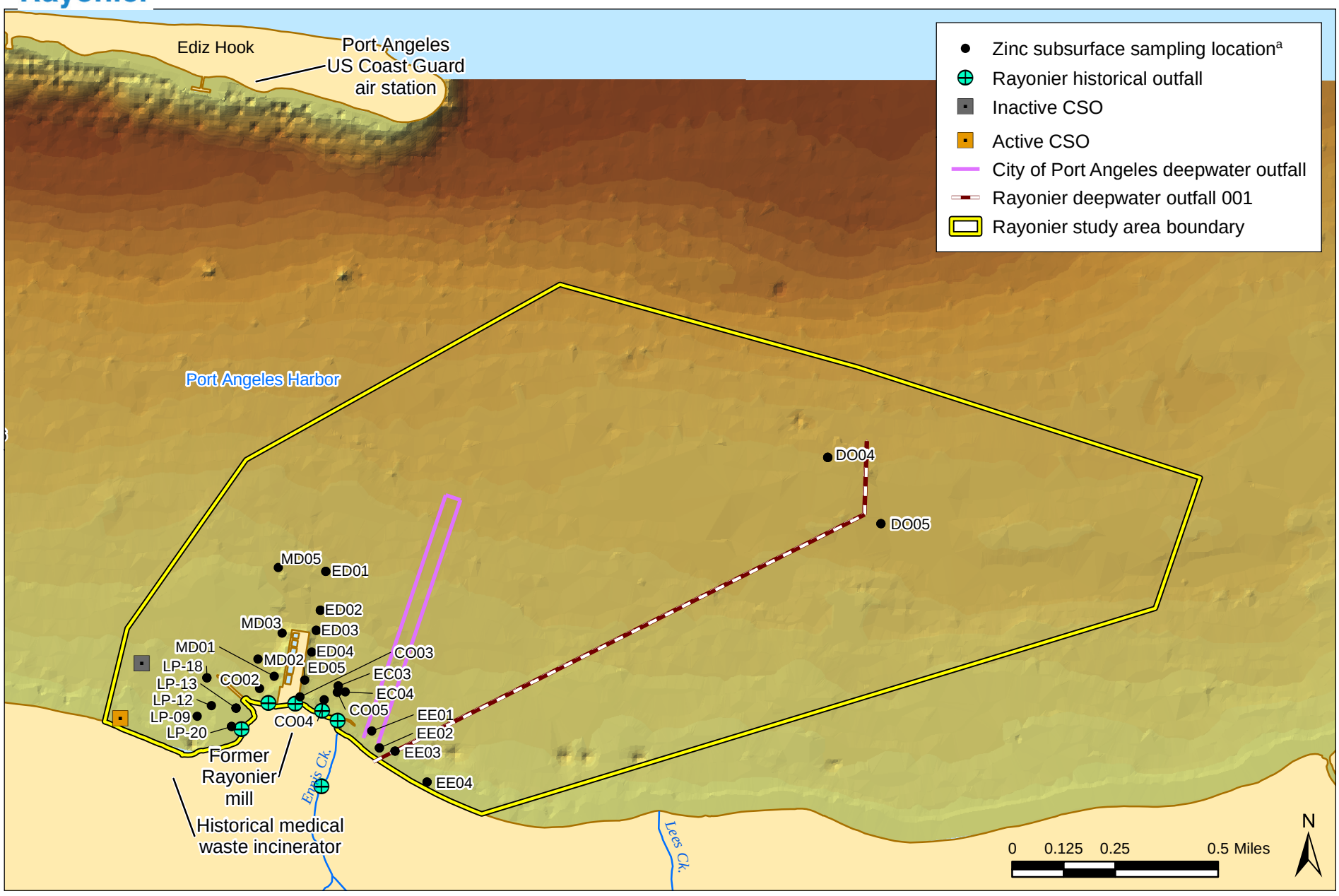
- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

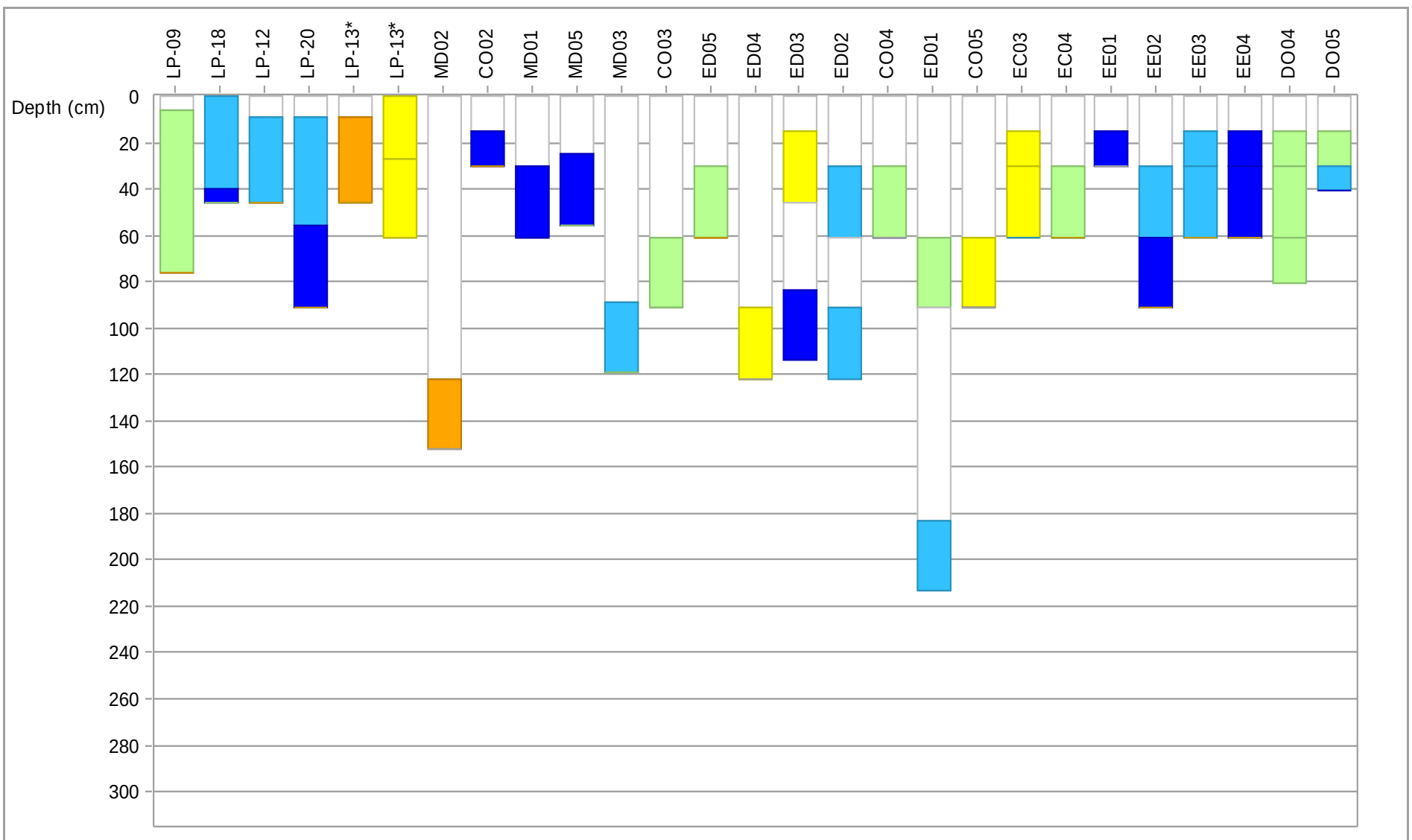
[a] Silver was detected in all 31 of the 31 subsurface sediment samples analyzed for silver. The non-detected concentration was calculated as one-half the reporting limit. Both detected and non-detected concentrations were used in calculating the percentiles.

Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-37. Silver concentrations in subsurface sediment samples from the study area

Wind Ward environmental LLC





*Samples collected from location LP-13 were analyzed at overlapping depth intervals.

Zinc concentration (mg/kg dw) in subsurface cores[a]

95th percentile = 117
75th percentile = 61
50th percentile = 43
25th percentile = 25
SCO = 410
CSL = 960

- > 117
- > 61 and ≤ 117
- > 43 and ≤ 61
- > 25 and ≤ 43
- ≤ 25
- Not detected
- Not analyzed

Bathymetry (Feet)

- -279 - -250
- -250 - -225
- -225 - -200
- -200 - -175
- -175 - -150
- -150 - -140
- -140 - -130
- -130 - -120
- -120 - -110
- -110 - -100
- -100 - -90
- -90 - -80
- -80 - -70
- -70 - -60
- -60 - -50
- -50 - -40
- -40 - -30
- -30 - -20
- -20 - -10
- -10 - 3

[a] Zinc was detected in all 40 of the 40 subsurface sediment samples analyzed for zinc. The non-detected concentration was calculated as one-half the reporting limit. Both detected and non-detected concentrations were used in calculating the percentiles.

Data source: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier. CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer and up-to-date, high-resolution imagery.

Map 2-38. Zinc concentrations in subsurface sediment samples from the study area

Wind Ward environmental LLC

APPENDIX A. PROJECT SETTING

APPENDIX A. PROJECT SETTING

Table of Contents

Tables

Figures

Maps

1 Introduction

The former Rayonier mill site is located in the city of Port Angeles in Clallam County, Washington, along the northern coast of the Olympic Peninsula, on the shore of Port Angeles Harbor (Figure A.1-1). Over the past century, the harbor has been used for a number of industrial purposes, with the primary industry being pulp and paper production. Other commercial and industrial uses of the harbor have included plywood manufacturing, marine shipping and transport, boat building and refurbishing, petroleum bulk fuel storage, marinas, and commercial fishing. This appendix describes the development history and land use in the vicinity of the site in Section 2, historical operations and discharges associated with the former Rayonier mill in Section 3, and discharges associated with other industrial sources in Port Angeles in Section 4. In addition, this appendix presents the environmental setting of the former Rayonier mill site and Port Angeles Harbor; the physical characteristics are described in Section 5 and the biological characteristics are summarized in Section 6.

Figure A.1-1. Location of the former Rayonier mill in Port Angeles

2 Development History and Land Use

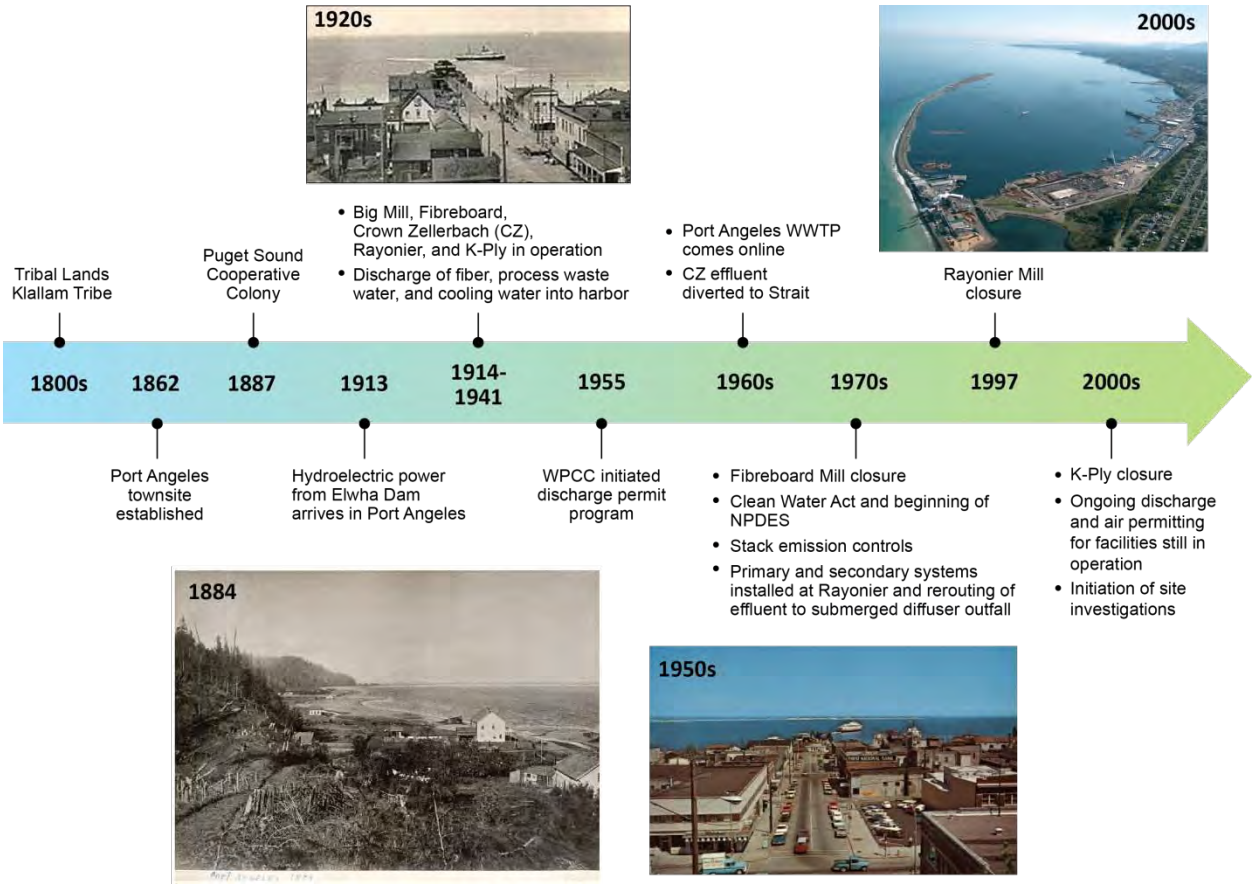
Prior to settlement by Europeans in the late 1850s, the Port Angeles area was home to the Lower Elwha Klallam Tribe (Wegmann et al. 2010). Two prominent villages are known to have existed along the waterfront: the Tse-whit-zen village, located along the inner harbor area at the base of Ediz Hook; and the I'e'nis village, located on the eastern bank of Ennis Creek in the vicinity of the former Rayonier mill site. In 1847, the I'e'nis settlement was reportedly occupied by about 200 members of the Klallam Tribe. After settlers arrived in the area and introduced diseases swept through the tribe, only a few Klallam residents remained.

When early settlers arrived in the area, they established economic interests based on the abundant natural resources. The arrival of the Puget Sound Co-Operative Colony in 1887 initiated one of the earliest periods of population growth in Port Angeles. The colony was established next to the I'e'nis village and was home to nearly 400 people at its peak. Some Klallam Tribe members lived at the village site east of Ennis Creek during the colony period, while most of the colony members lived at the former Rayonier mill site. The gradual movement of many colony members into the town and disputes over business profits led to the abandonment of the colony by 1893, and the colony went bankrupt in 1894. In 1917, the US government built a sawmill on the former colony site to mill spruce wood for the manufacture of aircraft. However, the sawmill sat idle until the site was purchased by Olympic Forest Products in 1929.

In terms of economic development, one of the most significant events in Port Angeles was the damming the Elwha River, which was completed in 1913. The dam provided inexpensive hydroelectric power, which served as the catalyst for the construction of three pulp mills along the shores of the Port Angeles Harbor: the Fibreboard mill, the Crown Zellerbach mill (now owned by Nippon Paper Industries),[1] and the Rayonier mill.

Given the abundance of the raw materials (wood and water) necessary to produce pulp and paper, readily available electricity, and natural deep harbor formed by Ediz Hook, the Port Angeles waterfront soon became dominated by the wood products and maritime industries. These two industries served as the economic engine for the region, providing the majority of employment, and Port Angeles became the urban center for the Olympic Peninsula. Continued population growth followed economic opportunity, and, in response, the city developed the infrastructure necessary to meet the demand (Figure A.2-1).

[1] The Crown Zellerbach Mill, later known as the Georgia Pacific Mill (Georgia Pacific was the successor to Crown Zellerbach), was also previously owned by Daishowa.



Source: Photographs courtesy of www.historylink.org, Essay 8210; Tim Riley; James Wengler (http://www.flickr.com/photos/james_wengler_photos)

Figure A.2-1. Timeline for Port Angeles Harbor

As in most urban areas in the early to mid-1900s, the City or Port Angeles used nearby water resources for the disposal of waste. Stormwater and sewage collection pipes were combined in a single collection and conveyance system that discharged directly into local water bodies without treatment. This meant that raw sewage was discharged into Port Angeles Harbor, either directly or indirectly via one of the streams that ran though the city.

As part of the development of Port Angeles Harbor as an economic and urban center, the shoreline was modified over time to meet the city's needs. In the late 1800s, a large portion of the Port Angeles shoreline was developed for the construction of a railroad track, which resulted in the filling of some shoreline features and the liberal use of riprap and other mechanisms to stabilize the new track bed.

Much of Port Angeles is built on historical tidal flats. Beginning in 1914, a regrade project was undertaken to eliminate coastal flooding of the central waterfront. Hydraulic mining and sluicing of nearby hills was used to raise street levels one full story above then existing street levels. Front Street and First Street were raised over 3.6 m (12 ft) during the filling project (Wegmann et al. 2010). The photographs

presented as Figures A.2-2 and A.2-3 show the central waterfront between the early 1900s and the 1960s and document the progression of development and filling of tidal flats to produce the present-day ferry terminal. Morse Dock (Figures A.2-2 and A.2-3) became the present-day terminal parking lot.

Source: www.historylink.org (Essay 8210)

Figure A.2-2. Port Angeles Harbor central waterfront circa 1920s

Source: www.historylink.org (Essay 8210)

Figure A.2-3. Port Angeles Harbor central waterfront circa 1960s

Currently, the former Rayonier mill site is located within the Port Angeles city limits, in an area of mixed industrial, commercial, recreational, and residential land uses. Most of the site is zoned heavy industrial. The area associated with the steep bluffs and ravine along the southern margin of the site is zoned for public buildings and parks. Two small areas along the bluff, south and southeast of the main process area, are zoned low-density residential. A small area at the southern end of the site is zoned commercial arterial. Land surrounding the site is occupied by the City of Port Angeles wastewater treatment plant (WWTP), the Olympic Memorial Hospital, several businesses, and numerous residences. In September of 2011, work began on the removal of the Elwha River Dam; the work was completed in late spring 2012.

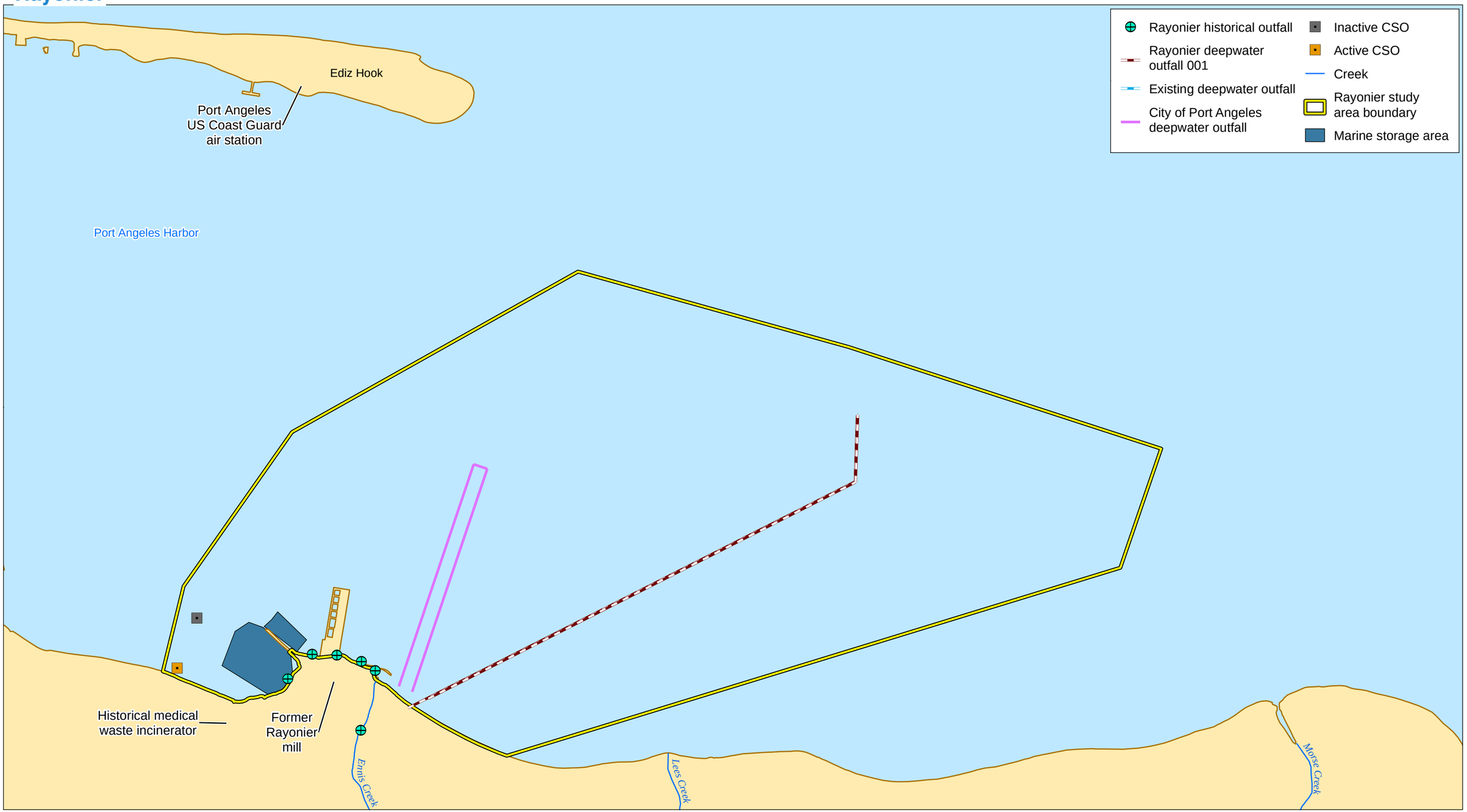
3 Rayonier Mill Operation History

A pulp mill was constructed at the former Rayonier mill site in 1930 by Olympic Forest Products, which purchased the parcel in 1929. Olympic Forest Products operated the mill until 1937 when it was acquired by Rayonier, Inc., which was formed through a merger with two other forest product companies. In 1997, Rayonier ceased operation of the mill and began dismantling the site. These activities were completed in October 1999. The site is currently held by Rayonier Properties LLC.

3.1 PULP PRODUCTION

This section describes the pulp production processes for the former Rayonier sulfite mill. Logs used in the pulping process were delivered to the mill via water or truck and then either rafted on the water or stored in the log yard until needed. Marine log storage areas are depicted in Figure A.3-1. Logs were temporarily staged prior to being towed to the log pond over a 210-ac area just south of Ediz Hook along the central portion leased from the Washington State Department of Natural Resources. Whole logs were debarked, washed to remove dirt and other contaminants, and then chipped in preparation for pulping. The next step in the process was to produce wood pulp by separating the cellulose fibers used to make paper and other products from all of the other organic components in wood.

Rayonier



Wind Ward LLC environmental

Outfalls: Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

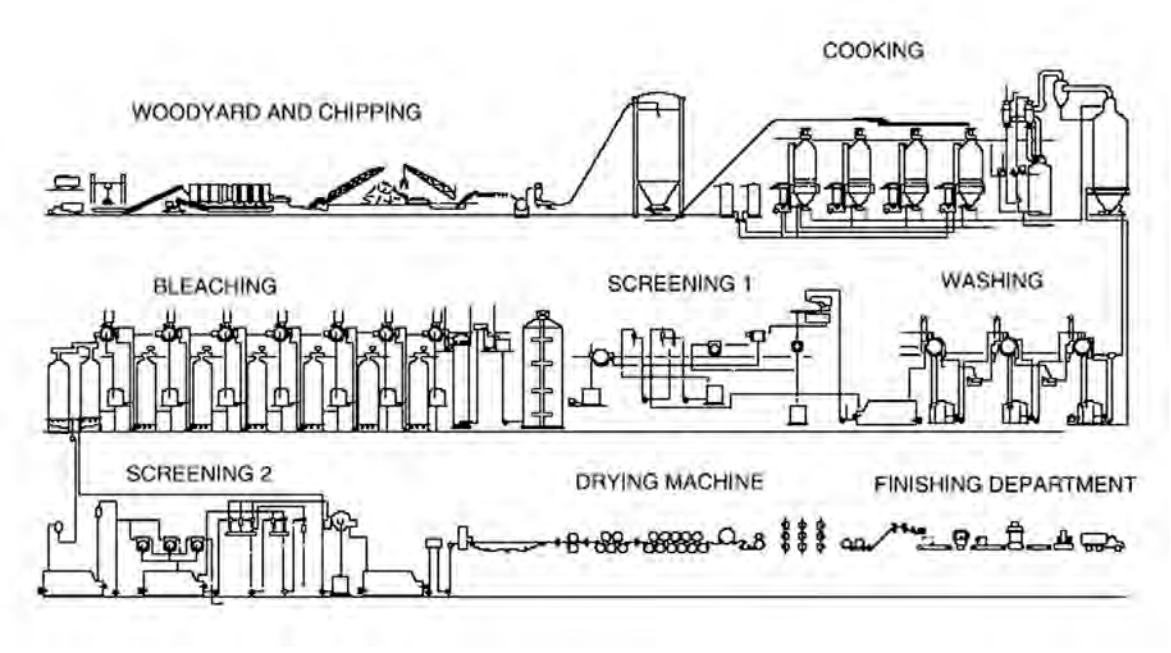
N

0 0.125 0.25 0.5 Miles

Figure A.3-1. Marine log storage areas in the study area

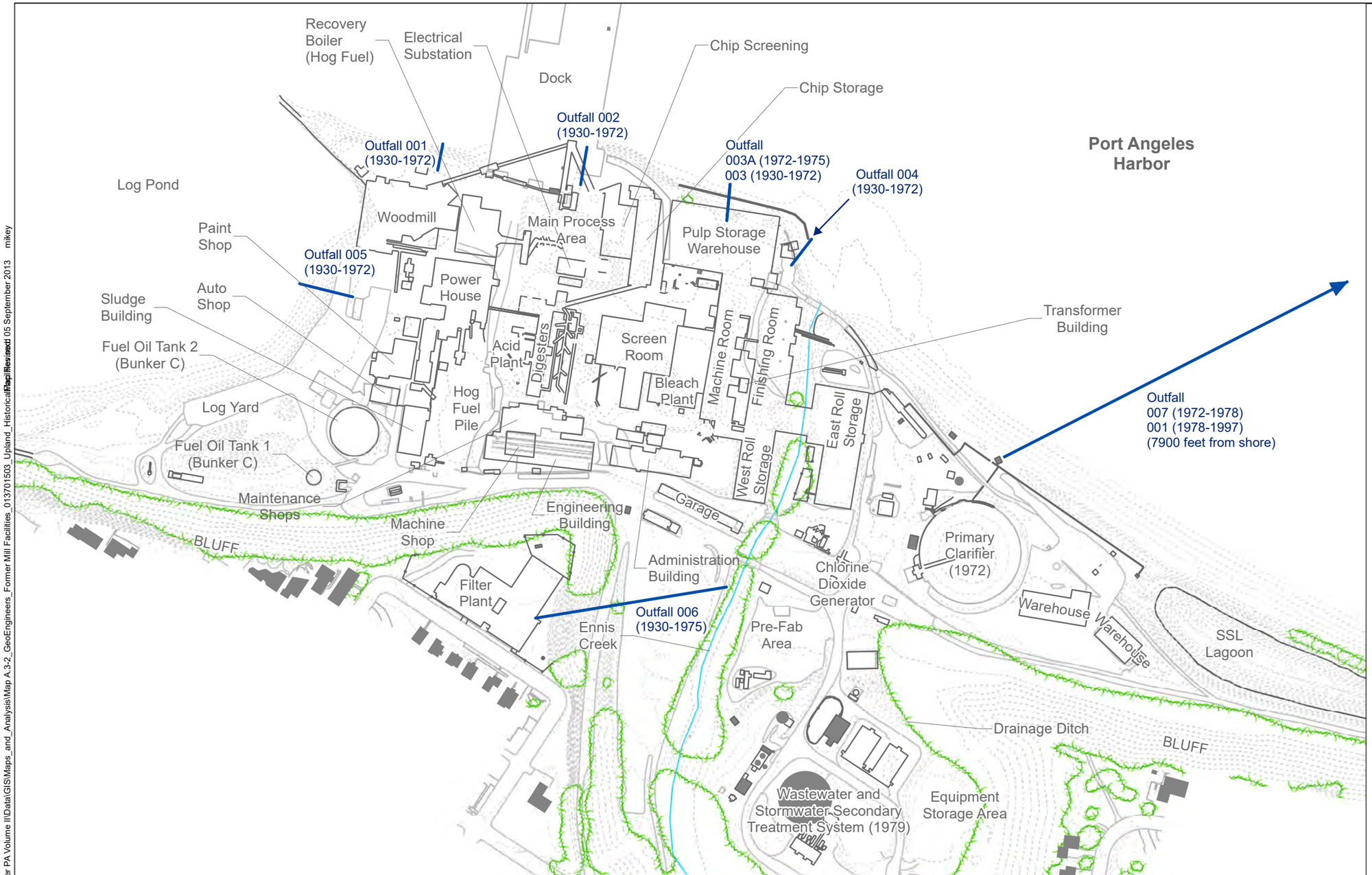
Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5640_Marine log storage areas within the study area_MTY_09032013.mxd

Chemical wood pulping involved "cooking" wood chips in a chemical solution under pressure at high temperature in order to dissolve the wood constituents that bound the cellulose fibers together. This chemical solution (the cooking liquor) was an acid solution that contained sulfur, ammonium, and water. After the sulfite cooking process was complete, impurities were separated from the fibers through washing and screening. To brighten pulp for paper or impart specific chemical properties for other uses, the mills used various treatments collectively referred to as bleaching. The general bleaching sequence was chlorine, caustic extraction, chlorine dioxide, another caustic extraction, another chlorine dioxide, and sulfur dioxide. Bleaching processes using chlorine dioxide, sodium hypochlorite, or hydrogen peroxide were subsequently applied to produce pulp of appropriate quality. Substitution of chlorine dioxide was limited because any other bleaching product would have yielded a product with different end products than what Rayonier's customers required. Chlorine dioxide (ClO_2) was generated on site using the Mathieson process. Sodium hypochlorite was also produced on site (Foster Wheeler 1997). Following bleaching and a subsequent final washing, the resulting mixture, known as cellulose slurry, which was composed of between 95 and 99% water, was sent to the machine room and sprayed on a tightly woven screen to form a sheet. Once the sheets had dried, they were pressed to form rolls for further processing by customers. Large volumes of fresh water were required throughout the pulping process. Figure A.3-2 presents a simplified schematic of the general chemical process for refining cellulose from wood chips. Figure A.3-3 shows the locations of where these processes occurred at the former Rayonier mill.



Source:www.forestproducts.sca.com/presentation by Dalia Jankunaite

Figure A.3-2. Simplified flow diagram for an integrated pulp mill



Explanation

- Upland Study Area Boundary
- Former Buildings and Structures
- Historical Outfalls
- Ennis Creek
- Tree Covered Area
- Existing Structure

N
W E
S

250 0 250
Feet

Data Source: Topography from Northwestern Territories, 2000.
Mill base features from Integral, 2007. Historic Outfalls from E & E, 1997.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Source: GeoEngineers (2011)

Figure A.3-3. Rayonier mill layout with process locations

Path: W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\Map A.3-2_GeoEngineers_Former Mill Facilities_013701503_Upland_HistoricalFacilities_Rev1.mxd 05 September 2013 mikey
Office: SEA

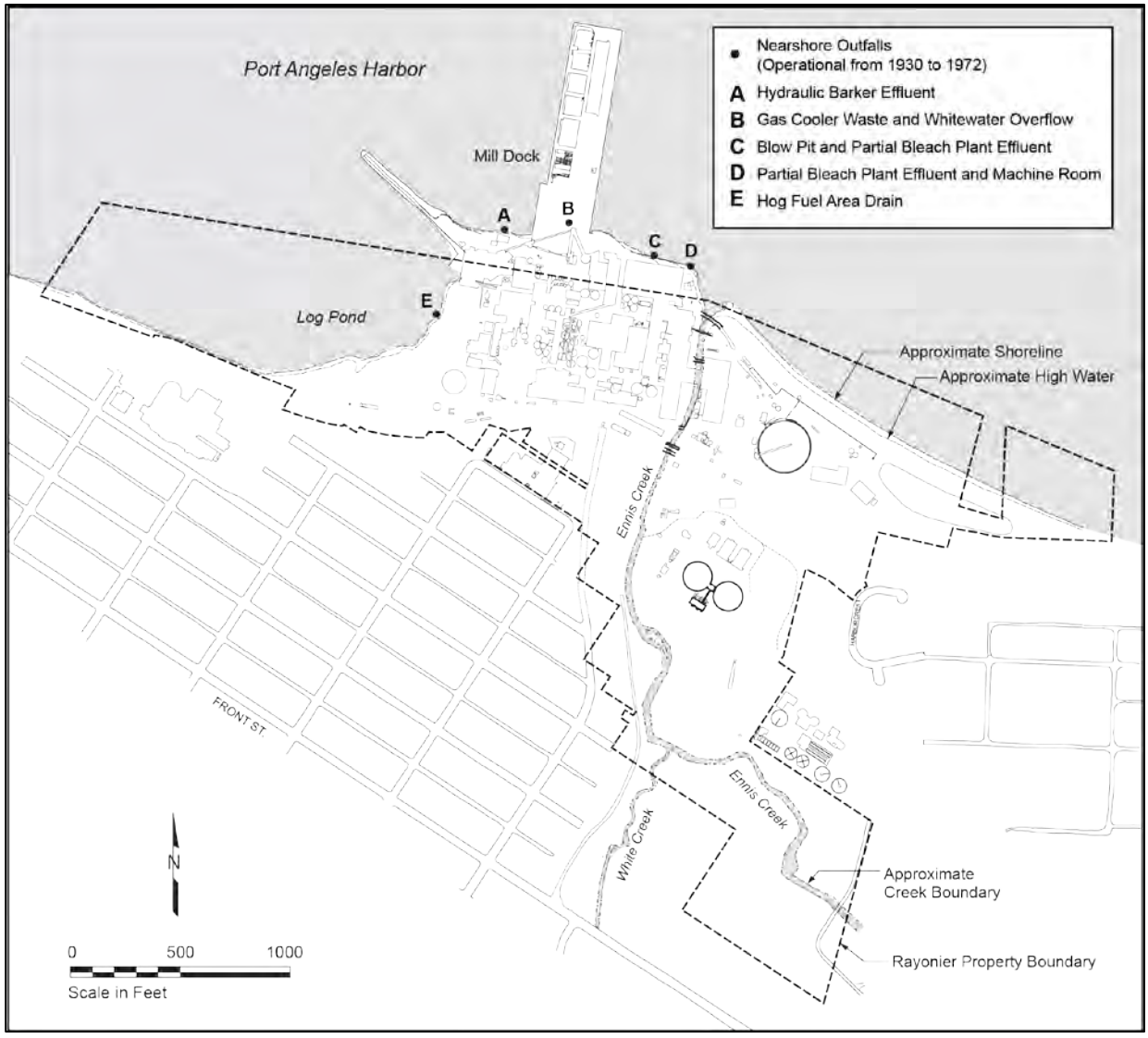
Process wastewater included spent cooking liquor that was not recovered, dissolved wood constituents, and wood chips and wood waste (e.g., knots) that were not completely dissolved during the cooking step. Prior to the development of environmental regulations, wastewater – which included domestic wastewater as well as process wastewater – was discharged to the harbor without treatment. In the early 1970s, the Rayonier mill undertook significant steps to manage and treat process wastewater discharges in order to comply with the 1972 Clean Water Act (CWA); wastewater began undergoing primary and secondary treatment prior to discharge, as discussed in detail in Section 3.3. In addition, the mill's five outfalls were consolidated and re-configured to discharge into deeper waters in the harbor (see Section 3.3).

3.2 WASTE MANAGEMENT

Multi-media waste management (i.e., recycling and disposal) was an integral part of the former Rayonier mill's operations. This section provides an overview of operational controls for managing wood waste, recycling chemicals, and reducing air emissions at the former Rayonier mill. Details on wastewater and stormwater discharges, which are of primary concern for marine environmental quality, are provided in Section 3.3. This section is a revision of text that was originally presented in the RI for the marine environment near the former Rayonier Mill site (Malcolm Pirnie 2007b).

3.2.1 Wood waste management

The process of turning wood chips into high-quality pulp resulted in the production of many wood chips and residual wood products that required disposal. In an effort to maintain the sediment depth and quality in the log pond where logs were stored, as well as around the mill dock where chips were transferred from barges (Figure A.3-4), these areas were periodically inspected and dredged. The dredged material was hauled to and deposited in one of two offsite landfills operated by the former Rayonier mill. No documents with details regarding specific dredging events, spoil amounts, or dates were located. General wood wastes such as bark, rejected wood chips, and debris were burned in the hog fuel boiler. The hog fuel boiler (No. 6), auxiliary power boilers (Nos. 4 and 5), and the recovery boiler generated steam, which was used in the pulp production process. When necessary, Bunker C fuel oil was used to supplement fuel demands. However, the recycling and burning of spent sulfite liquor (SSL) in the recovery boiler almost eliminated the necessity for burning fuel oil.



Adapted from Malcolm Pirnie (2007b) and Integral (2007).

Figure A.3-4. Former Rayonier mill

3.2.2 Chemical recycling and air quality management

In an effort to maintain air quality and to recycle chemicals used in the pulp production process, the mill had several controls in place. In 1974, Rayonier began monitoring air emissions – principally particulates, but also volatile organic compounds (VOCs), sulfur compounds, chlorine, carbon monoxide, and nitrogen oxides. From 1976 until the mill closed in 1997, hog fuel boiler emissions were monitored, and the air filtering technology in the hog fuel boiler (No. 6) was upgraded from a wet direct-contact scrubber to a dry electrostatic (gravel) scrubber.

Boiler ash, primarily fly ash from the hog fuel boiler was collected in a scrubber system, dewatered in a clarifier/dewatering system, and temporarily staged at a designated paved area near the log yard prior to disposal offsite in a landfill. Fine particulate matter from the recovery boiler was removed by means of glass fiber filters. Water from the wet scrubber system and clarifier was treated in the process wastewater system.

Sulfur dioxide was recovered from many of the onsite process areas. Recovery boiler gasses were passed through a cooling and absorbing filter system to recover sulfur dioxide in the form of ammonium bisulfite. Dissolved sulfur dioxide was recovered following the completion of the digestion process by venting steam and gases into high- and low-pressure condensers. The blow gas stripper system consisted of a water condenser, a condensate steam stripper, a stripped condensate storage and recycle tank, an absorption tower, duct work to convey the non-condensable blow gases to the limerock tower scrubbers, and other associated holding tanks and heat exchangers. The stored condensate was then fed back to the acid plant and recycled back into the cooking liquor. Finally, sulfur dioxide was removed from gasses in the red stock washer system washer hoods and filtrate tanks by being conveyed to the limerock tower scrubber.

Digestion chemicals (i.e., SSL) washed from the pulp were filtered to increase the solids content and stripped of sulfur dioxide through vapor recompression and the use of multi-effect evaporators. This process together with the energy from the hog fuel boiler allowed approximately 95% of the SSL to be burned in the recovery boiler to generate steam for the digestion process, which almost eliminated the need to burn fuel for energy production. Prior to being burned, the SSL was temporarily stored in the SSL lagoon, which was located on the easternmost portion of the site. This lagoon had a liner with a 1-to-2-ft-thick layer of clay (10^{-5} cm/sec permeability). In 1988, the lagoon was covered with a 60-mm, high-density polyethylene (HDPE) cover that floated over the liquid and significantly decreased odor-causing emissions from the lagoon.

3.3 WASTEWATER AND STORMWATER DISCHARGE

This section describes the historical and current discharge of wastewater and stormwater associated with the former Rayonier mill. This section is a revision of text that was originally presented in the marine RI (Malcolm Pirnie 2007b). The site of the former mill generally slopes to the north towards Port Angeles Harbor, with areas next to Ennis Creek generally sloping toward the creek (Figure A.3-4). All neighboring properties are located uphill of the former Rayonier mill site outfalls.

From 1930 until 1972, process wastewater and stormwater from the former Rayonier mill were discharged directly into Port Angeles Harbor by means of five nearshore outfalls (Map A.2-1). Regulatory oversight of the pulp mill began when Rayonier was issued a Washington State discharge permit on March 30, 1970. This permit required

that settleable solids be removed from mill wastewater and that effluent be adequately discharged and dispersed in the deep water of Port Angeles Harbor. In response to these regulations, Rayonier constructed an extensive sewer collection system and a primary treatment plant in 1972. The treatment plant routed all effluent and stormwater to a new outfall (Outfall 001), which extends 7,900 ft into the Strait of Juan de Fuca (Map A.2-1). All five nearshore outfalls were then removed from service. The last 940 ft of Outfall 001 has a diffuser with 48 6-in.-diameter ports spaced at intervals of 20 ft. Each port terminates with a 90-degree elbow that faces an alternating side of the outfall pipe. Maximum diffusion occurs because the diffuser intersects the predominant tidal currents at right angles.

The sewer collection system for primary treatment constructed in 1972 consisted of an elaborate piping system that accepted solids-bearing liquid discharges from all mill operations. This included roof drains, yard drains, and process sewers but not sanitary sewage. All sanitary sewage was pumped to the City of Port Angeles WWTP. Wastewater from the site was collected using 2 major pumping stations and 10 smaller gravity-fed sumps. The largest pumping station was located just south of the pulp storage warehouse, and it handled both high-solids and high-organic-content wastewater.

In 1972, Congress established the National Pollutant Discharge Elimination System (NPDES) program. Between 1973 and 1974, Rayonier and Ecology negotiated the terms of an NPDES permit for the former Rayonier mill. The effluent limits established for total suspended solids, pH, and biochemical oxygen demand were based on the Rivers and Harbors Act of 1899. The mill operated under NPDES permits from 1974 until the mill closed in 1997.

Also in 1972, EPA, through amendments to the Water Pollution Control Act, required that pulp mills have secondary effluent treatment in place by July 1, 1977. A secondary treatment system for wastewater and stormwater was constructed in 1979. The upgrade of the wastewater and stormwater treatment system resulted in the segregation of the collection system into three sewers: 1) a solids sewer (for wastewater that contained more than 0.3 pound of settleable solids per 1,000 gallons), 2) a strong sewer (for wastewater that contained less than 0.3 pound of settleable solids per 1,000 gallons), and 3) an uncontaminated sewer. In the pumping station, two pumps on the west side handled the solids sewer wastewater, and two pumps on the east side handled wastewater from the strong sewer. Solids sewer wastewater entered the solids sewer wet pit through a bar screen with a 5/8-in. screen to prevent large particles from entering the pumps. This sewer handled wastewater from the sidehills screens, machine room, finishing room, and the primary and secondary sludge dewatering complex, as well as miscellaneous pulp mill yard drainage.

The solids sewer also collected flow from the woodmill area (which included hydraulic barker and ground drainage from the woodyard power house, acid plant, and blow pits), and this wastewater was pumped directly to the primary clarifier

through the solids sewer force main. All solids sewer wastewater was directed to the primary clarifier, where a majority of the solids were removed through sedimentation. The resulting sludge was pumped to a dewatering device that was composed of three screw presses, and the dried sludge was burned in the hog fuel boiler (No. 6).

The strong sewer flow consisted of high-organic-content wastewater from the bleach plant washer seal tank overflow and the SSL recovery system. Wastewater from the primary clarifier (i.e., after primary treatment) was combined with wastewater in the strong sewer, and this combined flow was then sent to the secondary treatment system. Secondary treatment consisted of an activated sludge process in which primary-treated wastewater was aerated in tanks with micro-organisms that used the organic matter in the water (mostly sugars and organic acids) as a source of food. To ensure that biological activity was maximized, essential nutrients (including nitrogen in the form of aqueous ammonia and phosphorus in the form of phosphoric acid) were added, and ample oxygen was supplied through an elaborate diffuser system that was located at the bottom of each tank and powered by a 2,500-horsepower blower. Micro-organisms were separated from the wastewater in secondary dissolved air floatation clarifiers by means of rising gas bubbles. The micro-organisms formed a floating mat that could then be skimmed from the water surface. Foam accumulation in the tanks was controlled with defoamer spray, and pH in the tanks was controlled through the use of lime. Activated sludge removed from the secondary clarifiers was returned to the aeration tanks to maintain a sufficiently high concentration of biologically active micro-organisms and an acceptable level of treatment.

Much of the former Rayonier mill's wastewater (approximately 40%) (Ecology and Environment 1998) was uncontaminated; this included cooling water from the SSL recovery system surface condenser, limerock scrubbing tower water, blowpit recovery tower quench water, and washer seal tank overflows from the chlorine dioxide pulp washing. Wastewater from the secondary treatment system was combined with wastewater from the uncontaminated sewer, and the combined flow was discharged via gravity through Outfall 001. During mill operations, an average of 39 million gallons per day of effluent was discharged through Outfall 001.

Structural controls and site grading were used to prevent stormwater from flowing directly into Ennis Creek and into the marine environment. A drainage ditch that ran east-west and was located north of the secondary treatment area received surface water runoff from the treatment area and the bone yard. A sump at the west end of the drainage ditch directed water back into the treatment system. When the mill was operating, sumps were also located in the wood mill, log yard, and pulp mill area to divert stormwater into the treatment system.

In May 1989, a sheen was noted on Ennis Creek. Investigations found that hydraulic fluid from the finishing room presses (adjacent to and west of the creek) had leaked into the soil under the building and was seeping into the creek. Various remedial

actions were carried out between 1990 and 2003, when the removal of contaminated soil adjacent to Ennis Creek was completed.

Currently, the only direct discharge from the site is stormwater from the former industrial area (west of Ennis Creek), which percolates into the soil, and stormwater from the paved areas, which discharges through four discrete outfalls located in Ennis Creek. Rayonier prepared a stormwater management plan that described the facilities and procedures for managing stormwater during site dismantling and remediation activities. The purpose of the stormwater management plan was to minimize the erosion and transport of contaminated soil. The plan addressed the following:

- Structural controls (e.g., berms, trenches, curbing) for site drainage areas and the infiltration of stormwater through exposed soil areas
- Structural controls for and the infiltration of stormwater in areas east of Ennis Creek (during extended wet periods, stormwater is discharged through outfalls in Ennis Creek)
- Discharge to Ennis Creek of runoff from a parking lot located west of the creek
- A contained, paved area for excavated soil that had a dedicated stormwater collection and treatment system

4 Discharges into Port Angeles Harbor

The previous section describes discharges from the former Rayonier Mill into Port Angeles Harbor. This section describes discharges from sources other than the former Rayonier Mill. These discharges include waste from the other pulp mills, stormwater and sewage discharges, atmospheric releases, bulk fuel plants, golf course, and marine terminals.

4.1 Pulp and Paper Mills

Mills other than Rayonier that have operated in Port Angeles include Crown Zellerbach (currently Nippon), Fibreboard, and K-Ply Plywood (K-Ply) (Map A.2-1). The Crown Zellerbach mill began operations in 1928 and released process wastewater into Port Angeles Harbor until the 1960s, when it rerouted its outfall to discharge to the Strait of Juan de Fuca (Map A.2-1). The primary pulping process at Crown Zellerbach mill was mechanical grinding, although some sulfite was used in the processes as well. Because the mechanical process was less efficient than the sulfite chemical process in extracting cellulose from wood (FWPCA and WSPCC 1967), the amount of wood waste lost during pulping was 6 to 8 times higher for the mechanical process as compared with the chemical process (Lee et al. 1927).

Fibreboard (initially known as the Crescent Boxboard Company) began operations in 1918. Fibreboard did not upgrade its wastewater discharge system and, citing concerns over the economic viability of implementing the environmental upgrades

required by the pending new law, closed operations in 1970 (Basom c1969). Fibreboard primarily used the sulfite process, although some mechanical grinding was also used.

The K-Ply facility operated from 1941 to 2008. During its operation, the facility regularly discharged stormwater and wastewater, including boiler water treatment, boiler blowdown, and non-contact cooling water, into the harbor (SAIC 1999 as cited in Ecology 2009). K-Ply was cited for non-compliance for the discharge of boiler ash and ash-contaminated water to the storm system in 2004. As a result, K-Ply was required to implement best management practices (BMPs) to prevent the release of ash, fiber, and petroleum products to stormwater (Ecology 2004 as cited in Ecology 2009).

4.2 STORMWATER AND SEWAGE DISCHARGES

A 1967 report produced by federal and state agencies (FWPCA and WSPCC 1967) identified stormwater and domestic waste discharges from the City of Port Angeles, in addition to pulp mill discharges, as the most important contributors in terms of overall volume discharged into the harbor. Common stormwater contaminants include oil, grease, detergents, deodorizers, pharmaceuticals, cleaning products, pesticides, fertilizers, ash, and metals from brake linings of cars. In urban environments, contaminants are not only present in sanitary sewer discharges but are also washed from roofs, streets, and yards by rain or through human activities (e.g., washing cars, watering lawns) into streams, storm sewers, or other drainages that ultimately lead to the harbor.

The City of Port Angeles completed the construction of its primary WWTP in 1969. Prior to that time, sewage and stormwater were discharged into the harbor, either directly via outfalls located along the shoreline or indirectly through discharge to numerous creeks that surround the city (Map A.2-1) (Ecology 2008a). In 1969, the WWTP began discharging primary treated wastewater through a single deep-water outfall located 3,500 ft (1.1 km) offshore in the eastern end of the harbor (Map A.2-1). Today, the WWTP receives sewage and stormwater from approximately 11,642 ac of the Port Angeles watershed and operates under an NPDES permit.

Of the 11 outfalls that historically discharged untreated sewage and stormwater into the harbor, only 4 remain as combined sewer overflow (CSO) outfalls (Map A.2-1). Between 2000 and 2006, there were 973 overflow events from five outfalls (one CSO outfall was eliminated in 2005), with the result that over 233 million gallons of raw sewage were discharged into the harbor (Ecology 2008a). The City of Port Angeles is planning to improve its CSO system with the goal of conveying all wet-weather flows to the WWTP.

4.3 ATMOSPHERIC RELEASES

Contaminants have also been released to the harbor and shoreline areas via air emissions. Air emissions were released from various components at the former Rayonier mill site, including the recovery and hog fuel boiler stacks, the chlorine dioxide generator, and vents in the bleach plant, acid plant, and blowpits. Rayonier used wood chips, including salt-laden wood, in the hog fuel boiler. A recovery boiler was constructed in 1974, in part to reduce sulfur dioxide emissions. In addition, as discussed in Section 2.2.2.2, scrubbers and demisters were placed on the recovery boiler stack and on the hog fuel boiler (No. 6).

Three other hog fuel boilers have also operated in the area. Crown Zellerbach, Fibreboard, and K-Ply each operated a hog fuel boiler (Map A.2-1). The K-Ply facility used boilers fueled with wood-only waste produced onsite, supplemented with some purchased wood waste fuel (K Ply 2004). Some logs were rafted at the mill prior to processing, resulting in the use of some salt-laden wood waste in the hog fuel burner (K Ply 2004). The former Crown Zellerbach mill and Fibreboard mill also likely burned wood chips and wood wastes coming from logs floated in Port Angeles Harbor and other nearby bodies of water, although information on historical practices was not available. The Nippon mill (formerly owned by Crown Zellerbach) currently burns hog fuel (bark wood waste), cardboard, sludges, and residual oil No. 6 in its onsite boiler (Ecology 2008b). Other potential sources of contaminants to the environment from air emissions in the vicinity of Port Angeles include medical waste incinerators, crematoriums, automobiles, fires, and oil-fired furnaces.

4.4 BULK FUEL PLANTS AND MARITIME-RELATED SOURCES

Other potential sources of contaminants to Port Angeles Harbor include a number of former bulk fuel plants, Port of Port Angeles marine terminals, the Port Angeles Boat Haven Marina, and the Port Angeles Boat Yard (Map A.2-1). The bulk fuel plants were distribution and storage facilities that have had either underground or aboveground storage tanks and associated piping. Up to eight bulk fuel plants have operated at any one time in the vicinity of the Port Angeles Harbor. Many of these facilities have had enforcement and/or cleanup actions associated with spills and leaks (Ecology and Environment 2008).

In addition, the Port of Port Angeles operates four deepwater marine terminals (Terminals 1, 3, 4, and 7) (Map A.2-1); the principal activities at these terminals involve the loading and offloading of logs, lumber, pulp, paper, wood chips, chemicals, and petroleum products. Ship repair and maintenance is also conducted along the waterfront. A ferry to Victoria, BC, departs from Terminal 2 in Port Angeles.

5 Physical Characteristics

This section presents an overview of the physical characteristics of Port Angeles, including the geologic setting, hydrogeology, meteorology, bathymetry, and sediment characteristics. Sections 5.1 and5.2 are revisions of text that was originally presented in the marine RI (Malcolm Pirnie 2007b).

5.1 GEOLOGIC SETTING AND HYDROGEOLOGY

The former Rayonier mill site is located on a gently sloping area that drains to the north towards Port Angeles Harbor. Most of the former Rayonier mill site is relatively flat; surface elevations range from sea level to approximately 75 ft above the National Geodetic Vertical Datum (NGVD) (HLA 1993). The terrain rises to approximately 200, 265, and 150 ft above NGVD within approximately 1.0 mile southeast, south, and southwest, respectively of the former Rayonier mill site (HLA 1993). Hills within a mile southeast and southwest of the former Rayonier mill site gradually rise toward the foothills of the Olympic Mountains, which are approximately 5 miles from the site. The closest surface water bodies are Port Angeles Harbor, which borders the site on the north, and White and Ennis Creeks, which converge upstream of the former Rayonier mill and run through the site as Ennis Creek (Map A.3-1). A steep ravine is formed where White Creek cuts through the bluff on the southern end of the former Rayonier mill site and beyond. A site access road along the western side of this ravine drops in elevation from approximately 75 ft to just above sea level.

5.1.1 Regional geologic setting

The regional geology of the Olympic Peninsula is characterized by accretionary tectonics and can be divided into two geologic domains: the Olympic Core Terrane and the peripheral Crescent Terrane. The Olympic Core Terrane is comprised of complex deformed packages of Eocene to Miocene age sedimentary rocks with interbedded volcanic rocks. The terrane forms an accretionary prism thrust under the peripheral Crescent Terrane. The Crescent Terrane forms a horseshoe shape around the Olympic Core Terrane and is composed of the Crescent Formation, an Early to Middle Eocene oceanic tholeiitic basalt with associated interbedded marine sedimentary rocks (Rauch 1985; Tabor and Cady 1978; HLA 1993). The local site geology is characterized by Tertiary bedrock overlain by Pleistocene-age deposits and recent alluvium deposits.

The former Rayonier mill site lies in an area of alluvium deposited by Ennis Creek, beach deposits related to the Strait of Juan de Fuca, and fill material. Along the bluffs south of the site lie deposits of Vashon Till, an unsorted mix of gravel and cobbles in a matrix of sand, clay, and silt that blankets advance outwash deposits and other undifferentiated glacial deposits. Most of these glacial deposits are related to continental glaciations from the north, with minor amounts related to glaciation in the Olympic Mountains to the south. Depth to bedrock beneath the former Rayonier mill

site is unknown but is likely variable in the Port Angeles area based on local isolated outcrops of the Tertiary Twin River Formation (HLA 1993; Tabor and Cady 1978).

5.1.2 Hydrogeology

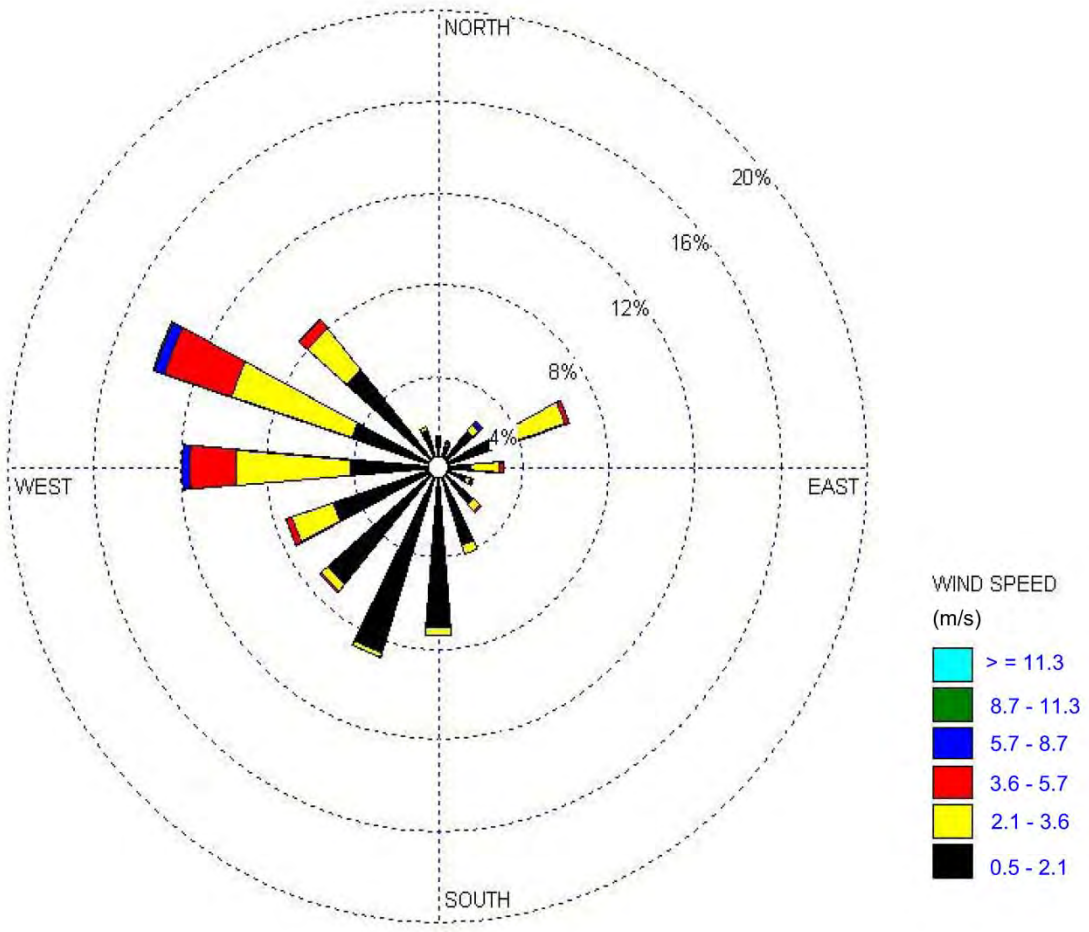
Site-specific hydrogeology is based primarily on groundwater data obtained during previous investigations conducted by HLA (1993), EPA (Ecology and Environment 1998), and Integral (2007) and more recently during an upland study area investigation conducted by GeoEngineers in 2010-2011 for Volume I of the interim action report (GeoEngineers 2011). Groundwater conditions observed during previous investigations indicated the presence of unconfined groundwater beneath the former Rayonier mill site in a shallow water-bearing zone consisting of near-surface fill and alluvial deposits. The depth to groundwater in this zone ranged from approximately 2 to 15 ft below ground surface (bgs). The water-bearing zone is variable in thickness; the base (generally defined by the top of the Vashon Till unit) varies from 12 ft bgs to > 30 ft bgs.

Groundwater elevations are influenced by tides (Ecology and Environment 1998) and, to a lesser degree, surface water fluctuations in Ennis Creek. Groundwater elevation measurements made during previous investigations indicated a predominantly northerly groundwater flow direction towards Port Angeles Harbor with a locally variable lateral component towards Ennis Creek. The groundwater flow direction does not appear to vary substantially on a seasonal basis. Groundwater elevations in monitoring wells in the upland study area were generally 1 to 2 ft higher during the February 2011 monitoring event than they were during the monitoring event completed in August 2010. This is consistent with seasonal rainfall patterns (i.e., more rainfall/infiltration occurs in February than in August) (GeoEngineers 2011). The 2010-2011 groundwater elevation data indicated that horizontal groundwater gradients generally ranged from 0.02 to 0.04 beneath the southern portion of the upland study area and from 0.004 to 0.01 beneath the northern portion of the upland study area.

The hydraulic conductivity of the shallow water-bearing zone above the glacial deposits was estimated to range from of 10^{-4} to 10^{-2} cm/s based on data collected in 2001 (Integral 2007). This range is consistent with the silty sand and gravel fill observed at the site. The significant contrast between the relatively low hydraulic conductivities of the glacial deposits (generally in the range of 10^{-7} to 10^{-5} cm/s) and the relatively high hydraulic conductivities of the shallow water-bearing zone (roughly three orders of magnitude difference, on average) suggests that the glacial deposits act as a low-permeability barrier to downward groundwater migration below the shallow water-bearing zone (GeoEngineers 2011). More detailed information on the hydrogeology of the site is presented in Volume I of the interim action report (GeoEngineers 2011).

5.2 METEOROLOGY

The mean annual temperature in Port Angeles is moderated by the warm currents that flow off the coast of Washington. Based on data gathered between 1951 and 1980 (Foster Wheeler 1997), average temperatures in the area range from 39° F in January to 59° F in July and August. Total annual precipitation (mostly occurring as rain at the lower elevations) is approximately 25.4 in., ranging from 0.5 in. in July to 4.4 in. in January. Winds in the area vary seasonally and are influenced by weather that approaches the coast. Winds measured during air quality monitoring at the former Rayonier mill were generally light to moderate, blowing primarily from the northwest (Integral 2007). A wind rose for the former Rayonier mill site that reflects both the wind speed and direction data from January 1998 to December 1998 (Figure A.5-1) shows that the predominant wind direction was from the west and west-northwest (Kennedy/Jenks 2004). Wind speed was most frequently between 0.5 and 2.1 m/s (1.1 and 4.7 mph). Wind speed and direction data were also collected by the Olympic Region Clean Air Agency at the base of Ediz Hook for a period of 18 months between December 2000 and May 2002; these data showed very similar patterns, with the wind direction being primarily from the west and west-northwest (Kennedy/Jenks 2004).



Source: (Kennedy/Jenks 2004)

Figure A.5-1. Wind rose for the former Rayonier mill site

5.3 BATHYMETRY

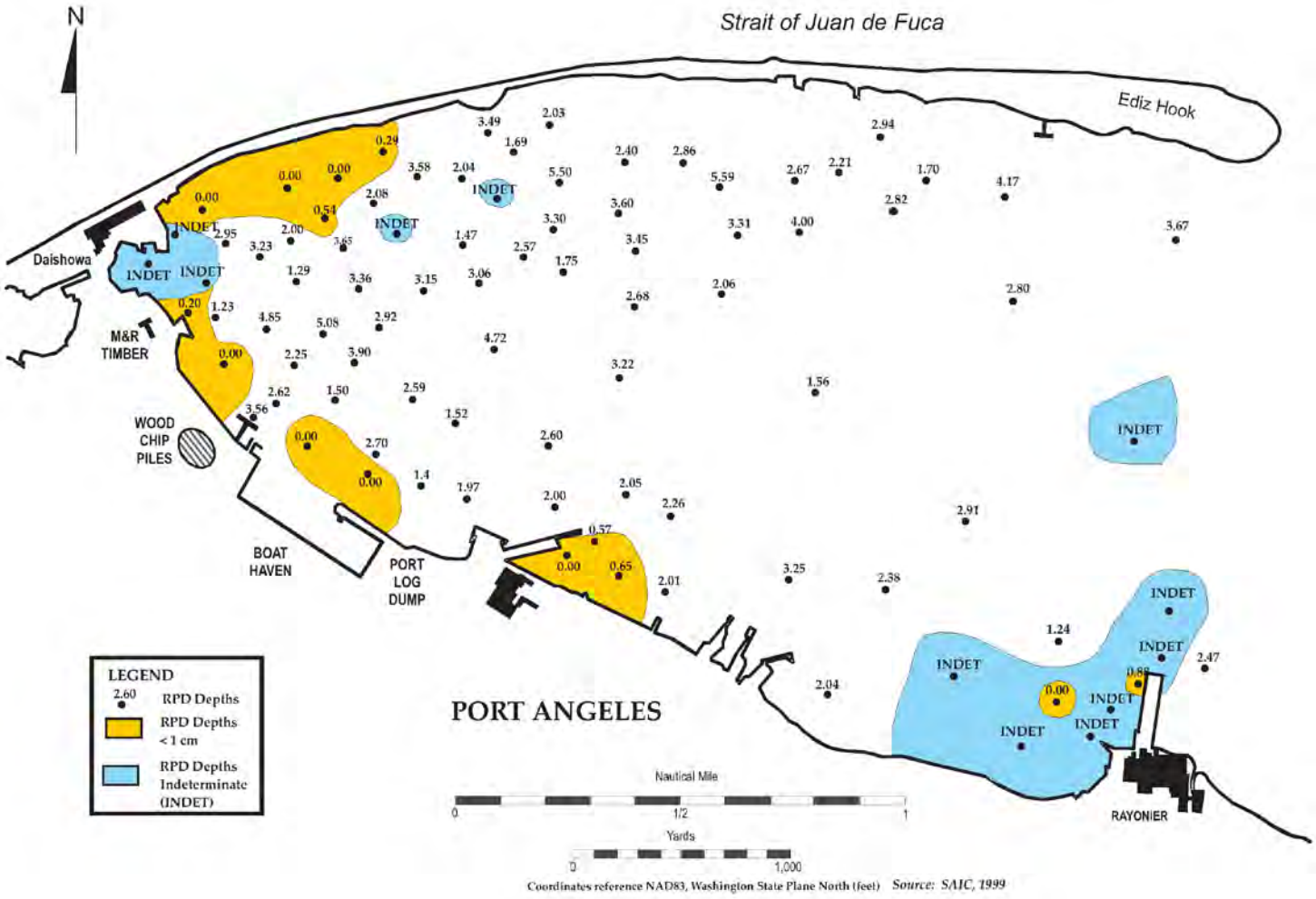
The southern shoreline of Port Angeles Harbor slopes relatively gently to the north until it reaches a maximum depth of over 135 ft in a channel just south of Ediz Hook (Map A.5-1). The southern shoreline of Ediz Hook drops relatively steeply into this channel.

5.4 SEDIMENT CHARACTERISTICS

This section describes the physical characteristics of sediment in Port Angeles Harbor, including the depth of redox potential discontinuity (RPD), total organic carbon (TOC), and sediment grain size.

5.4.1 Apparent RPD depth

The apparent RPD depth (depth of the oxygenated layer) was estimated from sediment vertical profiling system (SVPS) photography conducted by SAIC (1999). The apparent RPD depth is a sensitive indicator of infaunal succession, sediment bioturbation activity, and sediment oxygen demand. As expected, the central area of the harbor, where little or no wood waste has accumulated and where tidal exchange rates are high, showed the greatest apparent RPD depths; the maximum measured apparent RPD depth was 5.59 cm (Figure A.5-2). Apparent RPD depths were generally less than 1 cm in the active or former log boom areas. However, some areas with low apparent RPD depths had no accumulation of wood waste. At the two stations on the west side of the former Rayonier mill where the apparent RPD depth could be measured, it was less than 1 cm. At the single location on the east side of the former Rayonier mill dock, the apparent RPD depth was 2.47 cm.



Source: Malcolm Pirnie (2007b)

Figure A.5-2. Apparent RPD depths in Port Angeles Harbor

6 Biological Characteristics

This section describes general characteristics of the marine environment, marine species likely to be present, and endangered and threatened species.[2] The marine resources of the Port Angeles area have been described in a number of documents. One of the more comprehensive reviews (Shea et al. 1981) evaluated the history, dispersion, and effects of pulp mill effluents and included details on biological resources of the area. Other studies and reports have documented the specific distribution of salmon, marine fish, and shellfish in the area (e.g., Washington Department of Fisheries [WDF] (1992); Goodwin and Shaul (1978); Goodwin (1973); Goodwin and Westley (1969); Kittle (1976); Ecology (1976); Bishop and Devitt (1970); EVS Consultants (1994); Evans-Hamilton and DR Systems (1987); Simenstad et al. (1979); SAIC (1999); Ecology and Environment (1998)1998; Rayonier (1995); Washington State Department of Natural Resources (1977)). In addition, underwater video surveys were conducted along specific transects at the former Rayonier mill site in 2000 to evaluate the epibenthic community. The following sections summarize information on marine resources from a number of these publications and from video surveys conducted in Port Angeles Harbor (Foster Wheeler 2001; SAIC 1999).

The aquatic environment of Port Angeles Harbor has been described as an ecological transition zone between marine habitats to the west of Port Angeles and shallower, lower-salinity estuarine-type areas to the east (Shea, et al., 1981). The bottom contours of the southern portion of Port Angeles Harbor are characterized as a bench that generally slopes to deeper areas (more than 135 ft) to the north just on the inside of Ediz Hook. The shoreline along the southern border is characterized by either dock or port facilities in the inner harbor and riprap both east and west of the former Rayonier mill site. The beach and subtidal areas of the bench have a variety of soft substrates, including sand, gravel, and mud. No major natural outcrops of bedrock or other large hard-rock materials are evident (i.e., rocky shorelines are not present in the immediate area).

6.1 MARINE SPECIES

The marine species that use Port Angeles Harbor include phytoplankton and other marine plants, zooplankton, benthic invertebrates, shellfish, fish, birds, and mammals. Much of the data on these marine organisms were obtained from Shea et al. (1981). This section also identifies threatened, endangered, or sensitive species that may be present in Port Angeles Harbor.

[2] Most of this section is a revision of text that was originally presented in the marine RI (Malcolm Pirnie 2007b); the exceptions are Section 6.1.3, which was added, and Section 6.2, which was updated and revised.

6.1.1 Phytoplankton and other marine plants

Phytoplankton in Port Angeles Harbor include green algae, blue-green algae, euglenoids, diatoms, dinoflagellates, and microflagellates. These are generally considered primary producers that are prey of other organisms higher in the food web.

Benthic diatoms, which exist in and on the bottom substrate, are also present in the Port Angeles area (Shea et al. 1981); however, little is known about their distribution and abundance. Macroalgae are also present in the Port Angeles area; in general, macroalgae are attached to the substrate but may become detached through wind or wave action. Sea lettuce (*Ulva* spp.) and bladder kelp (*Fucus* spp.) may be present in shallow areas; laminarian kelp (*Nereocystis* spp.) maybe present in deeper areas. Large areas of *Nereocystis* (spp.) are present on the north side of Ediz Hook and in areas along the shoreline east of Port Angeles Harbor (Shea et al. 1981; WDF 1992).

The only notable seagrass species in the Port Angeles area is eelgrass (*Zostera marina*). Eelgrass is a rooted flowering plant that grows in sand or mud substrates from depths of mean lower low water (MLLW) to approximately -20 ft MLLW. The best locations for eelgrass within Port Angeles Harbor are along the inside of Ediz Hook (Shea et al. 1981). One small eelgrass plant, consisting of only a few shoots, was observed just east of the former Rayonier mill dock during video surveys conducted in 2000 (Foster Wheeler 2001).

6.1.2 Zooplankton

Zooplankton are primary consumers that feed mainly on phytoplankton. Because of their large numbers, they provide a significant biomass for consumption by higher-trophic-level species, such as baitfish, sportfish, or commercial species. Shea et al. (1981) described three types of zooplankton:

- Ichthyoplankton (eggs and larval forms of fish and shellfish)
- Microzooplankton (microscopic organisms)
- Macrozooplankton (very small but visible marine animals)

The abundance and distribution of zooplankton is highly affected by the season, tide, and location, among other factors. Ichthyoplankton from a wide variety of marine fish species (e.g., herring, sand lance, flatfish, rockfish, and cod) may be found in the Port Angeles area during certain seasons of the year. Ciliates are the most common microzooplankton in the vicinity of Port Angeles Harbor, and copepods are the most abundant macroplankton species (Chester et al. [1978]). Chester et al. ([1978]) reported the presence of about 60 species of copepods in waters in the vicinity of Port Angeles Harbor.

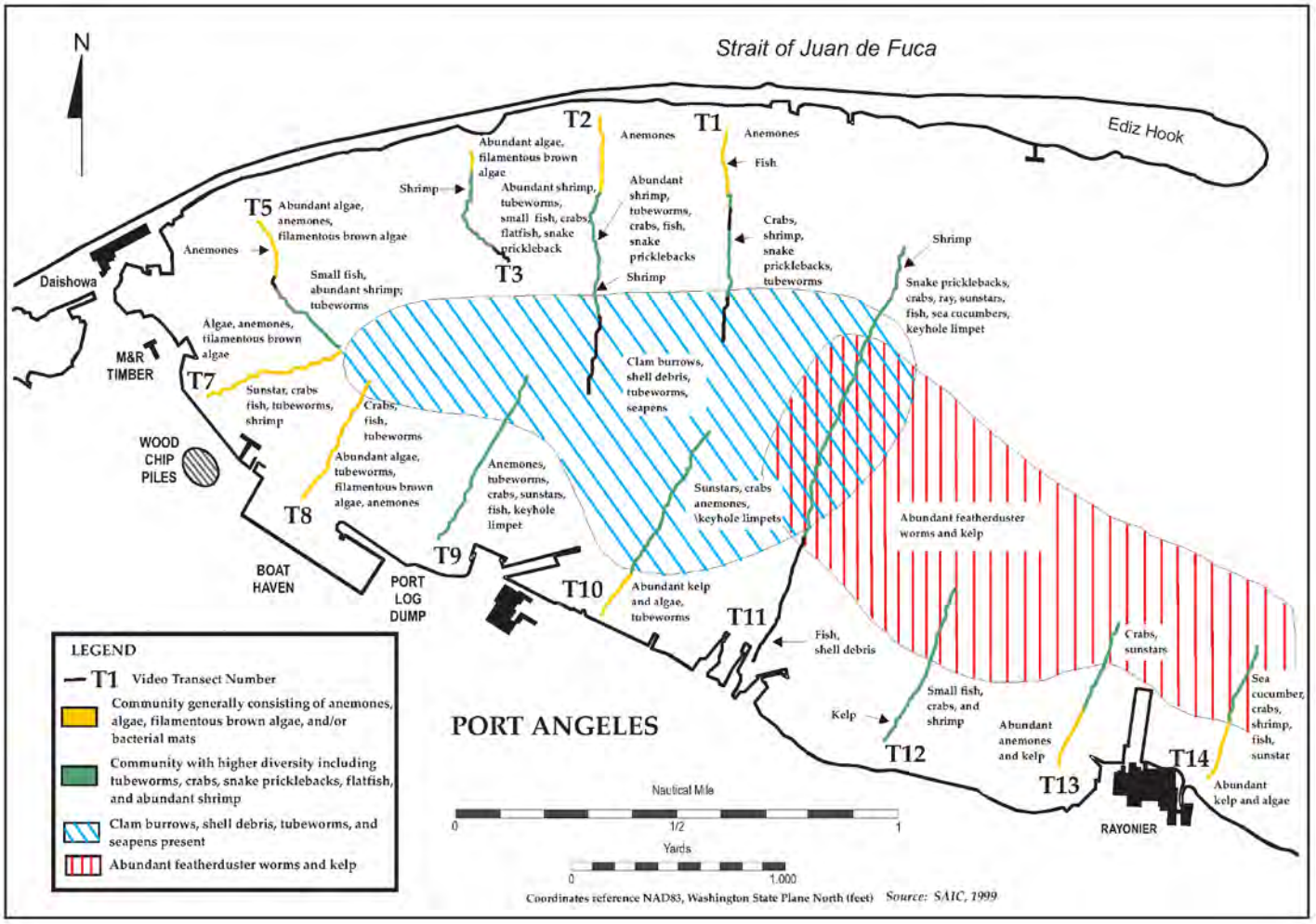
6.1.3 Benthic invertebrate community

Ecology (1998) collected samples at one station in central Port Angeles Harbor on an annual basis from 1989 to 1993 as part of a marine sediment monitoring program to evaluate the distribution and structure of benthic communities throughout Puget Sound. The results indicated that the benthic community was dominated by polychaetous annelids. These polychaetes were composed of two functional types; the most abundant type of polychaete included head-down deposit feeders in the family *Maldanidae*, and the second most abundant included species in several families that inhabit the upper 1 cm of the sediment surface, consisting of both free-living and tube-inhabiting detrital/deposit feeders (Ecology 1998, 2012). Over the 5-year period (i.e., 1989 to 1993), annelids comprised approximately 58 to 81% of the benthic invertebrate community, followed by crustaceans (approximately 8 to 20%), bivalves (approximately 7 to 18%), and gastropods (approximately 2 to 4%).

As part of the Port Angeles Harbor wood waste study (SAIC 1999), the SVPS photos were evaluated to determine the infaunal benthic community and its successional stage. The infaunal community in most areas of the harbor consisted of small surface feeding or filtering Stage I (pioneering) organisms and larger head-down deposit feeders (Stage III). Stage III organisms were most often found in the central open water areas of the harbor, and Stage I organisms were most often found in active or former log boom areas. Successional stage was determined only at 3 of the 11 stations near the former Rayonier mill site; 2 of the stations were identified as Stage I (consisting of very small organisms that live at or near the sediment-water interface), and the third station was identified as Stage I on III (with larger deep-burrowing infauna).

An organism-sediment index (OSI) was also calculated by SAIC (1999) using dissolved oxygen levels, apparent RPD depth, infaunal successional stage, and the presence or absence of methane bubbles. The OSI results indicated stressed communities were present along both the southern and northern shorelines in the western harbor. Data were insufficient to determine OSI values for all but two of the stations near the former Rayonier mill site. One of these stations located on the west side of the former Rayonier mill dock indicated a stressed community, and the station located on the east side indicated a healthy community.

In addition to the SPVS survey, SAIC conducted an underwater video survey of the bottom of Port Angeles Harbor as part of the wood waste study (SAIC 1999). Types of epibenthic organisms encountered during this survey are shown in Figure A.6-1. Epibenthos in the vicinity of the log pond included communities dominated by anemones and kelp, as shown in the underwater video. Epibenthos in the vicinity of the former Rayonier mill dock area included communities dominated by anemones and kelp in the nearshore areas; crabs and sunstars on the west side of the dock; and sea cucumbers, crabs, shrimp, fish, and sunstars on the east side of the dock.



Source: Malcolm Pirnie (2007b)

Figure A.6-1. Epibenthic activity in Port Angeles Harbor based on underwater video

6.1.4 Shellfish

Shellfish present in Port Angeles Harbor include clam, crab, and shrimp species. Table A.6-1, which is adapted from Shea et al. (1981), lists the commercial and non-commercial shellfish species that have been identified in the Port Angeles area. The main portion of Port Angeles Harbor (westward of a line between the tip of Ediz Hook and the former Rayonier mill dock) is currently closed to the harvest of shellfish as a result of pollution (WSDOH 2011); no details regarding this pollution were provided.

Table A.6-1. Commercial and non-commercial shellfish species present in the Port Angeles area

Taxonomic Category	Common Name	Scientific Name
Hard-shell clams	butter clam	*Saxidomus giganteus*
	cockle	*Clinocardium nuttallii*
	geoduck	*Panopea abrupta*
	horse clam	*Tresus* spp.
	native littleneck	*Protothaca staminea*
Soft-shell clams	bent-nose	*Macoma nasuta*
	macoma	*Macoma spp.*
	polluted macoma	*Macoma irus*
	Eastern soft-shell	*Mya arenaria*
	truncate soft-shell	*Mya truncata*
Miscellaneous clams, mussels, urchins, and sea cucumbers	blunt jacknife	*Solen sicarius*
	milky pacific venus	*Compsomyax subdiaphana*
	ample roughmya	*Panomya ampla*
	tellen	*Tellina* spp
	blue mussel	*Mytilus trossulus*
	green sea urchin	*Strongylocentrotus droebachiensis*
	sea cucumber	*Parastichopus californicus*
Oysters	Pacific oyster	*Crassostrea gigas*
Crab	Dungeness crab	*Cancer magister*
	red rock crab	*Cancer productus*
Shrimp	coonstripe shrimp	*Pandalus danae*
	pink shrimp	*Padalus jordani* or *P. borealis*
	side-striped shrimp	*Pandalopsis dispar*
	spot shrimp	*Pandalus platyceros*

Note: Adapted from Shea et al. (1981).

6.1.5 Fish

More than 60 species of marine fish have been observed in the Port Angeles area (Shea et al. 1981) (Table A.6-2). Species that are particularly important with regard to sport, commercial, and tribal harvests are salmon, halibut, rockfish, and flatfish, including flounder, sole, halibut, and sanddabs.

Table A.6-2. Marine fish species present in the Port Angeles area

Taxonomic Category	Common Name	Scientific Name
Sharks, Skates, Rays, and Ratfish (Class Chondrichthyes)		
Dogfishes (Family *Squalidae*)	spiny dogfish	*Squalus acanthias*
Ratfishes (Family *Chimaeridae*)	ratfish	*Hydrolagus colliei*
Bony Fishes (Class Osteichthyes)		
Herring (Family *Clupeidae*)	Pacific herring	*Clupea pallassii*
Smelt (Family *Osmeridae*)	longfin smelt	*Spirinchus thaleicthys*
	surf smelt	*Hypomesus pretiosus*
Anchovies (Family *Engraulidae*)	Northern anchovy	*Engraulis mordax*
Sand lances (Family *Ammodytidae*)	Pacific sandlance	*Ammodytes hexapterus*
	three-spined stickleback	*Gasterosteus aculeatus*
	tubesnout	*Aulorhynchus flavidus*
Salmon, trout, and char (Family *Salmonidae*)	Chinook salmon	*Oncorhynchus tshawytscha*
	chum salmon	*Oncorhynchus keta*
	coho salmon	*Oncorhynchus kisutch*
	pink salmon	*Oncorhynchus gorbuscha*
	sockeye salmon	*Oncorhynchus nerka*
	steelhead trout	*Oncorhynchus mykiss*
	cutthroat trout	*Oncorhynchus clarki*
Codfishes (Family *Gadidae*)	Pacific cod	*Gadus macrocephalus*
	Pacific hake	*Merluccius productus*
	Pacific tomcod	*Microgadus proximus*
	walleye pollock	*Theragra chalcogramma*
Pipefishes and seahorses (Family *Syngnathidae*)	bay pipefish	*Syngnathus griseolinatus*
Gunnels (Family *Pholididae*)	crescent gunnel	*Pholis laeta*
	penpoint gunnel	*Apodicthys flavidus*
	saddleback gunnel	*Pholis ornate*

Taxonomic Category	Common Name	Scientific Name
Pricklebacks (Family *Stichaeidae*)	high cockscomb	*Anoplarchus purpurescens*
	black prickleback	*Xiphister atropurpureus*
	rock prickleback	*Xiphister mucosus*
	ribbon prickleback	*Phytichthys chirus*
	snake prickleback	*Lumpenus sagitta*
Clingfish (Family *Gobiesocidae*)	Northern clingfish	*Gobiesox maeandricus*
Sculpins (Family *Cottidae*)	buffalo sculpin	*Enophrys bison*
	calico sculpin	*Clinocottus embryum*
	darter sculpin	*Radulinus boleoides*
	fluffy sculpin	*Oligocuttus snyderi*
	grunt sculpin	*Rhamphocottus richardsoni*
	manacled sculpin	*Synchirus gilli*
	mosshead sculpin	*Clinocottus globiceps*
	padded sculpin	*Artedius fenestralis*
	Pacific staghorn sculpin	*Leptocottus armatus*
	rosylip sculpin	*Ascelichthys rhodorus*
	saddleback sculpin	*Oligocottus rimensis*
	sharpnose sculpin	*Clinocottus acuticeps*
	silverspotted sculpin	*Blepsias cirrhosus*
	smoothhead sculpin	*Artedius lateralis*
	soft sculpin	*Psychrolutes sigalutes*
	tadpole sculpin	*Psychrolutes paradoxus*
	tidepool sculpin	*Oligocottus maculosus*
	cabezon	*Scorpaenichthys marmoratus*
Snailfishes and Lumpfishes (Family *Cyclopteridae*)	ringtail snailfish	*Liparis rutteri*
	showy snailfish	*Liparis pulchellus*
	tidepool snailfish	*Liparis florae*
Surfperches (Family *Embiotocidae*)	shiner perch	*Cymatogaster aggregata*
	striped perch	*Embiotoca lateralis*
Rockfishes (Family *Scorpaenidae*)	copper rockfish	*Sebastes caurinus*
	quillback rockfish	*Sebastes maliger*
	other rockfishes	*Sebastes sp*
Greenlings (Family *Hexagrammidae*)	kelp greenling	*Hexagrammos decagrammus*
	white-spotted greenling	*Hexagrammos stelleri*
	lingcod	*Ophiodon elongatus*

Taxonomic Category	Common Name	Scientific Name
Poachers (Family *Agonidae*)	sturgeon poacher	*Podotheus acipenserinus*
	tubenose poacher	*Pallasina barbata*
	warty poacher	*Occella verrucosa*
Righteye flounder, sole, and Halibut (Family *Pleuronectidae*)	starry flounder	*Platichthys stellatus*
	Pacific halibut	*Hippoglossus stenolepis*
	C-O sole	*Pleuronichthys coenosus*
	Dover sole	*Microstomus pacificus*
	English sole	*Pleuronectes vetulus*
	rock sole	*Pleuronectes bilineata*
	sand sole	*Psettichthys melanostictus*
	turbot	*Atheresthes stomias*
Sanddabs (Family Bothidae)	Pacific sanddab	*Citharichthys sordidus*
	speckled sanddab	*Citharichthys stigmaeus*

Note: Adapted from Shea et al. (1981). This list includes most of the species that have been recorded in the Port Angeles area. Additional species of sharks, rockfish, flatfish and other fish may also be present, but are not common. There is wide variation in the abundance, distribution, and seasonal occurrence of these species.

Salmon generally migrate through the Port Angeles area either as adults that are returning to freshwater areas to spawn or as juveniles that are migrating to the open ocean for maturation into adults. The five primary species of salmon that may be present are Chinook, coho, chum, pink, and sockeye. Some species (particularly Chinook and coho salmon) may be present in the Port Angeles area year-round, particularly if forage is present. In addition, steelhead and cutthroat trout may be present in creeks during migratory periods or when following schools of forage fish that move through the Port Angeles area.

The term "rockfish" is used for a number of different species that belong to the genus *Sebastes* (Kramer and O'Connell 1995). The term "bottomfish" is a much broader definition that applies not only to rockfish, but also to several other species (see Table A.6-2). The more common and important (i.e., commercial, tribal, or sport) bottomfish species within Port Angeles Harbor or near the former Rayonier mill include lingcod, copper rockfish, quillback rockfish, black rockfish, English sole, Dover sole, rock sole, starry flounder, sand dab, and perch. Seasonal migrations between shallow and deeper waters may occur. Other species, such as Pacific cod, Pacific hake, and walleye pollock, may be very abundant during certain seasons.

Table A.6-2 also includes forage fish such as herring, smelt, anchovies, and sand lance. Forage fish are a primary food source for fish species such as salmon, bottomfish, and other higher-trophic-level fish. They may also be heavily consumed by marine mammals and birds. Herring are a popular baitfish for salmon and other species. Herring eggs are also consumed by people. Schools of herring may be present in the Port Angeles area throughout the year, but herring likely migrate through the area in

pursuit of smaller food organisms. Herring spawning has been recorded in Dungeness Bay but is limited or does not occur in the immediate vicinity of Port Angeles. Sand lances may be present throughout the Port Angeles area and, as with herring, may be seasonally abundant.

6.1.6 Birds

Marine birds present in the Port Angeles area principally use the US Fish and Wildlife Service (USFWS) Dungeness National Wildlife Refuge (DNWR), which includes Dungeness Spit, Dungeness Bay, and the surrounding open water (Shea et al. 1981), but may also be found in the Port Angeles area. Birds that have been observed in the vicinity of Port Angeles (Shea et al. 1981) are presented in Table A.6-3.

Table A.6-3. Marine bird species present in the Port Angeles area

Taxonomic Category	Common Name	Scientific Name	Area in which Birds Were Observed			
			Strait of Juan de Fuca	Port Angeles Harbor	Ediz Hook	Dungeness Spit
Loons (Family Gaviidae)	common loon	*Gavia immer*	X			X
	artic loon	*Gavia pacifica*		X		X
	red-throated loon	*Gavia stellata*		X		X
Grebes (Family Podicipediformes)	red-necked grebe	*Podicepes grisegena*		X		X
	horned grebe	*Podicepes auritus*		X		X
	eared grebe	*Podicepes nigricollis*		X		X
	Western grebe	*Aechmophorus occidentalis*	X	X		X
Cormorants (Family Phalacrocorax)	double-crested cormorant	*Phalacrocorax auritus*		X		
	Brandt's cormorant	*Phalacrocorax penicillatus*	X	X		X
	pelagic cormorant	*Phalacrocorax pelagicus*	X	X		X
Herons (Family Ardeidae)	great blue heron	*Ardea herodias*		X		X
Waterfowl (Family Anatidae) Geese (Tribe *Anserini*)	Canada goose	*Branta canadensis*	X			X
	black brant	*Branta bernicla*		X		X
	white-fronted goose	*Anser albifrons*				X
	snow goose	*Chen caerulescens*		X		
Dabbling Ducks (Tribe *Anatini*)	mallard	*Anas platyrhynchos*		X		X
	pintail	*Anas acuta*		X		X
	green-winged teal	*Anas crecca*				X
	American wigeon	*Anas americana*		X		X
	shoveler	*Anas clypeata*		X		X

Taxonomic Category	Common Name	Scientific Name	Area in which Birds Were Observed			
			Strait of Juan de Fuca	Port Angeles Harbor	Ediz Hook	Dungeness Spit
Bay Ducks (Tribe *Aythyini*)	canvasback	*Aythya valisineria*				X
	greater scaup	*Aythya marila*	X			X
	lesser scaup	*Aythya affinis*	X			X
Sea Ducks (Tribe *Mergini*)	common goldeneye	*Bucephala clangula*	X	X		X
	Barrow's goldeneye	*Bucephala islandica*		X		X
	bufflehead	*Bucephala albeola*		X		X
	oldsquaw	*Clangula hyemalis*		X		X
	harlequin duck	*Histrionicus histrionicus*		X		X
	white-winged scoter	*Melanitta fusca*	X	X		X
	surf scoter	*Melanitta perspicillata*	X	X		X
	black scoter	*Melanitta nigra*	X			X
	hooded merganser	*Lophodytes cucullatus*		X		X
	common merganser	*Mergus merganser*		X		X
	red-breasted merganser	*Mergus serrator*		X		X
Sandpipers (Family Scolopacidae)	ruddy turnstone	*Arenaria interpres*			X	X
	black turnstone	*Arenaria melanocephala*			X	X
	whimbrel	*Numenius phaeopus*			X	X
	spotted sandpiper	*Actitis macularia*			X	X
	wandering tattler	*Heteroscelus incanus*			X	
	greater yellowlegs	*Tringa melanoleuca*			X	X
	knot	*Calidris canutus*				X
	least sandpiper	*Calidris minutilla*			X	X
	dunlin	*Calidris alpina*			X	X
	long-billed dowitcher	*Limnodromus scolopaceus*				X
	sanderling	*Calidris alba*				X
	Western sandpiper	*Calidris mauri*			X	X
	Wilson's phalarope	*Steganopus tricolor*			X	X
Rails (Family Rallidae)	American coot	*Fulica americana*		X		X
Plovers (Family Charadriidae)	semi-palmated plover	*Charadrius semipalmatus*				X
	killdeer	*Charadrius vociferus*			X	X
	black-bellied plover	*Pluvialis squatarola*			X	X

Taxonomic Category	Common Name	Scientific Name	Area in which Birds Were Observed			
			Strait of Juan de Fuca	Port Angeles Harbor	Ediz Hook	Dungeness Spit
Gulls, terns, jegers (Family Laridae) Gulls (Subfamily *Larinae*)	glaucous-winged gull	*Larus glaucescens*	X	X		
	western gull	*Larus occidentalis*		X	X	X
	herring gull	*Larus argentatus*		X		
	thayer's gull	*Larus thayeri*	X		X	X
	California gull	*Larus californicus*		X	X	X
	ring-billed gull	*Larus delawarensis*	X		X	X
	mew gull	*Larus canus*	X	X	X	X
	Heermann's gull	*Larus heermanni*	X		X	X
	Bonaparte's gull	*Larus philadelphia*	X		X	X
Terns (Subfamily *Sterninae*)	common tern	*Sterna hirundo*	X			X
Alcids (Family Alcidae)	common murre	*Uria aalge*	X			X
	pigeon guillemot	*Cepphus columba*	X			X
	marbled murrelet	*Brachyramphus*	X			X
	rhinoceros auklet	*Cerorhinca monocerata*	X			X
Kingfishers (Family Alcedinidae)	belted kingfisher	*Ceryle alcyon*		X		X
Hawks and eagles (Family *Accipitridae*)	bald eagle	*Haliaeetus leucocephalus*				X

Note: Adapted from Shea et al. (1981).

Shorebirds and waterfowl (ducks and geese) are migratory species, and thus their presence in the Port Angeles area is greatest in the fall and winter. Grebes, cormorants, and waterfowl are generally found along the long stretch of shoreline west of Port Angeles; the greatest numbers of these birds are found in the DNWR. Shorebirds also concentrate in DNWR and along Ediz Hook. Species that have been identified in Port Angeles Harbor include loons, grebes, cormorants, herons, geese, dabbling ducks, sea ducks, rails, gulls, and kingfishers. Bay ducks, plovers, sandpipers, terns, and alcids have not been seen in the harbor based on historical data presented by Shea et al. (1981) (Table A.6-3).

Intertidal and shallow subtidal submerged grasses, such as eelgrass and the benthic invertebrates that thrive in these areas, provide food for many birds. Diving ducks (bay ducks), cormorants, grebes, herons, hawks, eagles, gulls, terns, kingfishers, and alcids all may ingest fish. Areas of particularly abundant food and that provide habitat and shelter for birds (Shea et al. 1981) include the mouth of Morse Creek (east of the harbor), where beds of algae and seagrasses support benthic communities and are used by migratory shorebirds.

6.1.7 Mammals

Out of 20 species of marine mammals identified in the vicinity of Port Angeles, eight were common species (harbor seal, California sea lion, northern sea lion, minke whale, orca, Dall's porpoise, harbor porpoise, and river otter), seven were occasional species (northern elephant seal, northern fur seal, fin whale, gray whale, humpback whale, sperm whale, and Northern Pacific giant bottlenose whale), and the rest were infrequently observed (Table A.6-4). Seals are expected to congregate in areas where marine birds are found in higher numbers, such as in the area surrounding the USFWS DNWR and along Ediz Hook. Certain marine mammals may also be expected to use the area within Port Angeles Harbor. Harbor seals have been seen swimming and apparently foraging in the marine environment of the harbor, but no haul out locations are currently available. River otters (*Lutra candensis*) have also been documented in Port Angeles Harbor. Sea otters (*Enhydra lutris*) have not been documented east of Neah Bay (Malcolm Pirnie 2007a).[3]

Table A.6-4. Marine mammal species present in the Port Angeles area

Taxonomic Category	Common Name	Scientific Name	Presence
Seals and sea lions (Order Pinnipedia) *Seals (Family Phocidae)*	harbor seal	*Phoca vitulina*	common
	northern elephant seal	*Mirouga angustirostris*	occasional
	northern fur seal	*Callorhinus ursinus*	occasional
Sea lions (Family Otariidae)	California sea lion	*Zalophus californianus*	common
	northern sea lion	*Eumetropias jubata*	common
Cetaceans – whales, dolphins, and porpoises (Order Cetacea)	minke whale	*Balaenoptera acutorostrata*	common
	fin whale	*Balaenoptera physalus*	occasional
	gray whale	*Eschrichtius robustus*	occasional
	orca	*Orcinus orca*	common
	Dall's porpoise	*Phocoenoides dalli*	common
	harbor porpoise	*Phocoena phocoena*	common
	false killer whale	*Pseudorca crassidens*	rare
	goosebeak whale	*Ziphius cavirostris*	rare
	humpback whale	*Megaptera novaeangliae*	occasional
	shortfin pilot whale	*Globicephala macrorhynchus*	rare
	sperm whale	*Physeter macrocephalus*	occasional
	Northern Pacific giant bottlenose whale	*Berardius bairdii*	occasional
	Northern Pacific whiteside dolphin	*Lagenorhynchus obliquidens*	rare
	saddleback dolphin	*Delphinus delphis*	rare

[3] Personal communication, Tom Cyra, WDFW, Wildlife Biologist, January 31, 2001, as cited in the Rayonier Marine RI (Malcolm Pirnie 2007a).

Taxonomic Category	Common Name	Scientific Name	Presence
Carnivores (Order Carnivora) Mustelids (Family *Mustelidae*)	river otter	*Lutra canadensis*	common

Note: Adapted from Shea et al. (1981).

6.2 ENDANGERED AND THREATENED SPECIES

Information regarding federal- and state-listed sensitive and candidate Endangered Species Act (ESA) species was obtained from the WDFW and USFWS websites (WDFW 2013; USFWS 2013), which includes those species listed as state endangered, state threatened, state sensitive, or state candidate, as well as species listed or proposed for listing by the USFWS or the National Marine Fisheries Service (Table A.6-5).

Table A.6-5. Species of concern in the vicinity of Port Angeles

Common Name	Scientific Name	State Status	Federal Status
Mammals			
Fin whale	*Baleonoptera physalus*	endangered	endangered
Gray whale	*Eschrichtius robustus*	sensitive	none
Humpback whale	*Megaptera novaeangliae*	endangered	endangered
Orca whale	*Orcinus orca*	endangered	endangered
Pacific harbor porpoise	*Phocoena phocoena*	candidate	none
Sperm whale	*Physeter macrocephalus*	endangered	endangered
Steller sea lion	*Eumetopias jubatus*	threatened	threatened
Birds			
Bald eagle	*Haliaeetus leucocephalus*	sensitive	species of concern
Brandt's cormorant	*Phalacrocorax penicillatus*	candidate	none
Brown pelican	*Pelecanus occidentalis*	endangered	species of concern
Common loon	*Gavia immer*	sensitive	none
Common murre	*Uria aalge*	candidate	none
Marbled murrelet	*Brachyramphus marmoratus*	threatened	threatened
Peregrine falcon	*Falco peregrinus*	sensitive	species of concern
Western grebe	*Aechmophorus occidentalis*	candidate	none
Fish			
Black rockfish	*Sebastes malanops*	candidate	none
Bull trout	*Salvelinus confluentus*	threatened	threatened
Chinook salmon (Puget Sound)	*Oncorhynchus tshawytscha*	candidate	threatened
Chum (Hood Canal summer)	*Oncorhynchus keta*	threatened	threatened
Copper rockfish	*Sebastes caurinus*	candidate	species of concern

Common Name	Scientific Name	State Status	Federal Status
Pacific Hake (Pacific-Georgia Basin)	*Merluccius productus*	candidate	species of concern
Pacific herring	*Clupea pallasi*	candidate	species of concern
Quillback rockfish	*Sebastes maliger*	candidate	species of concern
Steelhead (Puget Sound)	*Oncorhynchus mykiss*	none	threatened

Four species of whales that may be present in the vicinity of Port Angeles (i.e., fin, humpback, orca, and sperm) are listed as endangered both federally (by USFWS) and on a state-wide basis (by WDFW). In addition, gray whales are listed by the WDFW as a state sensitive species, the Steller sea lion is listed by both the USFWS and WDFW as threatened, and the harbor porpoise is listed as a candidate species by the WDFW.

The brown pelican is listed as endangered in Washington State, although the populations have been increasing in other areas of the US. The brown pelican was removed from the USFWS endangered list in 2009 and is now listed as a federal species of concern. There have been reports of a brown pelican near the marina area, but this is likely a rare occurrence (Malcolm Pirnie 2007a).[4] Brown pelicans are pelagic birds and prefer nearshore coastal areas. The inner harbor of Port Angeles and the Puget Sound are not typical or critical habitat for these species. Brown pelicans do not breed in Washington State.

The marbled murrelet is listed as threatened on both federal and state lists and may forage within the bay, but numbers documented during the Puget Sound Ambient Monitoring Program (PSAMP) from 1992 to 1999 (Nysewander et al. 2001) were low. Marbled murrelets forage primarily for small fish and invertebrates in the nearshore environment and may forage near the former Rayonier mill site on occasion The closest known occupied nesting stands are within the Olympic National Forest, located approximately 6 miles south of the former Rayonier mill site. No suitable nesting habitat occurs within the former Rayonier mill site or its surroundings.

Other bird species listed as either candidate or sensitive species by WDFW or species of concern by USFWS include the bald eagle, Brandt's cormorant, common loon, common murre, peregrine falcon, and western grebe.

There are no federal- or state-listed endangered fish species identified in the Port Angeles area. Three fish species listed as threatened by WDFW and/or USFWS may be present in the Port Angeles area: Puget Sound Chinook salmon, Hood Canal summer-run chum salmon, and bull trout. These three species may be seasonally present within the nearshore environment of Port Angeles. Puget Sound steelhead salmon are listed as threatened by the USFWS but not by WDFW and may also be present in the Port Angeles area during migratory periods.

[4] Personal communication, Shelly Ament, Wildlife Biologist, WDFW, February 2, 2001, as cited in the Rayonier Marine RI (Malcolm Pirnie 2007a).

Five additional fish species that are listed as candidate species by the WDFW and have been observed in the Port Angeles area are black rockfish, copper rockfish, Pacific hake, Pacific herring, and quillback rockfish. All but one of these fish (black rockfish) are also listed by the USFWS as species of concern.

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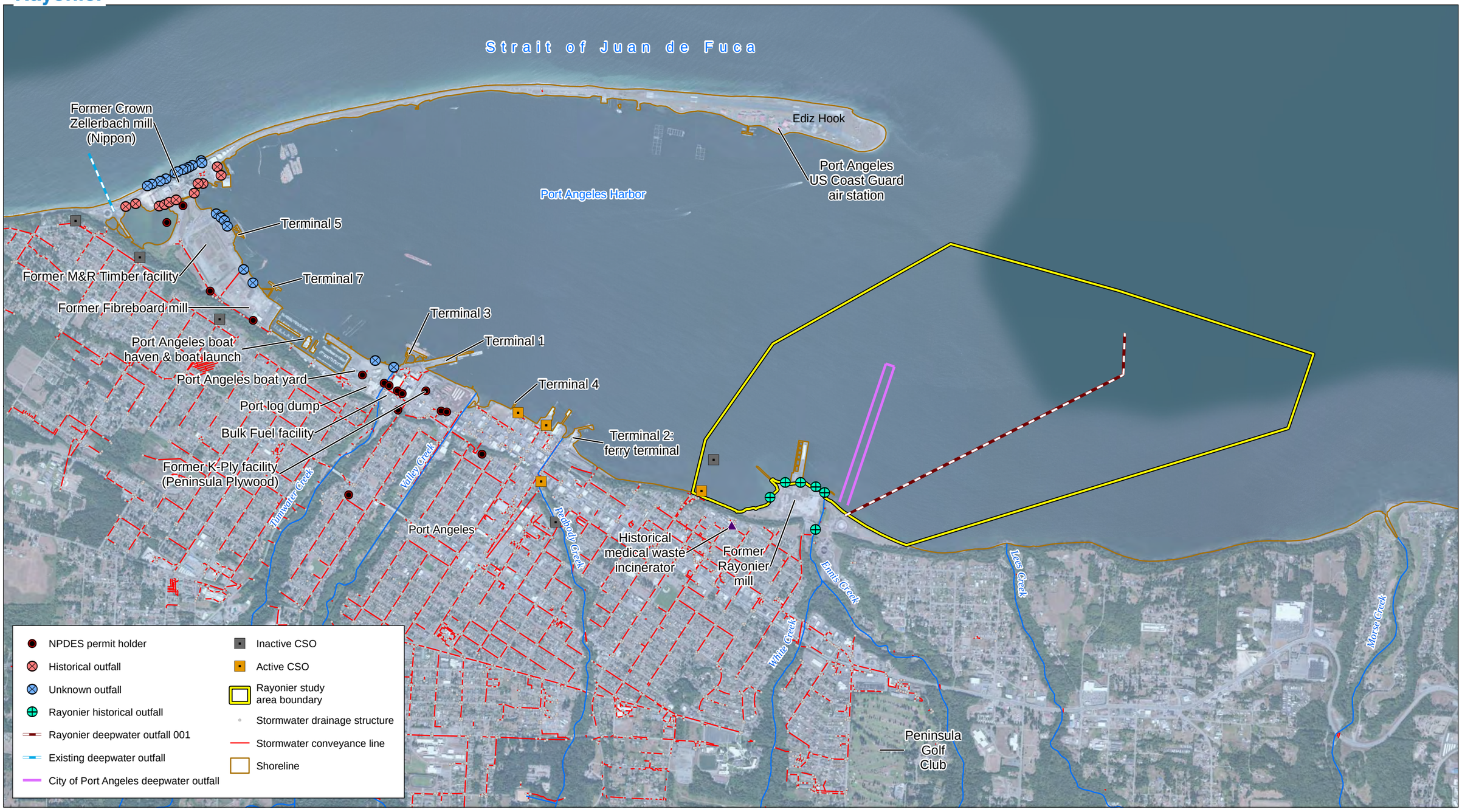
Rayonier



Wind Ward LLC environmental

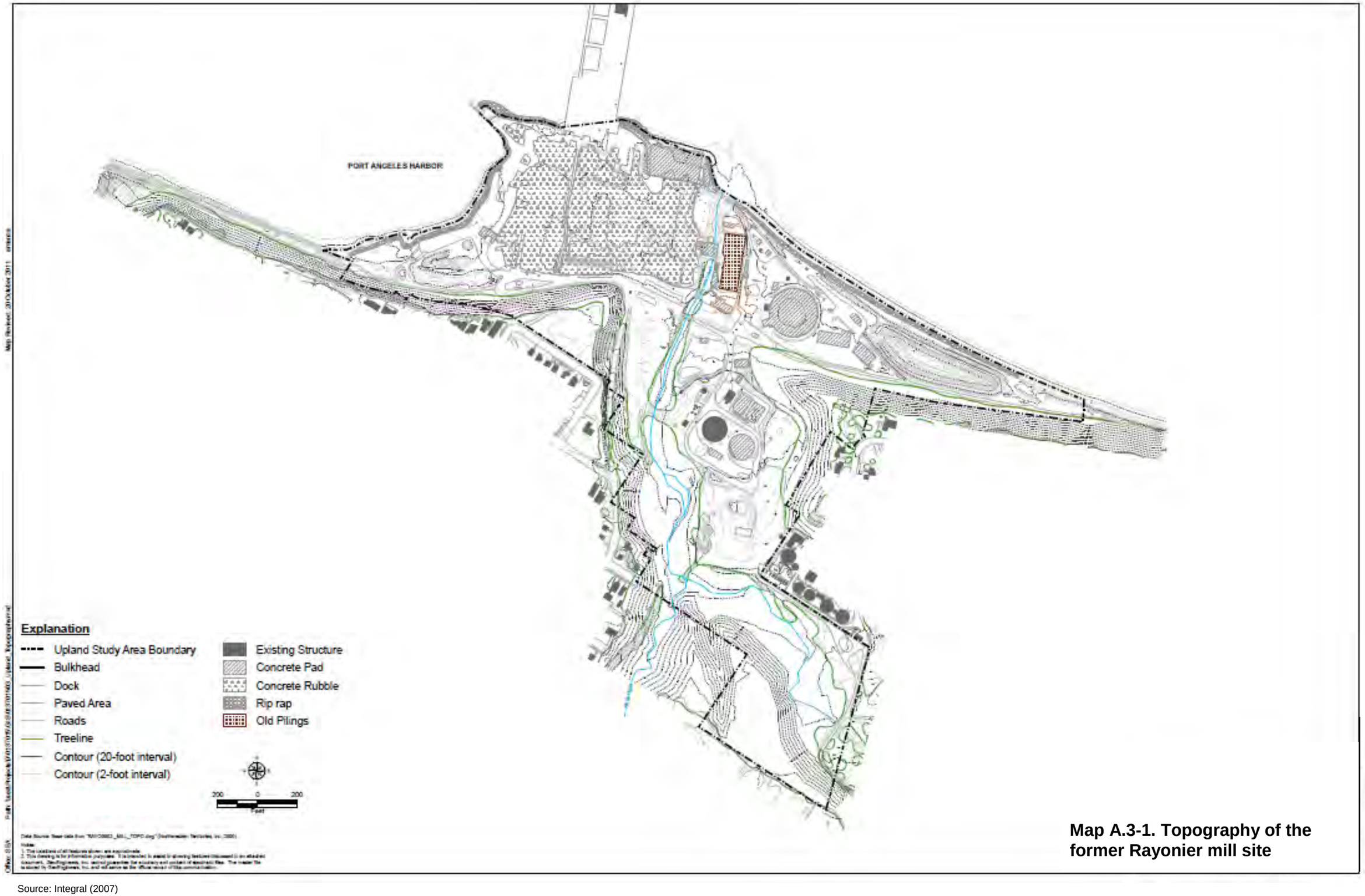
Data sources: Imagery provided by ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP
Outfalls: All outfalls near former Crown Zellerbach taken from Exponent (2008).
Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.25 0.5 1 Miles

Map A.2-1. Historical and current facilities and discharge outfalls to Port Angeles Harbor

Prepared by MTY, 01/18/12, map#5008; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis



Map A.3-1. Topography of the former Rayonier mill site

Source: Integral (2007)

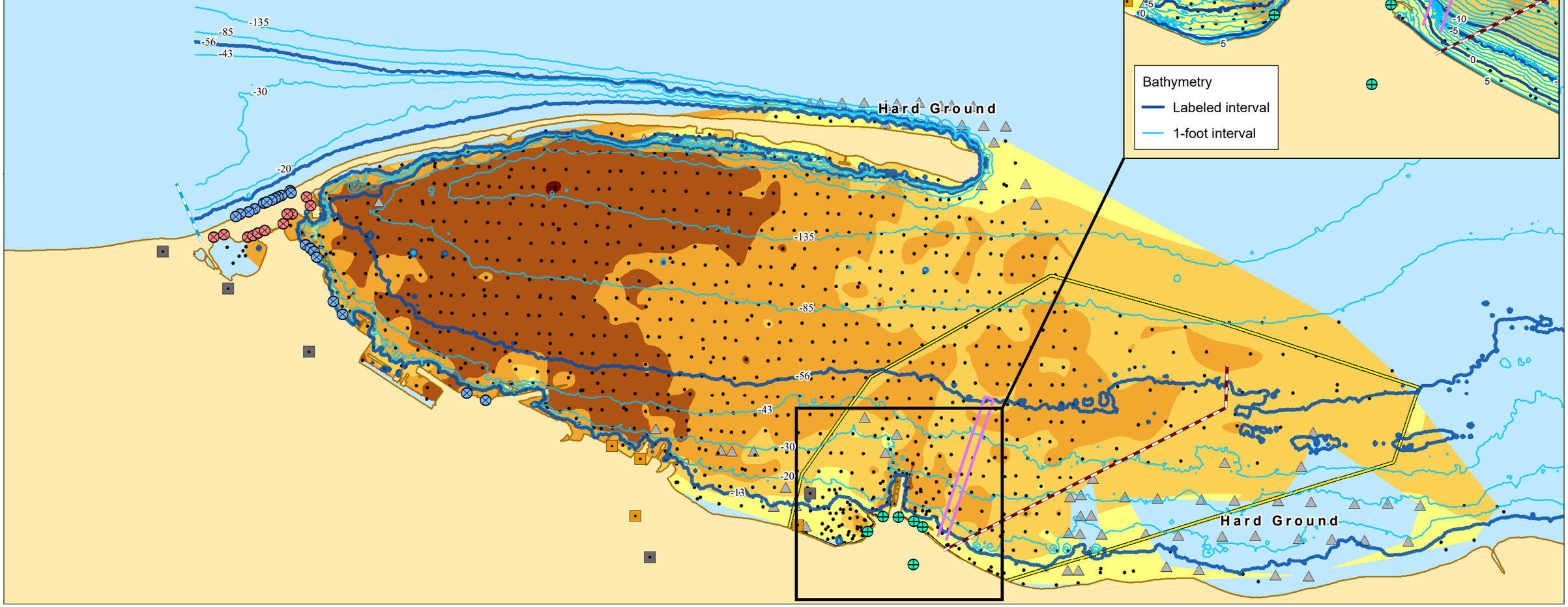
Rayonier

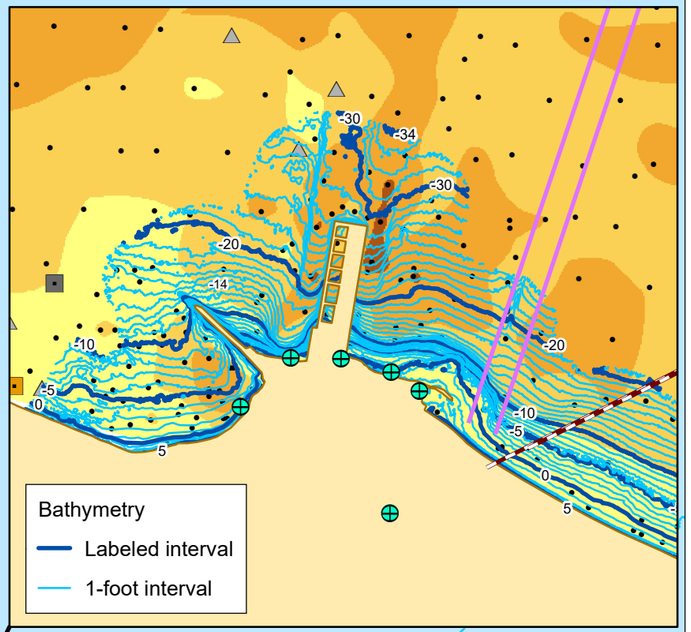
- Percent fines sample location
- Hard ground

Percent fines interpolation (%)
- > 80 and ≤ 100
- > 60 and ≤ 80
- > 30 and ≤ 60
- > 13 and ≤ 30
- ≤ 13

- Historical outfall
- Unknown outfall
- Rayonier historical outfall
- Rayonier deepwater outfall 001
- Existing deepwater outfall
- City of Port Angeles deepwater outfall
- Inactive CSO
- Active CSO

Bathymetry
Elevation
- -20 to -135
- -13 and -56





Wind Ward environmental LLC

Data sources: All outfalls near former Crown Zellerbach taken from Exponent (2008).
Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.
Inset bathymetry used NOAA soundings data to obtain 1 foot intervals.
Grain size data combination of STA and WW dataset.

N

0 0.25 0.5 1 Miles

Map A.5-1. Bathymetry and sediment grain size distribution in Port Angeles Harbor

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5518_Bathymetry and STA Grain Size_MTY_081913.mxd

APPENDIX B. SCREENING-LEVEL RISK ASSESSMENT SUMMARIES

APPENDIX B. SCREENING-LEVEL RISK ASSESSMENT SUMMARIES

Table of Contents

Tables

Figures

1 Introduction

A screening-level ecological risk assessment (ERA) and a screening-level human health risk assessment (HHRA) were conducted for Port Angeles Harbor by Ecology as part of the sediment characterization study (Ecology 2012). This section summarizes the conclusions of these documents. Section 2 discusses the data used in the assessments, and Sections 3 and4 discuss the methods and results of the ERA and HHRA, respectively. These assessments are summarized only for reference in Volume II; their inclusion in this manner does not imply concurrence with the methods or the results.

2 Data Used in the Risk Assessments

The chemical data used in the ERA and HHRA included historical data collected by multiple parties and data collected by Ecology for the *Port Angeles Harbor Sediment Characterization Study, Port Angeles, Washington: Sediment Investigation Report* (Ecology 2012) (Table B.2-1). Ecology's study was designed in part to fill data gaps related to the risk assessments (Ecology 2012). Most of the chemical data used in the risk assessments are from four studies. Three of these studies (Ecology and Environment 1998; Malcolm Pirnie 2005, 2007a) were focused on the former Rayonier mill; the fourth, the most recent study, was conducted by Ecology (2012). The Ecology study characterized the entire Port Angeles Harbor.

Table B.2-1. Studies with chemical data that were used in the risk assessments

Study Name	Reference
Port Angeles Harbor Sediment Investigation	Ecology (2012)
Environmental Baseline Investigation, Nippon Paper Industries USA	Exponent (2008)
Rayonier Phase 2 RI Addendum	Malcolm Pirnie (2007a)
Rayonier Marine RI	Malcolm Pirnie (2005)
Sediment Grab Sampling and Log Density Survey, Nippon Paper Industries USA	Anchor (2005)
Port Angeles Harbor Wood Waste Study[a]	SAIC (1999)
Expanded Site Inspection of Rayonier Mill	EPA (1998)

[a] Data from this study were not used in the HHRA because no contaminant data were collected.

Ecology – Washington State Department of Ecology
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
HHRA – human health risk assessment

3 Screening-Level Ecological Risk Assessment

This section summarizes the methods and results of the screening-level ERA (referred to as the ERA) conducted by Ecology (2012) for Port Angeles Harbor. Included are summaries of the selection of indicator hazardous substances (IHS), the assessment endpoints and measures, the risk evaluations[1] for plants, benthic invertebrates, fish, and wildlife, and the uncertainties associated with the ERA.

3.1 SELECTION OF IHS

A screening process was conducted to select the chemicals to be included in the ERA; these chemicals were identified as IHS. This screening process was conducted for both sediment and biota. Sediment was evaluated separately in two ways: as intertidal and subtidal sediment combined or as intertidal sediment alone. The IHS included in the ERA for sediment were selected based on the following three factors:

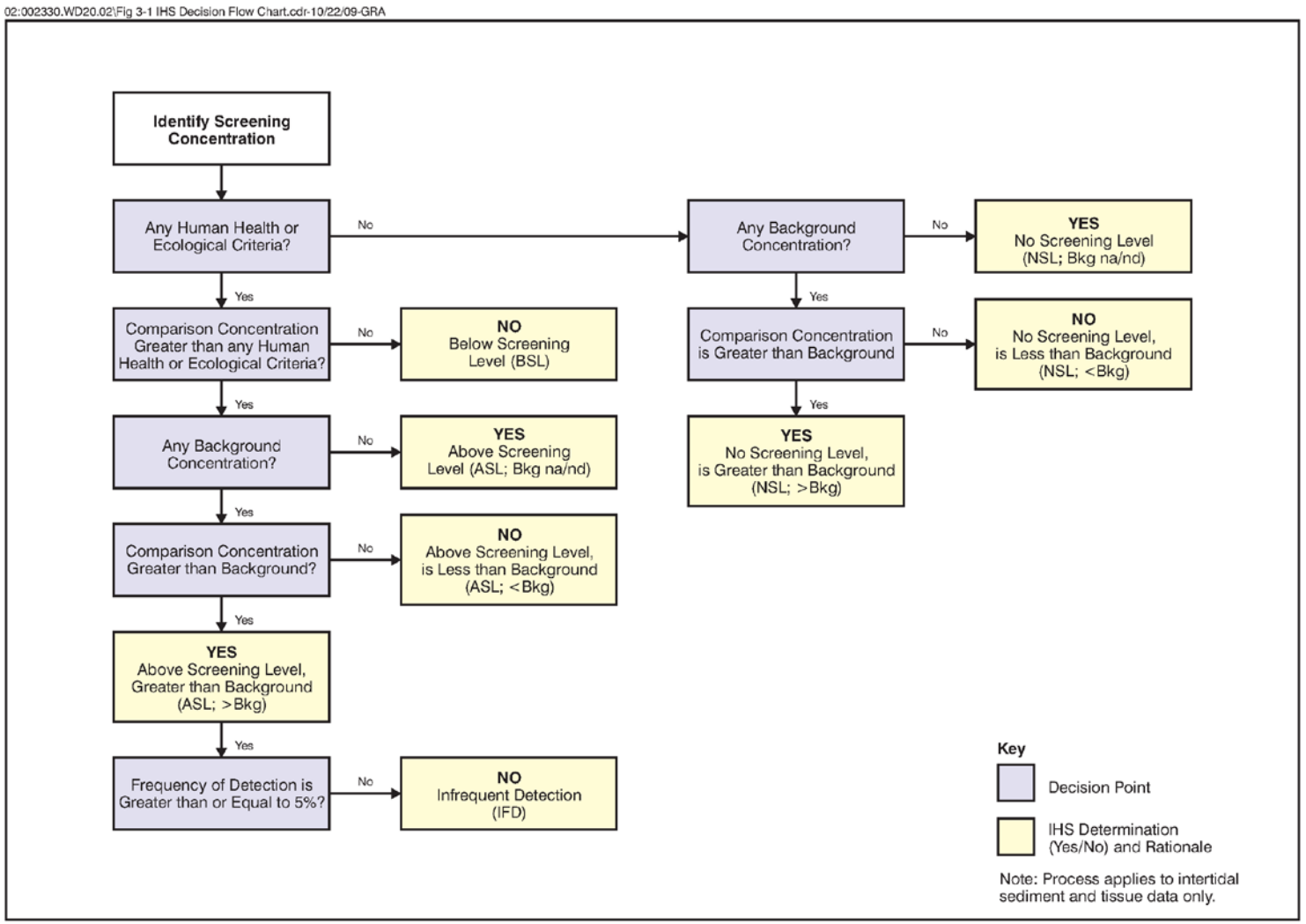
- Frequency of detection
- Comparison of maximum chemical concentrations in site sediment with background (Dungeness Bay) concentrations
- Comparison of maximum chemical concentrations in site sediment with sediment screening benchmarks; Washington State Sediment Management Standards (SMS) were preferred if available (other benchmarks used if SMS were not available included those presented in MacDonald et al. (2000), Michelsen et al. (1996), and Cubbage et al. (1997))

Nine different biological sample types were separately screened for IHS: bull kelp, eel grass, coonstripe shrimp, Dungeness crab hepatopancreas, Dungeness crab muscle, geoduck, horse clam, lingcod, and rock sole. The IHS included in the ERA for biota were selected based on the following two factors:

- Frequency of detection
- Comparison of maximum chemical concentrations in site biota with background (Dungeness Bay) concentrations

The steps of the screening process are shown in Figure B.3-1. In addition, although not indicated in Figure B.3-1, if the maximum concentration of a chemical did not exceed its sediment benchmark but had a log octanol-water partition coefficient (K_{OW}) greater than 3.5, it was retained as an IHS for sediment.

[1] The term "risk evaluation" was used in the ERA for individual risk characterizations for plants, benthic invertebrates, fish, and wildlife.



Source: Ecology (2012)

Figure B.3-1. Decision flow chart for IHS selection

For sediment, the total number of IHS selected for inclusion in the ERA was 54 for intertidal sediment alone and 66 for intertidal and subtidal sediment combined (Table B.3-1). For biota, the total number of IHS was 15 for eelgrass and bull kelp, 10 for fish, and 33 for shellfish.

Table B.3-1. Summary of IHS for the ERA

Chemical Group	Number of IHS				
	Intertidal and Subtidal Sediment[a]	Intertidal Sediment Only[a]	Eelgrass and Bull Kelp	Fish	Shellfish
PCBs[b]	2	1	2	1	2
PAHs[c]	2	2	2	1	2
Pesticides	19	16	0	0	8
SVOCs	8	4	0	0	2
Dioxins and furans	1	1	1	1	1
Organometals	2	0	0	1	2
Metals	15	4	10	6	17
Inorganics	3	1	0	0	0
Wood waste	1	0	0	0	0
Organic acids	11	17	0	0	1
Guaiacols	0	6	0	0	0
Petroleum	2	2	0	0	0
Total	**66**	**54**	**15**	**10**	**33**

[a] In addition, ammonia, sulfide, wood waste, diesel fuel, and motor oil were identified as IHS in sediment.
[b] IHS in the PCB chemical group included PCB Aroclors and dioxin-like PCBs.
[c] IHS in the PAH chemical group included HPAHs and LPAHs.

ERA – ecological risk assessment
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
IHS – indicator hazardous substances
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound

3.2 ASSESSMENT ENDPOINTS AND MEASURES

Based on the site ecology, site-related chemicals, and the ecological conceptual site model, the following ecological resources were selected as receptors of concern for the ERA: marine vegetation, benthic invertebrates, benthic fish, mammals, and birds. The assessment endpoints and the measurements (termed "measures" in the ERA document (Ecology 2012)) are listed in Table B.3-2.

Table B.3-2. Assessment endpoints and measures for the ERA

Assessment Endpoint[a]	Representative Species	Measures
Marine plants and macroalgae	eelgrass, kelp	sediment habitat quality based on the presence of wood waste
Benthic invertebrates	clams, polychaetes, crabs	sediment chemical concentrations compared with sediment benchmarks
		sediment bioassay results
		sediment habitat quality based on the presence of wood waste
Fish	rock sole, lingcod	fish tissue chemical concentrations compared with benchmarks
Carnivorous birds	bald eagle, cormorant	HQ method[b] based on concentrations of chemicals in sediment and marine fish
Omnivorous birds	greater scaup	HQ method[b] based on concentrations of chemicals in sediment, marine vegetation, and marine invertebrates
Herbivorous birds	brant	HQ method[b] based on concentrations of chemicals in sediment and marine vegetation
Carnivorous mammals	harbor seal	HQ method[b] based on concentrations of chemicals in sediment, marine fish, and marine invertebrates
Omnivorous mammals	raccoon	HQ method[b] based on concentrations of chemicals in sediment, marine fish, and marine invertebrates

[a] Sustainability (i.e., growth, survival, and reproduction) of listed communities and wildlife populations in and near Port Angeles Harbor.

[b] The HQ method involved the calculation of a body-weight normalized dietary dose for each chemical of concern and receptor species. The HQ is calculated as the dietary dose divided by the TRV for the chemical of concern and receptor species.

HQ – hazard quotient

TRV – toxicity reference value

3.3 RISK EVALUATION FOR MARINE PLANTS AND MACROALGAE

Risks to marine plants and macroalgae were evaluated based on one measure – sediment habitat quality – as determined by the presence of wood debris in Port Angeles Harbor as measured in several previous studies (Ecology 2012; GeoSea 2009; SAIC 1999). These studies found that 20 to 25% of the sediment surface area in the harbor was affected by wood debris. The primary areas of accumulation are located in the western portion of the harbor along the base of Ediz Hook, in the lagoon area at the base of Ediz Hook, along the waterfront at the Port of Port Angeles Management Area, in the former Rayonier mill log pond, and the area on the west side of the former Rayonier mill dock. Because a portion of the nearshore sediment in Port Angeles Harbor has wood waste, it was hypothesized (Ecology 2012) that the ability of the harbor to support marine plants and macroalgae has been compromised in areas of the inner harbor that have wood waste accumulation.

3.4 BENTHIC COMMUNITY RISK EVALUATION

The benthic community evaluation was based on a comparison of sediment chemical concentrations with sediment benchmarks, sediment bioassay results, and sediment habitat quality. Sediment chemical concentrations in the Port Angeles Harbor sediment characterization study (Ecology 2012) were compared with the sediment quality standards (SQS) and cleanup screening levels (CSLs) of the SMS. Four metals (arsenic, cadmium, mercury, and zinc) and four organic compounds (bis(2-ethylhexyl) phthalate [BEHP], butyl benzyl phthalate [BBP], 4-methylphenol, and phenol) had sediment concentrations that exceeded criteria (Ecology 2012) (Table B.3-3). Note that the surface sediment dataset for Volume II is larger than the surface sediment dataset used in Ecology's ERA (Ecology 2012). The dataset is described in Section 2.1.2 of the main document, and a comparison of the Volume II dataset to SQS and CSL criteria is present in Section 2.2 of the main document.

Table B.3-3. Summary of SQS and CSL exceedances using sediment data from the Port Angeles Harbor sediment investigation

Chemical	No. of Samples with Detected Concentrations > SQS and ≤ CSL[a]	No. of Samples with Detected Concentrations > CSL[a]
Arsenic	1	0
Cadmium	1	1
Mercury	3[c]	5
Zinc	3	1
BEHP	1	0
BBP	2	0
4-Methylphenol	0	1
Phenol	3	0

[a] If an individual sample had a TOC content > 3.5% or < 0.5% and the dry-weight concentration was > LAET and ≤ 2LAET, the concentration was considered to be > SQS and ≤ CSL.

[b] If an individual sample had a TOC content > 3.5% or < 0.5% and the dry-weight concentration was > 2LAET, the concentration was considered to be > CSL.

[c] Two of these SQS exceedances were considered CSL exceedances in Table 4-4 of the ERA (Ecology 2012) because the concentrations were equal to the CSL.

BEHP – bis(2-ethylhexyl) phthalate
BBP – butyl benzyl phthalate
CSL – cleanup screening level
Ecology – Washington State Department of Ecology
ERA – ecological risk assessment
LAET – lowest apparent effects threshold
2LAET – second lowest apparent effects threshold
PCB – polychlorinated biphenyl
SQS – sediment quality standards
TOC – total organic carbon

Toxicity data evaluated in Ecology's ERA were collected from 59 surface sediment locations as part of the Port Angeles Harbor sediment characterization study (Ecology 2012). Three sediment bioassay tests were conducted for each location: 1) a 10-day amphipod bioassay test using *Eohaustorius estuarius*, 2) an acute larval bioassay test using *Dendraster excentricus* (echinoderm), and 3) a chronic 20-day juvenile polychaete bioassay test using *Neanthes arenaceodentata*. Twenty-nine locations had an exceedance

of either the SQS or CSL criteria for bioassays. Five locations were identified as having co-occurring chemical and bioassay test SMS exceedances. It should be noted that the study design for selecting bioassay locations was unusual because it involved the selection of bioassay locations prior to determining where exceedances of SMS occurred. As a result, toxicity data were obtained at some locations that did not have SMS exceedances, and some locations that had SMS exceedances were not evaluated for toxicity.

Sediment habitat quality was evaluated based on the presence of wood debris in Port Angeles Harbor, as determined from several previous studies (Ecology 2012; GeoSea 2009; SAIC 1999). As described in Section 4.2.3, these previous studies reported that 20 to 25% of the sediment surface area of the harbor had wood debris. It was concluded in Ecology (2012) that the ability of the harbor to support a healthy benthic community was compromised in the inner harbor in areas with wood waste accumulation.

3.5 FISH RISK EVALUATION

To evaluate risk to fish, chemical concentrations in whole-body fish were compared with critical tissue-residue risk-based concentrations (RBCs) obtained from the scientific literature for the 10 IHS for fish (arsenic, inorganic arsenic, chromium, copper, mercury, selenium, methylmercury, HPAHs, PCBs, and dioxins/furans). The whole-body fish chemical data for Port Angeles Harbor consisted of two lingcod samples collected for the Port Angeles Harbor sediment characterization study (Ecology 2012) and three rock sole samples collected for the former Rayonier mill RI (Malcolm Pirnie 2007b). The arsenic concentration in rock sole was greater than the arsenic RBC by a factor of 2.8. The RBC for arsenic was a literature-based fifth percentile for tissue residue effects calculated from laboratory tests focused on community- and population-level effects such as mortality, growth, reproduction, behavior, and morphology (Dyer et al. 2000). No other chemicals in fish tissue exceeded their respective RBCs, which were based on no-observed adverse effect levels (NOAELs) for growth or survival. According to the ERA (Ecology 2012), these results indicated that fish in Port Angeles Harbor are unlikely to be adversely affected by the concentrations of chemicals in their tissue, with the possible exception of arsenic.

3.6 WILDLIFE RISK EVALUATION

Six wildlife species representing different functional groups were evaluated for the wildlife risk evaluation: brant, double-crested cormorant, greater scaup, harbor seal, raccoon, and bald eagle. The chemicals evaluated for wildlife were metals and organic compounds. Chemical exposure for each of these species was calculated as the sum of exposures from diet and incidental sediment ingestion. Dietary exposure was calculated by multiplying the chemical concentration in each food item by its fraction of the total diet and summing the contribution from each item. The total dietary

exposure was then multiplied by the receptor's site use factor (SUF), exposure duration (ED), and ingestion rate (IR), and then divided by the receptor's body weight (BW). Wildlife exposure to chemicals through incidental sediment ingestion was estimated in a manner similar to that used for dietary exposure. Specifically, the sediment chemical concentration was multiplied by the sediment IR and then multiplied by the SUF and ED and divided by BW. The total exposure was calculated as the sum of exposure from diet and incidental sediment ingestion.

Exposure point concentrations for chemicals in sediment and biota were calculated as the 95 or 97.5% upper confidence limit on the mean (UCL) for most chemicals. For chemicals that were detected in only one or a few samples, the maximum detected concentration was used as the exposure point concentration (EPC). If a chemical was not detected in sediment, one-half of the maximum detection limit was used as the EPC. For harbor seal, chemical concentrations in intertidal and subtidal sediment were used to estimate sediment EPCs. For raccoon, brant, cormorant, eagle, and scaup, only intertidal sediment data were used to estimate sediment EPCs.

NOAELs and lowest-observed-adverse-effect levels (LOAELs) for the chemicals of interest for this ERA were obtained from the peer-reviewed literature and identified as toxicity reference values (TRVs). The risks posed by site-related chemicals were determined by calculating a hazard quotient (HQ) for each contaminant and for each species. The HQ was determined by dividing the total exposure by the TRV.

According to the ERA (Ecology 2012), risks to wildlife were low, as indicated by the following results:

- No unacceptable risks were calculated for brant, eagle, cormorant, and scaup (all HQs were less than 1.0)
- For the raccoon, HQs based on the NOAEL TRV were greater than 1.0 for hexachlorobenzene and arsenic. The hexachlorobenzene HQ was based on an elevated detection limit for this chemical in horse clams. The arsenic HQ based on the LOAEL TRV was less than 1.0, so an adverse effect from arsenic exposure was not necessarily indicated for raccoon.
- For the harbor seal, the HQ based on the NOAEL TRV was greater than 1.0 for hexachlorobenzene. As noted in the previous bullet, the hexachlorobenzene result was an artifact of the elevated detection limit for this chemical.

Based on the above results, the ERA (Ecology 2012) stated that risks to threatened and endangered bird and mammal species that use Port Angeles Harbor were expected to be negligible.

3.7 UNCERTAINTY

The key uncertainties in the ERA, as presented by Ecology (2012), are summarized as follows:

- For screening purposes, background data were used if no screening criteria were available. If a given sample type and chemical were "non-detect" for background data and the chemical was detected in that type of sample from Port Angeles Harbor, the chemical was considered an IHS even if the detected concentration was less than the background detection limit. This approach is highly conservative.
- For the sediment screening, the OC-normalized SQS for organic chemicals were converted to dry-weight concentrations using 1% TOC and then compared with dry-weight concentrations from Port Angeles Harbor. According to the ERA (Ecology 2012), this was considered conservative because sediment TOC levels in Port Angeles Harbor are likely greater than 1%.
- For most biological sample types, the available sample size was small. In addition, the biological sample data available for used in the ERA was, in many cases, not ideal for estimating the exposure of and risk to the wildlife species evaluated. For example, the available fish data were for large predatory species (lingcod and rock sole) preferred by recreational and subsistence fishers but not likely preyed upon by the cormorant.
- Much of the biological data were taken from studies focused on the former Rayonier mill site, and, therefore, the EPCs are likely not representative of the entire harbor.
- Data for many chlorinated pesticides were not available for eelgrass, bull kelp, lingcod, or rock sole. Therefore, risks to wildlife from exposure to these chemicals could not be fully evaluated.
- The PCB analytical results for biota samples varied among studies, with older studies typically reporting Aroclor data and more recent studies typically reporting congener data.
- Wildlife TRVs were not available for some semivolatile organic compounds (SVOCs), including BBP, dibenzofuran, dibutylphthalate, p-cresol, pyridine, and retene.
- Sediment benchmarks were not available for guaiacols or resin and fatty acids, and tissue data were not available for marine plants, shellfish, or fish. Therefore, the risk to the benthic invertebrate community, fish, and wildlife from exposure to these chemicals could not be determined.

4 Screening-Level Human Health Risk Assessment

This section summarizes the methods and results of the screening-level HHRA (referred to as the HHRA) conducted by Ecology for Port Angeles Harbor (Ecology 2012). Included are summaries of the selection of IHS, the exposure assessment, the toxicity assessment, the risk characterization, and the uncertainty assessment.

4.1 SELECTION OF IHS

The MTCA rule includes a provision for focusing risk assessments by eliminating from further consideration those chemicals that represent only a small contribution to the overall threat to human health and the environment. The remaining hazardous substances are referred to as IHS for the purpose of defining site cleanup requirements. The IHS selection process included consideration of the following four factors:

- Screening values based on toxicological and physical characteristics of each chemical
- Reference area concentrations
- Evaluation of essential nutrients
- Frequency of detection

For a chemical to be designed as an IHS, the maximum concentration had to be greater than the applicable screening value and reference area concentrations, not be an essential nutrient, and be detected in 5% or more of the samples, unless it was identified as an IHS in other media. The manner in which each of these factors was applied to select IHS is summarized briefly below.

4.1.1 Screening values

Screening values were derived for both sediment and tissue, which were the two media of concern for this HHRA. Exposure to sediment can be indirect, through the consumption of seafood organisms that have come into contact with sediment, or direct, such as through incidental ingestion or dermal contact.

IHS in intertidal and subtidal sediment were identified based on bioaccumulation potential. Organic chemicals in sediment with a log K_{OW} that exceeded 3.5 were identified as IHS. For compounds without log K_{OW} values, EPA's designation as an important bioaccumulative compound was used for IHS selection.

MTCA soil cleanup values for unrestricted land use were used to identify IHS in intertidal sediment for direct exposure pathways. The maximum sediment concentration of each chemical was compared with the applicable MTCA soil cleanup value.

Tissue chemistry data were evaluated by comparing maximum concentrations with site-specific tissue screening values based on a target excess cancer risk of 1×10^{-6} and a target HQ of 0.1. Site-specific tissue screening values were derived by Ecology (2012) from exposure parameters recommended by the Ecology Science Advisory Board, based on population characteristics of the Lower Elwha Klallam Tribe. The site-specific exposure parameters included average body weight (79 kg), fish ingestion rate (583 g/day), and exposure duration (70 years). All species and tissue types were screened separately. If an IHS was identified in a specific fish or shellfish tissue, it was

determined to be an IHS for all fish and shellfish, except for bull kelp, which was screened independently of the other fish and shellfish tissue types because consumption practices associated with bull kelp are unknown.

4.1.2 Reference area concentrations

Ecology and Environment (2008) determined that Dungeness Bay, which is east of Port Angeles, was the most appropriate reference site for Port Angeles Harbor. The statistical methods for calculating reference area concentrations, as outlined in MTCA (Washington Administrative Code [WAC] 173-340-709), were followed in the HHRA. Because of sample size limitations, the recommended approach was followed only for dioxins and PCBs in sediment; reference area concentrations were not calculated for tissue.

4.1.3 Evaluation of essential nutrients

Chemicals considered to be essential nutrients were removed from consideration as IHS. These included magnesium, calcium, sodium, and potassium.

4.1.4 Frequency of detection

Chemicals that were detected in less than 5% of the samples and did not have reporting limits (RLs) that exceeded applicable screening levels were not identified as IHS, unless they had been identified as IHS in other media. For some chemicals, RLs were higher than applicable screening levels, leading to the designation of those chemicals as IHS.

4.1.5 IHS results

IHS were selected separately for intertidal and subtidal sediment (combined), beach/intertidal sediment, fish and shellfish, and bull kelp (Table B.4-1).

Table B.4-1. Summary of IHS

Chemical Group	Number of IHS			
	Intertidal and Subtidal Sediment	Intertidal Sediment Alone	Fish and Shellfish Tissue	Bull Kelp
Inorganics	8	2	16	2
Organometals	2	0	2	0
Organic acids	0	23[a]	0	0
PAHs	10	4	14	3
PCBs	1	1	1	0
Dioxins/furans	1	1	1	1
Pesticides	15	6	11	0
SVOCs	2	1	2	0

Chemical Group	Number of IHS			
	Intertidal and Subtidal Sediment	Intertidal Sediment Alone	Fish and Shellfish Tissue	Bull Kelp
VOCs	0	0	1	0
Total	**39**	**38**	**48**	**6**

[a] Not quantitatively evaluated because of the lack of relevant toxicity benchmarks.
IHS – indicator hazardous substances
PAH – polycyclic aromatic hydrocarbon
SVOC – semivolatile organic compound

Carcinogenic PAHs, dioxins and furans, and PCBs were evaluated as groups of compounds. The total number of IHS ranged from 6 for bull kelp to 48 for other fish and shellfish tissue.

4.2 EXPOSURE ASSESSMENT

The Port Angeles HHRA evaluated risks from site-related chemicals to four populations:

- Subsistence fisher
- Recreational fisher
- Residential user
- Recreational user

The manner in which the exposure of these groups to site-related chemicals was quantified is summarized below.

4.2.1 Identification of exposure scenarios

The four populations identified above included seafood consumers (i.e., subsistence and recreational fishers) and those that may come into direct contact with sediment (i.e., fishers and recreational and residential users). Although these populations may also come into contact with water in Port Angeles Harbor, this exposure pathway was considered minor and was not quantified, nor was the inhalation of beach/intertidal sediment. Each population was further divided into adult and child subpopulations. The seafood consumption scenarios included both reasonable maximum exposure (RME) and central tendency (CT) scenarios. The RME scenarios were intended to represent the highest reasonable exposure that could occur; the CT scenarios provided estimates of the average exposures that are applicable to most individuals within a population. The residential user and recreational user represented high-end and median exposure, respectively, for people engaged in recreational activities at the site, so RME and CT scenarios for these scenarios were not quantified.

4.2.2 Quantification of exposure

The primary route of exposure for the subsistence and recreational fishers is seafood consumption, but seafood harvesting may result in direct contact with sediment, particularly for clam harvesting. Therefore, direct exposure to sediment during clamming was quantitatively evaluated in the HHRA. Adults were assumed to be actively engaged in clamming, while children up to the age of 6 were assumed to be playing on the beach while their parents were clamming. Residential and recreational users may also consume seafood, but the scenarios used in the HHRA were focused on direct contact only through activities such as seafood harvesting, playing at the beach, picnicking, or walking pets. Seafood consumption was not included in the residential and recreational user scenarios.

The equations used to quantify exposure are standard equations from Ecology and EPA guidance, as presented by Ecology (2012). The derivation of the exposure parameters is described in detail in the HHRA and summarized in Table B.4-2 (subsistence and recreational fishers) and Table B.4-3 (residential and recreational users).

Table B.4-2. Summary of exposure factors for subsistence and recreational fishers

Exposure Route	Parameter	Unit	Value							
			Subsistence Fisher				Recreational Fisher			
			Adult		Child		Adult		Child	
			RME	CT	RME	CT	RME	CT	RME	CT
Ingestion – fish and shellfish	ingestion rate – all seafood	g/day	583	583	233	233	76.5	54.0	30.6	21.6
	ingestion rate – pelagic fish	g/day	56	56	22	22	7.3	5.2	2.9	2.1
	ingestion rate – bottom fish	g/day	29	29	12	12	3.8	2.7	1.5	1.1
	ingestion rate – shellfish[a]	g/day	498	498	199	199	65.3	46.1	26.1	18.4
	exposure frequency	days/year	365	365	365	365	365	365	365	365
	exposure duration	year	70	70	6	6	30	30	6	6
	body weight	kg	79	79	16	16	70	70	16	16
	averaging time – cancer	days	25,550	25,550	25,550	25,550	27,375	27,375	27,375	27,375
	averaging time – non-cancer	day	25,550	25,550	2,190	2,190	10,950	10,950	2,190	2,190
	fractional intake from contaminated source	unitless	1	0.5	1	0.5	0.5	0.5	0.5	0.5
Ingestion – sediment	ingestion rate – sediment	g/day	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2
	exposure frequency	days/year	104	104	104	104	53	37	65	10
	exposure duration	year	70	70	6	6	30	30	6	6
	body weight	kg	79	79	16	16	70	70	16	16
	averaging time – cancer	days	25,550	25,550	25,550	25,550	27,375	27,375	27,375	27,375
	averaging time – non-cancer	day	25,550	25,550	2,190	2,190	10,950	10,950	2,190	2,190

Exposure Route	Parameter	Unit	Value							
			Subsistence Fisher				Recreational Fisher			
			Adult		Child		Adult		Child	
			RME	CT	RME	CT	RME	CT	RME	CT
Dermal contact – sediment	skin surface area	cm^2	6,125.5	6,125.5	2,800	2,800	6,125.5	6,125.5	2,800	2,800
	event frequency	events/ day	1	1	1	1	1	1	1	1
	exposure frequency	days/year	104	104	104	104	53	37	65	10
	exposure duration	year	70	70	6	6	30	30	6	6
	body weight	kg	79	79	16	16	70	70	16	16
	averaging time – cancer	day	25,550	25,550	25,550	25,550	27,375	27,375	27,375	27,375
	averaging time – non-cancer	day	25,550	25,550	2,190	2,190	10,950	10,950	2,190	2,190
	soil-to-skin adherence factor	mg/cm^{2}- event	0.6	0.1	3.3	0.2	0.6	0.1	3.3	0.2
	dermal absorption fraction	unitless	chemical specific	chemical specific	chemical specific	chemical specific	chemical specific	chemical specific	chemical specific	chemical specific

[a] Shellfish ingestion rate was divided into fractions: 30% for Dungeness crab, 30% for horse clam, 30% for geoduck, and 10% for shrimp.

CT – central tendency

RME – reasonable maximum exposure

Table B.4-3. Summary of exposure factors for residential and recreational users

Exposure Route	Parameter	Unit	Values			
			Residential User		Recreational User	
			Adult	Child	Adult	Child
Ingestion – sediment	ingestion rate – sediment	g/day	0.1	0.2	0.1	0.2
	exposure frequency	days/year	50	65	6	10
	exposure duration	year	30	6	30	6
	body weight	kg	70	16	70	16
	averaging time – cancer	days	27,375	27,375	27,375	27,375
	averaging time – non-cancer	day	10,950	2,190	10,950	2,190
Dermal contact – sediment	skin surface area	cm^2	6,125.5	2,800	6,125.5	2,800
	event frequency	events/day	1	1	1	1
	exposure frequency	days/year	50	65	6	10
	exposure duration	year	30	6	30	6
	body weight	kg	70	16	70	16
	averaging time – cancer	days	27,375	27,375	27,375	27,375
	averaging time – non-cancer	day	10,950	2,190	10,950	2,190
	soil-to-skin adherence factor	mg/cm^{2}-event	0.6	3.3	0.6	3.3
	dermal absorption fraction	unitless	chemical specific	chemical specific	chemical specific	chemical specific

4.2.3 Exposure point concentrations

EPCs were calculated for each IHS following EPA guidance (2002) and using EPA's ProUCL software. For IHS with more than five results for a particular medium, the EPC was computed as the 95% UCL concentration. When fewer than five results were available, the EPC was set at the maximum detected concentration. If the IHS was not detected in any sample for a given species or group of sediment samples (i.e., beach/intertidal samples or all sediment samples combined), no EPC was calculated and no risk estimate was made for that IHS in that medium.

EPCs for dioxins/furans, carcinogenic PAHs (cPAHs), and PCBs were calculated in two different ways: 1) using zero for all non-detect results and 2) using one-half the RL for non-detect results.

EPCs were developed for several different seafood categories, as presented in Table B.4-4.

Table B.4-4. Seafood consumption categories for developing EPCs

Seafood Category	Representative Species	Tissue Type	Receptor(s)
Pelagic fish	ling cod	fillet	subsistence fisher; recreational fisher
Bottom fish	rock sole	fillet	subsistence fisher; recreational fisher
Shellfish	Dungeness crab	whole[a]	subsistence fisher
	Dungeness crab	muscle	recreational fisher
	geoduck	whole[b]	subsistence fisher; recreational fisher
	horse clam	whole[c]	subsistence fisher
	horse clam	edible tissue[d]	recreational fisher
	coonstripe shrimp	whole	subsistence fisher; recreational fisher

[a] Whole-body samples were mathematically created from crab muscle and hepatopancreas samples, assuming the whole-body composition (minus the shell and gills) of the crab was 75% muscle and 25% hepatopancreas.

[b] Includes whole-body samples and samples made up of siphon, mantle, and adductor muscle, which make up the bulk of the geoduck mass.

[c] Includes whole-body samples and samples that were mathematically created from edible tissue and visceral tissue samples, assuming the whole-body composition (minus the shell) of the horse clam was 44% edible tissue and 56% visceral cavity.

[d] Only dioxin/furan and PCB data were available for edible tissue. Concentrations in whole-body tissue were used for other IHS.

EPC – exposure point concentration
IHS – indicator hazardous substances
PCB – polychlorinated biphenyl

4.3 TOXICITY ASSESSMENT

Toxicity values used in the HHRA, including cancer slope factors (SFs) and reference doses (RfDs), were selected according to the following hierarchy:

1. Integrated Risk Information System (IRIS) (USEPA 2010)
2. EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)
3. Other values
    a. ATSDR minimal risk levels
    b. California EPA toxicity values
    c. EPA Superfund program's Health Effects Assessment Summary Tables (HEAST)

EPA (2004) has not developed SFs or RfDs for all chemicals but has provided a method for extrapolating dermal toxicity values from oral toxicity values by applying a gastrointestinal absorbance factor to the oral toxicity values.

cPAHs, dioxins and furans, and PCBs were evaluated as groups of compounds using the toxic equivalency factor (TEF) methodology. The TEFs used in the HHRA were all derived from MTCA.[2]

Both inorganic and total arsenic data were available for tissue samples. Because the toxicity values for arsenic are based on inorganic arsenic, tissue inorganic arsenic data were preferentially used when available. For ling cod, only total arsenic data were available, so the assumption was made that inorganic arsenic represented 10% of the total arsenic measurement.

Lead was identified as an IHS in tissue. Although the toxic effects of lead exposure are well known, there are no consensus toxicity values for lead in the sources identified above. Lead exposure was evaluated using physiologically based models for both children (the Integrated Exposure Uptake Biokinetic Model for Lead in Children [IEUBK]) and adults (the Adult Lead Model [ALM]). The application of these models followed standard practice supported by guidance documents.

4.4 RISK CHARACTERIZATION

Excess cancer risks and non-carcinogenic hazards were estimated by combining the exposure parameters discussed in Section 4.2.2 with the toxicity values discussed in Section 4.2.3. Excess cancer risks and hazards were summed for each target population across all pathways to obtain an estimate of total potential excess cancer risk and across all pathways with the same target organ to obtain an estimate of hazard.

MTCA allows for two options for assessing the risk of PCBs; both were used in this HHRA. One method includes total PCB results as Aroclors and the toxicity values for PCBs. The other method includes PCB congener data and the toxicity values, based on the TEF approach, of dioxin-like PCBs, based on the SF for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD).

Excess cancer risks for all scenarios are presented in Table B.4-5. Excess cancer risk estimates were integrated over both child and adult exposures, so a single estimate was given for each pathway/scenario combination.

Table B.4-5. Summary of excess cancer risk estimates

Pathway	Risk Estimate					
	Subsistence Fisher		Recreational Fisher		Residential User	Recreational User
	RME	CT	RME	CT		
Sediment – ingestion	5×10^{-6}	5×10^{-6}	2×10^{-6}	6×10^{-7}	2×10^{-6}	3×10^{-7}
Sediment – dermal	8×10^{-6}	9×10^{-7}	3×10^{-6}	1×10^{-7}	3×10^{-6}	5×10^{-7}

[2] WAC 173-240-90 Table 708-1 for dioxins/furans, Table 708-2 for cPAHs, and Table 708-4 for PCBs.

Pathway	Risk Estimate					
	Subsistence Fisher		Recreational Fisher		Residential User	Recreational User
	RME	CT	RME	CT		
Tissue – ingestion	1×10^{-2}	6×10^{-3}	3×10^{-4}	2×10^{-4}	na	na
Total	**1×10^{-2}**	**6×10^{-3}**	**3×10^{-4}**	**2×10^{-4}**	**5×10^{-6}**	**8×10^{-7}**

Note: Excess cancer risk estimates based on PCBs (as Aroclors), cPAHs, and dioxins/furans were calculated using one-half the RLs for non-detect values. Risk estimates were also calculated assuming zero for non-detect values, but total risk estimates were very similar to those presented in this table.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
PCB – polychlorinated biphenyl
RL – reporting limit
RME – reasonable maximum exposure

Excess cancer risks for tissue ingestion were approximately 100 to 1,000 times higher than those for direct sediment contact (Table B.4-5). The highest excess cancer risk for all pathways combined was for the subsistence fisher RME scenario (1×10^{-2}). Excess cancer risks for the other scenarios that included tissue ingestion were lower than those for the subsistence fisher RME scenario, but still greater than MTCA's 1×10^{-5} acceptable target risk level for multiple pathways or multiple chemicals. Excess cancer risks for the residential and recreational users, which included only direct sediment contact, were 5×10^{-6} and 8×10^{-7}, respectively, well below the MTCA threshold for multiple pathways.

The chemicals that contributed most significantly to the excess cancer risk estimates are shown in Figure B.4-1. Arsenic risks represented 62% (7×10^{-3}) of the total excess cancer risk across all pathways, followed by dioxins/furans at 18% (2×10^{-3}) and PCBs (as Aroclors) at 12% (1×10^{-3}).

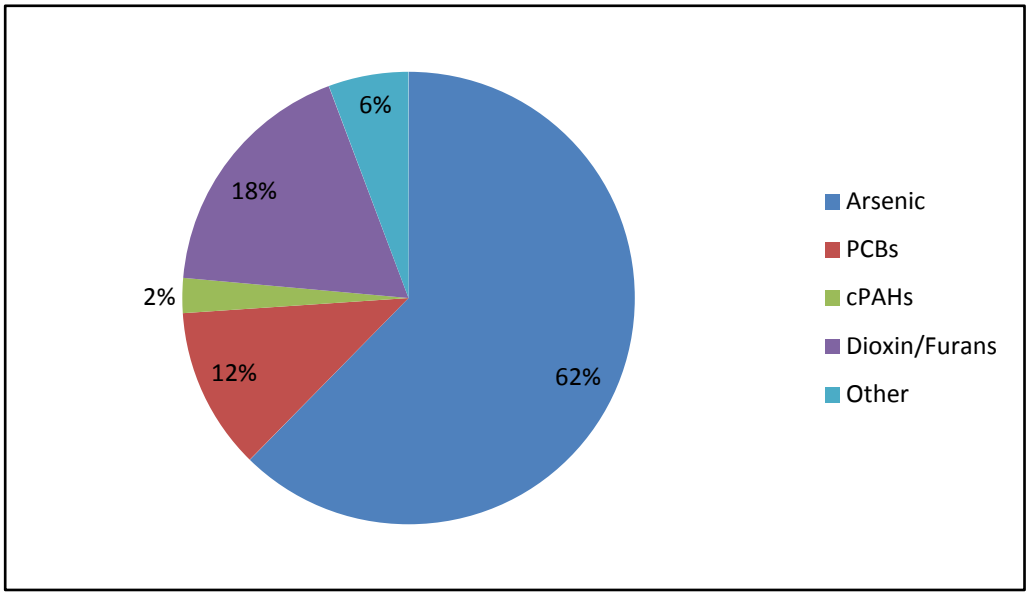


Figure B.4-1. Percent contribution by chemical to total excess cancer risk for subsistence fisher RME scenario

In addition to the four chemicals shown in Figure B.4-1, several pesticides (i.e., dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyltrichloroethane (DDT), alpha-benzene hexachloride (BHC), beta-BHC, and Lindane), hexachlorobenzene, and pentachlorophenol also had excess cancer risk estimates greater than 1×10^{-6} for both the subsistence fisher RME and CT scenarios (Table B.4-6). These other chemicals are included in the "other" category in Figure B.4-1.

Table B.4-6. Summary of chemicals that exceeded the excess cancer risk threshold of 1 in 1,000,000

Pathway	Chemical	Risk Estimate			
		Subsistence Fisher RME	Subsistence Fisher CT	Recreational Fisher RME	Recreational Fisher CT
Sediment ingestion	arsenic	4×10^{-6}	4×10^{-6}	1×10^{-6}	na
	TCDD TEQ[a]	2×10^{-6}	2×10^{-6}	6×10^{-6}	na
Sediment dermal	arsenic	4×10^{-6}	na	na	na
	TCDD TEQ[a]	3×10^{-6}	na	1×10^{-6}	na
Seafood ingestion	arsenic	7×10^{-3}	4×10^{-3}	2×10^{-4}	2×10^{-4}
	PCB – Aroclors[a]	1×10^{-3}	7×10^{-4}	1×10^{-5}	9×10^{-6}
	PCB TEQ[a]	3×10^{-4}	1×10^{-4}	9×10^{-6}	6×10^{-6}
	cPAH[a]	3×10^{-4}	2×10^{-5}	1×10^{-6}	8×10^{-6}
	TCDD TEQ[a]	3×10^{-3}	1×10^{-3}	2×10^{-5}	1×10^{-5}
	DDE	4×10^{-6}	2×10^{-6}	na	na
	DDT	3×10^{-5}	1×10^{-5}	na	na
	alpha-BHC	5×10^{-4}	3×10^{-4}	1×10^{-5}	1×10^{-5}
	beta-BHC	7×10^{-5}	3×10^{-5}	2×10^{-6}	1×10^{-6}
	Lindane	1×10^{-5}	7×10^{-6}	na	na
	pentachlorophenol	2×10^{-5}	1×10^{-5}	na	na
	hexachlorobenzene	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}

[a] Based on non-detects reported at one-half the RL.

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
na – not applicable; estimate less than 1 in 1,000,000
PCB – polychlorinated biphenyl
RL – reporting limit
RME – reasonable maximum exposure
TCDD – tetrachlorodibenzo-*p*-dioxin
TEQ – toxic equivalent

Hazard indices were also estimated for 14 different target organs for both adults and children, as presented in Table B.4-7. Hazard indices were highest for the developmental pathway (54 and 110, for subsistence fisher RME for the adult and child, respectively), with the highest concentrations from PCBs, dioxins/furans, and mercury, in that order. The hazard quotient for arsenic was the third highest of all IHS (behind PCBs and dioxins/furans), with a maximum of 29 for the subsistence fisher RME for the child.

Table B.4-7. Summary of hazard indices

Pathway	Hazard Indices											
	Subsistence Fisher				Recreational Fisher				Residential User		Recreational User	
	RME		CT		RME		CT					
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Cardiovascular	14	29	7	14	1	2	0.7	1	< 0.01	0.07	< 0.01	0.01
Developmental	54	110	27	53	2	2	1	2	< 0.01	< 0.01	< 0.01	< 0.01
Endocrine system	< 0.01	0.01	< 0.01	< 0.01	na	na	na	na	na	na	na	na
Gastrointestinal tract	2	4	1	2	0.06	0.1	0.04	0.07	na	na	na	na
Hematologic system	4	8	2	4	0.3	0.5	0.2	0.4	na	na	na	na
Immune system	0.04	0.08	0.02	0.04	< 0.01	< 0.01	< 0.01	< 0.01	na	na	na	na
Kidney	4	8	2	4	0.2	0.3	0.1	0.2	< 0.01	< 0.01	< 0.01	< 0.01
Liver	0.3	0.5	0.2	0.3	0.1	0.1	0.1	0.1	< 0.01	< 0.01	< 0.01	< 0.01
Lungs	0.02	0.04	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Nervous system	6	11	3	6	0.4	0.7	0.3	0.5	na	na	na	na
Reproductive system	16	32	8	16	1	2	0.8	1	na	na	na	na
Skin	16	32	8	16	1	2	0.8	1	na	na	na	na
Whole body	0.09	0.2	0.05	0.09	< 0.01	0.01	< 0.01	< 0.01	na	na	na	na
Not classified	34	67	17	34	0.9	2	0.7	1	na	na	na	na

CT – central tendency
na – not applicable
RME – reasonable maximum exposure

As with the excess cancer risk, > 99% of the hazard index calculated for multiple exposure pathways (i.e., tissue ingestion and direct sediment contact) was attributable to tissue ingestion. No individual hazard quotient was greater than 1 for direct sediment contact.

HQs were greater than 1 for up to 10 metals (depending on the scenario), PCBs, and TCDD toxic equivalent (TEQ) (Table B.4-8). The highest HQ was for PCB Aroclors for the subsistence fisher (child) RME scenario.

Table B.4-8. Summary of chemicals that exceeded the HQ threshold of 1 for seafood ingestion pathways

Chemical	Hazard Quotient							
	Subsistence Fisher RME		Subsistence Fisher CT		Recreational Fisher RME		Recreational Fisher CT	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Arsenic	14	29	7	14	na	2	na	1
Cadmium	3	6	2	3	na	na	na	na
Cobalt	4	7	2	4	na	na	na	na
Copper	2	4	na	2	na	na	na	na
Iron	3	5	1	2	na	na	na	na
Selenium	1	3	na	1	na	na	na	na
Silver	na	1	na	na	na	na	na	na
Vanadium	na	1	na	na	na	na	na	na
Zinc	na	1	na	na	na	na	na	na
Methylmercury	5	10	3	5	na	na	na	na
PCB – Aroclors[a]	31	62	16	31	na	1	na	na
PCB TEQ[a]	2	4	na	2	na	na	na	na
TCDD TEQ[a]	18	35	9	17	na	na	na	na

[a] Based on non-detects reported at one-half the RL.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
HQ – hazard quotient
na – not applicable; HQ less than 1
PCB – polychlorinated biphenyl
RL – reporting limit
RME – reasonable maximum exposure
TCDD – tetrachlorodibenzo-*p*-dioxin
TEQ – toxic equivalent

The models for lead exposure were run for the subsistence and recreational fishers using default parameters, except for the inclusion of lead in locally caught fish and shellfish. Application of the IEUBK model, which predicts blood lead concentration in children, indicated that 56.6% (RME) and 29.7% (CT) of children would be expected to have blood lead concentrations of 10 µg/dl, the blood lead concentration of concern. Results for the recreational fisher scenario were much lower and below EPA's risk reduction goal of 5% of the population below the 10 µg/dl blood lead threshold.

Results from the ALM, which was used to estimate risks to developing fetuses from pregnant adult women's exposure to lead, were also below EPA's risk reduction goal of 5%, indicating insignificant risk to this population.

4.5 UNCERTAINTY ASSESSMENT

Ecology (2012) identified many sources of uncertainty in this HHRA, as summarized in Table B.4-9. The potential impact on risk estimates varied for each area of uncertainty. Overall, the HHRA included intentionally conservative, health-protective assumptions throughout the risk assessment process so that the true risk was unlikely to be underestimated. This approach may have resulted in a substantial overestimate of the true risk at the site (Ecology 2012).

Table B.4-9. Summary of risk assessment uncertainties

Area of Uncertainty	Potential Impact on Risk
Environmental Sampling and Analysis	
Low sample numbers for tissue	overestimate or underestimate
No analytical data for some IHS	underestimate
Targeted sampling	overestimate
Limited reference sampling	overestimate or underestimate
Lack of screening levels	overestimate
Exposure Point Concentrations	
Inclusion of estimated results	overestimate
Inclusion of non-detected chemicals in EPC calculation	overestimate or underestimate
Use of 95% UCL or maximum concentration	overestimate
Exclusion of non-detected chemicals	underestimate
No analytical results for some IHS	underestimate
Limited data on whole-body burden	overestimate or underestimate
cPAH, 2,3,7,8-TCDD TEQ, and total PCB EPCs	overestimate
Arsenic concentrations in tissue	overestimate
Exposure Assessment	
Change in chemical concentrations not considered	overestimate or underestimate
Use of high end and default values	overestimate
Dermal exposure to sediment	overestimate or underestimate
Subsistence fisher ingestion rates and fish diet fraction	overestimate
Use of representative species	overestimate or underestimate
Toxicity Assessment	
Determination of toxicity values	overestimate or underestimate
Dermal toxicity values	overestimate or underestimate
Assumption of additive impacts	overestimate

Area of Uncertainty	Potential Impact on Risk
Not including synergistic effects	underestimate
Use of surrogates	overestimate or underestimate
Exclusion of IHS lacking toxicity data	underestimate
Use of lead models	overestimate or underestimate
Evaluation of dioxin and furan cancer potency	overestimate or underestimate
Risk Characterization	
Not considering risk caused by reference concentrations	overestimate
Not including preparation of food	overestimate or underestimate

cPAH – carcinogenic polycyclic aromatic hydrocarbon
EPC – exposure point concentration
IHS – indicator hazardous substances
PCB – polychlorinated biphenyl
TCDD – tetrachlorodibenzo-*p*-dioxin
TEQ – toxic equivalent
UCL – upper confidence limit on the mean

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APPENDIX C. CONCEPTUAL SITE MODEL

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Table of Contents

Figures

1 Introduction

This appendix addresses how sediment transports and deposits in the Port Angeles Harbor environment near the former Rayonier mill based on physical conditions and natural processes. Two near-field conceptual site models (CSMs) have been prepared: one by NewFields (2012a) and one by SeaEngineering, Inc. (SEI) (presented in this appendix). Both of these CSMs are summarized in this appendix. Section 2.1 presents the NewFields model exactly as it was presented in the *Port Angeles Harbor Supplemental Data Evaluation to the Sediment Investigation Report, Public Review Draft* (NewFields 2012a). Section 2.2 presents the SEI CSM and also addresses specific questions from Ecology regarding grain size distribution near the former Rayonier mill, wave properties, nearshore transport, offshore transport, and log pond morphology.

Key similarities and differences in the two CSMs are summarized in Section 2.4 of the main document. Any differences that may affect in-water remedial alternatives will be addressed in Volume III.

2 Near-Field CSMs

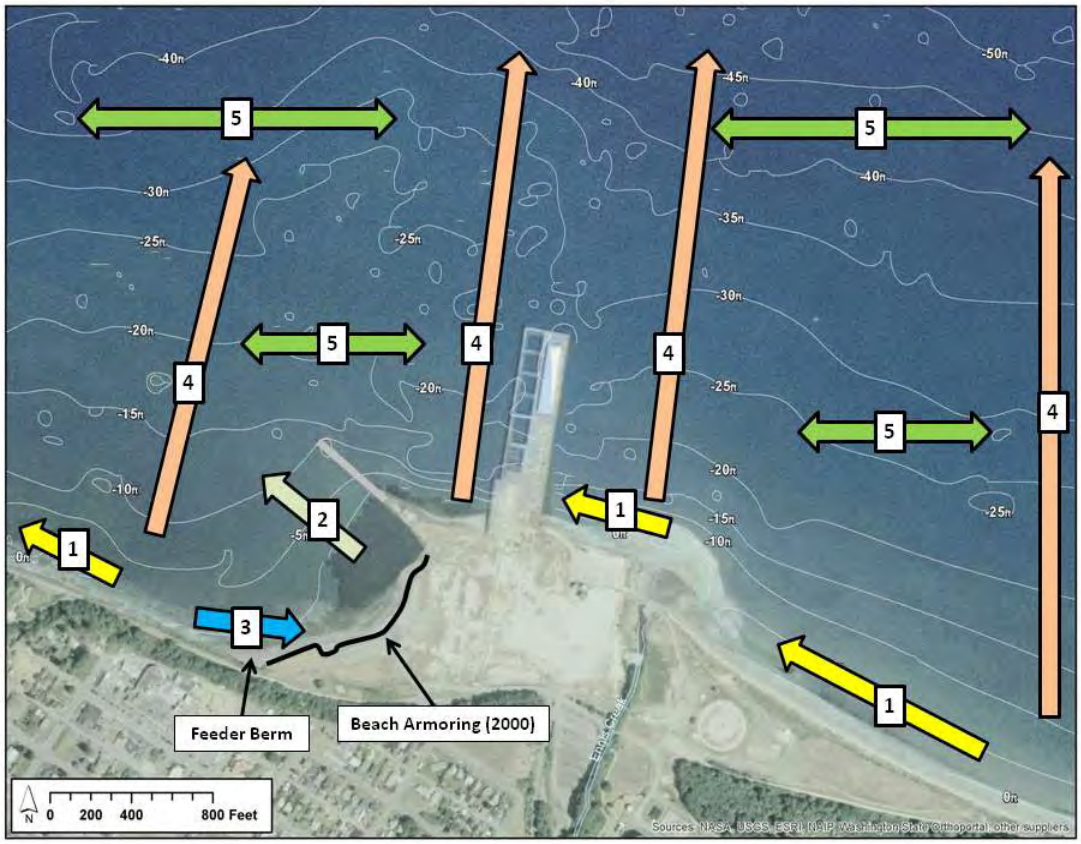
2.1 NEWFIELDS CSM (AS EXCERPTED DIRECTLY FROM ECOLOGY (2013))

The NewFields CSM (2012a) integrates the results of a current study, sediment trend analysis (STA), nearshore geomorphic analysis, and radioisotopic measurements conducted for the bay-wide characterization, as well as many previous hydrographic studies. Together these lines of evidence support the existence of multiple sediment transport pathways and can be used to infer the physical processes that drive transport. Significant differences are apparent in sediment transport pathways under low energy and high energy conditions.

Figure C.2-1 shows Ecology's CSM for the study area. This figure includes sediment transport arrows associated with both high and low energy conditions. Figure C.2-1 includes a table that identifies the separate mechanisms driving transport, the resulting transport directions, and examples of supporting evidence apparent for each transport mechanism. Sediment transport in the vicinity of the former Rayonier mill is characterized by:

1. Refracted swell entering the harbor from the Strait of Juan de Fuca, as well as wind-driven waves from the northeast, result in westward longshore sediment transport along the southern harbor westward of Lees Creek. However, this transport mechanism may be limited to fairly coarse-grained sediment in the nearshore zone.

2. Although the log pond is protected from northeasterly waves by the rock jetty, westerly waves enter the log pond unimpeded. After the log pond was no longer used for log rafting, the beach within the pond began eroding and required stabilization (Integral and Foster Wheeler 2004). While armoring the beach may protect it from erosion, westerly wave energy likely has the ability to erode shallow sediment in the log pond. Resuspended sediment within the log pond is expected to deposit in deeper, lower energy environments.
3. The log pond rock jetty protects the log pond shoreline from the swells and northeasterly waves that cause westward longshore transport outside of the log pond. Longshore transport within the log pond is eastward, driven by westerly waves. This transport mechanism spreads imported sand from an intentionally placed feeder berm eastward to the armored beach.
4. Northeasterly waves approaching the southern shoreline of the harbor resuspend shallow sediments and enhance bottom currents. Such bottom currents inhibit deposition of fine-grained sediment until a deeper, lower energy setting is encountered.
5. Suspended sediments throughout the harbor are subjected to alternating east-west tidal currents. Sediment transported westward in suspension is exposed to decreasing energy conditions, promoting deposition within the harbor. Sediment transported eastward enters an increasingly higher energy environment, inhibiting settling and allowing further transport. Over time this process has contributed to grain size pattern`s observed in the harbor.



Legend

Arrow	Driving Mechanism	Resulting Sediment Transport	Evidence
1	swell refraction, northeasterly waves	westward longshore transport	geomorphic indicators, historical charts
2	westerly waves	resuspension of fine-grained sediment and offshore transport	westerly wave height, beach stabilization activities required
3	westerly waves	eastward longshore transport	berm migration
4	northeasterly waves	resuspension of fine-grained sediment and offshore transport	northeasterly wave heights, surface sediment fining patterns
5	bi-modal tidal currents	multi-directional transport of fine-grained sediment	tidal currents, large-scale fining patterns

Source: NewFields (2012b)

Figure C.2-1. NewFields sediment transport CSM for the former Rayonier mill study area

2.2 SEI CSM

This section presents a synthesis conducted by SEI and Windward Environmental LLC (Windward) of relevant hydrodynamics and sediment transport information to develop a CSM for the study area (Figure C.2-2). The resultant CSM is referred to as the SEI CSM. Relevant transport features are:

1. Coarse sandy sediment deposits close to its point of entry and remains in the nearshore area. Fine sediment moves offshore, where it settles in a lower-

energy environment. The generally weak tidal currents in the region allow the fine material to settle out offshore, outside of regions of wave-induced resuspension, and become incorporated into the sediment bed. Analyses have shown that wave resuspension of fine silt material in the harbor during large wave events only occurs in water < 15 ft deep (Section 2.3.2). The lines of evidence include particle-size distributions, fiber mat observations, contaminant distributions, and quantitative analyses of wave-driven sediment transport.

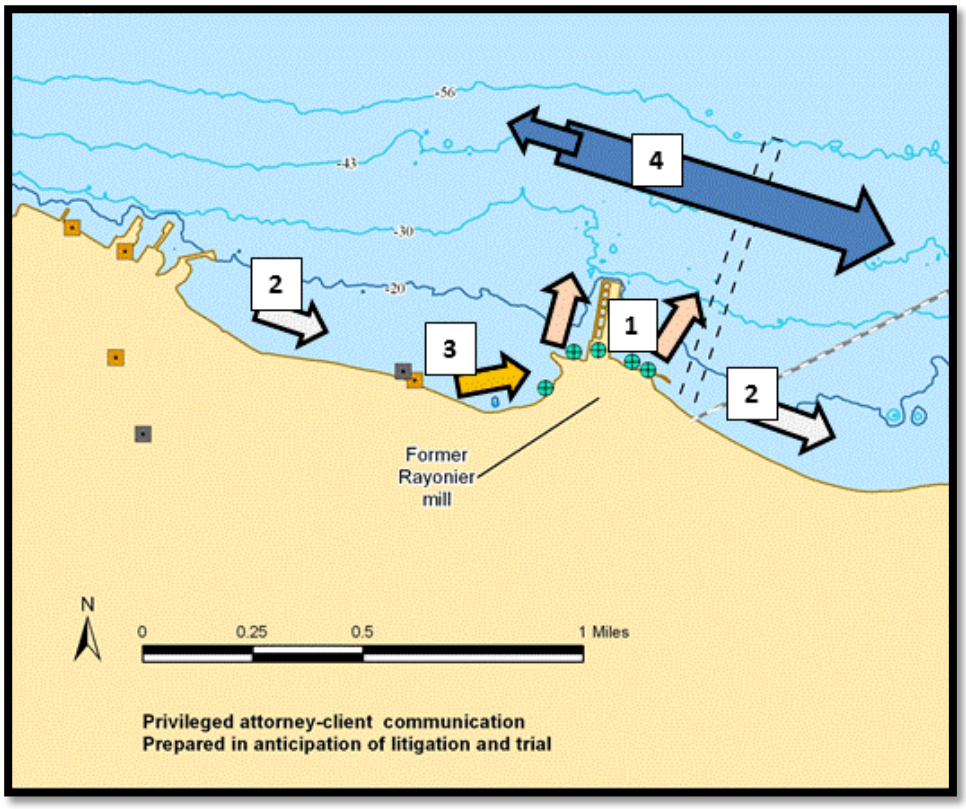
2. The dominant waves in Port Angeles Harbor are produced by local winds (WRCC 2008). Winds that are strong enough to develop significant waves in the harbor (> 8 kts) are from the west approximately 95% of the time.[1] When these westerly waves move eastward in the shallow waters of the southern harbor shoreline, they begin to exert a shear stress that can mobilize sediment. The mobilized sediment is transported along the shore during 95% of the higher wind events (>8 kts), resulting in a net eastward transport (Section 2.3.2). Lines of evidence include wind records, the geomorphology of the sand bar at the mouth of Ennis Creek, and nearshore wave-driven transport mechanics.

3. The feeder berm on the western end of the cove has been replenished with sand yearly, which has resulted in the development of a large beach. This beach has been growing steadily since the initial placement of material at the feeder berm. The transport of feeder material to the east is consistent with evidence of nearshore transport described above. The shoreline above the beach has shown evidence of bank erosion as the anthropogenic fill in the upper shore has moved toward a natural equilibrium after the cessation of log rafting. The subtidal regions have had significant infill (accretion) during this same period. Lines of evidence include shoreline monitoring conducted between 2003 and 2011, bathymetric surveys, and nearshore wave-driven transport mechanics (Section 2.3.5).

4. Port Angeles Harbor is a protected harbor with weak currents that flow in a net counter-clockwise direction. Summaries of previous work on offshore transport documented the easterly transport of effluent (Section 2.3.4). In addition, the skewing of observable fiber mats near the former Rayonier mill to the east is an indication of the long-term deposition of materials and associated contaminants that have been transported to the east. Although it is acknowledged that the tidal currents are bi-directional, weak counter-clockwise net circulation in the Harbor will have a net transport to the east. Furthermore, due to the weak tidal currents, particles (e.g., sand, clays, silt) that are introduced into the harbor tend to settle close to their source and are not significantly resuspended outside of

[1] It is important to note that these percentages are representative of moderate and larger wind events. This does not include low or average wind periods where transport is not significant.

the influence of waves (approximately a 15-ft-depth, Section 2.3.2). Lines of evidence include previous documented observations, current meters, deposited sludge bed and contaminant patterns, and sediment transport mechanics.



Legend

Arrow	Driving Mechanism	Resulting Transport	Evidence
1	cross-shore wave transport	transport and deposition of fine sediment offshore	particle-size distributions, sludge bed observations, contaminant distributions, bathymetry, and quantitative analysis of wave-driven sediment transport
2	longshore wave transport	net transport of nearshore sediment to the east	wind records, geomorphology of sand bar at the mouth of Ennis Creek, nearshore wave-driven transport mechanics
3	wave transport in the confined log pond	easterly and offshore transport of material in the log pond	shoreline monitoring conducted between 2003 and 2011, bathymetric surveys, nearshore wave-driven transport mechanics
4	tidal currents	offshore deposition and net easterly transport of suspended material	current observations and measurements, contaminant distributions, sludge bed observations, and bathymetry

Figure C.2-2. SEI sediment transport CSM for the former Rayonier mill study area

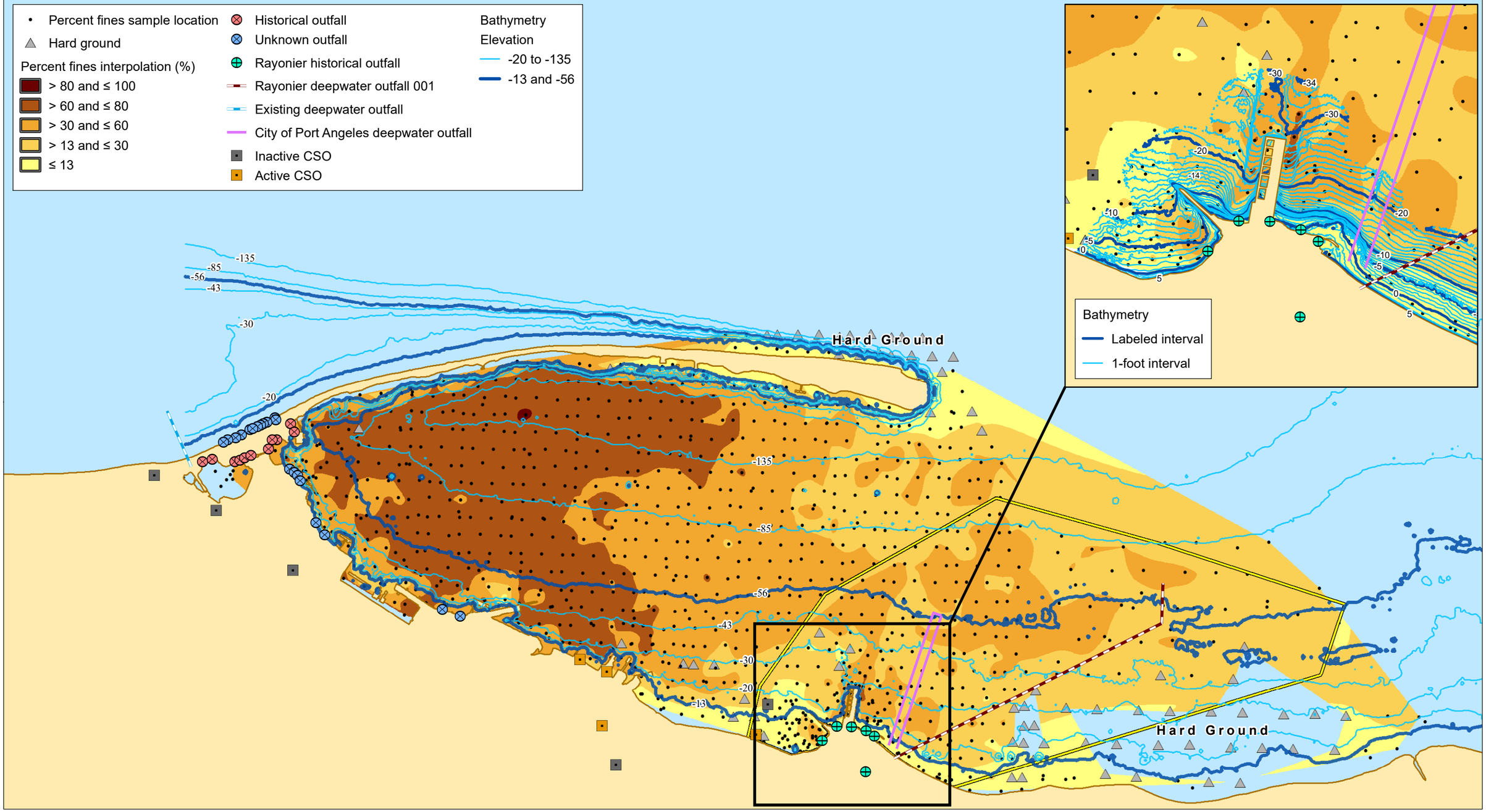
2.3 RESPONSES TO ECOLOGY QUESTIONS

This section includes discussions of grain size distribution near the former Rayonier mill, wave properties, nearshore transport, offshore transport and log pond morphology requested by Ecology. These lines of evidence support the SEI CSM presented in Section 2.2.

2.3.1 Grain-size distributions

Grain size data in the vicinity of the former Rayonier mill is shown in Figure C.2-3 as percent fines. Percent fines is a measure of the volume percentage of sediment smaller than 62.5 microns in diameter. Fine sediment is typically of interest in the transport of hydrophobic contaminants due to the generally high organic content associated with the fine fraction of sediment. Overall, the fines content in Port Angeles Harbor is highest in the northwest corner. As is common in many estuaries and harbors, the "head" of the harbor that is most protected from tides and waves is where the very fine portion of local watershed, outfall, and estuarine sediment will occur. Natural sources of sediment over the many-thousand-year life span of Ediz Hook have contributed to the overall higher percent fines in the northwest corner.

Rayonier



Data sources: All outfalls near former Crown Zellerbach taken from Exponent (2008).
Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.
Inset bathymetry used NOAA soundings data to obtain 1 foot intervals.
Grain size data combination of STA and WW dataset.

Figure C.2-3. Bathymetry and sediment grain size distribution in Port Angeles Harbor

Prepared by mikey, 11/13/2014; W:\Projects\Rayonier PA Volume II\Data\GIS\Maps_and_Analysis\5518_Bathymetry and STA Grain Size_MTY_081913.mxd

The portion of the harbor in the vicinity of the former Rayonier mill has grain size patterns that are consistent with classic coastal sorting (USACE 2002a). When sediment is discharged into nearshore areas, its movement is determined by the size and density of the particles and the currents and waves acting on the discharge region. Coarse sandy sediment, with its high settling velocities, tends to settle on the sediment bed much closer to its point of release and, because they are heavier, tend to remain in the areas in which they have settled. Finer, lighter sediment, silt, and clay, with their low settling velocities remain in suspension in nearshore areas, settling only when they move offshore to a lower-energy environment where waves do not have a significant effect (Figure C.2-4). These tendencies explain why, for the most part, sandy beaches exist in Port Angeles Harbor, with higher percent fines offshore (Figure C.2-3).

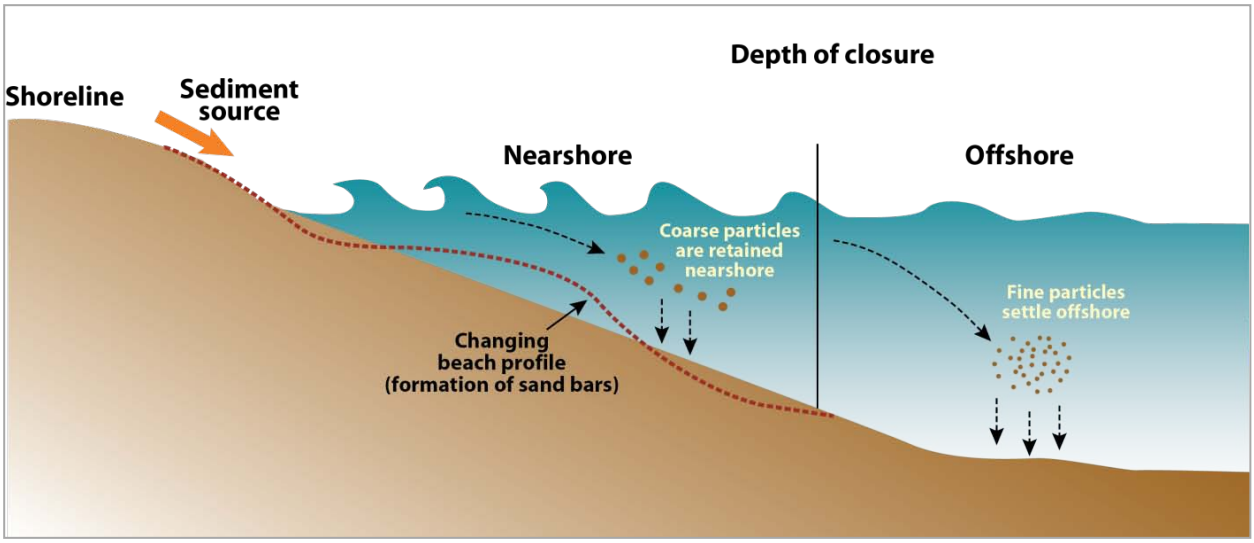


Figure C.2-4. Schematic of sediment deposition in nearshore and offshore areas

In particular, Figure C.2-3 shows that for the nearshore region near the former Rayonier mill, the area with less than ~ 15 ft of water is characterized by low percent fines (< 13%), including regions characterized by gravelly sand. This region is expected to have a low fines content and high percentage of sand due to the wave action in the shallow water. The waves resuspend fine material until they can settle in low-energy environments offshore (deeper than 15ft. The offshore regions adjacent to the former Rayonier mill show an increase in fines content from 13 to 60% and higher adjacent to the pier, indicative of where the fine material settles. Sediment with a fines content over 10% often behaves in a cohesive manner (i.e., exhibit inter-particle cohesion) (Lick 2009; Winterwerp and Kesteren 2004). Once sediment reaches the offshore regions, no processes exist to intensify bottom currents sufficient to re-suspend cohesive sediment in offshore waters. Since the most intense wave energy is

confined to relatively shallow nearshore portions of the harbor (less than 15 ft deep), there are no identified processes to resuspend fine sediment in the offshore regions.

NewFields (2012a) used STA to further elucidate transport patterns beyond the basic interpretation of sediment sorting noted above. STA cannot be used to evaluate sediment transport in the Harbor. The failure of the method has been recognized in the peer-reviewed analysis of STA by Poizot et al. (2008). Three additional independent peer-reviewed site studies concluded that the STA approach was not valid and did not accurately describe transport conditions at those sites (Flemming 1988; Guillen and Jimenez 1995; Masselink 1992). Because the scientific community generally rejects the application of STA to deduce sediment transport pathways, it cannot be used to analyze sediment transport at sites such as Port Angeles Harbor.

2.3.2 Wave properties

The dominant waves in Port Angeles Harbor are produced by local winds (WRCC 2008). Based on wind measurements made by the US Coast Guard (USCG) station on Ediz Hook, winds that are strong enough to develop significant waves (~ 8 kts) are primarily from the west throughout the year (Figure C.2-5).

Regionally, in the Strait of Juan de Fuca, waves originate from the west and can reach up to 2 m [6.7 ft] in size (Thomson 1994). Although these waves could propagate into the harbor, the amount of wave energy that would be lost during refraction and diffraction around the tip of Ediz Hook (an approximately 90-to-180-degree turn) would reduce the wave height by 90 to 99% by the time the waves reached the harbor's southern shore (USACE 1984). The refracted and diffracted waves of 0.2 m [0.7 ft] or less in height would not significantly influence transport within the harbor. Thus, there is no evidence to suggest that westerly waves in the strait would result in a significant change in the harbor's circulation pattern, even during large events.

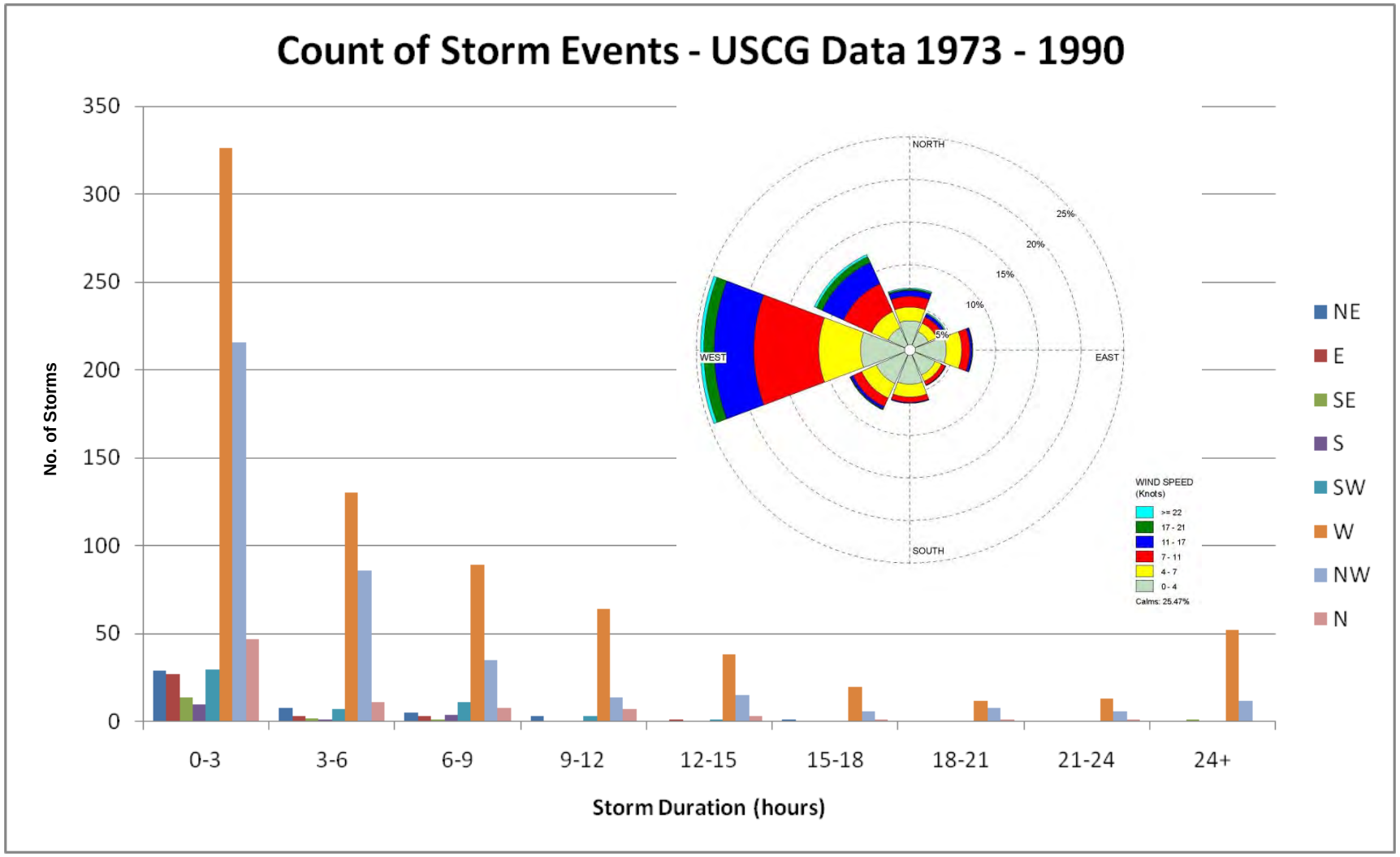
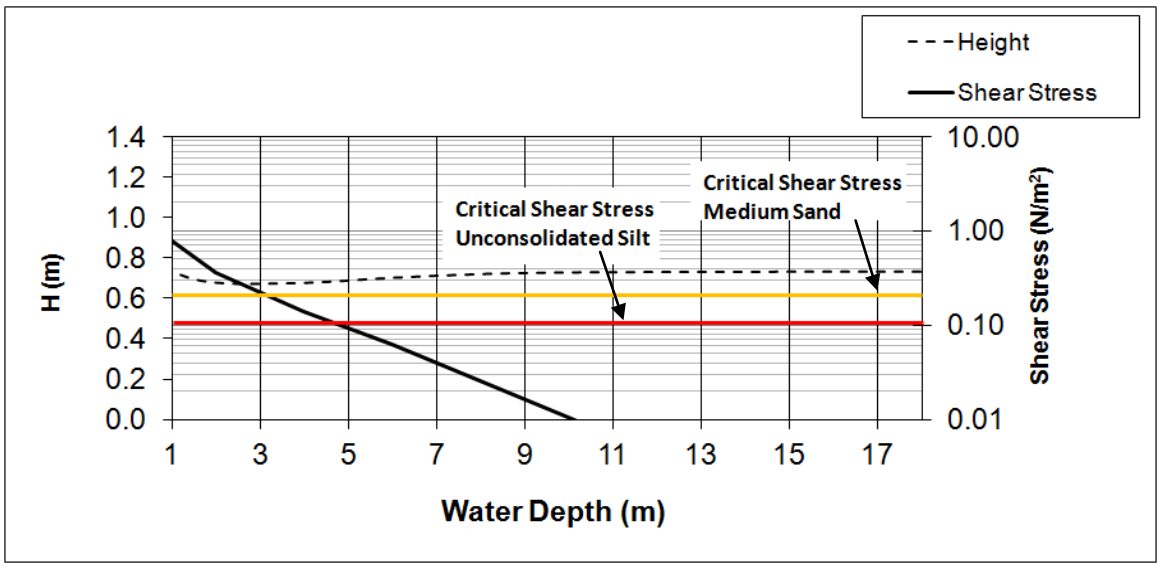


Figure C.2-5. Number of storm events as a function of wind duration and direction at the USCG station on Ediz Hook and a standard wind rose

Extreme events are considered to be rare storm events that occur less than 5% of the time and can have a significant impact on sediment transport patterns. Extreme events in the Pacific Northwest include winter storm fronts with rain and strong winds from westerly and northerly directions (Figure C.2-5). Tidal currents are essentially unmodified by extreme events because of the relatively short duration (Figure C.2-5) of the events. The majority of the moderate and larger wind events from 1973 to 1990 were less than 6 hours in duration, and 95% of all events were from the west. Surface currents may briefly grow stronger in shallow regions as a result of locally strong winds that blow on the water surface, but large-scale studies in Puget Sound have shown no changes in overall tidal circulation patterns or magnitude due to strong winds (Thomson 1994).

A rigorous calculation method based on the force exerted by waves on the sediment surface was used to help determine a realistic depth at which sediment would be re-suspended by high-wind waves during a storm event. Although most of the moderate and larger wind events were from the west, a small percentage (~ 5%) of the wind events emanated from the north and northeast (Figure C.2-5). Wind waves from these northerly directions can be considered a worst-case scenario because of the larger fetch. Using standard equations for the prediction of wind waves from the *Coastal Engineering Manual* (USACE 2002b), with the 45-km fetch to the northeast of the former Rayonier mill, a north-northeasterly storm would have a 0.73-m significant wave height and a 3.4-s wave period offshore. As this wave moves closer to shore, it exerts a shear stress on the sediment. When the shear stress exceeds a critical shear stress for the sediment, the sediment begins to move.

The determination of critical shear stress is from the common shield curve outlined in Van Rijn (1993). For unconsolidated silt at the surface of the sediment bed, the critical shear stress is 0.1 Pa; while for a medium sand (typical of most of the Port Angles Harbor beaches), the critical shear stress is 0.2 Pa. Figure C.2-6 illustrates the increasing shear stress (right-hand Y-axis) exerted by the wave as it moves into shallower water (X-axis). The depth of water when the silt begins to move is 15 ft (4.5 m) and shallower and the medium sand begins to move at a depth of 9.8 ft (3.0 m) and shallower. It is important to note that the silt depth of motion is still considerably shallower than the 55 ft (17 m) reported by Herrera (2011). It is unlikely that any significant transport resulting from wave activity occurs in water deeper than the 15-ft (4.5-m) depth, even during rare storms from the north and northeast. In addition, the presence of fines in water deeper than the 15-ft contour indicates that fines accumulate in these regions (see Figure C.2-3).



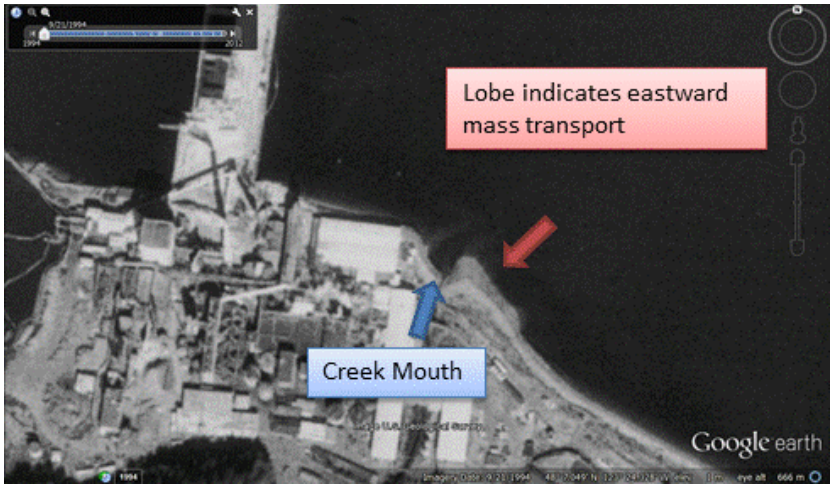
Note: Critical shear stress is shown for silt (red) and medium sand (yellow).

Figure C.2-6. Calculated wave height (H) and shear stress (N/m^2, Pa) as a function of water depth

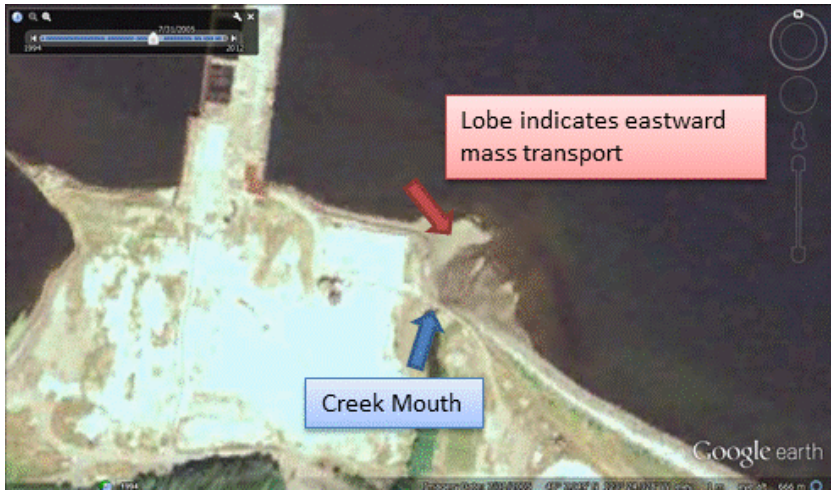
2.3.3 Nearshore transport

Once fine material and any associated contaminants are discharged in the nearshore, they may settle during typical low-wave conditions, but once resuspended by waves, they will move in the nearshore currents and be dispersed offshore.

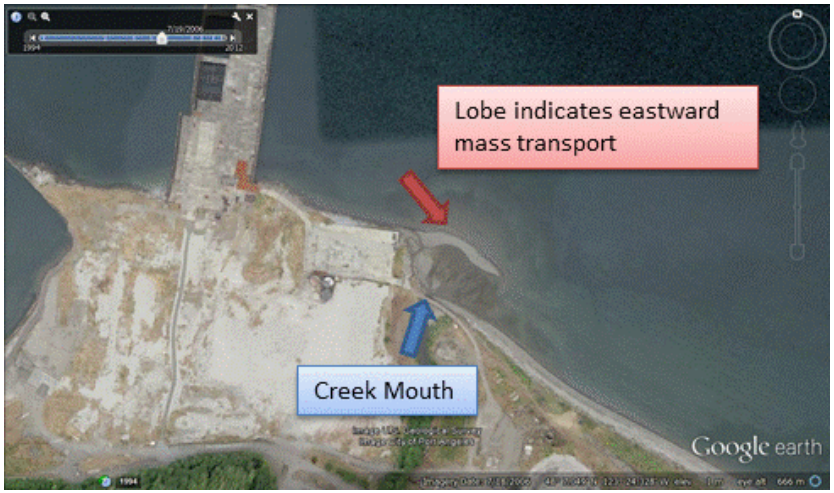
As described in Section 2.3.2, the larger waves in Port Angeles Harbor are produced by west winds approximately 95% of the time. When these westerly waves move eastward and break along the southern shoreline, the energy generated essentially "pushes" sediment to the east in the nearshore, consistent with the standard principles of longshore transport (USACE 2002a). The geomorphology of the sand bar at the mouth of Ennis Creek over time demonstrates the net effect of this transport on sandy sediment discharged from the creek. Figures C.2-7 and C.2-8 show a dominant east skewing of the sediment lobe of sand from the creek.



1994



2005

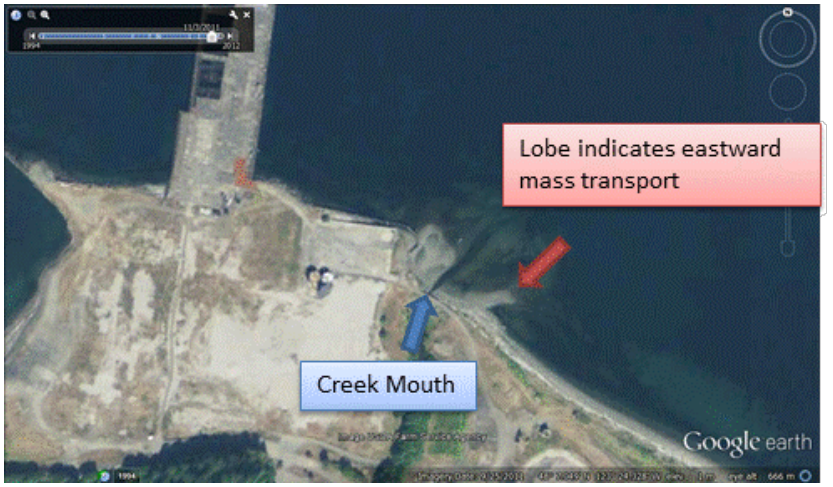


2006

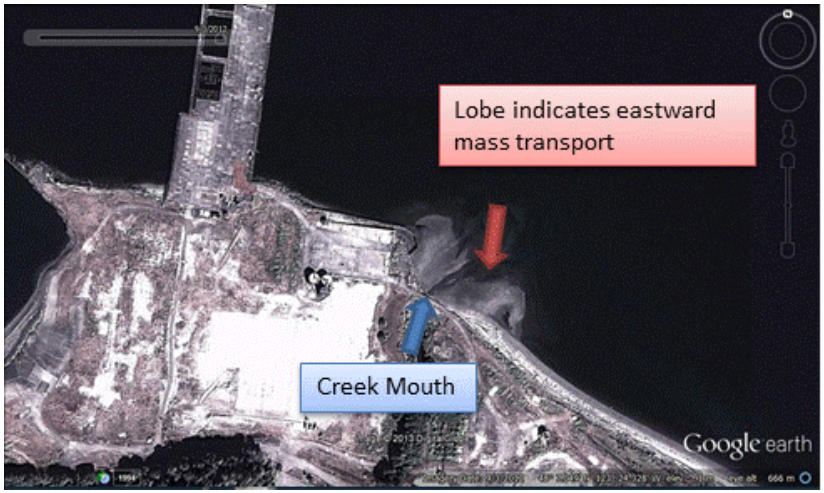
2008

Figure C.2-7. Sand bar at mouth of Ennis Creek from 1994 to 2008

2009



2011



2012

Figure C.2-8. Sand bar at mouth of Ennis Creek from 2009 to 2012

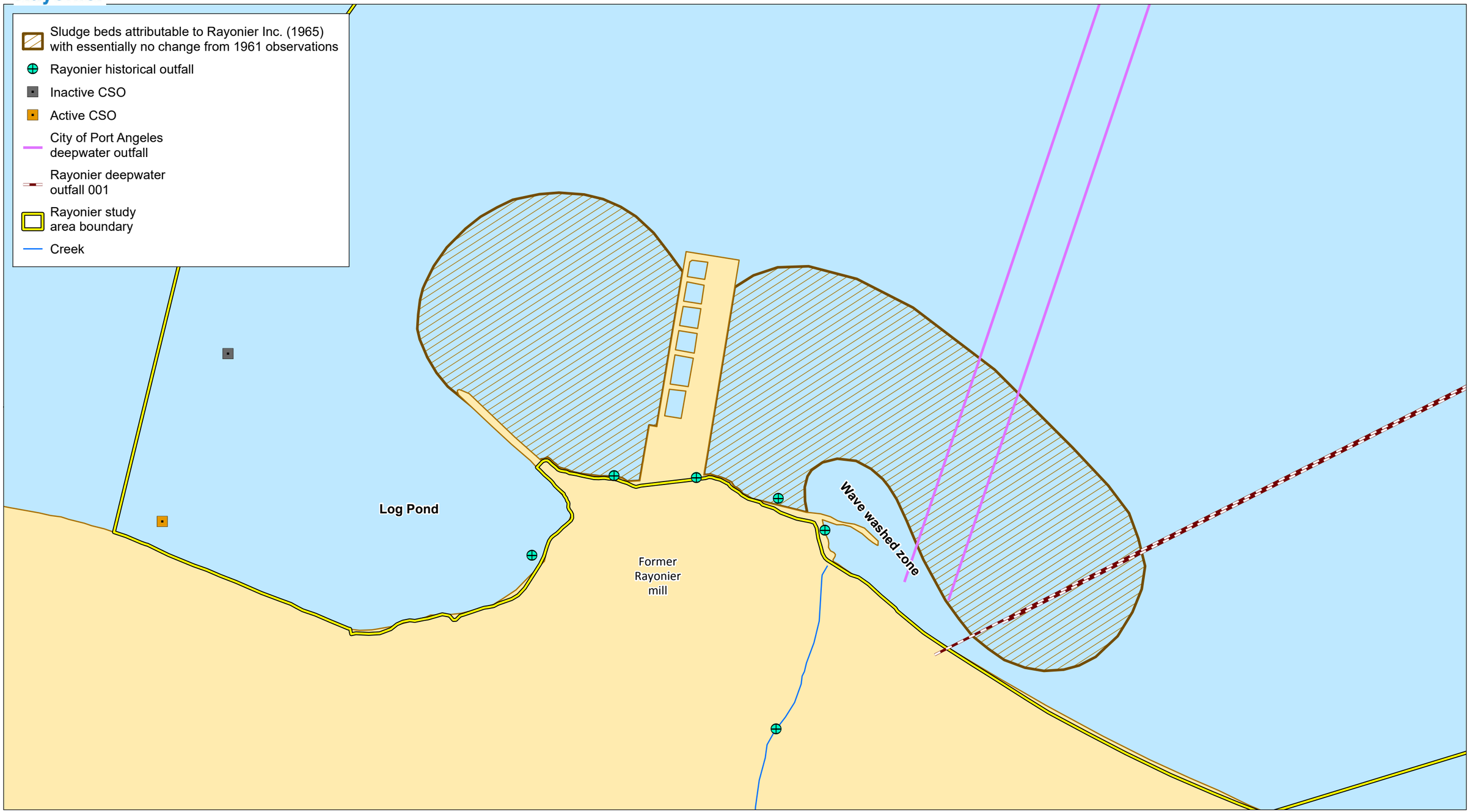
2.3.4 Offshore transport

Once sediment moves out of the nearshore to the offshore, material remaining in the water column will be transported by the tides as it settles to the sediment bed. Of particular importance to determining where the material from the former Rayonier mill outfalls moves are studies related to the observation of effluent discharge. A comprehensive EPA (1974) study of sulfite waste liquor concluded that discharges from the former Rayonier mill were transported in an eastward direction and was enhanced by the dominant westerly wind patterns. While tides are certainly bi-directional, in estuaries there is generally a dominant, or net, transport direction of the water at any given location (Dyer 1997). Based on observations of the effluent from all facilities in Port Angeles Harbor, the study (EPA 1974) also concluded that there was weak counter-clockwise circulation in the harbor, resulting in an eastward transport of the former Rayonier mill effluent.

The conclusion that Ebbesmeyer et al. (1979) also reached was that the effects of wind and mean current favored eastward transport near the shore where the former Rayonier mill outfalls are located. The Shea et al. (1981) study documented that the former Rayonier mill effluent was forcefully transported to the east on a flood tide and that most of the material "curled" out of the harbor outside of Ediz Hook during an ebb tide. This eastern transport is consistent with the pattern of deposited material near the outfalls. Figure C.2-9 shows the results of sludge surveys from 1961 and 1965 (Denison 1975). The skewing of the sludge to the east is an indication of the long-term deposition of materials and associated contaminants that have been transported to the east. All of these results suggest that while there is tidal dispersion from the former Rayonier mill shoreline in all directions, the dominant direction of transport is to the east. These same processes will act on material resuspended on nearshore sediment transported offshore during storm events.

In 1972, the deepwater outfall began to discharge treated effluent from the mill through a 1,000-ft-long, 48-port diffuser located to the east of the mill, outside of Port Angeles Harbor. The depth at the diffuser ranges from 16 to 20 m (52.5 to 65.6 ft), which is deeper than the effects of waves. Therefore, any solids in the effluent that would settle to the sediment bed would be primarily transported by local tidal currents. As discussed in EPA (1974), Ebbesmeyer (1979), and Shea (1981), the net transport of the effluent, especially near the diffuser, would be to the east. Battelle (2004) showed that the effluent deposition was diluted by 1,000 and that only the coarse silt fraction deposited within the mouth of the harbor. Material that settles from the plume during normal tidal action would not undergo resuspension during wave events based on the calculations discussed above.

Rayonier



Data source: All outfalls near former Crown Zellerbach taken from Exponent (2008).
Rayonier outfalls and City of Port Angeles outfalls provided by Rayonier.
CSO locations are approximate and were pinpointed using a City of Port Angeles storm drain CAD layer, NOAA electronic charts, and up-to-date, high-resolution imagery.

N

0 0.0225 0.045 0.09 Miles

Figure C.2-9. Extent of observed sludge material

Prepared by MTY, 03/04/13, map#5163a; W:\Projects\Rayonier Port Angeles\Data\GIS\Maps_and_Analysis\Revised_CSM

2.3.5 Log pond morphology

The west cove at the former Rayonier mill log pond (Figure C.2-10) provides a good example of the eastward nearshore transport mechanisms. A feeder berm containing 275 cubic yards (cy) of sand and gravel was placed near the western end of the former log pond; and between 2003 and 2011, approximately 1,000 cy of additional material was added to the berm annually (Snyder 2012). The feeder berm on the western end of the cove has been replenished every year for more than a decade through the intentional placement of imported material (i.e., sand). The sand has been replaced as waves have transported the excess sediment in the nearshore. Over time, this sediment equates to approximately 12,000 cy of sand added to the nearshore providing an excellent tracer for nearshore transport.

Figure C.2-10. Log pond at the former Rayonier mill showing beach accretion east of the feeder berm

Sand from this feeder berm is regularly transported eastward into the cove, which has resulted in the development of a large beach (Figure C.2-10). The beach has been growing steadily since the initial placement of sandy material at the feeder berm. Based on monitoring conducted between 2003 and 2011, data from six of the eight surveyed stations on the shoreline indicate that the beach east of the feeder berm is continually accreting (Snyder 2012).

Bathymetric surveys were conducted in 2000 by Rayonier (Foster Wheeler 2002) and 2010 by the US Geological Survey (USGS) (Cochrane et al. 2008). Starting from a computer-aided design (CAD) file of the bathymetry presented on Page 29 of the Foster Wheeler 2002 Volume II final public sampling and analysis plan for the marine remedial investigation (ca. 1999) (Foster Wheeler 2002), the processing steps were as follows:

- The 2000 data were imported into ArcGIS, transformed to a geographic information system (GIS) polyline layer, and then converted to a point file.
- Next, the vertical datum was converted from North American Vertical Datum (NAVD) of 1929 (NAVD 29) to NAVD 88 (using the VDatum tool, the National Oceanic and Atmospheric Administration's [NOAA's] vertical datum transformation tool).
- The output from VDatum (x, y, and z data) was imported into ArcGIS, and the ArcGIS Spatial Analyst "Topo to Raster" was used to interpolate a point layer to create a new topographic raster for the 2000 dataset.
- The 2000 topographic raster was then compared with the 2010 Lower Elwha Klallum Tribe (LEKT)/USGS topographic raster, using the ArcGIS Spatial Analyst Map Algebra/Raster Calculator. This calculator subtracted the 2010 data from the 2000 data to calculate the differences. They both shared the same vertical datum of NAVD 88 and Washington State Plane North US survey feet projection and North American Datum (NAD) of 1983 (NAD83) horizontal datum.

In addition, multibeam sonar bathymetry collected by Sea Engineering, Inc., in 2014 (Sea Engineering 2014) was compared with the 2010 LEKT/USGS data, which confirmed the results of the 2000/2010 comparison. The 2010 bathymetry was "flatter," with less of a depth difference in the 2010/2014 comparison than in the 2000/2010 comparison. This observation is consistent with the expectation that the rate of infill will slow as the bathymetry approaches a new stable state following the final maintenence dredging conducted circa 1996.

Figure C.2-11 shows the change in elevation between the surveys as erosion or deposition. These surveys illustrate the net effect of a decade after the cessation of log rafting. The survey differences show an accumulation of up to 9 ft on the eastern corner of the log pond. These results are consistent with the CSM of nearshore transport to the east. The nearshore currents reach the jetty, where they are deflected offshore and diminish into deeper water. The longshore sediment transport deposits sediment in this region. Once log rafting ceased, the predominant waves were allowed to reach this region and deliver sediment load. In addition, the estimated depositional volume of 24,680 cy is approximately two times the amount of sediment added to the feeder berm (~12,000 cy), suggesting that the shoreline and creeks to the west are acting as an additional source of sandy sediment to the area.

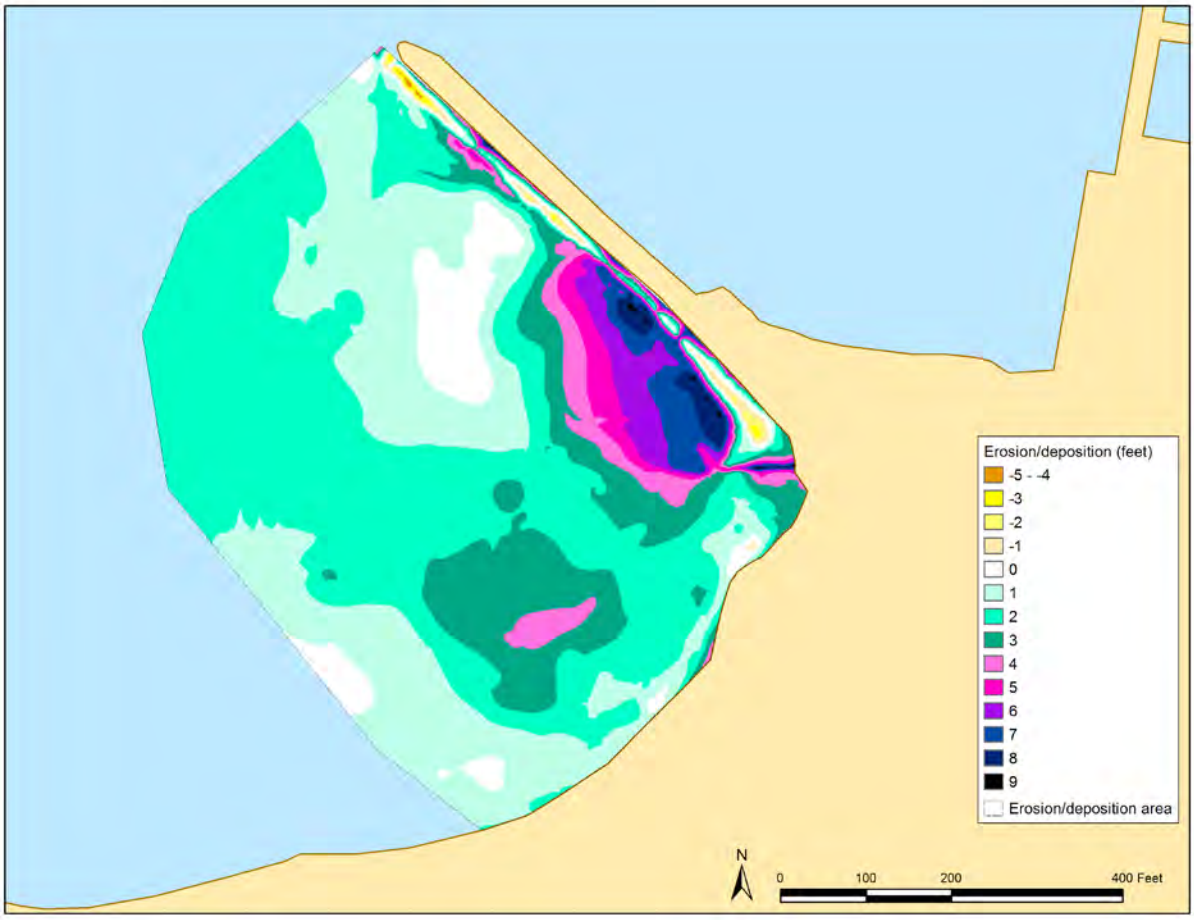


Figure C.2-11. Log pond sediment erosion and deposition pattern

Transport along the southern shoreline is diverted by the log pond jetty and by the mill dock. Water flowing along the shoreline has to move around these features, causing easterly transport to follow a more circuitous pathway. The prevalent pattern (during west and northwest wind events) is as follows. As sediment is transported east, the coarsest material is deposited, or trapped, in the log pond. The fines, which do not settle in the nearshore, move offshore and may be retained in low-energy areas on the lee side. The dredged berths around the mill dock also affect sediment transport because of the greater depth of these features. The greater depths create a lower-energy zone that can "trap" fine sediment. The eastern berth, sheltered by the pier from prevailing westerly wind and waves and is most efficient at accumulating material.

The structures and the resulting transport are responsible for the pattern of contamination observed (i.e., highest contamination is predominantly in the log pond, becoming lower just past the tip of the jetty, rising again in the western berth and second highest east of the eastern berth [Figure C.2-12]).

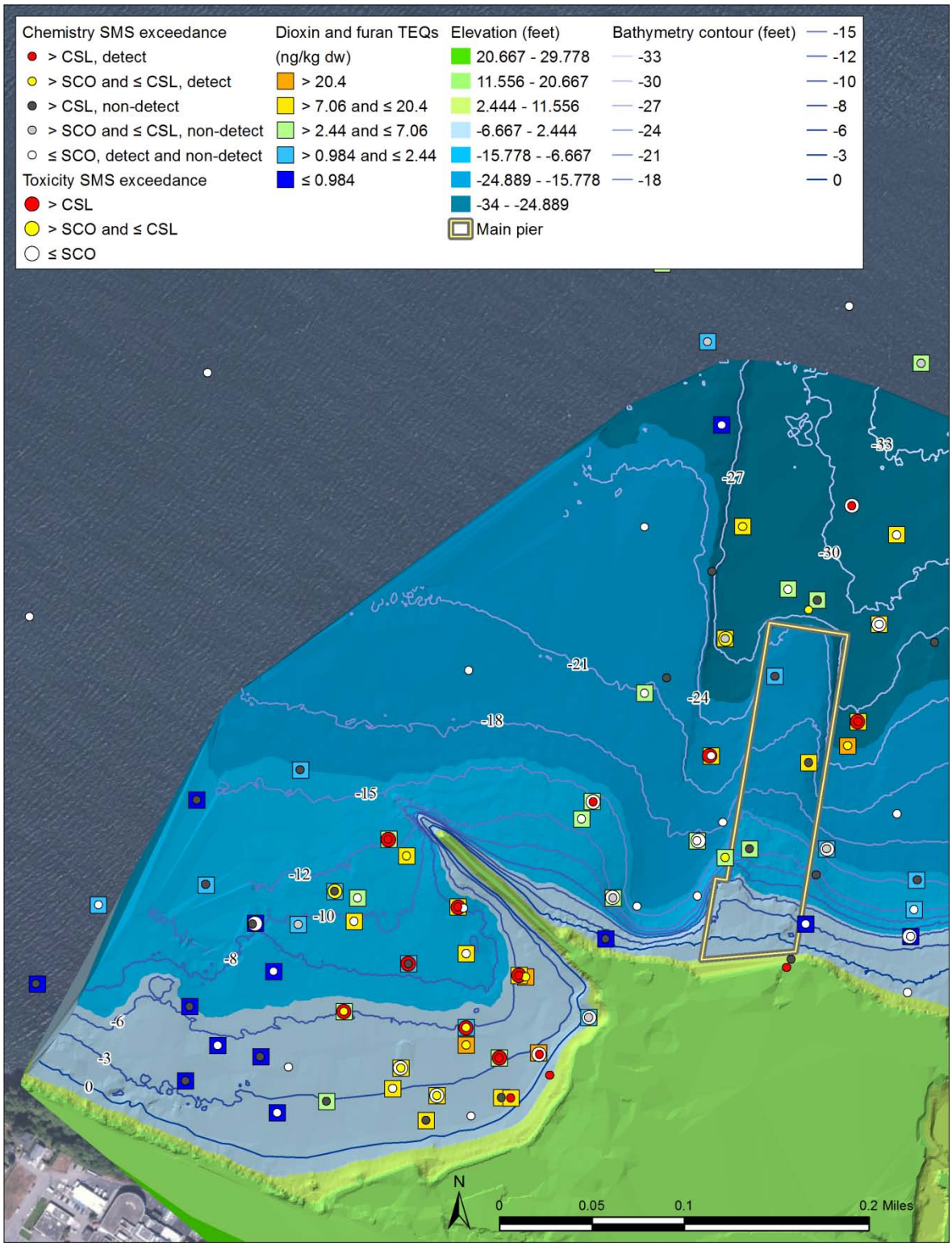


Figure C.2-12. Patterns of dioxin/furan TEQ and SMS exceedances in the mill dock area

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APPENDIX D. DATA MANAGEMENT

APPENDIX D. DATA MANAGEMENT

Table of Contents

Tables

1 Introduction

This appendix presents a summary of the data management rules and practices used to derive the Volume II dataset. A summary of the available data (by station) is presented in Attachment D-1.

2 Laboratory Replicates

Chemical concentrations obtained from the analysis of laboratory duplicates or replicates (two or more analyses performed on the same sample) were not combined with the original sample.

3 Multiple Samples from the Same Location

The surface sediment dataset contains multiple field duplicate pairs. In these instances, both the original and duplicate samples were created from splits of a single field-collected sample. The field duplicate results were not combined with the original sample results.

In cases where split sediment or tissue samples were collected and analyzed by a second party using a separate laboratory, the primary data were used. In some cases, the second party split samples were analyzed for chemicals not included in the primary analyses, in which case the second party data were added to the dataset for those analytes.

The surface sediment data were reviewed to determine if any samples were collected at the same location on different dates.[1] During the Rayonier marine RI sampling event in 2002, 12 locations were resampled approximately 2 weeks after the initial sampling event. The only replicate analyses were for grain size. The grain size data from the first sampling event were excluded from the surface sediment dataset for these 12 locations. In addition, two locations that were sampled as part of the Expanded Site Inspection in 1997 (SD42 and SD43) were resampled (MD-10 and MD-05, respectively) during the Rayonier marine RI sampling event in 2002. The older data from 1997 were excluded for chemicals that had more recent data from 2002. However, some chemicals were only analyzed in 1997 and were therefore retained in the dataset. These chemicals included a subset of metals and VOCs.

[1] A location was considered the same if the distance was ≤ 10 ft between the two sampling locations.

4 Significant Figures and Rounding

The laboratories reported results with different numbers of significant figures depending on the instrument, parameter, and the concentration relative to the RL. The reported (or assessed) precision of each observation was explicitly stored in the project database as a record of the number of significant figures assigned by the laboratory. Tracking of significant figures is important when calculating averages and performing other data summaries.

When a calculation involves addition, such as totaling polychlorinated biphenyls (PCBs) or polycyclic aromatic hydrocarbons (PAHs), the calculation is only as precise as the least precise number in the calculation. For example (assuming two significant figures):

> 210 + 19 = 229 would be reported as 230 because 19 is reported only to 2 significant digits, and the enhanced precision of the trailing zero in the number 210 is not significant. 210 + 19.0 = 229 would also be reported as 230.

When a calculation involves multiplication or division, such as when carbon normalizing is used, all significant figures are carried through the calculation, and then the total result is rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example:

> 59.9 × 1.2 = 71.88 would be reported as 72 because there are two significant figures in the number 1.2.
>
> 59.9 × 1.0 = 59.9 would be reported as 60 because there are two significant figures in 1.0. Note that 59.9 × 1 would also be reported as 60, although in that case, the 0 would not be considered significant.

When rounding, if the number following the last significant figure is less than 5, the digit is left unchanged. If the number following the last significant figure is equal to or greater than 5, the digit is increased by 1.

5 Multiple Results for the Same Analyte

Multiple analyses of a sample for a group of analytes can occur as a result of laboratory quality assurance (QA) issues that may only affect a subset of the analyte group. In these cases, there may be multiple results for certain analytes for the same analytical method. In addition, multiple results may also occur when a single analyte is reported by more than one analytical method. The best result was selected using best professional, technical judgment. The following rules were followed to select a single value when multiple results were reported for a single analyte.

- If all results were detected without qualification as an estimated value (i.e., without J- or E-qualifier), then the result from the lowest analytical dilution was selected. If multiple, unqualified results from the same analytical dilution were

available, the highest concentration was selected as a health-protective approach.

- If a mixture of estimated (i.e., J-qualified) and unqualified detected results were reported, then the unqualified detected result was selected.
- If all results were reported as detected with estimated qualification, the analytical methods used were evaluated, and the data associated with the most sensitive and accurate method were selected.
- If both undetected and detected results were reported, then the detected result was selected.
- If all results were reported as undetected, then the lowest RL was selected.

6 Interpreting EMPC Laboratory Qualifiers

When PCB congener or dioxin/furan results were qualified by a laboratory with an estimated maximum possible concentration (EMPC) qualifier, the result was interpreted as a non-detected result at the concentration reported. Therefore, when EMPC-qualified results were used to calculate TEQ values, they were treated as non-detected results.

7 Calculating Totals

Concentrations for several chemical sums were calculated as follows:

- **Total PCBs** based on Aroclors were calculated using only detected concentrations for seven Aroclor mixtures (1016, 1221, 1232, 1242, 1248, 1254, and 1260)[2] in accordance with Washington State Sediment Management Standards (SMS) (Washington Administrative Code [WAC] 173-204). For individual samples in which none of the seven Aroclor mixtures was detected, total PCBs were given a value equal to the highest RL of the seven Aroclors.
- **Total PCBs** based on congeners were calculated only if congener data were available for all 209 PCB congeners. The total PCB concentration was calculated using only the detected concentrations of congeners. For individual samples in which none of the 209 congeners was detected, total PCBs were given a value equal to the highest RL of the congeners.
- **Toxic equivalents (TEQs)** were used for totaling certain groups of chemicals, specifically dioxin/furan TEQ, PCB TEQ, and carcinogenic PAH (cPAH) TEQ. These totals are discussed in Sections 8 and 9.

[2] For several sediment samples, Aroclors 1262 and 1268 were also included in the total PCB calculation, although these Aroclors are rarely identified and quantified.

- **Total DDTs** were calculated from detected concentrations of three to six isomers: 2,4′-dichlorodiphenyldichloroethane (DDD), 2,4′-dichlorodiphenyldichloroethylene (DDE), 2,4′-DDT, 4,4′-DDD, 4,4′-DDE, and 4,4′-DDT. For samples in which all individual isomers were undetected, the single highest RL for that sample was assigned to represent the sum of the three to six isomers.
- **Total chlordane** was calculated using only detected values for the following compounds: alpha-chlordane, beta-/gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor. For individual samples in which none of these compounds was detected, total chlordane was given a value equal to the highest RL of the five compounds listed above and assigned a U-qualifier, indicating the lack of detected concentrations.

8 Calculation of PCB Congener TEQs

PCB congener TEQs were calculated using the World Health Organization (WHO) consensus toxic equivalency factor (TEF) values for mammals (Van den Berg et al. 2006) as presented in Table D.8-1. The TEQ was calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration was reported as non-detected, then the TEF was multiplied by half the RL.

Table D.8-1. PCB congener TEF values for mammals

PCB Congener Number	TEF Value (unitless)
77	0.0001
81	0.0003
105	0.00003
114	0.00003
118	0.00003
123	0.00003
126	0.1
156	0.00003
157	0.00003
167	0.00003
169	0.03
189	0.00003

PCB – polychlorinated biphenyl
TEF – toxic equivalency factor

9 Calculation of Dioxin/Furan Congener TEQs

Dioxin/furan congener TEQs were calculated using the WHO consensus TEF values (Van den Berg et al. 2006) for mammals as presented in Table D.9-1. The TEQ was calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration was reported as undetected, the TEF was multiplied by half the RL.

Table D.9-1. Dioxin/furan congener TEF values for mammals

Dioxin/Furan Congener	TEF Value (unitless)
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	0.1
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8-Pentachlorodibenzofuran	0.03
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin	1
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1
2,3,4,7,8-Pentachlorodibenzofuran	0.3
2,3,7,8-Tetrachlorodibenzofuran	0.1
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin	1
Octachlorodibenzofuran	0.0003
Octachlorodibenzo-*p*-dioxin	0.0003

TEF – toxic equivalency factor

10 Calculation of cPAH TEQs

cPAH TEQs were calculated using the potency equivalency factor (PEF) procedure presented in Washington State's Model Toxics Control Act (WAC 173-340-708[e]). The PEF relates the toxicity of each of the cPAHs to benzo(a)pyrene (Table D.10-1). The TEQ was calculated as the sum of each cPAH concentration multiplied by the corresponding PEF. When the cPAH concentration was reported as non-detected, the PEF was multiplied by half the RL.

Table D.10-1. Potency equivalency factors for cPAHs

cPAH	PEF (unitless)
Benzo[a]pyrene	1
Benz[a]anthracene	0.1
Benzo[b]fluoranthene	0.1
Benzo[k]fluoranthene	0.1
Chrysene	0.01
Dibenz[a,h]anthracene	0.1
Indeno[1,2,3-cd]pyrene	0.1

cPAH – carcinogenic polycyclic aromatic hydrocarbon
PEF – potency equivalency factor

11 Non-Urban Puget Sound Dataset

As part of the Feasibility Study (FS) for the Lower Duwamish Waterway (LDW) (AECOM 2012), a non-urban Puget Sound dataset was compiled using available data from Puget Sound that was not collected near an urban area or a known source. This dataset contains data for four of the key COPCs dicussed in Section 3.2 (arsenic, cPAH TEQ, dioxin/furan TEQ, and total PCBs).

11.1 DATA RULES

This section provides a summary of any important data rule differences between the Rayonier project data rules and the data rules used to compile the non-urban Puget Sound dataset.

- **PEFs for cPAH TEQs –** The PEFs used to calculate the cPAH TEQs for the non-urban dataset were slightly different from those in the Rayonier project data rules (see Table D.10-1). A PEF of 0.4 was used for dibenz(a,h)anthracene in the non-urban Puget Sound dataset, as compared with a PEF of 0.1 for the Rayonier database.
- **Reporting limit (RL) vs. detection limit (DL) for cPAH TEQs –** Data reported in Ecology's Environmental Information Management (EIM) database (the main source of the non-urban Puget Sound database) defaulted to the use of the DL for non-detected results, and thus the cPAH TEQ for the non-urban dataset was calculated using the DL for non-detected components. The Rayonier project data rule was to use the RL for non-detects, leading to the calculation of different TEQs for the same samples.
- **Calcuation of whole body crab concentrations –** Concentrations in the non-urban Puget Sound database were calculated from edible meat and hepatopancreas concentrations using weighting factors of 0.69 and 0.31, respectively, based on crab tissue data collected from the Lower Duwamish

Waterway in Seattle, Washington. In the Rayonier database, weighting factors of 0.75 and 0.25 were used for the edible meat and hepatopancreas fractions, respectively. Concentrations are generally higher in hepatopancreas samples, meaning that concentrations calculated for the non-urban Puget Sound dataset would be slightly lower if the Rayonier database weighting factors were used because crab hepatopancreas would account for 6% less of the total value.

11.2 CORRECTION OF EIM DATABASE ERROR

The non-urban Puget Sound dataset was presented as-is from the LDW FS, with one exception. The dioxin/furan data for three samples from an Ecology 2008 sampling event were mis-reported in the EIM database at the time when the LDW FS dataset was compiled. The corrected values are presented in Table D.11-1.

Table D.11-1. Potency equivalency factors for cPAHs

Species	Sample ID	Dioxin/Furan TEQ (ng/kg ww)		Ecology Reference for Corrected Value
		Original Value	Corrected Value	
Geoduck	RF06TG	1.42	0.085	Ecology (2012), Table C-T1
Horse clam	RF04TH	1.57	0.079	Ecology (2012), Table C-T2
Horse clam	RF05TH	1.42	0.000287	Ecology (2012), Table C-T2

cPAH – carcinogenic polycyclic aromatic hydrocarbon
ID – identification
TEQ – toxic equivalent
ww – wet weight

The non-urban Puget Sound dataset was corrected to incorporate the values presented in Table D.11-1. As discussed with Ecology, no other changes were made to this dataset.

12 References

AECOM. 2012. Final feasibility study, Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. AECOM, Seattle, WA.

Ecology. 2012. Port Angeles Harbor sediment characterization study, Port Angeles, Washington: sediment investigation report. Washington State Department of Ecology, Lacey, WA.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol Sci 93(2):223-241.

ATTACHMENT D-1. DATA SUMMARY

Locations, COPCs analyzed and SMS exceedances

Sampling Event	Medium	Area	Location Name	In Study Area	COPCs Analyzed																					SMS Exceedances	
					Arsenic	Arsenic (Inorganic)	Cadmium	Cobalt	Copper	Iron	Total Mercury	Selenium	Silver	Vanadium	Zinc	PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	Carcinogenic PAHs	DDE	DDT	alpha-BHC	beta-BHC	gamma-BHC (Lindane)	Hexachlorobenzene	Pentachlorophenol	Exceeds SCO but less than CSL	Exceeds CSL
LDWRI-BI	Softshell clam (whole body)	Dungeness Bay	DU-C1	N	X																					na	na
LDWRI-BI	Softshell clam (whole body)	Dungeness Bay	DU-C123	N	X																					na	na
LDWRI-BI	Softshell clam (whole body)	Dungeness Bay	DU-C2	N	X																					na	na
LDWRI-BI	Softshell clam (whole body)	Dungeness Bay	DU-C3	N	X																					na	na
LDWRI-BI	Softshell clam (whole body)	Dungeness Bay	DU-C4	N	X																					na	na
PA Harbor Ecology 08	Surface Sediment	Dungeness Bay	RF01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Dungeness Bay	RF02A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Dungeness Bay	RF03A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Out of Area	EC01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Out of area	EC02A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BA01A	N	X		X		X		X		X		X												0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BA02A	N	X		X		X		X		X		X												0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL02A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL03A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL04A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL05A	N	X		X		X		X		X		X	X											0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL06A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL07A	N							X					X											0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	BL08A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	CO01A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	CO02A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	CO03A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	CO04A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	CO05A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	DO01A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	DO02A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	DO03A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	DO04A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	DO05A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EC03A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EC04A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EC05A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	ED01A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	ED02A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	ED03A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	ED04A	Y	X		X		X		X		X		X	X		X	X						X	X	0	1
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	ED05A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EE01A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EE02A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EE03A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EE04A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EE05A	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EH01A	N	X		X		X		X		X		X												0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EH02A	N	X		X		X		X		X		X												0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EH03A	N	X		X		X		X		X		X												0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EH04A	N	X		X		X		X		X		X												0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EI01A	Y	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EI02A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EI03A	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EI04A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EI06A	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	EI07A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FP01A	N	X		X		X		X		X		X	X				X	X	X	X	X			0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FP02A	N	X		X		X		X		X		X	X				X	X	X	X	X			0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FP03A	N	X		X		X		X		X		X	X				X	X	X	X	X			0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT02A	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT04A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT05A	N	X		X		X				X		X				X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT06A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT10A	N	X		X		X				X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT11A	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT12A	N							X							X									0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	FT13A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE03A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE04A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE05A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE06A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE07A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE08A	N							X																0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE09A	N	X		X		X		X		X		X	X		X	X						X	X	1	1
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE10A	N							X																0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE11A	N	X		X		X		X		X		X	X											0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE12A	N	X		X		X		X		X		X	X		X									0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE13A	N	X		X		X		X		X		X	X			X						X	X	1	1
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE14A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE15A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IE16A	N	X		X		X		X		X		X	X			X						X	X	0	1
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IH01A	N	X		X		X		X		X		X	X		X	X						X	X	0	3
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IH02A	N	X		X		X		X		X		X	X		X	X						X	X	2	1
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IH03A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IH04A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IH05A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	IH06A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP02A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP03A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP04A	N	X		X		X		X		X		X			X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP05A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0

Locations, COPCs analyzed and SMS exceedances

Sampling Event	Medium	Area	Location Name	In Study Area	COPCs Analyzed																					SMS Exceedances	
					Arsenic	Arsenic (Inorganic)	Cadmium	Cobalt	Copper	Iron	Total Mercury	Selenium	Silver	Vanadium	Zinc	PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	Carcinogenic PAHs	DDE	DDT	alpha-BHC	beta-BHC	gamma-BHC (Lindane)	Hexachlorobenzene	Pentachlorophenol	Exceeds SCO but less than CSL	Exceeds CSL
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP06A	N							X															0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP07A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	KP08A	N	X		X		X		X		X		X	X			X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LA01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	2	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LA02A	N							X							X	X						X	X	1	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LA03A	N							X							X	X						X	X	2	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LP01A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LP03A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LP04A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	LP05A	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MA01A	N	X		X		X		X		X		X	X		X	X						X	X	1	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MA02A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MA03A	N	X		X		X		X		X		X	X		X	X						X	X	1	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MA04A	N	X		X		X		X		X		X	X		X	X						X	X	2	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MA05A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MA06A	N							X																0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MD01A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MD02A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MD03A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MD04A	Y	X		X		X		X		X		X	X		X	X						X	X	1	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	MD05A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	OH01A-R	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	OH02A	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	OH03A	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	RL01A	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	RL02A	N							X																0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	RL03A	N							X																0	0
PA Harbor Ecology 08	Surface Sediment	Port Angeles Harbor	WW01A	Y							X							X									0	0
PA Harbor Ecology 08	Subsurface Sediment (10 - 25 cm)	Port Angeles Harbor	MD05	Y												X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (122 - 152 cm)	Port Angeles Harbor	IE01	N	X		X		X		X		X		X				X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (122 - 152 cm)	Port Angeles Harbor	KP08	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (122 - 152 cm)	Port Angeles Harbor	MD02	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (122 - 152 cm)	Port Angeles Harbor	MD03	Y												X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (137 - 168 cm)	Port Angeles Harbor	KP02	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	CO02	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	DO04	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	DO05	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	EC03	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	5	1
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	EE01	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	EE03	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	EE04	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	EI02	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	FT12	N	X		X		X		X		X		X				X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	LP05	Y															X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	MA02	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 30 cm)	Port Angeles Harbor	MD01	Y												X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 46 cm)	Port Angeles Harbor	ED03	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (15 - 46 cm)	Port Angeles Harbor	MD04	Y												X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (152 - 198 cm)	Port Angeles Harbor	BL02	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (157 - 188 cm)	Port Angeles Harbor	IE14	N	X		X		X		X		X		X				X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (178 - 208 cm)	Port Angeles Harbor	IH02	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (183 - 213 cm)	Port Angeles Harbor	ED01	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (198 - 229 cm)	Port Angeles Harbor	KP03	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (249 - 254 cm)	Port Angeles Harbor	IH06	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (249 - 279 cm)	Port Angeles Harbor	IE05	N	X		X		X		X		X		X				X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (25 - 56 cm)	Port Angeles Harbor	MD05	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (272 - 302 cm)	Port Angeles Harbor	IE12	N	X		X		X		X		X		X				X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 41 cm)	Port Angeles Harbor	DO05	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	BL08	N	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	CO04	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	DO04	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	EC03	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	2	6
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	EC04	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	ED02	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	ED05	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	EE02	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	EE03	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	EE04	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	FT04	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	FT06	N	X		X		X		X		X		X	X			X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	IE05	N	X		X		X		X		X		X	X		X	X						X	X	0	1
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	IE12	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	IE14	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	IE16	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	IH02	N	X		X		X		X		X		X	X		X	X						X	X	0	3
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	IH06	N	X		X		X		X		X		X	X		X	X						X	X	2	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	KP02	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	KP07	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	MA02	N	X		X		X		X		X		X	X		X	X						X	X	1	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	MD01	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (30 - 61 cm)	Port Angeles Harbor	MD02	Y												X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 81 cm)	Port Angeles Harbor	DO04	Y	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 91 cm)	Port Angeles Harbor	CO03	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 91 cm)	Port Angeles Harbor	CO05	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 91 cm)	Port Angeles Harbor	ED01	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 91 cm)	Port Angeles Harbor	EE02	Y	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 91 cm)	Port Angeles Harbor	KP03	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (61 - 91 cm)	Port Angeles Harbor	LA02	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (76 - 107 cm)	Port Angeles Harbor	IE01	N	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (84 - 114 cm)	Port Angeles Harbor	ED03	Y	X		X		X		X		X		X	X		X	X						X	X	0	0

Locations, COPCs analyzed and SMS exceedances

Sampling Event	Medium	Area	Location Name	In Study Area	COPCs Analyzed																					SMS Exceedances	
					Arsenic	Arsenic (Inorganic)	Cadmium	Cobalt	Copper	Iron	Total Mercury	Selenium	Silver	Vanadium	Zinc	PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	Carcinogenic PAHs	DDE	DDT	alpha-BHC	beta-BHC	gamma-BHC (Lindane)	Hexachlorobenzene	Pentachlorophenol	Exceeds SCO but less than CSL	Exceeds CSL
PA Harbor Ecology 08	Subsurface Sediment (89 - 119 cm)	Port Angeles Harbor	MD03	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	BL02	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	BL08	N	X		X		X		X		X		X			X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	ED02	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	ED04	Y	X		X		X		X		X		X	X		X	X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	FT04	N	X		X		X		X		X		X	X			X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	FT06	N	X		X		X		X		X		X	X			X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	FT12	N	X		X		X		X		X		X				X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	IE09	N	X		X		X		X		X		X	X		X	X						X	X	1	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	IE16	N	X		X		X		X		X		X				X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	KP07	N	X		X		X		X		X		X				X						X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	KP08	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Subsurface Sediment (91 - 122 cm)	Port Angeles Harbor	LA02	N	X		X		X		X		X		X	X		X	X	X	X	X	X	X	X	X	0	0
PA Harbor Ecology 08	Bull kelp (Leaves)	Port Angeles Harbor	IE25TM	N	X		X		X		X		X		X	X	X	X	X						X	X	na	na
PA Harbor Ecology 08	Geoduck (Whole organism)	Dungeness Bay	RF06TG	N	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Geoduck (Whole organism)	Port Angeles Harbor	MD08TG	Y	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Dungeness Bay	RF04TH	N	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Dungeness Bay	RF05TH	N	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	EC06TH	Y	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	EI08TH	Y	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	IE18TH	N	X		X		X		X		X		X		X	X	X						X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	IE20TH	N	X		X		X		X		X		X		X	X	X						X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	MD06TH	Y	X		X		X		X		X		X		X	X	X						X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	MD07TH	Y	X		X		X		X		X		X		X	X	X						X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	MD08TH	Y	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Horse clam (Whole organism)	Port Angeles Harbor	MD09TH	Y	X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X	na	na
PA Harbor Ecology 08	Lingcod (Fillet with skin)	Port Angeles Harbor	IE22TL	N	X		X		X		X		X		X	X	X	X	X						X	X	na	na
PA Harbor Ecology 08	Lingcod (Fillet with skin)	Port Angeles Harbor	IE23TL	N	X		X		X		X		X		X	X	X	X	X						X	X	na	na
PA Harbor Ecology 08	Lingcod (Whole organism)	Port Angeles Harbor	IE21TL	N	X		X		X		X		X		X	X	X	X	X						X	X	na	na
PA Harbor Ecology 08	Lingcod (Whole organism)	Port Angeles Harbor	IE24TL	N	X		X		X		X		X		X	X	X	X	X						X	X	na	na
PA Harbor Ecology 08	Seagrass (Leaves)	Port Angeles Harbor	IE26TM	N	X		X		X		X		X		X	X	X	X	X						X	X	na	na
Rayonier EPA ESI 97	Surface Sediment	Dungeness Bay	SD84	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Dungeness Bay	SD85	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Dungeness Bay	SD86	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC01	N	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC02	N	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC03	Y	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC04	Y	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC05	N	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC06	N	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC07	N	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Out of Area	EC08	N	X		X	X	X	X			X	X	X								X				0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD01	N	X		X	X	X	X	X	X	X	X	X	X			X								2	1
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD02	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD03	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD04	N	X		X	X	X	X	X	X	X	X	X	X			X								2	1
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD05	N	X		X	X	X	X	X	X	X	X	X	X			X								1	1
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD06	N	X		X	X	X	X	X	X	X	X	X	X			X								2	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD07	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD09	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD10	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD11	N	X		X	X	X	X	X	X	X	X	X	X			X								1	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD12	N	X		X	X	X	X	X	X	X	X	X	X			X								0	1
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD13	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD14	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD15	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD16	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD17	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD18	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD19	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD20	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD21	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD22	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD23	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD24	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD25	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD26	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD28	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD29	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD30	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD32	Y	X		X	X	X	X	X	X	X	X	X												0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD33	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD34	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD35	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD36	Y	X		X	X	X	X	X	X	X	X	X	X			X								5	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD37	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD38	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD39	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD40	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD41	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD42	Y				X		X			X	X													0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD43	Y				X		X			X	X													0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD44	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD45	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD46	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD47	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD48	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD50	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD54	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD55	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0

Locations, COPCs analyzed and SMS exceedances

Sampling Event	Medium	Area	Location Name	In Study Area	COPCs Analyzed																						SMS Exceedances	
					Arsenic	Arsenic (Inorganic)	Cadmium	Cobalt	Copper	Iron	Total Mercury	Selenium	Silver	Vanadium	Zinc	PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	Carcinogenic PAHs	DDE	DDT	alpha-BHC	beta-BHC	gamma-BHC (Lindane)	Hexachlorobenzene	Pentachlorophenol	Exceeds SCO but less than CSL	Exceeds CSL
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD56	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD57	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD58	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD59	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	1
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD60	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD61	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD62	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD63	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD64	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD65	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD66	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD67	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD68	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD69	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD70	N	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD71	N												X											0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD72	N	X		X	X	X	X	X	X	X	X	X				X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD80	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD81	Y	X		X	X	X	X	X	X	X	X	X	X			X								2	1
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD82	Y	X		X	X	X	X	X	X	X	X	X	X			X								1	8
Rayonier EPA ESI 97	Surface Sediment	Port Angeles Harbor	SD83	Y	X		X	X	X	X	X	X	X	X	X	X			X								0	0
Rayonier EPA ESI Tissue 1998	Geoduck (Whole organism)	Dungeness Bay	98RMGD00	N	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	na	na
Rayonier EPA ESI Tissue 1998	Geoduck (Whole organism)	Port Angeles Harbor	98RMGD01	Y	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	na	na
Rayonier EPA ESI Tissue 1998	Geoduck (Whole organism)	Port Angeles Harbor	98RMGD02	Y	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	na	na
Rayonier EPA ESI Tissue 1998	Red rock crab (Muscle tissue)	Dungeness Bay	98RMCB00	N	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	na	na
Rayonier EPA ESI Tissue 1998	Red rock crab (Muscle tissue)	Port Angeles Harbor	98RMCB01	Y	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	na	na
Rayonier EPA ESI Tissue 1998	Red rock crab (Muscle tissue)	Port Angeles Harbor	98RMCB02	Y							X					X		X	X	X	X	X	X	X	X	X	na	na
RayPA 2002 LEKT Sed	Surface Sediment	Port Angeles Harbor	MD-10	Y														X									0	0
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-L1	N	X		X		X		X				X	X		X	X								2	1
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-L2	N	X		X		X		X				X	X		X	X								0	0
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-L3	N	X		X		X		X				X	X		X	X								0	0
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA1	N	X		X		X		X				X	X		X	X								1	0
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA10	N	X		X		X		X				X	X		X	X								0	1
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA2	N	X		X		X		X				X	X		X	X								1	0
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA3	N	X		X		X		X				X	X		X	X								0	3
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA4	N	X		X		X		X				X	X		X	X								0	3
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA5	N	X		X		X		X				X	X		X	X								0	0
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA6	N	X		X		X		X				X	X		X	X								0	1
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA8	N	X		X		X		X				X	X		X	X								0	1
RayPA DNR 2008	Surface Sediment	Port Angeles Harbor	NPI-PA9	N	X		X		X		X				X	X		X	X								0	1
RayPA DNR 2008	Subsurface Sediment (104 - 132 cm)	Port Angeles Harbor	NPI-PA9	N	X		X		X		X				X	X		X	X								0	0
RayPA DNR 2008	Subsurface Sediment (30 - 74 cm)	Port Angeles Harbor	NPI-PA4	N											X	X											0	1
RayPA DNR 2008	Subsurface Sediment (74 - 102 cm)	Port Angeles Harbor	NPI-PA2	N	X		X		X		X				X	X		X	X								0	0
RayPA DNR 2008	Subsurface Sediment (89 - 117 cm)	Port Angeles Harbor	NPI-PA1	N	X		X		X		X				X	X		X	X								0	0
RayPA DNR 2008	Subsurface Sediment (94 - 124 cm)	Port Angeles Harbor	NPI-L2	N	X		X		X		X				X	X		X	X								1	2
RayPA NipponPaper 00	Surface Sediment	Port Angeles Harbor	NPI-SS-01	N	X		X		X		X				X												0	0
RayPA NipponPaper 00	Surface Sediment	Port Angeles Harbor	NPI-SS-02	N	X		X		X		X				X												0	0
RayPA NipponPaper 00	Surface Sediment	Port Angeles Harbor	NPI-SS-03	N	X		X		X		X				X												0	0
RayPA NipponPaper 00	Surface Sediment	Port Angeles Harbor	NPI-SS-04	N	X		X		X		X				X												0	0
RayPA RI 2002 Cores	Subsurface Sediment (0 - 27 cm)	Port Angeles Harbor	LP-13	Y	X		X					X			X	X		X									0	0
RayPA RI 2002 Cores	Subsurface Sediment (0 - 40 cm)	Port Angeles Harbor	LP-18	Y	X		X					X			X	X		X									1	0
RayPA RI 2002 Cores	Subsurface Sediment (27 - 61 cm)	Port Angeles Harbor	LP-13	Y	X		X					X			X	X		X									0	0
RayPA RI 2002 Cores	Subsurface Sediment (40 - 46 cm)	Port Angeles Harbor	LP-18	Y	X		X					X			X	X		X									0	0
RayPA RI 2002 Cores	Subsurface Sediment (56 - 91 cm)	Port Angeles Harbor	LP-20	Y	X		X					X			X	X		X									0	0
RayPA RI 2002 Cores	Subsurface Sediment (6 - 76 cm)	Port Angeles Harbor	LP-09	Y	X		X					X			X	X		X									1	0
RayPA RI 2002 Cores	Subsurface Sediment (9 - 46 cm)	Port Angeles Harbor	LP-12	Y	X		X					X			X	X		X									0	0
RayPA RI 2002 Cores	Subsurface Sediment (9 - 46 cm)	Port Angeles Harbor	LP-13	Y	X		X					X			X	X		X									1	0
RayPA RI 2002 Cores	Subsurface Sediment (9 - 56 cm)	Port Angeles Harbor	LP-20	Y	X		X					X			X	X		X									1	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-01	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-02	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-03	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-04	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-05	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-06	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-07	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	HS-08	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	IT-04	Y	X		X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	IT-05	Y	X		X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	IT-06	Y	X		X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	IT-07	Y	X		X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	1	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	IT-08	Y	X		X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-01	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-02	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-03	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	1	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-04	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-04b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-05	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	1	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-06	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	2	3
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-06b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-07	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-07b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-08	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-09	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	1	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-10	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	2	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-11	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-11b	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-12	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-13	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	1	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-14	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-14b	Y														X									0	0

Locations, COPCs analyzed and SMS exceedances

Sampling Event	Medium	Area	Location Name	In Study Area	COPCs Analyzed																						SMS Exceedances	
					Arsenic	Arsenic (Inorganic)	Cadmium	Cobalt	Copper	Iron	Total Mercury	Selenium	Silver	Vanadium	Zinc	PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	Carcinogenic PAHs	DDE	DDT	alpha-BHC	beta-BHC	gamma-BHC (Lindane)	Hexachlorobenzene	Pentachlorophenol	Exceeds SCO but less than CSL	Exceeds CSL
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-15	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-16	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	1	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-17	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-18	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	0	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-18b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-19	Y	X	X	X		X		X	X	X		X	X			X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-19b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	LP-20	Y	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-01	Y	X		X		X		X	X			X				X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-02	Y	X		X		X		X	X			X				X	X	X	X	X	X		X	0	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-02b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-03	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-03b	Y														X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-04	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	1	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-05	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-06	Y	X		X		X		X	X			X				X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-07	Y	X		X		X		X	X			X				X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-08	Y	X		X		X		X	X			X			X	X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-09	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-10	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-11	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-12	Y	X		X		X		X	X			X				X	X	X	X	X	X		X	0	1
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-13	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-14	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-15	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-16	Y	X		X		X		X	X			X	X		X	X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-17	Y	X		X		X		X	X	X		X	X		X	X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	MD-18	Y	X		X		X		X	X			X	X		X	X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-01	Y												X			X								X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-02	Y												X			X								X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-03	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-04	Y	X		X		X		X	X			X	X			X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-05	Y	X		X		X		X	X			X	X		X	X	X	X	X	X	X		X	0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-06	Y												X		X									0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-07	Y												X											0	0
RayPA RI 2002 Sed	Surface Sediment	Port Angeles Harbor	OF-08	Y												X											0	0
RayPA RI 2002 Sed	Surface Sediment	Sequim Bay	SB-01-SS	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Sequim Bay	SB-02-SS	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Sed	Surface Sediment	Sequim Bay	SB-03-SS	N	X	X	X		X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	0	0
RayPA RI 2002 Tiss	Coonstripe shrimp (Whole organism)	Dungeness Bay	DBCS	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Coonstripe shrimp (Whole organism)	Port Angeles Harbor	PACS	Y	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Dungeness crab (Hepatopancreas)	Dungeness Bay	DBDC	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Dungeness crab (Hepatopancreas)	Freshwater Bay	FBDC	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Dungeness crab (Hepatopancreas)	Port Angeles Harbor	PADC	Y	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Dungeness crab (Muscle)	Dungeness Bay	DBDC	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Dungeness crab (Muscle)	Freshwater Bay	FBDC	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Dungeness crab (Muscle)	Port Angeles Harbor	PADC	Y	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Geoduck (Whole organism)	Dungeness Bay	DBGD	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Geoduck (Whole organism)	Freshwater Bay	FBGD	N	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Geoduck (Whole organism)	Port Angeles Harbor	PAGD	Y	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Horse clam (Whole organism)	Dungeness Bay	DBHC	N	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Horse clam (Whole organism)	Freshwater Bay	FBHC	N	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Horse clam (Whole organism)	Port Angeles Harbor	EBHC	Y	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Horse clam (Whole organism)	Port Angeles Harbor	LPHC	Y	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Horse clam (Whole organism)	Port Angeles Harbor	MDHC	Y	X	X	X		X		X	X			X	X			X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Rock sole (Fillet)	Freshwater Bay	FBRS	N	X	X	X		X		X	X			X			X									na	na
RayPA RI 2002 Tiss	Rock sole (Fillet)	Port Angeles Harbor	PARS	Y	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Rock sole (Whole organism)	Dungeness Bay	DBRS	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Rock sole (Whole organism)	Freshwater Bay	FBRS	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Rock sole (Whole organism)	Port Angeles Harbor	PARS	Y	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI 2002 Tiss	Starry flounder (Fillet)	Dungeness Bay	DBSF	N	X	X	X		X		X	X			X	X		X	X	X	X	X	X	X		X	na	na
RayPA RI02 Tiss AP	Dungeness crab (Hepatopancreas)	Port Angeles Harbor	PADC	Y														X									na	na
RayPA RI02 Tiss AP	Dungeness crab (Muscle)	Port Angeles Harbor	PADC	Y														X									na	na
RayPA RI02 Tiss AP	Geoduck (Whole organism)	Freshwater Bay	FBGD	N														X									na	na
RayPA RI02 Tiss AP	Geoduck (Whole organism)	Port Angeles Harbor	PAGD	Y														X									na	na
RayPA RI02 Tiss AP	Horse clam (Whole organism)	Dungeness Bay	DBHC	N														X									na	na
RayPA RI02 Tiss AP	Horse clam (Whole organism)	Freshwater Bay	FBHC	N														X									na	na
RayPA RI02 Tiss AP	Horse clam (Whole organism)	Port Angeles Harbor	EBHC	Y														X									na	na
RayPA RI02 Tiss AP	Horse clam (Whole organism)	Port Angeles Harbor	LPHC	Y														X									na	na
RayPA RI02 Tiss AP	Horse clam (Whole organism)	Port Angeles Harbor	MDHC	Y														X									na	na
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-01-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-02-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-03-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-04-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-05-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-06-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-07-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-08-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-09-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-10-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Dungeness Bay	DB-11-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-02-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-03-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-04-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-05-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-06-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-07-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-08-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-09-2006	N													X	X									0	0
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-10-2006	N													X	X									0	0

Locations, COPCs analyzed and SMS exceedances

Sampling Event	Medium	Area	Location Name	In Study Area	COPCs Analyzed																					SMS Exceedances	
					Arsenic	Arsenic (Inorganic)	Cadmium	Cobalt	Copper	Iron	Total Mercury	Selenium	Silver	Vanadium	Zinc	PCB Aroclors	PCB Congeners	Dioxin/Furan Congeners	Carcinogenic PAHs	DDE	DDT	alpha-BHC	beta-BHC	gamma-BHC (Lindane)	Hexachlorobenzene	Pentachlorophenol	Exceeds SCO but less than CSL	Exceeds CSL
RayPA RI2 2006 Sed	Surface Sediment	Freshwater Bay	FB-11-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-01-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-02-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-03-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-04-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-05-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-06-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-07-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-08-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-09-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-10-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	EP-11-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-01-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-02-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-03-2006	Y													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-04-2006	Y													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-05-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-06-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-07-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	LP-08-2006	Y													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-03-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-04-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-05-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-06-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-07-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-08-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-09-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-10-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-11-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-12-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-13-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-14-2006	Y													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-15-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-16-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-17-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-18-2006	Y													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-21-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-22-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-23-2006	Y													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	MD-24-2006	Y													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-01-2006	N													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-02-2006	N													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-03-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-04-2006	N													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-05-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-06-2006	N													X	X								1	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-07-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-08-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-09-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-10-2006	N													X	X								0	0
RayPA RI2 2006 Sed	Surface Sediment	Port Angeles Harbor	WP-11-2006	N													X	X								0	1
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Dungeness Bay	DB-01-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Dungeness Bay	DB-02-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Dungeness Bay	DB-03-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Dungeness Bay	DB-04-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Freshwater Bay	FB-01-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Port Angeles Harbor	MD-01-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Port Angeles Harbor	MD-02-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Hepatopancreas)	Port Angeles Harbor	MD-04-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Dungeness Bay	DB-01-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Dungeness Bay	DB-02-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Dungeness Bay	DB-03-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Dungeness Bay	DB-04-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Freshwater Bay	FB-01-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Port Angeles Harbor	MD-01-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Port Angeles Harbor	MD-02-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Dungeness Crab (Muscle)	Port Angeles Harbor	MD-04-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Geoduck (Tissue)	Freshwater Bay	FB-02-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Geoduck (Visceral Cavity)	Freshwater Bay	FB-02-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Tissue)	Dungeness Bay	DB-04-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Tissue)	Freshwater Bay	FB-01-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Tissue)	Port Angeles Harbor	LP-01-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Tissue)	Port Angeles Harbor	MD-01-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Tissue)	Port Angeles Harbor	MD-02-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Tissue)	Port Angeles Harbor	MD-03-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Visceral Cavity)	Dungeness Bay	DB-04-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Visceral Cavity)	Freshwater Bay	FB-01-BI	N													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Visceral Cavity)	Port Angeles Harbor	LP-01-BI	Y													X	X								na	na
RayPA RI2 2006 Tiss	Horse Clam (Visceral Cavity)	Port Angeles Harbor	MD-03-BI	Y													X	X								na	na

na - not applicable